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Landscape Architecture
The Sense of Places, Models and Applications

Edited by Amjad Almusaed

LANDSCAPE ARCHITECTURE - THE SENSE OF PLACES, MODELS AND APPLICATIONS

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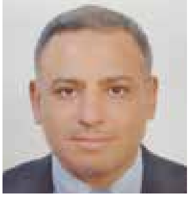
Meet the editor



Dr. Amjad Almusaed was born in January 15, 1967. He holds his PhD degree in Architecture (Environmental Design) from the "Ion Mincu" University of Architecture and Urbanism, Bucharest, Romania. He completed his postdoctoral research in 2004 on the sustainable and bioclimatic houses from the Aarhus School of Architecture, Denmark. He has more than 28 years of experience in sustainability in architecture and landscape with innovative orientation. He has carried out a great deal of research and technical survey work and has performed several studies in the area mentioned above. He is an active member of many international architectural associations. He has published and edited many papers, articles, studies, and books in different languages.

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Preface

Creating a new green area and protecting, preserving, and extending the existing ones are necessary means of combating the action of pollutants and improving people's living environment. If a person wants to be an environmentally responsible being, he or she must do more than others. It is a matter of taking the case alone and making the words to action. There is no doubt that we as a society today face some new and complex environmental challenges. These challenges concern us all—as individuals, governors, and communities. As a community, we want to take our share of responsibility and help solve these environmental challenges. It may seem like a big mouthful for us. Nevertheless, we are determined to do our best. Continuous studies indicate that the concentration of greenhouse gases in the atmosphere, such as CO_2, is a contributing factor to global warming and climate change. These environmental issues can have severe consequences for the world we know today. To transform a place from an underdeveloped area into an attractive, functional external area, requires an accomplished landscape provider. Just as the creator has to remark on the visual potential and practical issues an outer space offers, the landscape entrepreneur must have originality and a varied range of real abilities to interpret the creator's concepts. Landscape architecture embraces the spatial organization of outdoor spaces to meet people's requirements and wishes while protecting or improving the natural environments and processes. Landscape architecture usually requires human beings to labor in different ways. The architect's objectives are to make spaces that correspond to social, environmental, cultural, esthetic, and applied needs.

An urban settlement, town or city, is one of the primordial and predominant expressions of human sociability on a territorial basis. The outward, visually perceptible manifestation of the compound, a multiform social structure that constitutes a town, is the three-dimensional plastic townscape. In everyday terms, landscape architecture is mostly a product, such as a park, a garden, a fountain, a wetland, and its flora and fauna that are planned for protection, a nature reserve or a roadmap. The town plan gives a single plan, a graphic abstraction of a townscape at a fixed date. In a town plan, one of the most critical study areas is landscape. Landscape architecture is a three-dimensional spatial organization of the territory, the combination of natural, building, and architectural components into an elemental composition bearing a specific artistic image. Like architecture and town planning, landscape architecture refers to spatial types of art. Deciphering of the landscape as a superb ensemble - in general or in part – bears a sign of localization recognition, of component elements. In contrast, the profession of landscape architecture is broad and complex. It deals with multiple scales that range from a single site to a whole region. Practicing landscape architects work on a wide range of project types. These include, but are not limited to: urban design, community design, historic preservation, ecological restoration, parks and park systems, infrastructure and stormwater management, institutional landscapes, memorials, cemeteries, industrial site reclamations, golf courses, wilderness areas and trails, residential landscapes, and gardens. The profession is both an art and a science. Successful landscape architects are creative professionals who hold an environmental imperative and a social conscience. They are also excellent facilitators able to bring numerous disciplines and professions together to work on complex projects in the landscape. Different landscape features, dissimilarities in activity, urban and community structures, interests, and actors help draw a picture of new potentials in a regional context of "attractions and relationships" that characterize that region's identity. The landscape features are interesting as they are used to designate areas where future growth can be logical and attractive to both citizens and businesses. Activation and use of these sites must be organized. The correct strategy intends must cater to the diversity of interests, to enhance the nature of places, and to contribute to activity focusing on regional identity. Creating an artistic landscape requires architectural vision, necessary to respect the main objectives of the mission based on observational experience: analysis—tool, strategy—action, intervention—maneuvers, while drawing inspiration from examples. From the landscape observation experience and analysis tool, an action is derived from which the policy can be formulated. The approach leads to concrete maneuvers, which are expressed through the use of selected interventions. Architecture, landscape architecture, and all forms of creation from which people build a physical, social life (including garden art) consist of internal spaces. This will be experienced by approaching the concepts of entrance/exit, internal/external, front/back, and up/down. When these spaces are aligned with humans, landscape architecture grows and becomes comprehensible. I imagine that human placement relative to the entrance/exit, inside/outside, front/back, and up/down is crucial to the comprehensiveness of architecture. It is from the assembly where human beings have a central position in space, to where its location in space is at most peripheral. In this relationship between space and humanity, the possibilities are endless.

This book is intended as both an introduction to the discipline for students of landscape architecture, architecture, and planning, and a source of continuing interest for more experienced environmental designers. The book offers various materials for landscape architects and other planning professionals. Theoretical foundations, theories, methods, and applications will be essential parts of this book. The heart of this book is the application case studies that present the state of landscape architecture in different environmental therapies. The book is divided into 4 parts and 17 chapters.

Part I "Introduction to the Landscape Architecture Theme" is general reading on landscape architecture.

Part II "Art's Replica and Landscape Architecture Model" includes three chapters. This part represents a theoretical and sensitive visual interpretation of landscape architecture. The second chapter "Unity and Diversity in Geometric Gardens" focuses on many examples to test its response to specific designing elements of landscape and how it reflects its experience of designing the garden. The third chapter "Mobile Eye Tracking in Landscape Architecture: Discovering a New Application for Research on Site" presents the process of establishing a laboratory for mobile eye tracking in real-world, open-space environments within the field of landscape architecture at the Osnabruck University of Applied Sciences, as well as the latest results from the feasibility study "Point de Vue", which defines the basis for future qualitative interaction analyses in landscape architecture. The fourth chapter "The Role of Ornamental Gardens of Rural Settlements in Landscape Architecture" deals with the status of rural ornamental gardens in the Czech Republic throughout history and describes the individual styles and typical elements of garden architecture from the oldest medieval gardens around the castles and monasteries, through the Renaissance and Baroque ornamental gardens around the typical renaissance villas and chateaus, to the landscape parks of classicism and romanticism and modern gardening.

Part III "Sustainable Prototypes of Contemporary Landscape Architecture" includes four chapters, with sustainability as a concept and guiding thought. The fifth chapter "Ecological Esthetics: Design Thinking to Landscape Beauty with Healthy Ecology" tries to demonstrate that the esthetic preference has changed with time and may reflect the public understanding of ecology, which provides a critical linkage between humans and ecological processes. Sixth chapter "Retrofitting Biophilic Design Elements into Office Site Sheds: Does 'Going Green' Enhance the Well-Being and Productivity of Workers?" is quite detailed, but the most important area is an investigation of the impact of incorporating plants, natural sunlight, , ventilation, open spaces, and windows to an office environment through retrofitting the design of a site shed. Seventh chapter "Modular Green Roofs in Urban Ecospace" essentially begins with green roof systems, with an overview of the green building industry and analyzes both traditional green roof structures, so-called green roof "pie," and innovative modular green roof systems. Chapter eight "Improving Traditional Spate Irrigation Systems: A Review" provides reference materials for teaching, training, and research activities and plays a great role in the efforts of sustainable spate irrigation system development, rehabilitation, and management programs.

Part VI "Landscape Architecture Around the World (Study Cases)" contains examples from different geographical practical cases. Chapter nine "Natural and Cultural Landscapes in Atacama Desert: Between Tradition and Innovation" attempts to demonstrate that the architecture of the desert is extreme, responding equally to the intensity of the high daytime solar radiation as well as low night temperatures; in this thermal contrast, the architecture of the desert finds its most genuine formal expressions. Chapter ten "Rural Landscape Architecture: Traditional versus Modern Façade Designs in Western Spain" explores the visual quality impact of a façade based on its complexity degree. The aim is, in particular, to identify visual preference patterns in ornamentations with stone or wood of novel rural buildings. In Chapter eleven "Evolution and Dynamics of Fractal Growth of the Urban Green Spaces in Seville (Spain)" the author tries to demonstrate that increases in the area of urban green spaces can be described using fractal design, a measure of the dynamic evolution of public space of leisure and recreation, associated with the growth form of the city. Twelfth chapter "Renovation Spaces in Heritage Districts: The Revivingand Renovation of Culturally and Historically Open Spaces in Islamic Regions" demonstrates dependance on spatial orientation to open urban spaces in heritage cities for potential investment opportunities, after clearing up the garbage and ruination. Many of the alleys in the ancient cities of Baghdad, Cairo, and Damascus have been consumed and vandalized without considering their tremendous value represented by these heritage cities. Chapter thirteen "The Relevance of Vegetation Series on the Maintenance and Sustainability of Public Spaces in the Southwest Iberian Peninsula" demonstrates that a landscape architecture project is dynamic and considers the fourth dimension: time—mainly regarding vegetation development, creating new volumetric spaces, and considering their natural evolution. A deep knowledge of plant material is seen as a critical factor for sustainable landscape planning at several levels. Chapter fourteen "Wind Farms as a New Element of the Polish Landscape" determines the previous practices of locating wind farms in Poland, the effects resulting from the presence of wind turbines in the landscape, and the guidelines for designing wind farms in the context of impact on the landscape. Chapter fifteen “Promenade as Landscape Architecture Strategy for Riverbanks of Small Danube Cities—Komárno and Štúrovo” looks at the concept of a promenade that has moved from the city’s public spaces, the streets and the parks, to shopping malls and virtual public spaces. Chapter sixteen “Landscape Architecture of the Atacama Desert” also covers the architecture of the desert under extreme thermal contrasts and conditions. The last chapter, chapter seventeen “Recreational Landscape Value in Tourism Development of General Yakutia” attempts to present the results of an analysis of the recreational landscape of the “Orto Doidu” tourist complex, which is open year-round and located in the Khangalassky region of Central Yakutia.

I would like to thank all the contributors for their imaginative and eloquent writing. I would also like to express my sincere sense of appreciation and thankfulness to all the authors for their valuable contributions. At the same time, special thanks go to the kind Ms. Romina Skomersic, IntechOpen’s Author Service Manager, for her honest assistance and efficiency in the management process of this book, and her cooperation at various phases of book publication.

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Section 1

Introduction to the Landscape Architecture Theme

Chapter 1

Introductory Chapter: A General Reading Process on Landscape Architecture

Amjad Almusaed

Additional information is available at the end of the chapter

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1. Introduction

Landscape architecture is a multidisciplinary of different fields of knowledge that combines various artistic, technical, and scientific sphere aspects such as visual arts, design, descriptive geometry, history and architecture theory, urbanism, fundamental notions of botany, pedagogy, hydrology, sociology, economics, and so on. It supports a clear combination between designing and managing according to certain principles and techniques of external functional spaces in which human activities will take place, where the activity of the landscape architect addresses both urban and rural environments, irrespective of its jurisdiction (private or public). The landscape painter deals with both small-scale projects (landscaping and landscaping, etc.) and large-scale projects (urban design, parks, etc.). Among the activities, it includes many extra areas such as gardens, terraces, green/brown roofs, vertical gardens, parks, urban squares, green strips and street alignments, protection plantations, university campuses, botanical and zoological gardens, cemeteries, residential complexes, design urban, and so on. Over time, the range of plants has widened, and gardens are beginning to have ornamental and recreational characters, offering shades and coolness. In the orient, due to the warm climate and torrential summers as well as extensive desert and arid lands, the gardens were regarded as true oases of coolness, relaxations, rests, and pleasure. The creation of these gardens required the creation of water supply and irrigation systems, being stimulated by the development of architecture by creating palaces, temples, and sumptuous residences. The orient gardens were synonymous with the notion of Paradise or Heaven on earth, being, in fact, privileged places that offered pleasure and relaxation through the greenery and the shade offered by the numerous woody species, the aromas of the various aromatic species, or the cooling of the water in the form of waterfalls or ponds. The concept of landscape architecture is involved in open spaces surrounded by fences and also by open spaces without any fence or wall, such as squares, parks zone, green belts, and wild landscapes. The critical difference between the two is that gardens tend to be enclosed and to be designed for the private individual, whereas landscape architecture is concerned with open space, the public realm, and the relationship between the humanity's development activities and the natural environment. Landscape architecture is concerned with the public good, with community values and with human development and its impact on the land. The scale of landscape planning may be regional or even national: landscape architects can design the whole new agricultural landscapes and forests [1]. The portion of territory overlooked, forming it as a natural state or through human intervention, which had the intention to create an esthetic ensemble. Landscape architecture, or green space design, is the art of land planning, design, management, preservation, and repair, as well as the development of artificial structures. Landscape role in urban sector is to directly influence the physical and biological environment and diminish many operative impressions of metropolitan development through decreasing the negative effects of climate and saving energy as well as eliminating carbon dioxide, adjusting the operative rainfall runoffs, improving the air quality, sinking the acoustic levels, protecting the nature, and improving the attractiveness of metropolises [2]. The history of landscape architectural discipline, an element which has to be analyzed, is related to the gardening sector, but not confused with it. The two disciplines labor with the confirmation of plantations and external adaptations, where gardening is more interested in public and private areas by enclosed or fenced spaces, such as parks and gardens. A worthy landscape architecture directly influences the physical and biological environments and diminishes the efficiency in many impacts of urban development by moderating the macro- and micro-climate, conserving the energy, improving the air quality, controlling the rainfall runoffs and flooding's, lowering the acoustic levels, harboring the wildlife, and improving the desirability of cities [2]. In other words, it represents the interference of discipline, with a high rank of art and science, which deals with development and arrangement of the system of green spaces. That has to be a whole and of the green spaces, in particular, according to certain principles and techniques, by associating the natural elements (vegetation, water, soil, and rocks) with the artificial elements (buildings, installations, etc.) to fulfill certain functions. Landscape architecture includes planning, design, and landscape management. Accordingly, landscaping involves the subordinate landscaping and design of the outdoor environment. Landscape refers to all cultural and natural land and water areas in the city and the countryside. Minor areas such as parks, squares, gardens, and walkways make up various components of the landscape. In an architectural domain, landscape not only shows the relationship between man and nature but also expresses the cultural content. Human civilization is the beginning of the face of all things to create a human world. The "symbiotic ecological" relationship between mankind and its living environment is often times forgotten [3]. Consequently, the "landscape architecture" caring is from the natural land of the humanities to the urban and rural areas, communities, home environment planning, and space design. The efficient process of a comfortable and esthetically valuable environment is carried out with the help of natural materials (relief, water, vegetation, etc.) and architectural structures while maintaining existing and creating artificial landscapes and designing landscaping and recreational zones. In contrast to landscape architecture, the subject is much broader and consists of the organization of many components of the spatial environment of human life. The scope of this book includes landscape design, environmental restoration, land preparation, residential development, parks and recreational planning, and historic preservation, which are closely related to geography, architectural design, urban design, town planning, and regional planning. In other words, landscape architecture represents a 3D spatial organization of the territory, the combination of natural, building, and architectural components into an elemental composition bearing a certain artistic image. Like architecture and town planning, landscape architecture refers to spatial types of art. Landscape architecture can therefore alternatively be described as the overall knowledge as a practitioner used by a landscape architect in the implementation of projects. At the same time, the process of creating green areas in the sites is not the mere filling of the empty spaces between buildings with different natural elements such as stones, grass, flowers, and trees [4]. It requires profound philosophy of the organization of these areas in the harmonious form by using diverse plant forms, the dynamic chromaticity of the flowers and leaves, water mobility, and the relief of the trees in contrast with different construction backgrounds. Landscape, in general, represents the culture and the nature where human being needs productive, practical, beautiful, and lasting scenery in cities, settlements, and natural areas. Landscape dialogs and activity elements carry neighbors in a composed form, melting variances between racial and ethnic communities, where the effect of landscape elements becomes an operative device to unite localities. Landscape in a set form upon urban areas represents a worldwide language, which can bring the community objectively to be together. Besides the major role of landscape, it contributes effectively to reduce the domestic violence levels in communities [5]. Landscape architecture is a profession search for procedures that comprehend evident spirit, where the main goal of the career is to weigh the interests and values into an attractive, long-term, and sustainable consequence of a whole subject. The subject anchoring is found in the history of landscape architecture, social architecture and garden art, the theories of landscape architecture, and the esthetic experience, with artist-like working methods. Within the landscape architecture, a variety of methods are used. However, the core subject is the design method of the freer—heuristic architect through sketches, drawings, images, and physical and digital models. Green areas help much in reduction of environment pollution where the function of the reduction of environmental pollution can be achieved precisely by the ability of the vegetation to retain, fix, and sediment particles suspended in the atmosphere, fine powders, or smoke [6]. Solutions will be talented to touch the main objectives of the topic. In fact, the landscape is the survival of the human state in the earth on the specific performance.

2. Natural lighting as a tool of the flourishing process of landscape architecture concept

In landscape architecture discipline, the light is an important element that must take cognizance of all design processes where the light can create harmony, contrast, drama, and life. It is possible to work consciously with the light, taking advantage of the shining backlight, a light opening in the decoy, and the reflections of a living water surface. The specialization must be used by landscape architects as a tool to exploit the importance of light for the experience of shapes, colors, febricity, and spaciousness. The specialization is experience-oriented, not oriented toward technical calculations. The specialty thus depicts the light as you experience it, not the light, as a light meter would indicate, or an engineer would calculate it [7]. At the end of the thesis, the light is described as a design tool. Based on the experiences from the theory and theories' example, the section gives examples of how landscape architects can affect the nature of the lighting and the experience of form, color, febricity, and spaciousness. Landscape architects can work consciously with light contrasts, such as when the light in a water pillar of a fountain is seen against a shadowy background. We can choose from the different light sources, such as the bright-colored sunlight or the weaker diffuse skylight, and we can utilize the direction of light. We can work with screens to filter the light and surfaces to receive and reflect it, and we can create static or dynamic light experiences. In the theory of theory, the light, as well as the sensing device, describes the eye and consciousness—which together allows the person to perceive space, its surfaces, and objects. There are four variables that describe the light. These are the strength of light, the color of light, the hardness of light, and the direction of light. Hereafter, the light is described from the different natural light sources—sunlight, skylight, and reflected and transmitted light. It describes how the light influences the experience of shapes, colors, febricity, and spatiality and finally describes the variability of light throughout the day and the year.

3. Cultural environment analysis as a tool for reaching landscape architecture

Landscape architecture and cultural environment, like the nature and the environment, should be managed with a special care. The development of recent decades has meant that landscape architecture and cultural environment resources have been lost, and the diversity and quality of landscape and cultural history are threatened. The characteristics of the affected landscape architecture and cultural environment can be identified by describing dominant features/main features, distinctive elements, and the special nature. The dominant features of landscape architecture are linked to the scale of the landscape (small scale/large scale), forms (hilly/flat), water areas, spatial effects (open/closed), and so on. The significant elements can, for example, be the valley, the lake, or the marked hill. The particular nature can be attributed to the characteristics of the land, the use of land, the degree of insanity, and so on. The cultural history features can be linked to a cultivation system, the overall structure of buildings, and so on. The bearing historical elements can, for example, be the station in the station city, the main farm, and its road and garden [8]. The special character can, for example, be linked to a time span (share time, prehistoric time, etc.) or a function (fishing, infrastructure, etc.) or the landscape context. An important point is that each of the landscape architecture and cultural environment has its own characteristics, which may be more or less sensitive to the impacts of the current project. It is, therefore, crucial to identify these properties in order to assess the impact. Similarly, it is important to retrieve the relevant data and information and not, for example, build the entire cultural environment description solely on registered memorials. Criteria for determining the values associated with landscape and cultural environment may be designations that appear in regional plans, conservation plans, municipal atlas, conservation, and so on. It may be necessary to make a concrete assessment of the value in the current situation. An important tool for sustainable exploitation of landscape architecture and cultural environmental resources is environmental impact assessments.

4. A creative project of landscape architecture "analyzing process"

In an effective analyzing process of a creative landscape architecture project, it is important to work systematically with different data and information of an existing situation. Analysis process has to be considered and should obey the following steps.

4.1. Screening of target region

The core aim of the screening is to clarify whether an environmental impact assessment is to be carried out in connection with a proposal landscape project. This should be done by the estimated procedure of a preliminary assessment to have a significant impact on the environment [9]. For a landscape architecture expert, "natural areas" mean areas that are designed to achieve substantial protection of, inter alia, landscapes and cultural values. It is important to note that the designation of valuable cultural environments takes place as a progressing process. It is also different from region to region if there are selected valuable landscapes and/or landscapes and cultural environments, which are included in the selection of natural areas. Therefore, a concrete assessment should always be made up of whether important landscape architecture or cultural environments are affected. It should be noted that in connection with, for example, projects in historical urban areas or plans for major changes in land use, it may also be relevant to conduct a screening under the regular rules. The main objective of the screening of external expertise in the landscape and cultural environment, inspection, and so on depends directly on the current situation, including the plot foundation and the competent authority's expertise and local knowledge. In order to assess whether there is a planned risk, plants can significantly affect landscape. It is important that urban planners, designers, and ecologists, therefore, need to focus on urban green space strategies that are 'just green enough' and that explicitly protect social as well as ecological sustainability [10].

4.2. Scoping of the main conception zone

The main aim of scoping is to ensure that the following environmental impact study contains all relevant information related to the impact of the project or plan on landscape area and cultural environment while avoiding unnecessary studies. As a part of the scoping phase, an investigation of the project or plan's potential significant impacts on landscape and cultural environment. There are requested ideas and suggestions from the citizens, where the essential issues related to landscape and cultural environment are drawn forward. The main elements and the methodology shown in the description of the screening phase should be used in the scoping analysis. The call for ideas and suggestions may partly result in additional information about the landscape and cultural-historical conditions that should be incorporated into its investigation and in alternative proposals.

4.3. The input to the study program

The requirement for alternatives, justification measures, and the main issues to be addressed in the further investigation is clarified and elaborated by supplementary studies of the affected areas. Here too, it is about identifying the dominant landscape features, cultural history features, distinctive elements, and the special nature. The properties are valued, and the vulnerability to the project is described in order to clarify the need for (complimentary) alternatives and the main issues for the subsequent study. As in the other phases of the process, this happens in the interaction between many considerations—also with input from interests other than the landscape and cultural environment.

4.4. Respecting of study programs: alternatives and influences impact zones

An important part of the scoping phase is to determine the alternatives and the geographical area to be investigated. It may be a good idea to make sure that the zone is not set too narrow, so that you can start from the beginning. The extent of the influenza zone (research area) will vary widely, inter alia depending on the nature of the project, the alternatives to be investigated, and the nature of the affected area, which are determining alternatives. An important element of the scoping phase is to determine alternatives or identify, where future options for alternative solutions should be investigated. Landscape and cultural environmental considerations are one of several considerations that can justify alternatives, nevertheless an important input for the development of alternatives. The size of the geographical area to be examined—the influenza zone—naturally depends on the alternatives to be investigated and their location.

4.5. Environmental impact study

That is sure that employment of more plants in green areas and similar in dense urban environments, annoying to put excessively much nature in the city in the form of big open green spaces can reduce the thickness to the point, where everyone has to make everywhere, with negative environmental consequences. It also reduces the energy of the city [11]. The scope and content of the environmental impact study are laid down in scoping study program. The study consists of three main elements, such as screening and scoping analyzes the nature and impact of the project, the nature of the landscape and the environment, and an analysis of the extent and nature of the consequences. The impact assessment must, in a transparent manner—and as far as possible "measurable" way, describe the consequences of the project on the landscape and the environment. The analysis of the nature and impact of the project, on the one hand, and the characteristics of the landscape and the environment, on the other hand, must determine the vulnerability of the area to the current measures. The two analyses take place simultaneously, so that the necessary information about the project and its effects is obtained on the basis of the previously completed studies of landscape and cultural environment. These previous analyses have given a preliminary characterization of the landscape and the environment. In some situations, the landscape will be divided into different landscape types. Public consultation and preliminary analyses may have resulted in the setting of alternatives whose consequences for landscape and environment will now be examined further. It is necessary to engage researchers in the worldwide greenly architecture community and for those interested in biophilic architecture [12].

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4.6. Analysis of landscape and cultural environment

The previous analyses were supplemented with more detailed study within the framework of the study program and under the impression of the project options to be investigated. A part of this is to identify and define distinctive landscapes that may have different vulnerabilities to the project. Similarly, characteristic cultural-historical contexts are defined—cultural environments. If a project affects a large geographic area or area with very different landscapes, it may be necessary to "break down" the landscape into smaller areas with each of their characteristics and vulnerability to the project. In other situations, where the landscape is very uniform or the extent of the impact is limited, it will not be relevant for a subdivision of the landscape. The landscape is a wide-ranging concept with many dimensions, and there is not one method for analyzing the landscape. Therefore, in the analysis of the landscape, the facts that are most relevant in the specific situation must be taken into account. In order to identify the landscape profile, it will typically be natural to treat topics such as natural land, historical development, terrain conditions, wetlands/coasts, vegetation, farm structure, housing patterns, and infrastructure (roads, lanes, and pipelines).

4.7. Landscape characteristics and value

The main objective of the analysis is to identify the significant landscapes, elements, and structures that characterize the landscape features and that can be influenced by the current project. In addition, their significance is valued. The landscape with its towns and villages tells the story of how we have utilized natural resources over time, power relations and religion, technological development, and so on. The combination of natural conditions—geology, soil, and climate—and historical development differs in different ways with each region and each local area. It is important in the analysis of the landscape to find out the special landscape profile—the special characteristics—which characterizes the area. The analysis of landscape properties consists of two elements: first, an analysis of the "physical landscape" with the dominant landscapes, vegetation, and settlement patterns as well as distinctive landscape elements such as a hilltop, river valley, and churches and second, a spatial/visual analysis of the appearance of the landscape and the individual forms, patterns, and elements, state and undisturbedness. The significant elements can be sub-areas and/or structures, and they can, for example, be characterized as strong or weak in relation to being bearable/representative of the landscape character on the determined area.

4.8. Implicated the characteristic and the value of the cultural environment

The main goal of the analysis is to identify the cultural-historical main features and bearing elements within the delimited cultural environments that may be affected by the current project. In addition, their significance is valued. However, in order to characterize and value the designated cultural environments, it is important to understand the landscape and historical context as they are part of. The cultural-historical main features are linked to both physical and functional conditions. The starting point can be the overall housing structure such as the location of the settlement on the edge of the valley, between the high-rise cultivation areas and the wet meadows along the river, which together constitute the resource base of the building.

In such cases, the functional context is as important to the identity and value of the environment as the physical structure. But also understanding the mechanisms by which natural environments contribute to stress reduction or restoration is important if this contribution is to be exploited for public health improvement [13].

5. A sustain reading of historical world's landscape architecture

Concerns about the arrangement of planted areas, in general, have existed since ancient times, with some ancient peoples having a special cult for this. Human beings have always wanted to shape nature and to be surrounded by the elements of nature (trees, shrubs, grasses, rocks, water, etc.), to harmonize them, and to integrate them into the artificial environment created by it; a fact upon which have marked the culture and traditions of the people concerned. Thus, in the course of history, different conceptions and ways of green spaces were developed. There were many planted areas developed, and others disappeared, found, interfered, enriched, and developed, passing through from one region to another and from one era to the next, shaping well-defined styles and schools with their principles and ways of realizing gardens. Historical proofs such as mural paintings, bas-reliefs, mosaics, historical texts, vestiges of ancient buildings attest to the emergence, and development of gardens in the west and east of Asia and North Africa (Egypt) and later in Europe (Greece, Ionic peninsula) and around the Gulf of Mexico. The antiquity gardens at first had a utilitarian purpose, many of which were grown as food-producing plants, later attained a religious and divine character or a meditative character.

In **Mesopotamia,** builders from the Western part of Asia are trained to make buildings that can fulfill certain required functions while giving full consideration to all sites and environmental conditions [14]. The great civilizations of south central and the north of Iraq such as " Sumerians, Babylonians, and Assyrians "who have developed in the region between the Tigris and the Euphrates. It is characterized, among other things, by the growth of the historical cities, by the monumental architecture of the palaces and temples, which encompassed within the enclosure's luxurious gardens, arranged in closet form parallel with the architectural lines. Thus, the famous hanging gardens in Babylon (sixth century BC) considered one of the seven wonders of the ancient world. The climate from Mesopotamian region is dry summer, cold winter, and a pleasant spring and fall. Roughly 90% of the annual rainfall occurs between November and April. General readings of Mesopotamian gardens consist, in part, of the palace of the King and were built on a massive stone construction, the garden from the north area of Iraq "Assyrian civilization" was built by irregular form. The water using in irrigation systems was concepts in the different form, but the majority was direct from the rivers, but the irrigation system for hanging gardens was as sophisticated as can be imagined, where the water was headed by a hydraulic system under the first terrace, being brought from the Euphrates River through a feeding channel and further driven through three wells embedded in the construction. The plantations were free, creating a harmony of the architectural lines with the regular and irregular forms of vegetation. As species used are recollected: foliage, palm trees, various shrubs, poplars, pines, lotus, or many species of flowers [15].

In **Egypt** antique, on the banks of the Nile, in the third millennium BC, there were many fertile fields, crossed by irrigation canals, cultivating figs, dates, pomegranates, cocoons, sycamores, vines, and numerous vegetables. The majority of the landscape included gardens of relaxation and pleasure. They were considered as natural extensions of the building being surrounded by a massive wall and a considerable wooden fence with a regular shape (rectangle). The green areas had designed as a central element, a water channel, or an elongated or T-shaped rectangular basin with colored fish in which lotuses were cultivated. The plants were distributed in different forms. Near the canal or basin, there were shrubs or small trees, and at the perimeter, along the perimeter alley, there were tall trees with a pyramidal port. As species used were some fruit species, and various forest species, but also numerous forest species as well as many floral species such as mixers and roses.

Greece antique, the planted areas originally appeared near temples or different religious establishments, is the place where the glory ceremonies were held. The Greeks cultivated in their garden species with a food role: fruit trees, vines, and various vegetables. The temples devoted to the various divinities were situated in natural landscapes of remarkable beauty. The ancient civilization of southern Europe has seen tremendous development in all fields, the art of gardening has no exception. As with other arts, it was with the arrival of the renaissance that the design of gardens was revived with exceptional achievements. During the fourteenth, fifteenth, and sixteenth centuries, private gardens were implanted in the most area of Europe [16]. The gardens continued to develop throughout the renaissance until the sixteenth century, and in the seventeenth century, during the Baroque. In the second and fourth centuries BC, there were gardens beside palaces, gymnasiums, and academies of relatively small size, which had many artistic elements such as statues, fountains, pergolas, porticos, and elements that filled the abundant vegetation.

Romans antique planned and designed in large-scale landscaping, where Vitruvius analyzed in deep form of various topics upon landscape in the city, such as the planning of cities, which still today interest landscape architects. The landscaping of the gardens in the Romans had an important development during the Roman Empire, being influenced by the art of the subjugated people. The green spaces have appeared beside the imperial palaces, the luxurious villas of the patricians, the temples, and the meeting places. The archeological remains reveal the existence of the sumptuous gardens around the large villas located in natural places of great beauty, and the land is arranged in terraces with great views, but there were also small gardens of the dwellings. The gardens surrounding suburban villas have become true parks, systematized in different sectors with different constructions and arrangements. The villa was always located on the slopes of the hills where the best panoramic views were located and the surrounding terrain was set up on the terraces. The architectural center consisted of dwelling, and the garden was a completion and a continuation of the house. The general systematization implied the existence of several architectural sectors with the symmetrical organization, subordinated to an axis of the general composition of an edifice or a decorative construction (canal, basin, colonnade) being correlated with each other by naturally free zones, forming a unitary unit.

Italian antique about “Renaissance age,” the Italian green arrangement had the greatest glory and the greatest refinement. The gardening principles were taken from the ancient gardens, especially for the gardens of the suburban villas, such as symmetry over an axis of composition; the architectural organization of the premises toward the building; the connection between the building and the garden through decorative elements built; the presence of sculptures, ornamental pots, and ornamental parapets; the use of tuna vegetation; the layered systematization of the garden and its subordination to a main axis of perspective with the descending slope of the slope, on successive terraces; along the axis and on the terraces were created decorative sides arranged in the form of different drawings; and an abundant use of water basins, canals, and waterfalls. In the seventeenth century, Baroque style, architectural style, is also emerging in the art of green spaces. The essential principles have been maintained, in terms of balance and symmetry, but rigid schematic disappears, the rectilinear paths being merged with broad, curved lines. The free arrangement of the trees was adopted, giving up the perfect geometric layout.

In **France** "Renaissance age," landscape areas were built in France at the beginning of the sixteenth century AD in the castles of Amboise, Blois, and Gaillon by an Italian architect who brought new elements to terraced land (with low-level differences). Enrichment of ornaments with marble fountains and the introduction of new models of the parties (toward the medieval gardens) existed. Only after a half century, the sixteenth century began to radically change the medieval conceptions of landscaping of the gardens. Thus, the fortifications of French cities and castles disappear with walls and water channels, where the gardens were on the premises, resulting in vastly enlarged spaces. In some situations, the channels have been preserved, also having a decorative function and utilitarian function, and later became a feature of the French Renaissance parks. The composition of the garden was systematized according to a dominant shaft represented by a central alley. The land was modeled on large terraces, with flower-decorated partitions. Between buildings and the garden, there is an architectural cohesion. There were huge canals and lakes.

In **England,** "medieval" landscape in England dominated the walls with trimmed vegetation regularly symmetrical. Later, as in the rest of Europe, Italian and French influences were felt. But while in Europe, the art of gardens evolved under the strong influence of the French style in England. Since the eighteenth century, under the influence of literature, landscape painting and the new cultural movement, the art of gardens evolved in the direction of returning to nature, renouncing the rigidity and artificiality of the French style. At first, the trees were cut off, the walls were removed and the ditches replaced, creating a connection and opening to the surrounding landscape. The parts disappeared and were replaced by green carpets (lawn). The axis was kept dominant but introducing winding paths, irregular watercourses, and vegetation clustered freely.

Islamic region has put its mark on all the countries that were part of the great Islamic empire (beginning with the seventh century AD), but they also assimilated elements from the civilization of the subjugated people. This has also happened in the art of green spaces with Arab landscape design having an oriental, predominantly Persian influence, and then acquired their own specifics. The small dwellings had a single, regular garden, and the largest one, a garden suite. The garden was divided into four equal parts, where the space allowed by dividing two channels of water. The water was used either in pools and canals or in the form of artesian fountains, connected by small channels of terracotta or marble.

In **China,** landscape architecture is lost in ancient times and reflects the strong cult of nature intimately linked to religion. Religious philosophies in China promote the idea of the realization of man's communion with nature, the acquisition of moral perfection, peace of mind, and divine peace. Religion has spurred the creation of green spaces and the finding of a natural framework conducive to spiritual life in close relation to the elements of nature. A characteristic of all the gardens in China, regardless of the historical period, is their size of very large areas in which the vegetation was natural harmony with the natural landscapes. The terraces were drawn freely, irregularly, having a natural character with the straight lines being excluded and driving the viewer from one point of interest to another.

In **Japan,** the art of gardens in Japan was taken over from China and later personalized to become a national art. Larger or smaller green spaces were present everywhere, alongside homes and temples or palaces. Imperial gardens were designed according to the Chinese model but on a smaller scale (Nara—the capital of the country, and in Kyoto, the eighth century AD). Temple gardens were the predominant elements of the building, being a component of it. The philosophical symbolism was used to the fullest with the application of all elements of nature that are processed according to certain compositional rules and different symbols. In these gardens, a landscape full of mountains, hills, lakes with islands, cascade brooks, corner cliffs, rounded stones, sand, gravel, trees, and shrubs, various plants with or without flowers were either reconstructed on a small scale at certain scenic scenes (more developed in different periods) such as mountain gardens, moss gardens, and arid gardens. Large green areas where complete landscapes could be created included various buildings or architectural elements such as bridges, tea pavilions, stone flashlights, and gates.

In **the modern concept,** the term landscape architecture was invented by Gilbert Laing Meason in 1828 and was first used as a professional title by Frederick Law Olmsted in 1863. Gilbert Laing Mason used for the first time in 1828 the term "landscape architecture" in his work "The Landscape Architecture of the Great Painters of Italy". The combination of modern planning and the landscape gardening tradition gave the architecture of the landscape its particular orientation. In the second half of the twentieth century, Frederick Law Olmsted created a series of parks that continue to have a profound influence on the current practices of landscape architecture. These include New York's Central Park, Brooklyn's Prospect Park, Montreal's Parc du Mont-Royal, and Boston's Emerald Necklace Park network. Capability Brown, who remains one of the most renowned landscape gardeners today, was also the creator of places. During the nineteenth century, the term landscape gardener came to be applied to people who built. "Ian McHarg" had an important influence on the architecture of the modern landscape and on the adaptation of the soil in particular.

6. Landscape architecture categories

The categories of the landscape are numerous, being different in size, location, facilities, and functions. They can be classified according to several criteria in the following paragraphs.

6.1. Placing and position

Placing area suburban or urban includes recreational green areas, public gardens, squares, green strips, and planted street alignments as well as botanical gardens and plantations beside some public facilities, landscaping on the premises of institutions, businesses, education or social-cultural units, plantations in cemeteries, green roofs—suburban including: cultural and resting parks, recreation areas (recreation forests, park forests, and parks), botanical gardens, plantations of alignment along roads or railways (localities, soil, water, and spa-climatic resorts), and nurseries.

6.2. Accessibility

It can be divided into two access forms as follows:

- Unlimited access to general usage that is also called public green spaces is managed by the mayoralties, including public parks, gardens and squares, street green spaces or residential neighborhoods, and recreation forests.
- Limited access, where the access is made according to certain rules for a fee or just for a given category of people, some green spaces even having a private character (the individual dwellings' gardens) being administered by legal or physical persons. This can include green spaces within cultural or educational establishments, hospitals, sanatoriums or industrial facilities, sports parks and bases, botanical gardens, and individual dwellings' gardens—with strict access, where access is only allowed to those who work in these areas, or in the case of studies or works of art, including experimental stations, nurseries, anti-erosion, water protection or traffic routes, and firefighting plantations.

6.3. Urban functions

Green spaces with a recreational role: squares, gardens and public parks, park forests, recreational forests, sports parks, green spaces for children and youth specialty green areas: botanical gardens, exhibition parks, parks and zoos, dendrological parks, rosaries, climbing, green spaces in cemeteries landscaping green spaces with a decorative role of decorative squares, landscaping near administrative, cultural or educational institutions, and private green spaces for dwellings [17].

Utility and protection green spaces: Alignments along roads or railways, plantations for the protection of watercourses and open water accumulations, parasitic plantations, protection curtains, anti-erosion consolidation plantations, nurseries, lands floral, or lawn production. Landscape architecture aims at an effective spatial design of plants, materials, land, and water. The starting points in landscaping are the landscape as a dynamic system along with the needs, intentions, or interests of the people. Modeling and delivery of alternative development opportunities are central. Landscape architecture continued its development as a design discipline during the twentieth century and took advantage of various movements of design and architecture [18]. At present, the spirit of innovation still offers excellent results in the design of public roads, parks, and gardens. At the moment, the system became the basis of the current geographical information systems (GISs). The system assigned a layer to every qualitative aspect of a place, such as a history, hydrology, topography, and vegetation. At this moment, the system is used universally in landscape architecture for the analysis of materials on and on the ground, in the same way, that they are used by urban planners, geographers, forestry, and natural resource.

7. Woody plants selecting for an operative "open space"

The advantages of using woody plants in different units of green space are to create the form of open spaces, where it represents a model of space unclosed version. Wood species "mainly trees and shrubs" embody more than about 70% of a floral species that represents approximately 5–10% of the total area of the verdant space unit. Woody vegetation is the "main building material" of a grassy space, a material that can be changed in volume, color, texture, and shape over a long period of time. By using woody plants in open spaces, architect and designers can create different landscape arrangements, colors, volumes, and compositions, all at the same time. They can form the harmonizing that binds all anthropogenic elements, which will eventually create landscape unity. The main advantages of using woody vegetation are as follows:

- The great malevolence of the contour of woody plants, which are extremely freely (proper to the respective species) or geometric (when certain cuts are used to obtain different desired shapes).
- The great diversity of green (summer) and yellow, rust, red or brown (autumn) in fallow species.
- The diversity of branches, leaves, flowers, and even fruits of certain species or taxa (including the texture of the crown surface).
- The lower cost of propagating material and maintenance work over time.
- The higher resistance of specimens of wood species to environmental conditions.
- The fulfillment to a much greater extent of the sanitary function compared to the floral or lawn species.

7.1. Species selecting criteria

7.1.1. The ecological requirements of wood species

The most important aspect to consider when choosing wood species is precisely the correlation of local conditions with the requirements of those species. Thus, an account must be taken of as follows: the requirements of the species in relation to climatic ecological factors, such as light, air temperature, atmospheric humidity, and wind; edible environmental factors, such as texture and depth of the soil, soil humidity regime, soil fertility, and the skeleton content; geomorphological factors, such as altitude, exhibition, slope, and terrain configuration; biotic factors, such as animal and vegetal; and anthropogenic factors, such as pollutants [19].

These factors will be taken into account differently in urban green spaces compared to periurban ones. Thus, in urban green spaces that are much smaller than peri-urban areas and where utilities are easier to achieve, some factors can be improved by applying for different special works: irrigation, fertilization, pest prevention, and control. Microstation in urban areas is more sheltered due to the presence of buildings that diminish the intensity of the wind or that increase the temperature of the air by radiation phenomena, which influences the decrease of the daily or annual thermal amplitudes. In periurban green areas, the improvement of these conditions is very difficult, and the species will be chosen in such a way that these conditions correspond to the best ecological requirements of the species.

7.1.2. The biological features of the species

- The height of the copies

This is important in choosing, but especially in the combination and location of species, a feature that takes place over time and cannot always be corrected. In designing a particular composition, the landscape artist must "see" in the future how they will look, how much the respective specimens will have, and how they fit into that composition. High-grade species are recommended for recreational forests and alignments; large urban green space units; masking unsightly targets (industrial halls, factories, etc.); shading of buildings; and obtaining vertical accents in different compositions. They can be used alone or in combination with other small species or even big shrubs. Small species and shrubs are recommended for small green areas along the arteries aimed at the shading of pedestrian walkways as well as the containment of exhaust gases, dust, etc.; realization of live fences and shrubs bring diversity to the unity of the composition is highly appreciated for its distinctive decorative effect, its rapid growth, and its ability to blossom in younger ages. Conveniently, the wood species are divided into three categories: trees of size I—over 25 m, size II—15–25 m, and size III—7–15 m; shrubs, species with heights below 7 m, with numerous stems branched from the base, which can be high shrubs with a height between 2 and 7 m, medium shrubs 1–2 m, and dwarf shrubs less than 1 m; liane, voluminous, climbing, clinging, or even creeping wood species, where the stems can have lengths from 1–2 to 10–20 m and even more [20].

- The shape and the size of the crown

The crown of the shafts falls more or less in a geometric form according to the ratio of height to diameter. This distinguishes the type of crown: cylindrical, conical, spherical, oval, obovoid, tabular, and with a sinuous outline. The shape of the crown is noticeable in any season and influences the viewer's mental state. For example, around the stadiums or along a road, species with columnar or conical crowns will be preferred, and on a sidewalk with a spherical or tabular crown. According to the density of the branches and the richness of the foliage (shape, size, and arrangement of the leaves), there are species with a transparent crown and species with a dense crown. This feature plays an important role in the composition, especially in directing the effects of light—shadow. Dense crown species are used to create the backgrounds for other compositions—mask unsightly objects; balance the volumes of neighboring buildings; and street alignments for protection against sunlight, dust, and wind, especially in the plains and hills. Transparent crown species are used for street alignments in the mountain regions; near certain buildings that are not to be masked, but besides which there is a need for wooden specimens; the recreation area, the creation of multi-story stands, or the installation of an herbaceous rug appropriate to picnic activities.

- Plant leaves, color, and shape

The leaves of trees and shrubs vary greatly in their shape, size, and color. Some species have simple or compound leaves, small or large, with a limb of different shapes and sizes: cordate, rhombic, lanceolate, ovoid, obovate, elliptic, and so on. The edge of the tongue may be whole, slightly incised and deeply incised. The leaves of composite leaves may be small (*Sophora* sp., *Robinia* sp., and *Gleditsia* sp.) or large (*Ailanthus* sp., *Juglans* sp., and *Aesculus* sp.). Species with small leaves, with a distinct shape of the tongue or with the sinuous or laminated edge, are recommended to be planted in the hot climates, while species with large, compound, dark-colored leaves are recommended to be planted in the cold climates. There are species where the color does not vary greatly from one season to another (tuna, biota, and juniper) or where the green hue (green—dark green) varies at most, as is the case with resinous species. However, there are many species in which the color varies from raw green, bright (spring) to intense green (summer), and yellow-orange-red (autumn) (**Figure 1**).

First, the most plant leaves are green, where the essential role of the most categories of leaves is to convert sunlight energy into carbohydrate, which the plant uses in various ways. The green leaf is green, so it is because the blade absorbs the other colors and reflects the green color, where the wavelengths of the other colors are absorbed, like some energy sources. Because if the same wavelengths were emitted again, the other colors would be emitted from, for example, the magazine, and it would not just be green. Sunlight attacks the chlorophyll, then photosynthesis takes to function. Sunlight is made up of many colors. When sunlight falls against a glass prism, the prism breaks the light into its rainbow of colors. Chlorophyll and carotene are both known as pigments. Inconsistent life, the mixing of pigments, creates diverse colors. In fact, during the summer, green plants must continually create new chlorophyll to replace what has been destroyed. This creation or synthesis of chlorophyll requires not only sunlight but also warm temperatures, so you can see why fall's cooler weather encourages our trees' leaves to begin showing colors other than green. There is another substance in many leaves

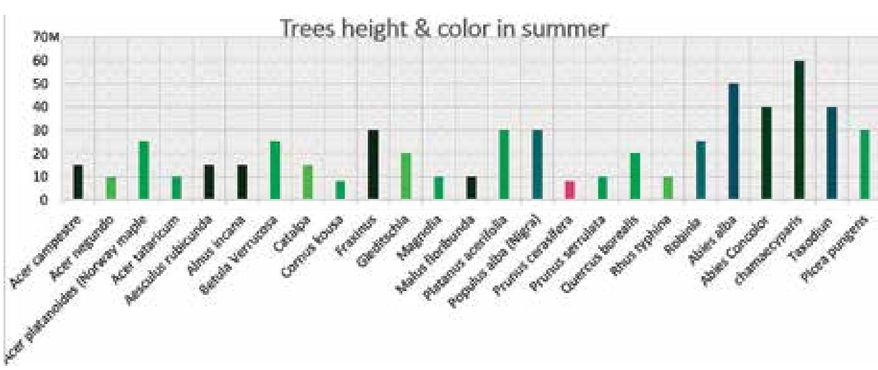

Figure 1. Different kinds of plants described by size and color in summer.

known as carotene, which is a kind of "chlorophyll helper." This is because carotene absorbs sunlight energy like chlorophyll, but instead of keeping that energy and conducting photosynthesis with it, it passes its energy on to chlorophyll, which then uses that energy to perform photosynthesis. Carotene is known technically as an "accessory absorber." Carotene holds up much better under sunlight than chlorophyll, so often in the fall when chlorophyll disappears from leaves, carotene is left behind. Flower shape and color, the flowering period for many artistic and arboreal species, the shape, color of the flowers, and the flowering period are the main criteria for choosing them [21]. The color range of flowers is quite varied, although white, cream, or yellow flowers are more common.

8. Green areas scenes and physical elements

Buildings are used as background elements or to fit, maintain, dominate, organize, or enhance the landscape features or shapes. All buildings present in a green space must be aligned with the surrounding landscape in order to achieve the unity of the building with it [22]. Harmonization can be achieved by similarity or by contrast. Designed green spaces are pavilions, kiosks, stairs, balustrades, belvedere, pergolas, trenches, columns, arches and porticos, plant stands, bridges and bridges, benches and chairs (garden furniture), sculptural groups, decorative pots, and green theater.

8.1. View scene between green area and physical elements

Pavilions are constructed with the circular, square, hexagonal, or octagonal base and designed to house visitors, orchestras, or fanfare. These can be made up of wood, concrete, or brick, in a simple yet esthetic form, is located on the Esplanade, at the edge of the water, at the end of alleys, in squares or perspective points. Kiosks are smaller pavilions, light constructions, located in green spaces. They can be opened at the top and side (with only metal bars or wood that serves as a support for hanging plants called natural kiosks and covered but open lateral kiosks). Tempered and closed side kiosks are not recommended. Implementing the semiotic (landscape language) genius with informative, technical data collected and inserted (**Figure 2**).

8.2. Adapted innovative design by landscape elements

For creating an efficient involvement on the landscape image, it is necessary to (**Figure 3**):

- conserve the major elements of the landscape by adopting the design ideas to the specific character of the site.
- involve the minor elements of the landscape. For example, intervention on the "shape" of the landscape through the following actions:
  - conserving the natural species
  - destructing the natural form

- ○ choosing the natural form
- ○ enhancing the natural form

The general scene of landscape character has to be:

- dynamic in a form
- dramatical in impression
- attractive in effect
- correspond to an architectural function
- positive effect

The relationship of contrast is the opposition to the landscape through a form of human creation in the idea of obtaining an echoing, balanced anxiety. The relationship that is required to create a contrast effect by creating stable plans, forms, with a possibility of realizing some essential points inside the composition, variation of color, light, and texture [23]. Attention is the correlation of the scale of the ensemble with that of the micro landscape. Forgetting a notion of important beautiful view, the direction of light, gravity trend should be simple. General scenes of landscape architecture have to be able to assemble many types of woody

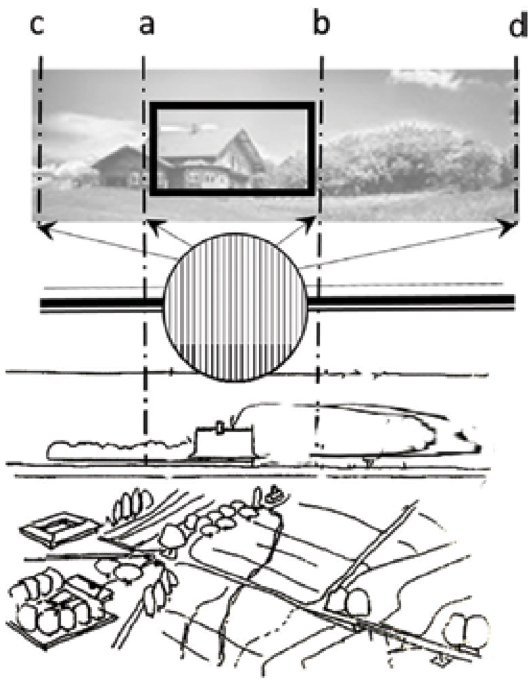

Figure 2. The configuration of a landscape architectural scenes, where (a) and (b) perspective and (c) panorama 270° (the central image is an angle of less than 90°); orthogonal view (less expressive); axonometric (present in all elements of the landscape).

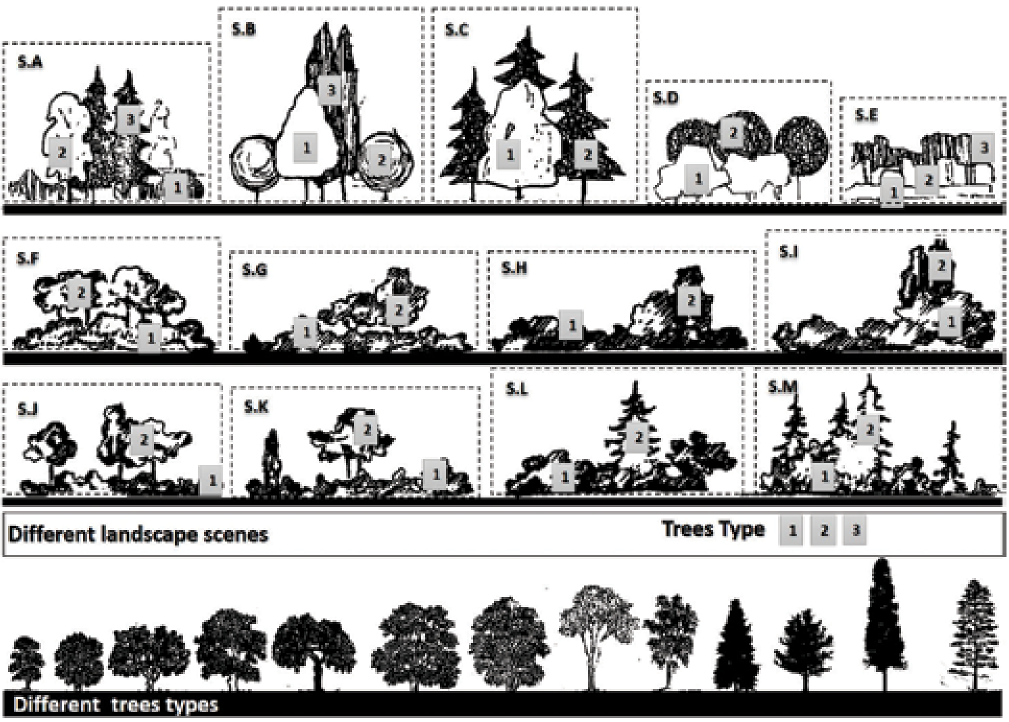

Figure 3. Different scenes of plants on landscape architecture in diverse conception.

plants, by colors, where the different kinds of plants in landscape architecture, which can create by various conceptions.

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Section 2

Art’s Replica and Landscape Architecture Model

Chapter 2

Unity and Diversity in Geometric Gardens

Kabila Faris Hmood

Additional information is available at the end of the chapter

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Abstract

There are different types of gardens; each one is influenced by time, place, and science. Gardens' design was inspired by the scientific results of a particular age. It transforms the practical need of people into beautiful edifice and provides users with comfort and convenience. Gardens are characterized by the deep thinking of geometry and beauty, as in Andalusia, Istanbul, Iran, Afghanistan, and Italy. Besides simplicity, shapes in geometric gardens have unity and diversity. These foundations can achieve harmony. Geometric gardens have a type, embodied in many models and organized by this main type, leading to common characteristics. This chapter will discuss these characteristics and their diversity with a comparative analytical study between East and West gardens to find the bases of diversity and the elements' unity. It will discuss many models of geometric gardens through the concept of type and model. The chapter focuses on many examples to test its response to specific designing elements of landscape and how it reflects its experience of designing the garden. The conclusion is based on the interactive vision type, model, diversity, and unity to find common and noncommon characteristics in geometric gardens of different places and ages.

Keywords: geometric gardens, unity and diversity, place and time, symmetry and axially, type and model, common characteristics

1. Geometric gardens introduction

In urban environment of geometric gardens, people were looking for comfortable and convenient gardens to increase the harmony of their surroundings (**Figure 1**).

Through ages, gardens had multiform, different elements, design foundations, materials, etc. This chapter will discuss the geometric gardens in a comparative analytic methodology. The chapter adopted this methodology to identify both the common and uncommon characteristics within the geometrical design type in the landscape and the design of the gardens with

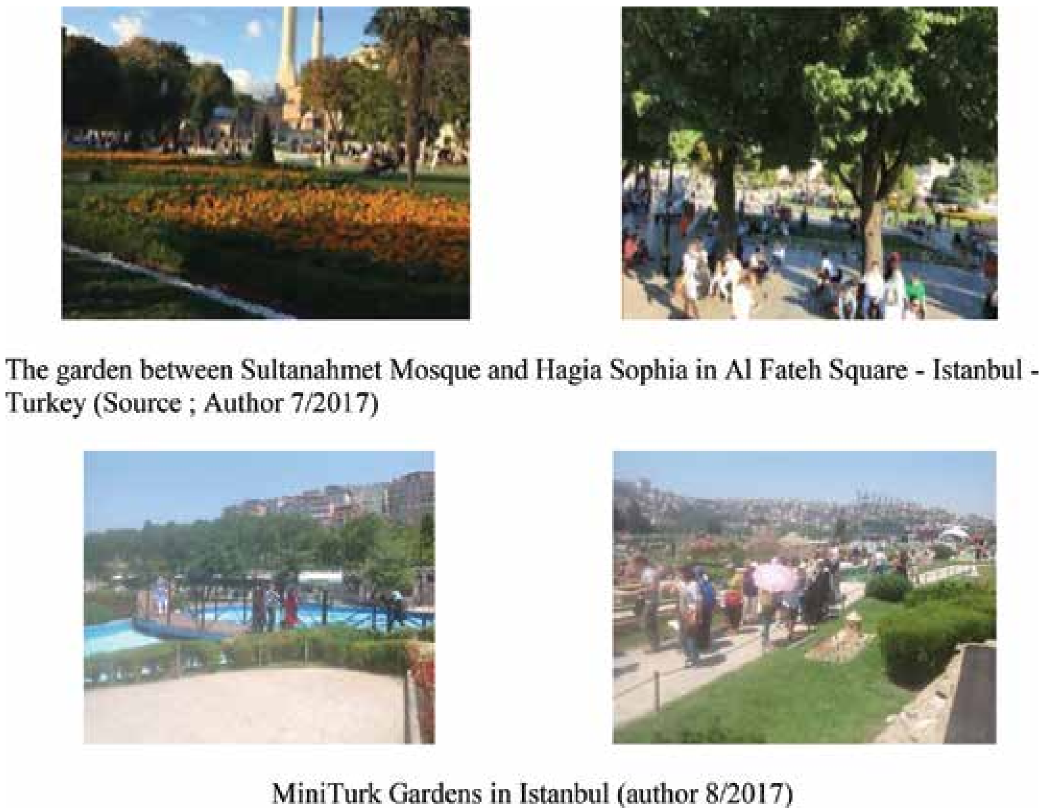

Figure 1. Models of gardens in the geometric type that provide us with comfort, the importance of gardens in the urban fabric of humans (author 2017).

different sizes, according to the differences of place and time through the comparative analytical approach. There are several systems for planning the gardens such as the regular system, the natural system, the mixed or double system, and the modern system. This chapter talks about the regular system or the geometrical system. It is one of the types used in designing the gardens that humans have a clear role in forming according to the geometric shapes along with emphasizing the principle of symmetry as one of the most important elements of this design. This type is used in most gardens in different places and times. We can see it in the pharaonic Egyptian gardens; such gardens are divided into four sections, along with water as the main element and the symbol of beauty [1]. The Persian and the Greek gardens were also classified within the geometrical type. Moreover, the most famous garden in that era was Platon's garden. On the other hand, the Roman gardens joined both the natural and geometrical type. The Greek and Roman societies considered the gardens as the most suitable places for poetries because of their esthetic elements, regardless of whether they have a geometrical or natural type.

The origin of the geometrical gardens goes back to the ancient civilizations of Egypt. The hieroglyphics gave us the historical evidence on this aspect, but we did not receive sufficient ones in Mesopotamia. These two civilizations were based on the water element, by having the Nile River in Egypt and the Tigris and Euphrates Rivers in Mesopotamia [2].

2. Type and model: diversity and unity phenomenon

This chapter will use the term geometric garden as well as the term ornamental garden given by George Plumptre for the Renaissance gardens of Europe in particular. Plumptre assures that the classical traditions of the Greeks and Romans were reinterpreted until they became the backbone of the architecture and the ornament of the garden in the Renaissance period. He also assures that the gardens of the Renaissance can be fully understood through the past 400 years, especially in the Italian Renaissance gardens. The gardens' primary prototype is shown in Medici around Florence, but its origin was in Rome in 1503 by the architect Bramante. The most prominent element in the geometrical garden was the main axis, which crosses other axes at different levels of land. It appeared as terraces, fountains, sculptures, and stairs/staircases. Bramante was not the only architect who created those gardens, but the Renaissance architects created the designs of such gardens too. Renaissance gardens were not limited to Italy but flourished in France, England, and most of the Western world. The largest gardens were in France. The size of Versailles gardens allowed Louis XIV to present himself as the absolute king. On the other hand, the French and Dutch type influenced English gardens in England, in the seventeenth century. The instinct and innate love of English people of the countryside to live peacefully with the surroundings made them less influenced by the French type [3]. The Renaissance gardens have large spaces with geometric designs. Gardens in Italy were often held on sloping ground, which made it harder to achieve the geometric type in its gardens. In Versailles gardens in France, the balance between all elements of the garden can be seen without preference for an item over another neither esthetically nor functionally. Versailles garden was designed over an area of 6614 ha. It has trees and natural and human-made lakes. What distinguishes the garden are the main axes that are perpendicular to some secondary axes, with emphasis on the main axis that achieves the symmetry in the design. The symmetrical geometrical system was adopted in the English gardens' design before the natural gardens of England appeared in the eighteenth century [4]. The question is were the Renaissance gardens the only gardens that embodied the principles of geometric ones? Alternatively, were they among the models that embodied those principles that characterized the geometric type?

The goal of all designers is to create a connection with nature through the ages. Moreover, this is confirmed by all the scientific sources. They also confirm that the first gardens were geometric and that man intervened in their formation by controlling the natural factors. So, geometry is embodied in all the elements of the natural and human-made gardens. This gives the pattern style straight or circular lines. Therefore, we can notice the symmetry even in the planning of trees and shrubs. The trees are symmetrical in rows in regular dimensions, with uniformity of the green areas and the fences surrounding the garden to take a regular shape. The climbing plants are also planted on regular geometric wooden walls [5]. As previously mentioned, the pharaonic or Egyptian garden is one of the geometric gardens that came before the Renaissance gardens. It is considered as one of the first architectural models of gardens. It was originally closed for privacy, and then walls surrounded it. Its trees are organized in geometric rows, and the water was in rectangular basins and canals. In addition to the vineyards with statues, carvings, trees, and shrubs, which were planted in ceramic pots, they were undoubtedly influenced by the design of the Mesopotamia gardens [6]. The Persian gardens were influenced by the ancient Egyptian and the Mesopotamia gardens, which were embodied later on in the Islamic gardens, especially the Mughal gardens in India. The Persian gardens (and then the Islamic gardens in Iran) were called the paradise gardens or Eden gardens. The main purpose of establishing the garden was to create a rich context to enjoy the beauty of the garden. The garden's most important feature is that it is isolated from the outside, to achieve privacy, safety, and security. [7] Despite the minor differences between the Persian gardens, which form the noncommon characteristics of these models, gardens often originated from the same structure that was imposed by the location. Most of the gardens have rectangular shapes, and they were divided into square or semisquare shapes. In contrast to the western gardens, the geometric structure of the Persian gardens does not follow the perspective principal, but it is mostly based on the integrative unity creation. The rectangular shape of the garden may change slightly in response to the different climatic conditions. The scheme of Shahzadeh-Mahan garden (in Kerman) is an example of the Chahar-Bagh pattern. It has a rectangular shape where the pavilion is located in the middle of the main water channels that define the north and the south axes. The Fin Garden (in Kashan) is also an extended form of Chahar-Bagh in a series of squares and rectangles with a pavilion and a square basin in the center. In the Chahar-Bagh garden, or Paradise garden, there are four canals of water, which usually carry the water to a central pond or fountain. These canals are considered as four rivers in paradise, filled with milk, honey, wine, and water (**Figure 2**) [8].

The Persian garden emphasizes the principle of closeness or openness to the inside (inward looking), which achieves the privacy especially in the gardens that were designed after the

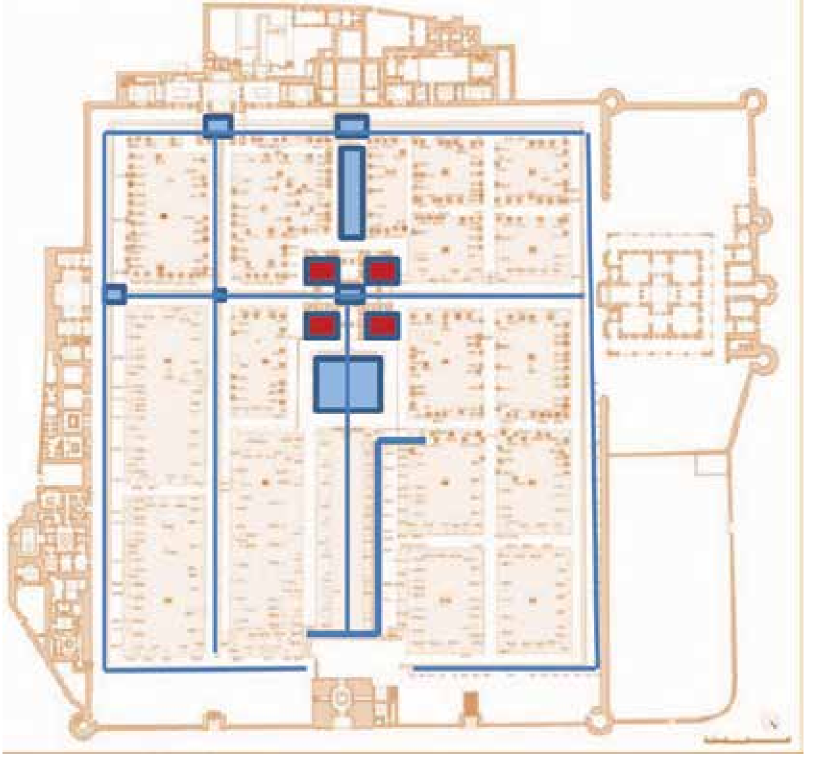

Figure 2. Geometric type in the Bagh-e Fin garden in Kashan (Iran) (author + Flickr).

spread of Islam in Iran. This design principle was to protect the garden from the outside. The creation of closed places and the existence of the broad open view without any optical barriers provide an interactive opportunity with nature. Persian gardens seek to achieve that by adopting the philosophy of trying to arrange the components in their spatial coordinates not imposing any system on the landscape [9]. The interaction with nature is a common characteristic in the Islamic city, which was integrated with the climate and nature, corresponding to the human needs in the city (buildings and open spaces) [10].

The principle of openness to the inside is consistent with the design of the traditional houses, mosques, schools, palaces, and khans, except two khans: As'ad Basha Khan, which was built in Damascus, Syria, in 1156 AH/1743 AD, and Murjan Khan, which was built by the governor of Baghdad, Ameen Al-Deen Murjan, in 760 AH/1358 AD [11]. The garden's entrance starts from a public area to a semipublic one and then to a private sector. This principle forms a hierarchy of privacy starting with the public to a semipublic or semiprivate to the private entrance and then achieving the space that is called "Hashti." Waterways usually determine the path to the monument or the endpoint. This sequence or gradient is illustrated by the height, the color, and the size of the entire garden's components (**Figure 3**).

Symmetry as a classic esthetic tool was an indisputable principle design of the Persian gardens. Different aspects of symmetry can be found in designing the central open spaces, the palaces, the streams and the irrigation network, and the type and place of planting trees and plants, especially along with the garden's axes. However, under this apparent symmetry, vegetation provides an attractive view. Although the trees and plants are arranged symmetrically, plants cannot grow equally. Therefore, we can say that the garden is a symmetrical container, but nature's elements that are in the garden are asymmetry [12]. This is the first

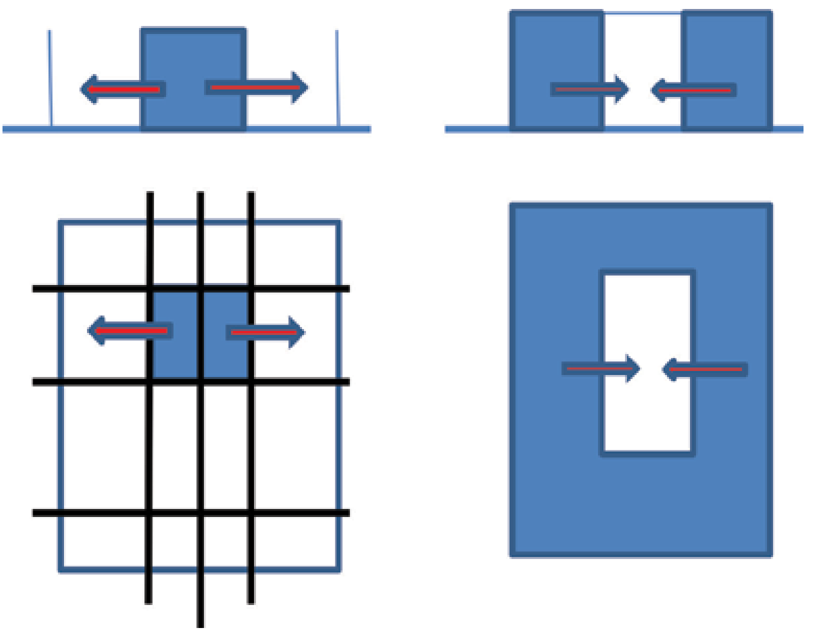

Figure 3. Privacy in models of geometric type gardens (author).

clarification of the unity and diversity phenomenon that this chapter will talk about: Mughal gardens are one of the most outstanding gardens that have contributed to the characteristics of the Persian gardens after Islam. Mughal gardens were influenced by the Persian gardens and gave them an innovative way of observing the characteristics of the Islamic gardens. The garden has a symmetrical and geometrical design, but it is larger than the Persian gardens. Mughal gardens are surrounded by palaces not centered by them like the Andalusia gardens. Therefore, they lacked the patio that was established by Islamic gardens. Their most prominent elements are water, along with the shadows to mitigate temperature (especially the Mughal gardens in India, where the most important items that developed greatly in the Islamic Mughal gardens are the intensive use of water, but they used less water in Humayun's tomb garden). Those gardens have few industrial establishments as Andalusia gardens. The garden was surrounded by trees with equal intervals, especially cypress trees. Mughal gardens were similar to the Islamic gardens by using the aromatic plants and fruit trees [13].

The Islamic garden is a reflection of paradise garden that awaits Muslims. As Ruggle sees it, it has achieved the development and diversity in forming the art that created the Islamic gardens and the landscape. All the models of the Islamic gardens have a close relation with the Islamic art, which is concerned with fine details in all fields. The Islamic garden has the Islamic spirit and a geometrical style with straight lines adorned with trees, shrubs, and flowers. It is surrounded by small fountains whose water is sprinkled in ponds and canals. Water is one of its most essential elements, which was used in various forms on the patio. Although the Islamic gardens have begun from the practical need to organize the land and enhance the yield of the land and the distribution of natural resources, they are distinctly evolving from these early agricultural efforts to the top of the beauty as in the famous gardens of Alhambra Palace in Spain and Taj Mahal in Agra [14], as well as the outstanding gardens that still exist in the palaces of the Ottoman sultans, which reflect the characteristics of the geometric type, the concept of the courtyard, the symmetry, and the pivotal. The ottoman gardens used the fountains and pools despite being located on the river banks and the Bosporus shores, as the Topkapi Palace in Istanbul, and the other ottoman palaces and the fountains that are nearby mosques like the arena fountain that lies between the two great buildings, Sultan Ahmet Mosque (the blue Mosque) and Hagia Sophia, in Istanbul. The Islamic garden was characterized by the balance between its horizontal and vertical components and between the natural, the industrial, and the construction elements. Attention was paid to colors and strong aromatic smells by choosing flowers and plants that possess this characteristic, such as roses, jasmine, and *Rosmarinus officinalis*. In general, Islamic gardens have rectangular shapes and are often divided into four quarters, and their water channels represented the four Life Rivers. The Islamic garden was expanded widely in the Islamic world from India to Morocco and Spain for several centuries. [15]

The Islamic gardens are not confined to the gardens that are in India, Iran, Spain, Turkey, Morocco, and other countries of the Islamic world. There are gardens in Umayyad and Abbasid era, which cannot be found now, but they were mentioned in poems, literature, and history books. As Samarra Gardens in Al Manqoor or Balkuwara Palace, Jawsaq Al Khaqani Palace, or Bab Al Amma (Public Gate) Palace which was built by the Caliph Al-Mutasim. It is described as the palace of the city for its large area (172 hectars). It is characterized by its longitudinal axis, which starts from the gate and passes through a large pond surrounded by gardens

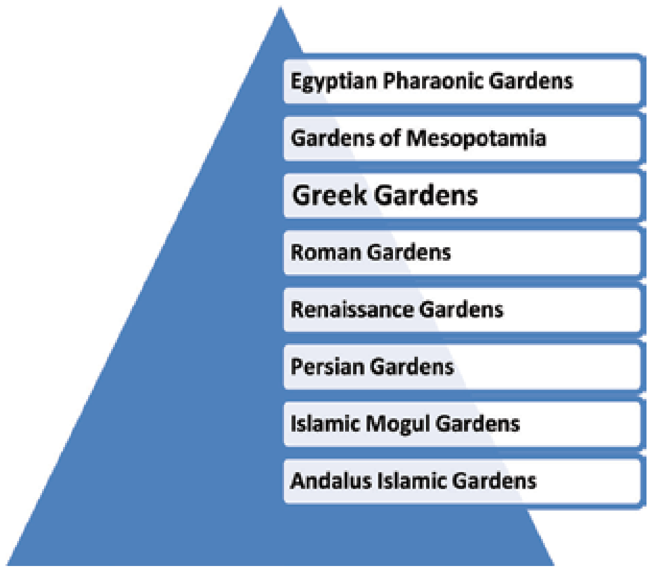

Figure 4. Geometric types of gardens with many models.

on both sides, down to the Tigris River through the pavilion. The Mediterranean garden is considered as one of the geometric gardens. So, what is the Mediterranean garden? Some say that it is just a courtyard with fruit trees and vineyards. It can be found in the countries that surround the Mediterranean Sea and enjoy a Mediterranean climate as desert climate, semi-desert climate (semidry), tropical climate, seasonal climate, and Mediterranean climate [16]. It often has vernacular features (this is what we consider as the main reason for the existence of noncommon characteristics of the geometric gardens, which lead to have a diversity phenomenon, at the time that the common features for these gardens have achieved the phenomenon of the unity). Others say that the Mediterranean garden is a place to grow plants within the temple or the palace. It has a specific area where different skills are developed to offer the ideal service for humans regardless of place or time. It was either a source of production or beauty. In the eastern gardens, there were no boundaries between these two sources. However, the western gardens were known more as a productive source and a place for enjoyment. This clear difference came from the different concept of paradise in the East and West. The diversity of employment, technologies, and the quality and quantity of requirements for designing the garden can influence and be influenced by the scale and size of the garden [17].

Andalusia gardens are considered as the ideal Mediterranean garden. They touch all man's senses: the sense of sight by seeing the lights, the shadows, and the colors; the sense of smell by smelling the fragrances of blooming fruit trees that also satisfies the sense of taste; the sense of hearing by hearing water sound; and the sense of touching by feeling the texture of garden's elements. Water is the most prominent element in the gardens, and it is essential for plant life. The black palace gardens are one of Andalusia gardens. At the turn of this century, some changes were made in Alhambra Palace in Granada, as planting plants that used to grow during Bani Alahmar time, making it 50 centimeters deeper than the pavement, so the traditional method of irrigation became easier [18]. Al Rayhan courtyard in Alhambra garden has a large pool, which reflects the dome of the sky. The courtyard is divided into a linear shape. Water reaches the basin through two marble basins located at each end. On both sides of the courtyard, there are two columns with cubic capitals that have seven semicircular arches decorated with hollow diamond shapes.

Andalus gardens were characterized by the use of evergreen and aromatic trees, such as orange trees, roses, flowers, jasmine, and violet. Alhambra gardens were considered as the most beautiful among other Islamic gardens, because of their harmony with nature and attachment to the palace courtyards that have a rectangle and semisquare shapes. Water played a great role in these gardens especially in Al Areef that has a steep slope where water comes from the top to the bottom in channels between trees (**Figure 4**) [19].

3. Common characteristics and other noncommon characteristics of geometric gardens

One of the main features of the geometric garden is the regular lines of plants, arranged in symmetrical sites and geometric designs. Plants are usually arranged in rows or other regular patterns. The architectural style of the gardens echoes the classical architecture in Greece and Italy. Although Islamic gardens were based on geometric lines, the classical influence and Renaissance had a stronger influence on the garden design over the centuries. Versailles and Fontainebleau are of the most famous gardens and were built by Andre Le Notre. These gardens are huge, but their characteristics can also work well on a small scale. The main principles of the geometric garden design include:

3.1. Symmetry

It is the symmetry that occurs on a central line, which may be a path or a garden, or over a central planting bed. In general, symmetry is achieved by having an axis that focuses on a dominant feature through a focal point that may be a statue, a building decoration with one prominent element or more on the rest of the designing elements. In the extensive gardens, we may find more than one axes intersecting each other and generating great views in multiple directions. When designing a geometric garden, the garden's space is often divided into two halves or quarters. The divisions of the garden should be large to create an extended visual impact. Water anchors, water pools, and garden paths are considered as the common features of the geometric design [20]. Symmetry is one of the most important elements of designing the Islamic geometric garden; it is achieved through the symmetry of the channel axis, which divides the space into two symmetrical parts. The symmetry in the patio or the courtyard is an important component of the Islamic garden. Symmetry can be achieved by having a high axial and the similarity of the adopted designing elements. The symmetry in the geometry gardens may be binary where the elements are repeated on both sides of the primary axis or a doubled symmetry in which the design unit is repeated several times on both sides of the primary axis or the secondary axes and can be used in medium or large spaces that were designed according to the geometric system. The symmetry may also be round or oval, in which the parts/units are repeated in a circular or oval way around a circular or oval unit in the center of the garden, and it can be bilateral or doubled. It can be followed in the circular public squares or in the gardens that have fountains or statues or any building block. Symmetry can also be achieved where the garden's parts are repeated and are all out from one circular or oval source (**Figure 5**) [21].

Water is one of the most important elements used in the geometric garden. It is the moving element alongside the presence of man, which gives the feeling of life in the garden. Moreover, the static water gives the feeling of calm and unity. Water is considered as the axis that connects the parts of the geometric garden. The form in which water is used is often associated with the climatic factors. In a humid climate, water is employed in the static form. In hot and dry climate, water is used to reduce the effect of the climate by having fountains or waterfalls or large pools. Moving water helps to soften the environment more than the static water. Water is used in geometrical design to achieve tranquility rather than excitation [22]. In the symmetrical

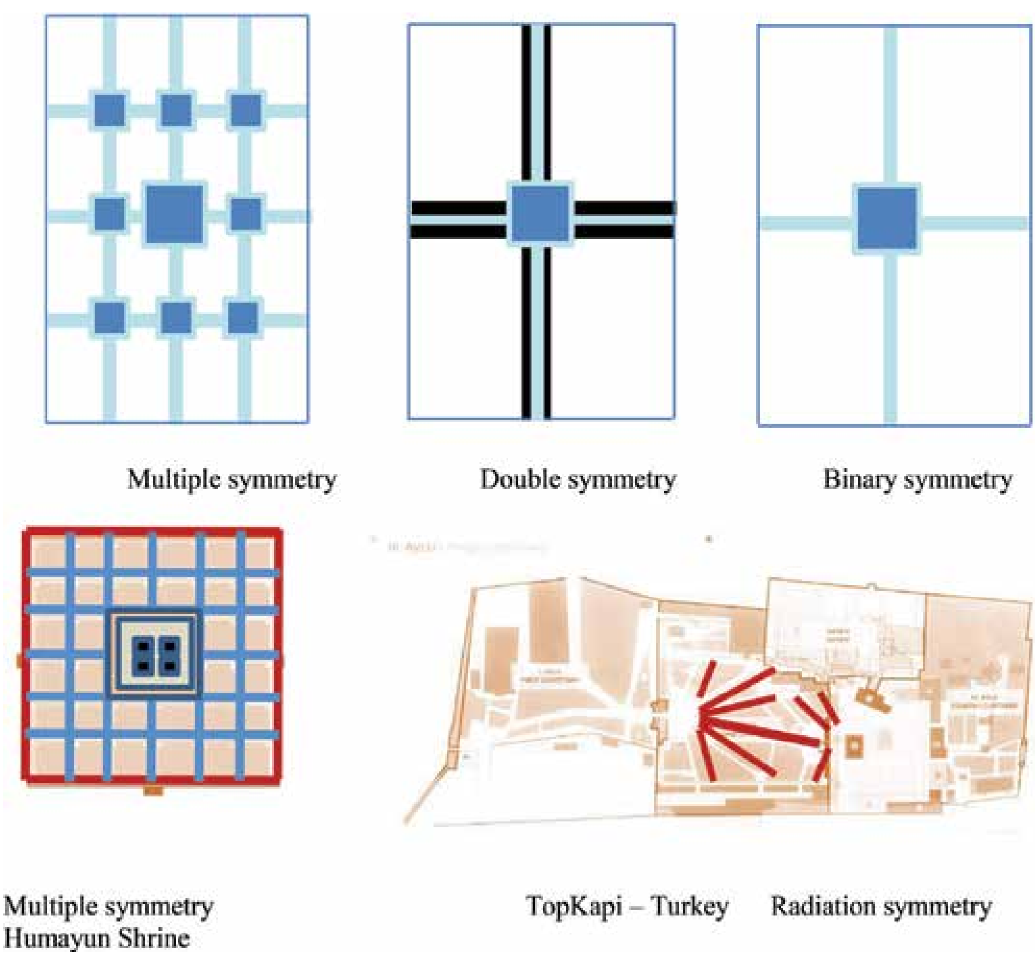

Figure 5. Types of symmetry in plans of some models in geometric-type gardens (author).

geometric system, the garden's parts are repeated around the main axis, which divides the garden into two symmetrical halves. Flower basins are on both sides of the axis in a parallel symmetrical way. Trees, shrubs, and other plants are distributed symmetrically regarding consistency of the flower colors the leave's shapes and types. This system includes planting the symmetrical trees of the same kind according to equal and regular proportions and maintaining green areas and cutting them consistently to look in regular shape. Symmetry as an important common feature of the geometric garden type can be achieved through axiality.

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3.2. Axially: which it means having one or more main axes that are perpendicular to a group of secondary axes

Each garden has its axes that depend on the garden's area. The axes are imaginary lines; some of them are main and longitudinal, and others are secondary or horizontal intersecting with the main one. Each axis has a beginning as the fountain and an end as the winning point on the opposite side. Having a submersible in the middle of the garden and a terrace overlooking the entire garden increases its beauty. What is called the main designing axis is important in designing the geometric garden type (**Figure 6**).

Water is one of the most important geometric designing–type elements that contributed effectively in achieving the axiality. In Chahar-Bagh garden in Isfahan-Iran, water axes led the visitor to the garden from its entrance to the main central pavilion and the secondary pavilion, through the turquois water channel. The Chehelsotun garden design has a square shape to focus on the pavilion that exists at the intersection of the main axis with two large pools and another secondary axis with a small pool on the west side of the garden [23].

It is necessary to concentrate on the greatness of designing the gardens that have been implemented in Iran, which have exceeded with their quality the other best similar global examples that refer to different cultures and civilizations. (Chahar-Bagh and its side gardens were previously designed before Champs Elysees in Paris and Unter den Linden Avenue in Berlin). "Shahan square" includes a regular rectangle courtyard, with dimensions of 510 × 165 m, surrounded by two-level arcades dedicated for commercial spaces. Gardens have been planted on either side of the arena, whereas the center of the garden was for the big parties of racetrack and polo, a hockey-like sport practiced on horses with long rockets and wooden balls. The new buildings of the capital were located around the arena, as "Sheikh Lutf Allah" Mosque, which is located in the middle of the eastern side of the arena. Opposite the west side, there lies "Ali Kabi" the Shah's palace, while the entire northern side is connected to the building that forms the "Bazar." Its primary activities are the following:

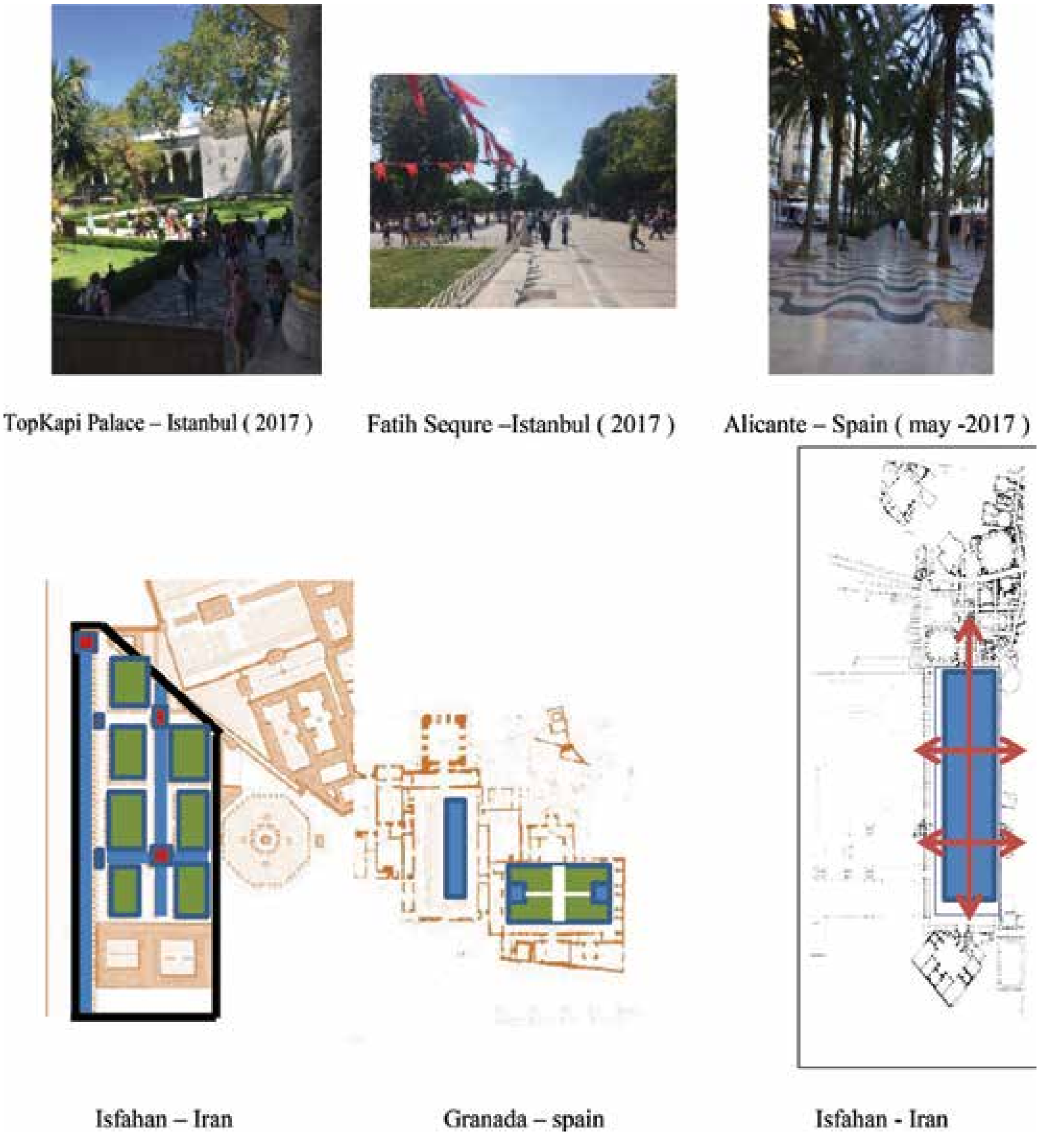

Figure 6. Axiality and high geometry in a number of geometric-type gardens (author).

Water plays a great role in this garden. It can be found in water basins in front of the main entrance of the mall, in the middle of its patio, and on both schools' channels that are located on either side of the prayer halls. The roofs of water basins reflect many sections of the building. In many cases, they double the height of its architectural elements to increase the importance of these elements and their great role in creating creative formations [24].

The ancient Persians used water in their gardens; those traditional designs in the Islamic gardens were created after Persians converted to Islam. Water in their gardens was the source of happiness. This was reflected in the geometric gardens through crosscutting channels as the traditional Chahar-Bagh garden, which made the intersection of those channels an attraction and a focal point. It is embodied in a building or a water reservoir, in an attempt to express the paradise, which is flooded with water. Water is what distinguishes the Islamic garden with its overall symmetrical scheme.

There are other examples of the use of water in designing the geometric gardens. In the Renaissance, in Lante Villa, they used the water. Moreover, as Osbert Sitwell said, water is the spirit of the garden, which is embodied in the blue fountains that reflect the purity of the sky. Water was first used in the gardens for functional reasons, like irrigation. Everything grows because they need water, but the esthetic, spiritual, and philosophical reasons for using water have been added to the gardens. Fountains and waterfalls revive plants and trees and refresh the souls and minds by meditation. In many cases, they overlap and integrate with the sculptures in the gardens. Water may be as pools and lakes with bridges to complement the esthetic landscape (**Figure 7**) [25].

3.3. Centrality

Centrality is clarified in the pavilion of the Persian gardens when the main axis of the garden intersects, as a focal point and a central area. It is emphasized through the regular tree rows that create the movement paths in the garden. In other geometric gardens, sculptures are the focal point, as gods' statues and the mythical creatures in the classical gardens (**Figure 8**) [26].

3.4. Privacy

Privacy is evident in the geometric gardens that have been fenced by the wall or adopted the idea of the patio or the courtyard. The Andalusia gardens and the Ottoman palaces adopted the second style. However, the first style can be clarified in the Persian and Islamic Mughal gardens. One of the unique features of Persian gardens is that they are fenced. The layout and structure of the Persian garden make it a walled garden, enclosed by walls to provide the mental picture of paradise in the heart of the deserts to be protected from strangers. The function of these walls was not only to create borders but also to act as an insulator between the hot, dry outer area and the inner green area, interior shaded area and semiparadise (**Figure 9**) [27].

The symmetry is achieved by having a high axial and the similarity of the adopted designing elements. The symmetry in the geometry gardens may be binary where the elements are repeated on both sides of the primary axis or a doubled symmetry in which the design unit is repeated several times on both sides of the primary axis or the secondary axes and can be used in medium or large spaces that were designed according to the geometric system.

The symmetry may also be round or oval, in which the parts/units are repeated in a circular or oval way around a circular or oval unit in the center of the garden, and it can be bilateral or doubled. It can be followed in the circular public squares or in the gardens that have fountains or statues or any building block. Symmetry can also be achieved where the garden's parts are repeated and are all out from one circular or oval source.

The Islamic gardens in Iran and India are the largest Islamic gardens that still have walls for privacy. In the past, the garden was part of the building in the courtyard model garden, and then the building became part of the large garden.

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Figure 7. Water in geometric-type gardens in Turkey, Spain, and Iran.

The Alhambra Palace can be divided into two large suites: Qamaresh Pavilion with the Ambassadors' Hall and Qamaresh Tower, which is above the hall. Moreover, the Lions Pavilion which the Lions Courtyard and a beautiful Lions Fountain in the middle of the lobby center. On the round marble basin of the fountain, there are twelve marble lions, where water comes out from their mouths according to day and night hours. The Lions courtyard is designed according to the perpendicular axes type, clarified by having two water channels that meet the courtyard fountain. They extend into the hallway arcades that surround the courtyard from the four sides, the channels in the arcades and with small fountains that have low basins. Al Rayhan courtyard and Patio de Alberca centered by a pool and shaded by beautiful basil trees are also there.

Figure 8. The main axis and the focal point in gardens. Photo by: Author 2017.

The courtyards are important parts of the Islamic garden, especially in the palaces in Andalusia and Turkey, including the Abbasid palaces in Iraq, where there are multiple courtyards for having multiple buildings within one place.

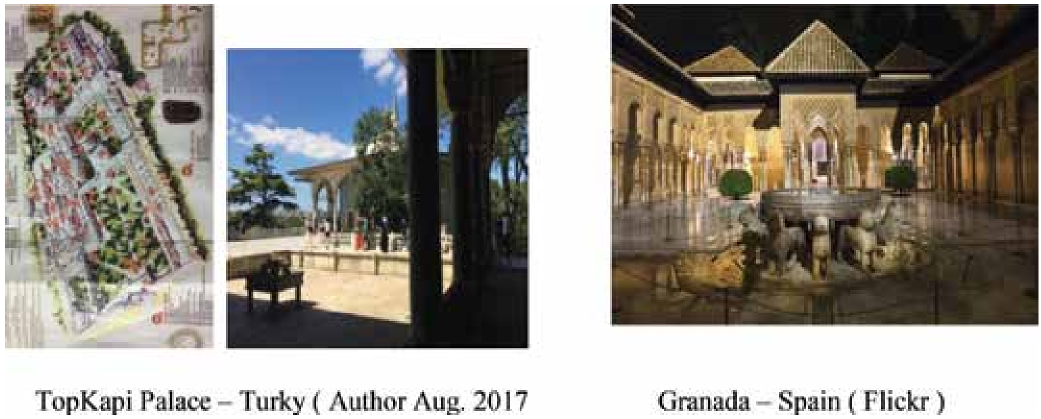

Figure 9. Patio or courtyard in the geometric-type gardens in Turkey and Spain.

To achieve privacy, it is important while planning the garden to identify it, by creating a view that isolates it from differences of opinion so the view will be limited only to its content. Plants or walls fence the garden. In some cases, the design requires isolating the design's elements from each other to attract attention to its contents. This can be achieved by building a regular fence in the garden or by using a group of trees and shrubs to block the natural garden behind it. Thus, an isolated and independent place is identified to represent a certain character in the garden, but it is associated with the rest of the garden [28].

3.5. Harmony and balance

Harmony is achieved by linking two elements of the design, or each item with elements. Harmony is like plants, trees, shrubs, colors, and other materials. The difference of the plant's nature or its growth leads to the contrary. The choice of inconsistency or compatibility in designing gardens depends on the location and the importance of the designing element. If trees and shrubs are planted in a nearby area, it is preferable to be compatible. If planted at the end of the garden's boundaries, their inconsistency should be observed to attract the attention. Inconsistency maybe observed to show the importance of a particular component as the focal point in the garden.

Harmony is achieved by replicating some components of the garden's design, in the same system with a rhythm. Replicating the elements of the design of the symmetrical geometric garden is necessary. Diversity requires the use of frequency replicating. This is also used in designing the asymmetrical geometric gardens and nature landscape.

In the Persian gardens, harmony was used in various forms in organizing and designing the gardens' components, such as the types and locations of the green landscape, duplicating the geometric shapes between the natural and architectural elements, in the use of fountains, pools, floors, and in designing the walls around gardens. Moreover, integrating vertical linear of trees with the horizontal linear of waterways and pathways provides a harmonious rhythm in the gardens [29].

Along with the harmony between the components of the garden's design, there should be a clear proportion between its parts to achieve balance. Proportion is a general phenomenon in the universe and is one of the most important elements of esthetic values. It uses the language of mathematics and geometry, to create musical harmony through its rhythm, in an attempt to form harmonic relationships [30]. Proportion plays a great role in designing and planning. The proportional systems take into account the relation between the whole with the part and the part with the other parts. The garden must have a balance between its parts and components. All parts of the garden must be balanced around the axes. The balance is identical in the geometric gardens. To give the sense of balance, both of them should be equal in attracting the attention. They may not be equal in numbers, but their effect must be the same.

3.6. Scale

Scale varies according to the area of the geometric gardens and the scale of its natural or industrial components. Scale and proportion are important factors in making a successful design because they affect the cluster size, the road's width, and the height of the plants. If the garden has small size and space, the designer must design it in a way that makes it look bigger. The measure of each part is related to the other part as well as the human's scale to be suitable for human's use [31].

Finally, in geometrical style, gardens are united by their centrality and symmetry. However, they vary in the simple geometric shapes, the adopted symmetrical type, and the parts that are used as a focal point such as plants, trees and their fruits, the ways of using the water, materials, colors, scales, size, and the existence of the courtyard for privacy. With this unity and diversity, all the elements work separately to fulfill the garden's purpose and to develop the interaction between man and nature by adopting simplicity. This helps to achieve the unity and the balance between the garden's size and the natural or industrial element assimilation, without forgetting the idea of diversity that increases the esthetic value of the garden and keeps it away from boredom (**Figure 10**).

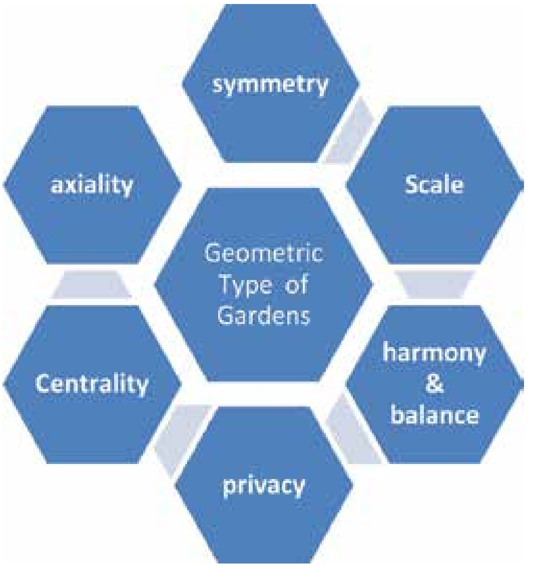

Figure 10. The main common key principles and characteristics for design of geometric gardens. Source: Author.

4. Conclusion

By reviewing studies of the adopted types in designing gardens, the researchers found that there are multiple types of designing the garden and the open urban spaces within the city fabric or the buildings within the city, for example, the palaces, mosques, shrines, schools, etc. Four types determine them: the geometric, the natural, the double or mixed system, and the modern one. This research focuses on the geometric type of gardens and landscape (the geometric type). It is a type in which man has a clear role in designing, despite its compatibility with climate and natural environment. It often appears with straight or circular lines in geometric shapes without reducing its beauty, peace, and security that man enjoys. Those were associated with many models of this type by the idea and the philosophy of paradise that man yearns for in different times, places, beliefs, customs, traditions, and cultures.

The origin of the geometric type of gardens goes back to thousands of years (BC). It is part of the achievements of the ancient civilizations of Egypt and Mesopotamia, the classical Greek, Persian, and Islamic civilizations, the Islamic gardens including Mogul Gardens in India, the Gardens of Spain, the Gardens of Iran or Turkey, and gardens of all western countries and especially the European countries.

The researcher referred to the term of "ornamental gardens." In studying the geometric type of the garden, it was found that the ornament was one of the different characteristics of this kind. Perhaps, it is more relevant to the European Renaissance gardens, or unclear in the other models of this sort, or none of them in others.

Repetition was one of the methods that were adopted in the geometric type to make all or some of its characteristics common. The different features contributed in achieving the main idea of separation, which emphasizes the existence of unity along with diversity in the geometric types of gardens.

In the regular geometric type, the various components of the garden are replicated with a focal point that is dominant without compromising the compatibility and harmony of the garden's elements. The rhythm achieves a clear hierarchy and proportion between its parts because of its importance in achieving the balance and the harmony in colors. Symmetry, axiality, and centrality are important in forming the principal keys of the geometric type, as well as privacy that was evident in the geometric type of gardens. However, the means of achieving privacy varied among the models of that type, because of the existence or the absence of the courtyard. Alternatively, perhaps it achieved by adopting other methods, as using fences or isolating the garden from the surroundings in different ways. The geometric-type gardens are also varied in scale, size, and space for various reasons (**Figure 11**).

The chapter dealt with the fundamental principles of the garden. However, water is one of the elements and the designing means of producing geometric-type gardens. It focused on water because it had practical, philosophical, and intellectual dimensions, so it is a means and goal at the same time.

Gardens are united by their centrality, symmetry, and axiality. However, they vary in the simple geometric shapes, the kind of the adopted symmetry, and the means by which the

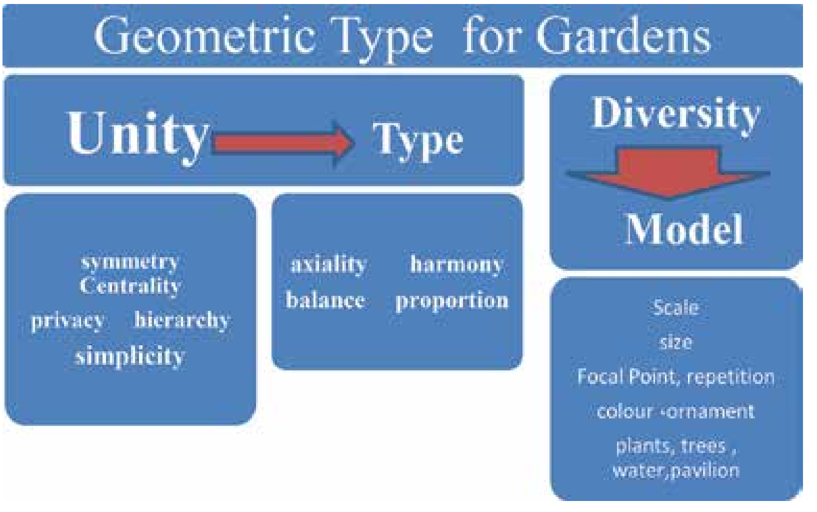

Figure 11. Unity and diversity in geometric gardens (types and models): common and noncommon characteristics. Source: Author.

models of these gardens match their centrality or symmetry or axiality. What vary also are the elements that are used as a focal point, plants, trees, and fruits, the ways of using water, materials that are used, colors, scale, and size. With all this unity and diversity, all elements work separately to achieve the purpose of the garden and the development of the interaction between human and nature, without neglecting the idea of diversity. This increases the esthetic value of the garden and keeps it away from boredom and monotony. Diversity achieves models within a specific type to emphasize the idea of type and model.

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Chapter 3

Mobile Eye Tracking in Landscape Architecture: Discovering a New Application for Research on Site

Dirk Junker and Christian Nollen

Additional information is available at the end of the chapter

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Abstract

This chapter presents the process of establishing a laboratory for mobile eye tracking focussing on real-world, open-space environments within the field of landscape architecture at the Osnabrück University of Applied Sciences (D) as well as the latest results from the feasibility study 'Point de Vue', which defines the basis for qualitative interaction analyses in landscape architecture. Eye tracking is a tool that has been used extensively in the domains of psychology, marketing, usability and user experience in remote and mobile applications, but has rarely been used in real-world open spaces because of technical limitations. To check the possibilities of mobile eye tracking as a new application in open spaces, several exploratory tests and a feasibility study with long-term experiments have been carried out in urban settings as well as in world famous parks such as 'Grosser Garten' in Hannover (D) and 'Stourhead' in Wiltshire (GB). These experiments have shown extraordinary results that enable us to use mobile eye tracking as a new tool in open space research to gain knowledge about how people act, react and interact in open-space environments. Being able to see and understand what catches one's eye and the response to it will be a guide to better design.

Keywords: historic parks, landscape architecture, mobile eye tracking, usability, landscape analysis, human behaviour, urban planning, open space design, user experience, UX, Stourhead, Grosser Garten, Point de Vue, interaction, common shared experience (CSX), path-related interaction protocol (PrIP), eye tracking collective (ETC.la), qualitative interaction analysis

1. Introduction: What do you really see?

How interesting would it be if we could look through someone else's eyes and get directly inside their mind? The movie Being John Malkovich [1] gives an idea of how it would be to see the world through the eyes of another person and get a deeper understanding of their actions and even their thoughts. Mobile eye tracking (**Figure 1**) is able to realise this to a certain extent and gives us first insights. Therefore, it is broadly used to study human behaviour in marketing and usability research, and it is a unique method for documenting instant interaction with a stimulus. What do people see? How do they act or react to what they see? What makes a person interested in or spend time at a specific place or makes them leave when bored [2]? All these questions were important to guide this research in landscape architecture and to understand the difference that mobile eye tracking can make if used as a tool. The basic question is whether this new mobile technology can provide the possibility of being an invisible companion to a normal visitor to an open space and to understand his behaviour and reactions. Besides several content questions, such as the testing of design concepts or the identification of 'good places', the evaluation of its feasibility was the main focus. Crucial for that was the development of experimental as well as evaluation methods.

The acquired knowledge is the sum of results (answering the research questions), insights (based on the broad documentation of interactions) and a general understanding of the research area through spending time in the landscapes and interviewing visitors. The essential result and a basis for further studies is the developed, experimental method 'common shared experience' (CSX) which allows an unobtrusive look through the eyes of the subject. The verbal mood map (VMM) as well as the path-related interaction protocol (PrIP) were developed as evaluation methods. These detected salient spots for profound analysis processes in the research area.

Anticipating the results of the research project 'Point de Vue' (see Section 4), it can be said that visitors to historic gardens and parks behave differently than the planner predicted and that even those historic gardens are changing over time. Interaction analyses not only confirmed traditional viewpoints in the Stourhead landscape garden ([3], p. 217) but partially defined new viewpoints and also landscape windows, which are subtle lookouts.

Figure 1. Mobile eye tracking in Stourhead landscape garden. National Trust, Steve Haywood (2016).

2. No future without roots

The ‘Eye Tracking Collective’ (ETC) is an interdisciplinary research association established at the University of Applied Sciences in Osnabrück (D) in 2015. Founded and coordinated by the authors of this chapter, the main issues are international research projects and academic teaching. The disciplinary section in the fields of landscape architecture and urban planning is the ‘Eye Tracking Collective.landscape architecture’ (ETC.la).

After first getting into contact with mobile eye tracking research through Prof. E. Fujii (Chiba University, Japan), the group started with the overall support of the Faculty of Agricultural Sciences and Landscape Architecture to focus on the research of human behaviour in real-world environments under non-laboratory, outdoor conditions to get as close as possible to a realistic insight. Two master theses started the process and compiled essentials for eye tracking research in landscape architecture [4] and tested the capability of mobile eye tracking in open-space research [5]. A next step was to discuss research approaches within the discipline of landscape architecture [6] and with other practitioners and scientists working in other complex, real-world environments.

After the ETC.la was established and equipped with a mobile, outdoor lab for field studies, the first study ‘Point de Vue’, funded by the ‘Sievert Foundation for Science and Culture, Osnabrück’ led by Prof. Dr. Hans-Wolf Sievert, enabled a jump from small scale to large scale and the development of new methods [7]. One of them, the ‘Common Shared Experience’ (CSX), is described in the following chapter. The Sievert Foundation supported this research investigating the application possibilities of mobile eye tracking in landscape architecture. ‘Point de Vue’ aimed to check whether mobile eye tracking was a proper, on-site research application in open spaces and defines the basis for future qualitative interaction analyses in landscape architecture.

3. Technical aspects of mobile eye tracking and method combinations

The eye tracking glasses (ETGs[1]) consist of a scene camera which films nearly all of the subject’s visual field and overlays it with an infrared-based measurement of the pupil’s position to produce a gaze video. Eye movements are measured at a frequency of 60 Hz by two infrared cameras implemented in the spectacle frame [8].

It works together with a smartphone recording unit (**Figure 2**) and therefore provides virtually unaffected mobility to the subject. This is fundamentally important for field studies ensuring a high ecological validity. The individual gaze videos are assembled and evaluated by a special software for educational and scientific use (BeGaze 3.7), so that researchers can review and thereby understand what the subject is doing and get insights into why the subject is doing

[1]Version: ETG 2w by Senso Motoric Instruments (SMI).

Figure 2. ETG and smartphone recording unit. Detlef Heese (2017).

it. In addition, the sounds of the environment and the subject's conversations are recorded so that gaze videos can be regarded as a documentation of a multi-sensory experience.

Made for real-world environments and meanwhile applicable under sunny weather conditions, ETGs measure the durations and spatial distributions of the eye's fixations. The scene camera additionally documents the surrounding conditions with its overall atmosphere and disturbances as well as the subject's movement, sounds, utterances and other interactions. With these approaches, it is possible to analyse the subject itself, the object and the interaction between both. The possibilities of qualitative and quantitative analyses and interpretations of these massive datasets will be explained in Chapter 4 by reference to small scale, exploratory tests and the feasibility study 'Point de Vue'.

The outdoor lab (**Figure 3**) is also a part of the technical equipment for mobile eye tracking trials. First tests showed a necessity of having an obvious start and endpoint, which unobtrusively fits into the environment but with an appealing character for potential subjects. A weather-resistant tent with foldable furniture as a workspace for the researcher and room for information and ETG setups proved to be appropriate equipment.

Figure 3. Outdoor lab in Stourhead. ETC.la (2017).

Besides mobile eye tracking as a research method in itself, there is a need to combine it with various other methods because 'eye tracking can't answer all questions ([9], p. 97)'. The interrelationships between complex research questions in disciplines like user experience (UX) or usability and a recommendable mix of methods were described, inter alia, by Bojko [9] and Holmquist et al. [10].

Figure 4 describes a combination of methods utilised in the fields of applied research where collected data can be separated into two domains: verbal and technical data. The technical data is considered as passive because it measures the body's responses, whereas verbal data always requires the spoken word of the subject or observation skills of the researcher. Thus, verbal data collection as described in **Figure 4** always has constraints in its ability to express or to observe something. Well-discussed method combinations supporting eye tracking studies are think aloud (TA) or retrospective think aloud (RTA) protocols [9, 11], which both have their individual side effects on data quality or ecological validity. The ETC.la method of dealing with this is the CSX. Subjects are not separated from the group they arrived with in the park or in the research area. Subjects are generally not given a task or a predetermined route to follow. Instead, subjects are asked to spend as much time as they want and are not limited in movement. Subjects tend to behave normally after the first few steps in an interesting, impressive and often cognitively demanding park such as Grosser Garten or Stourhead and this is what the CSX aims for. Examples for normal subject behaviour are the reading and writing of private messages on mobile devices, children running, playing or climbing on trees or subjects spitting on the ground without feeling caught in the act (although they are), to name just a few.

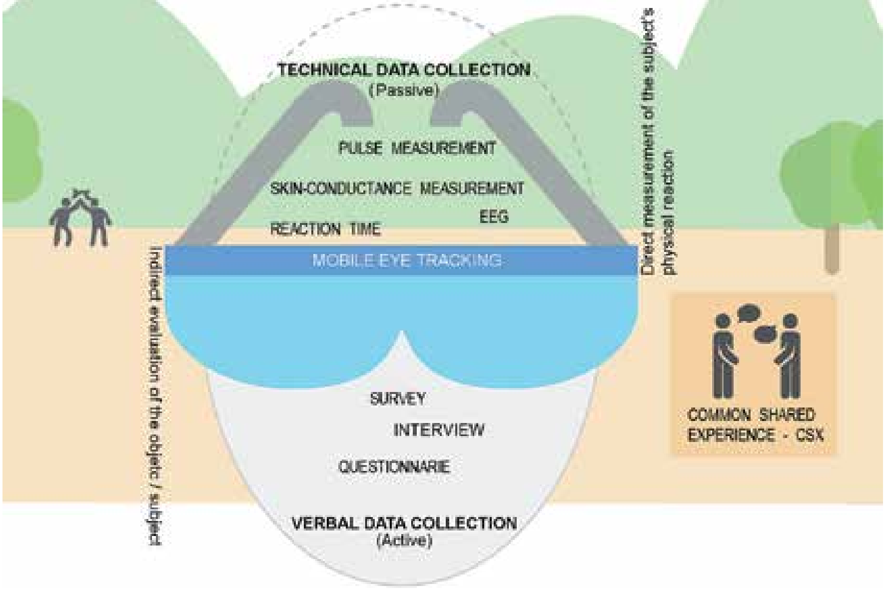

Figure 4. Mix of methods. ETC.la (2017).

With verbal and technical data collection, it can be assumed that ETG is a beneficial tool for real-world research with a high demand on ecological validity because they both provide and combine gaze videos with documented auditive and visual signals beside measured eye metrics.

4. Mobile eye tracking in landscape architecture

Mobile eye tracking is not a new technique and is frequently and standardly used in medicine, psychology, usability and UX or disciplines such as reading research. All of these different eye tracking applications have their justifications or origins in the endeavour to heal or understand humans or to improve a product, meaning an increase in sales figures. Both have a measurable positive effect on public health or economy. Another aspect of eye tracking is that it is usually applied in controlled environments with a defined group of subjects to achieve valid results and that the majority of studies deal with stationary (remote) eye tracking. This is because, beside other reasons based on the individual research design, data collection and analysis can be processed standardised or even automated.

However, landscape architecture has different demands on generating scientific knowledge. Basically, there are not many eye tracking researchers in natural or urban environments and only a few of them conduct mobile eye tracking trials. An overview of mobile eye tracking studies in real-world, outdoor environments with a strong relation to landscape architecture is given in Nollen [5].

> *'Similar to most studies in the field of empirical aesthetics, the current study only recruited (psychology) students whose intrinsic motivation to see the artworks in uncertain. This approach guarantees homogeneous samples […] and facilities the control of level of art expertise. Nevertheless, further studies should be conducted with spontaneous art museum visitors to raise the level of ecological viability and enlarge our knowledge about art experience in the museum.* [12]'

This quotation is exemplarily for a growing demand for out-of-the-lab studies and shows that the focus in future studies should be more on the ecological validity. This approach provides a guideline for mobile eye tracking research in landscape architecture as presented in the following sections.

4.1. Exploratory tests

The master thesis 'Mobile eye tracking in Landscape Architecture - Empirical testing of its capability as a new data collection method' was embedded in the long-term establishment process of mobile eye tracking in landscape architecture and the implementation of the ETC. la. All tests were conducted with ETG version 2.0 and were exploratory tests to test the glasses' applicability and limitations concerning sunlight, darkness or moving artefacts as well as basic information for designing future research designs including timelines for data collection and the very time intense analysis of gaze videos. The following subsections present two tests examining inner-city, fear-of-crime situations at night and the awareness of different service levels on pruned *Prunus laurocerasus* [5].

The following insights have not been deepened since the presentation of the master thesis and have never been presented before. Thus, this is a possibility to present and to discuss those approaches for the first time regarding mobile eye tracking as a purposeful method for developing planning guidelines for these topics.

4.1.1. Fear-of-crime causing elements at night

The objective of the experiment was to analyse the behaviour of female pedestrians in a street in the old town of Osnabrück (D) and to better understand the inner-city fear-of-crime causing situations at night using the mobile eye tracking as a data collector. The borders between subjective insecurity and fear vary broadly. This trial was an exploratory study aiming to check if there are indications for a possibility to learn about those phenomena.

(In-)Security is based on social structures, which are clustered by space, sex and power [13], whereby the material environment influences the fear of crime, for example, the brightness, structure and arrangement of objects can sometimes create a feeling of insecurity which can sometimes hardly be empathised with by men [14]. Other aspects to describe a situation are atmosphere and perception, which are closely related to personal moods and can change instantly at dusk and at night [15].

As far as is known, Guedes et al. [16] are the only ones following similar ideas to the authors but based on remote eye tracking with the presentation of stimuli on monitors. 'Fear of crime has been defined as a negative reaction to crime or symbols associated with it […]. Fear of crime (as the crime itself) has an unequal spatial and temporal distribution […]. The hot spots of crime and hot spots of fear of crime do not always overlap […]. Several authors point out the incivilities - […] such as graffiti, litter and vandalism - as having a negative impact on fear of crime […]. Blocked viewpoints where potential offenders can hide and/or areas with blocked escape are associated with fear of crime […]. Also, the lack of lighting is one of the greatest cue associated with increased fear ([16], p. 42)'.

Regarding the study area, litter, obvious vandalism such as peeled off bark or graffiti, corners, parked cars, entrances (to houses and gardens), shrubs and trees were determined to be eight potentially threatening objects/situations out of a total of 24 areas of interest (AOIs). Those eight are marked with a black dot (**Figure 8**). Recruiting participants was critical; only women were asked to take part and potential subjects were only recruited at the starting point. It was important not to recruit subjects elsewhere. They should be part of the scenery to increase the ecological validity of this study. Recruitment and conduct of trials took part during seven nights with good weather between 10:30 pm and 0:30 am. Recruitment proved difficult and led to only five participating subjects (N = 5) with sufficient local knowledge to find their way to the destination without the help of maps. All trials were conducted in addition to an RTA based on the recorded gaze video to better understand the relationship between gaze direction and emotion. In reference to Guedes et al. [16], the chosen route was no crime hotspot, neither in the crime statistics nor in the cognitive maps of the subjects.

Figures 5–7 present screenshots with heat map visualisations of approximately 1 s duration. They illustrate how the subject's gaze jumped from one object to another. Most interesting

Figure 5. Fixations on dark shrubs. BeGaze (2015).

Figure 6. Fixations on potential entrance. BeGaze (2015).

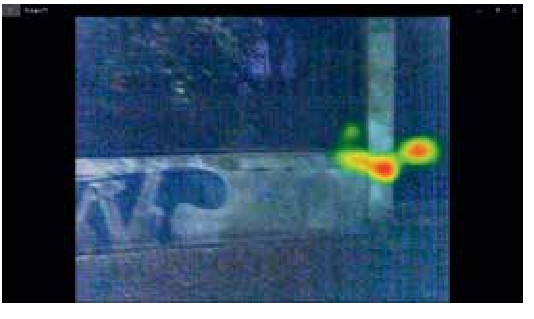

Figure 7. Revisit on garden door. BeGaze (2015).

are long fixations (dark red) or revisits, when a subject looked back at an AOI after exploring another. Revisits are crucial details in gaze videos and are a good way to identify salient situations because looking back after passing the garden gate shows the interest towards an object, and it is possible to interpret how the subject feels: doubt, fear, insecurity, and so on. By defining AOIs and creating a reference image, it is possible to code the recorded fixations and to get numeric results for proportions of looks at each AOI based on chosen parameters such as fixation duration (total or average), number of revisits or individual key indicators.

By watching the gaze videos (recorded with the ETG), it is possible to analyse and interpret relevant fixations on objects or situations. Instances of fixations on situations can be brief fixations on objects with the head turned to the left while turning right at a junction. This leads to the insight that, besides a conventional analysis based on reference images with manifested AOIs, 'Emotional Referencing' (ER) could be an alternative way to gain results. Fixations could easily be referenced to the AOIs as a 'surprising situation', 'threatening situation', 'neutral situation' or 'possibility for social interaction' leading to similar results in comparison between different researchers.

Answering the research question whether fear-of-crime causing elements can be revealed by mobile eye tracking, different procedures have been trialled. The abovementioned ER did not lead to a result because it lacks accuracy and has no link between time and space. However, it does help in understanding the emotional states of the subjects. Even focus maps as a tool to qualitatively analyse AOIs did not lead to a conclusion. Furthermore, standard parameters such as revisits and total or average fixation duration were analysed but were not useful either. Only by calculating the AOI-specific key indicator of total fixation duration divided by quantity of revisits (**Figure 8**), results can be obtained.

Knowing that every revisit means a further glance at an AOI with one or more fixations, it is remarkable that the highest value is on shrubs with 554 ms per glance. This is followed by the art object (524 ms), trees (499 ms), entrances (440 ms) and cars (430 ms). These encompass four of the determined potentially threatening objects. Considering incivilities and corners are hardly looked at, one can assume that the evaluated key indicator is able to identify fear-of-crime causing objects. The reason why the art installation has such a high value might be because of its

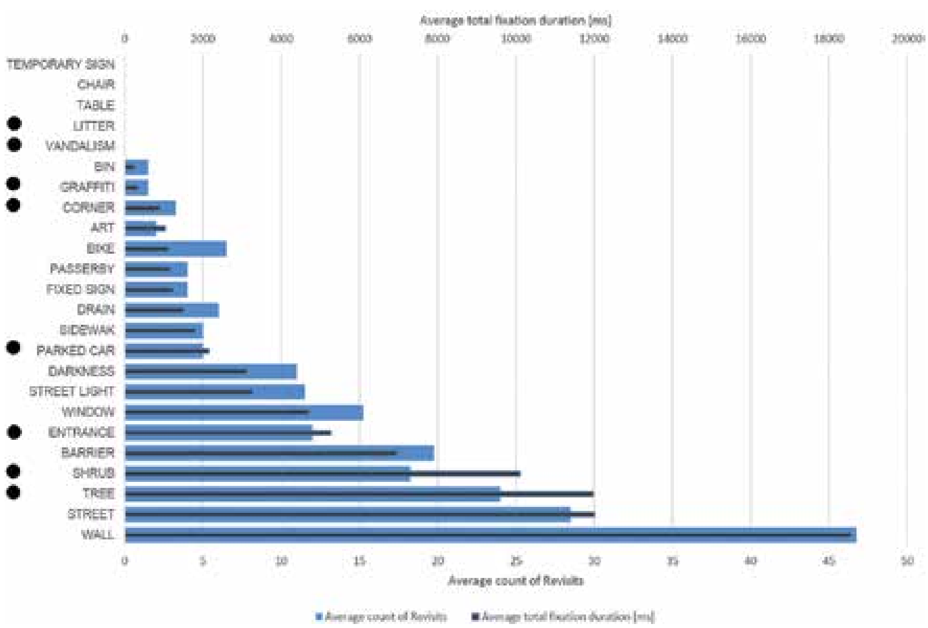

Figure 8. Key indicator for fear-of-crime causing elements. ETC.la (2015).

shape. A 3-m high figure is a potential hiding place, which was not considered to be such when defining the marked threatening objects.

It was soon recognised that investigating qualitative details such as key indicators does not provide the necessary general understanding of human interactions in open spaces. Although research questions were answered by this, it is still very important for the entire research project to qualitatively learn from the gaze videos and to comprehend how different subjects behave in order to synthetise insights and findings.

4.1.2. Maintaining public green spaces based on the users' awareness

This test study sought to investigate the users' awareness of different quality levels of pruned *Prunus laurocerasus* (Prunus l.) in one of the most important entrance areas to the campus of the Faculty of Agricultural Sciences and Landscape Architecture at Osnabrück University of Applied Sciences. This campus is called the green campus due to the study programmes on offer and its appearance as a grand park. The main structures on the chosen square are a fountain and six circular plantings of Prunus l. of approximately 6 m in diameter, each of them with a tree with pinnate leaves providing a smooth shadow. Three of those Prunus l. circles have not been pruned for a period of time and have grown up to 1.60 m, whereas the other three are nicely cut to a height of 80 cm (**Figure 9**). This square was chosen because students tend to meet there before entering the campus and a common behaviour, waiting there for somebody, can be observed. This is of importance for the trial.

The subjects were students from the campus from 11 different study programs, different sexes and ages with an average age of 25.3 years. Vision was corrected to nearly normal by adjusting correction lenses on the ETG. All trials were conducted in addition to an RTA based on the previously recorded gaze video to better understand relations between seeing and recognising. All subjects (N = 15) were spontaneously recruited in 2 days with a recruiting rate of approximately 60%. Subjects were asked to proceed alone to this well-known square as a phase of familiarisation with the ETG. They were told that the researcher would approach

Figure 9. Pruned and unpruned *Prunus laurocerasus*. ETC.la (2015).

them there to give them the task for the trial. After 4–5 min, when the subject was obviously bored, the trial was stopped.

The phase of boredom was important for the trials because it was an incidental investigation of what subjects do when bored and whether mental states shifting from boredom to searching could objectively be defined by different researchers.

Answering the main research question if there is a difference in the awareness of users towards different quality levels of pruned Prunus l., the results seemed to contradict what only becomes clearer when quantitative and qualitative results are combined. The quantitative results indicate a preference for pruned Prunus l. represented by a higher fixation rate (4.65% compared to 3.73% on unpruned Prunus l.), a higher average fixation duration (222 ms compared to 122 ms on unpruned Prunus l.), a greater number of revisits (8.4 compared to 6.2 on unpruned Prunus l.) and a total fixation duration over all subjects of 57.594 ms which is 2.25 times longer than on unpruned Prunus l. Only the sequence shows a different image: over all subjects, the unpruned Prunus l. was the first AOI to be looked at followed by the pavement, tree trunks, tree crowns and pruned Prunus l., on rank 5, followed by the rest of the defined 26 AOIs.

The result of the RTA is that only five subjects (33%) mentioned the Prunus l. but without naming differences between pruned and unpruned ones.

Against the background of the research question, it is remarkable that pruned Prunus l. were regarded more frequently and longer, but this has to be questioned by the qualitative results of the RTA as well as general trial observations such as the spatial distribution of the different Prunus l. Half of the Prunus circles had been pruned randomly by the gardeners, but the trial observation shows that those in the direction where the subject came from were unpruned. On the other hand, pruned Prunus l. were close to the sunny area, where subjects stopped to wait. Additionally, nobody named the different quality levels of maintenance even though the subjects talked about the quality of other materials and overall design quality.

The results can also be interpreted in two other ways. On the one hand, subjects unconsciously chose an area with more pruned Prunus l. to wait for somebody or, on the other hand, they displayed a deepened consideration of the spatial distribution in relation to their maintenance quality. So, one can assume that pruned Prunus l. were coincidentally closer to the main waiting position and that the unpruned Prunus l. in the background did not lead to losses in the overall quality awareness. This implies the possibility to define quality awareness ranges to govern maintenance and care of public green spaces. This in turn means less intense maintenance, while holding the same quality awareness level, or to invest the same amount of human resources while increasing the quality awareness level.

4.2. Feasibility study 'Point de Vue'

The research project 'Point de Vue' sought to investigate the effects of gaze guidance and usage behaviour in promenade gardens from different eras and styles by utilising mobile eye tracking (ETG 2w). This represents a study of the feasibility of the implementation process of mobile eye tracking as a new method in landscape architecture. Furthermore, it was of interest to examine the impact of 'Points de Vue' on interactions in and with the stimulus and if

Figure 10. 'Point de Vue': world-famous scenery in Stourhead landscape garden. ETC.la (2016).

mobile eye tracking generally is an appropriate method for landscape architecture. During three research trips of 4–6 days each, it was possible to recruit approximately 90 subjects and to record gaze videos of their experience and thereby carry out suitably grand-scaled research. The trials were conducted in the baroque garden Grosser Garten in Hannover (D) which is a part of Herrenhausen Gardens and the masterpiece Stourhead landscape garden in Wiltshire (GB), which is run by the National Trust (**Figure 10**). Despite all the differences in garden types, both parks combine historical, local and superregional importance and they claim to offer the paying visitors an excellent park experience. Subjects were recruited in situ in the reception building (Grosser Garten) or while passing the outdoor-lab, as presented earlier (**Figure 3**). Recruitment rates were better, if done in the outdoor-lab instead of in the reception building [7]. The CSX method (see Section 3) was applied and stimuli were presented in unmodified conditions. To observe the most natural behaviour, no task was given to the subjects or to their companions.

4.2.1. Learning from experimental procedures

When developing the research designs, there were worries about recording too much gaze video material because gardens are very big and strollers can spend several hours in the gardens. This is why a small timer was given to the subjects on the first research trip to Grosser Garten. After 30 min, it rang and they were asked to proceed to the Great Fountain. However, even this procedure influenced the behaviour too much and came close to ruining these trials. Therefore, it was decided to remove these limitations for the subsequent research trips to Stourhead, which enabled the recording of natural interactions. A big advantage of the CSX is that, in comparison to the (R)TA, the subject does not have to verbalise something and the video does not have to be reviewed afterwards. That saves time for both the subject and the researcher. Instead, it increases ecological validity, and during the analysis process, the stimuli for verbalising something can be speculated upon.

Considering **Figure 11a** and **b**, it becomes obvious that subjects in Grosser Garten had a greater variability in route selection and became confused by repeating geometrical structures. As a result, they tended to turn around quite often, which in turn made the analyses very difficult. Subjects used different paths to get to the final point leading to an enormous

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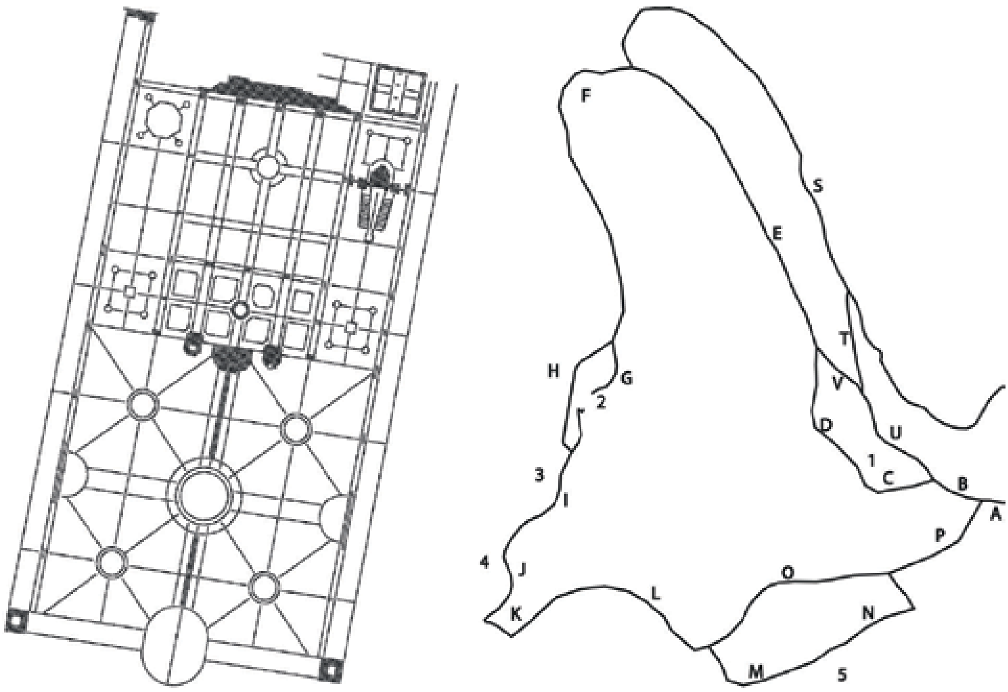

Figure 11. Comparing path networks in (a) Grosser Garten and (b) Stourhead (both unscaled). ETC.la (2017).

reduction of subjects in certain areas. These two constraints reduced the quality of the path-related interaction protocol as well as the possibility of creating representative gaze interaction images like heat maps or scan path diagrams. The problem of creating time consuming and, coincidently, poor PrIPs for Grosser Garten could have been solved if GPS-trackers had been added. Despite that, it was a trial with meaningful insights, and in this phase of the study, it was more important to develop the CSX and to learn about general coherences between potential subjects and the park as a real-world environment stimulus. Future studies will be conducted in combination with GPS-tracking.

4.2.2. Key results of 'Point de Vue'

Against the background of 'Point de Vue' being a feasibility study with uncontrollable real-world environments as stimuli, it can be seen as a self-learning, knowledge process. The cluster of evaluated results and gained insights can be summed up as the overall acquired knowledge.

One of the main results is that mobile eye tracking is a proper application for research in landscape architecture, unfolding its power through various possibilities for analysing the object, the subject and interactions between both. This is why the focus in the analyses switched from quantitative to qualitative. The fixation analysis is now seen as a way to deepen the qualitative findings without a main outcome. This leads to a definition of the research area as qualitative interaction analysis.

CSX has to be mentioned once again with reference to Section 3. It is of particular importance because it is the basis for further analyses and the only possibility to be an 'invisible companion' for the entire length of the trial, which can be over 2 h long. Only because of this fact, it is possible to run mobile eye tracking trials in such extensive gardens and landscapes.

'Point de Vue' also showed that the ETG are comfortable enough to wear for a couple of hours and that the developed analysis methods, VMM and PrIP, are able to deal with the enormous volumes of recorded data.

4.2.2.1. Path-related interaction protocol

The PrIP is a map-based evaluation method and result chart developed during the 'Point de Vue' study. It represents different kinds of interactions during the study. In a first step, only the chosen routes were transferred to the PrIP, which showed that track and path networks in Stourhead were not always identical. Later, additional information was evaluated and displayed: the frequency on path segments, average walking speeds or stops (resting times and places), including gaze direction and objects of special interest (**Figure 12**).

Figure 12 is presented as an example for a PrIP and visualises stops and remarkable viewpoints together with the predominant gaze direction for a sample of 10 subjects (n = 10). Stops are marked with the total resting time [sec] if two or more subjects have stopped at the same place. Beyond the quantitative stopping time, one can see a blue square indicating the stopping time through varying sizes. Stops can have multiple reasons and only if people stopped to enjoy the view on a focal point or the scenery, this is marked with a blue triangle. Other

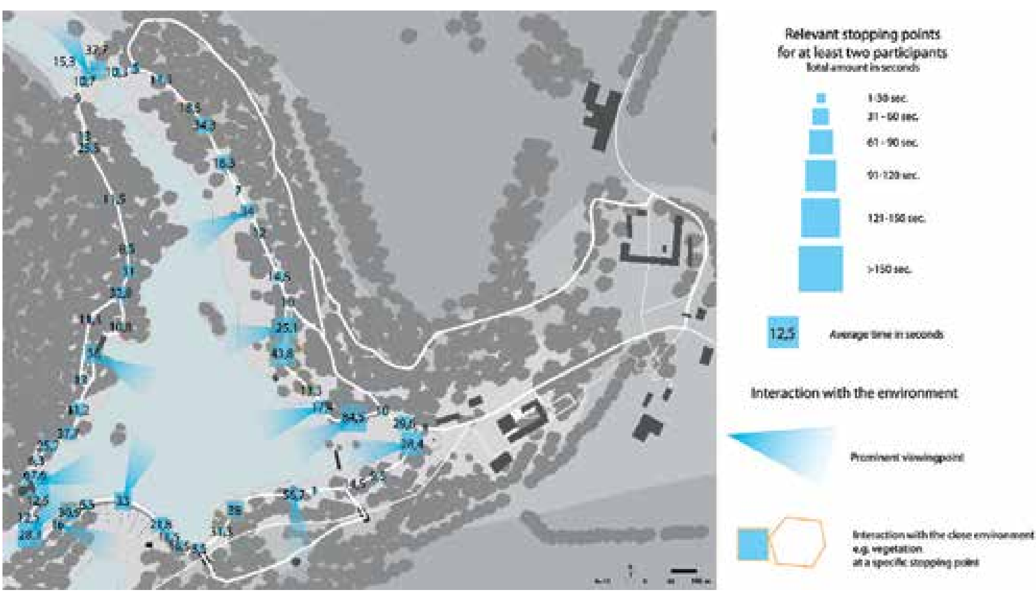

Figure 12. PrIP with stops and gaze directions in Stourhead. ETC.la (2017).

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main purposes for stopping were the interaction with vegetation such as big trees or flowering bushes. If remarkable, these objects are marked with an orange outline.

This map enables a differentiation between seasonal focal points or objects, which are not recognised in a way they should be, which leads to the analysis of historical and current viewpoints.

4.2.2.2. Verification of viewpoints

Many viewpoints have been planned as such and are still manifested in historic parks. They are usually on, or at least close to, buildings or constructions. Some examples are the balcony at Herrenhausen castle or the nearby platform on the Great Cascade from where a beautiful view over the Great Parterre of Grosser Garten is provided. Stourhead has multiple viewpoints all around the lake and all of them are likewise associated with buildings or constructions.

Nijhuis presents these viewpoints against the historical background (**Figure 13**, left) ([3], p. 217). Current interaction analyses indicate minor, but relevant, changes. Comparing the maps in **Figure 13** (right), most of the traditional viewpoints were confirmed, but the one on the bridge close to the Pantheon was defined as a new viewpoint. This is based on measured stopping times, explicit verbalisations and locally occurring changes in interactions. In addition to the numbered viewpoints, the authors also defined landscape windows (L), which are lookouts of minor relevance, based on gaze video and interaction analyses. They are, for example, short impressions or picturesque views one gets 'along the way'. Even, or especially, those views have to be recognised as important for the subconsciously gained, overall impression and thereby have to be maintained and developed by the gardening team responsible for the maintenance.

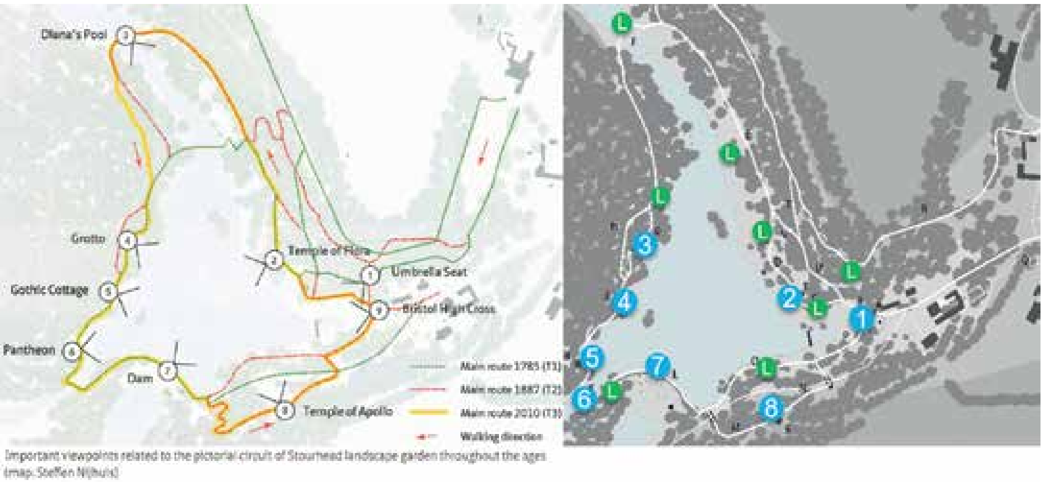

Figure 13. Comparison between historical and current viewpoints in Stourhead. Left: Nijhuis (2015), right: ETC.la (2017).

Another important piece of information is that viewpoint 1 (Umbrella Seat) [3] is marked as a landscape window in the above-mentioned figure. This was due to the fact that while trials in Stourhead were conducted, there was no building or construction as in former times and shrubs began to grow high. But this situation was restored in summer 2017 by installing an enormous curved bench in combination with the associated gardening works. So, from then on, it has been a viewpoint again.

4.2.2.3. Gaze metrics

Gaze metrics can be visualised overlaid on reference images to represent inter alia fixation durations, sequences or gridded distributions of, for example, revisits. **Figure 14** compares the heat map with the average number of revisits displayed as a Gridded AOI. There is only one intersection of the respective hotspots, which is in the centre next to the Pantheon. This area provides the most dynamic composition: starting with the upper edge of the bridge, going up to the reflecting water surface, the architecturally curved dam, the natural shoreline beyond the Pantheon, an early-autumn colouring shrub and the intensively viewed left edge of the Pantheon. All this is arranged in the centre of this prominent viewpoint and is visible with one glance and thereby easy to perceive.

This seems to be a clear reason for the concentration of visual attention in this region and why this is the most prominent viewpoint and typical postcard image. But regarding the isovist on the plane of the water level, it is clear that the whole shoreline cannot be explored in the region and thus also the extended lake which lies behind the visible scenery [17]. This means a higher cognitive workload for the visitor which supports the general tension as described earlier. This scenery is highly complex and many more investigations will be necessary to disclose all the secrets of this beautiful scenery.

4.2.2.4. Positive effects on visitors

In addition to the mobile eye tracking trials and the applied CSX, the authors conducted guideline-based interviews and asked ordinal and interval-scaled questions [18]. As briefly described in Junker and Nollen [7], one of these questions asked whether the garden was interesting for children. Comparing the interestingness of Grosser Garten for children to the

Figure 14. Heat map (left) and gridded AOI (right) overlaid on viewpoint 1 (Bristol Cross) in Stourhead. ETC.la (2017).

adult's assumption of how interesting the garden was for children, the difference in weighted mean shows a + 2.23 points greater mean (scaled from 1 to 10) for the children group (≤ 18 years) and families accompanied by children (7.23, n = 15) in contrast to adults walking without children (5.04, n = 26) [7]. This result goes in line with analysed gaze videos from juvenile subjects and the general observations, which show that children interact more actively by means of playing and running around with peers and adults or multi-sensorial, exploring the stimulus; but always with great respect for the age and wealth of detail. Strolling in the garden seems to be a time spent together with the family and away from electronic devices. That is why children are not bored as adults interact with them.

Another aspect was to have a look at mood changes by using four opposite pairs of words such as tired/rested, withdrawn/talkative, nervous/calm and inattentive/focussed. Subjects marked their current mood on the sheet directly after recruitment (before setup and further explanations) and then directly after arriving back at the endpoint (before taking off the ETG and doing the interviews). The overall mood changes—potentially caused by spending time in a park— are predominantly positive with the mood score (scale from 1 to 7) increased by +7.63% (Grosser Garten: +8.28%, n = 39; Stourhead: +6.31%, n = 19) [7].

5. Conclusion and prospects

Within the framework of several master theses and the feasibility study 'Point de Vue', the method of mobile eye tracking was successfully implemented in landscape architecture. 'Point de Vue' was a basic research gaining impressive qualitative and first quantitative results, which are fundamental to follow-up projects. The guiding, resulting method is the described common shared experience (CSX), as an experimental method which, in line with the effect of the 'invisible companion', proves the unobtrusive functionality of mobile eye tracking in real-world, open-space environments. This chapter concludes that mobile eye tracking will be a relevant tool in many different approaches for making open spaces better and for, consequently, increasing the quality of life.

More efforts must be invested in the further development of map-based path-related interaction protocols (PrIP). These complex illustrations are based on multi-methodical data collections and analyses, enabling better knowledge transfer. Furthermore, the method combinations (**Figure 4**) to record even more detailed interaction and analyses of body responses offer great potential. GPS is an out-of-the-box technology but requires method development in terms of GIS-based PrIPs and also mobile EEG-measurement, which will be a basic research in itself.

A next step will be to enhance the developed experimental and evaluation methods and to apply them in various subsectors of landscape architecture. One idea amongst many is to define a pioneering method to analyse and to optimise intersections of the (im)material provisions of an open space and the user's expectations thereof along with documentation of the behaviour. The basis for this will be developed and tested approaches such as the CSX. It will be a holistic approach within the qualitative interaction analysis with strong relations to usability, user experience and human machine interaction, never losing sight of the human.

Finally, it is necessary to say that mobile eye tracking will hardly be used as a problem-solving method, but instead for generating outstanding, specific knowledge such as analysing user's demands, questioning the adequacy of (realised) planning measures, managing green spaces including public housing, the subjective sense of security, coherences between historical garden arts and contemporary aesthetics and many more.

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Nomenclature/list of abbreviations

Common Shared Experience (CSX)	An experimental method for mobile eye tracking trials developed by the ETC.la. The CSX has similarities to the think aloud protocol.
Eye Tracking Collective.landscape architecture (ETC.la)	Eye tracking laboratory specialised on analysing human interactions in real-world environments under non-laboratory outdoor conditions.
Eye Tracking Glasses (ETG)	Mobile eye tracking device by SensoMotoric Instruments. Versions used: 2.0 and 2w both with smartphone recording unit
Gaze video	Recorded by the HD scene camera of the ETG with overlaid fixations, represented as circles or crosshairs.

Isovist	An isovist is the set of all points visible from a given point in space and with respect to the environment [17]
Path-related Interaction Protocol (PrIP)	Map-based evaluation method and result graphic developed by the ETC.la. It represents different kinds of interactions during the stroll such as average walking speed or resting times.
(Retrospective) Thinking Aloud [(R)TA]	Protocol of the subject's verbalisations recorded during (or after) the trial. It is a complementary method, which helps understanding the behaviour of the subject.
Stimulus	The stimulus is the presented research object, meaning the garden/park, including the whole environment with its entirety of objects. By interacting with or within the stimulus, the subject is able to influence it and thereby become a part of it.
Verbal Mood Map (VMM)	Map-based evaluation method developed by the ETC.la. It visualises the agglomerated verbalised spontaneous reactions to create a link between the viewpoint and the perceived stimulus (focal point).

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Chapter 4

The Role of Ornamental Gardens of Rural Settlements in Landscape Architecture

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Additional information is available at the end of the chapter

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Abstract

This chapter deals with the status of rural ornamental gardens in the Czech Republic throughout history. In this chapter, the individual styles and typical elements of garden architecture from the oldest medieval gardens around the castles and monasteries, through the Renaissance and Baroque ornamental gardens around thy typical Renaissance villas and chateaus to the landscape parks of classicism and romanticism and modern gardening, will be described. For each of the key periods, a few typical representatives of ornamental gardens from the countryside of the South Bohemian region will be described, including their original and contemporary composition, composition of wood and plants and the buildings and furniture in the garden locality.

Keywords: ornamental gardens, rural landscape, history, landscape architecture

1. Introduction

Gardens and parks are the most important components of landscape architecture [1]. They had a long development that reflects the maturity of the company's visions of garden architects and designers, the work of gardeners, and the ideas of those who have found places of escape from the outside world in gardens and parks [2]. The garden expresses the close relationship between civilization and nature, it is an idealized image of the world, and it often shows a miniaturized form of landscape [3], becomes a paradise, and testifies to the culture and originality of the creator [4]. Parks and gardens are to serve the inner and outer well-being of a person [3], represent a redevelopment of paradise, and have a great recreational and educational significance.

Historic gardens and parks are an important part of human culture. They present the natural conditions, architectural, and religious-philosophical differences of the individual regions. Over the last decades, gardens and parks have become increasingly popular. Today, we often encounter the activities of citizens and civic associations to protect natural elements and trees in historic gardens and parks [5]. The historic gardens are monuments of garden art, which are associated with an artistic style of the era in which they were created [6]. The historic garden is a cultural monument as well as historic building. Many historic gardens and parks have disappeared or changed into public greenery; others are neglected, deserted, and only some of them receive adequate care and attention to their meaning [7]. They document the interesting development of garden art, and they are essential part of the cultural landscape [8].

The designation "historic garden" includes both thin, small and very large formal or landscaped parks. It is mostly attached to the building and is an integral part of it as it cannot be separated from its environment, whether it is artificially created or natural [9]. Historic garden is an architectural and vegetation composition that is important in terms of history or art [3]. These gardens are then integrated within the cultural heritage, and these are protected by heritage conservation [10].

The historical gardens are divided not only according to the developmental periods but also by different species. The basic species of the ornamental gardens are the medieval castle [11] and monastery gardens [12], the most widespread chateau gardens and parks [13], deer parks [14], villa gardens [15], landscape parks [16], urban or city parks [17], and cemetery gardens [11].

2. Materials and methods

For this work, the South Bohemian Region was used as area of interest, where garden objects were selected as representatives of individual types of gardens in rural areas.

Individual objects were selected based on a literary research. For each identified type of rural ornamental gardens, several representatives were elected. In the case of such objects, a thorough literary review was carried out first, covering the whole period of development of the individual buildings of these ornamental gardens, including visual documentation.

3. Analysis of the historical development of ornamental gardens in the South Bohemian region

The first part of the chapter results is devoted to the description of the shaping of the gardens in the individual stages of the historical development of the countryside of the Czech Republic and their role in the rural landscape. The second part of this chapter is devoted to the description of ornamental gardens that have been chosen as typical representatives of the development of garden art and architecture in rural environment. The territory of the Czech Republic has undergone various styles of garden art.

3.1. Medieval gardens

The first mentioned gardens in our country began to form around the twelfth century. From the twelfth to the sixteenth century, gardens retained their arrangement in the form of castle and monastery gardens and gardens within fenced cities, where smaller gardens also had parishes and palatial burgher houses. Compared with the Middle East gardens, our medieval gardens were more moderate, resulting from different climatic conditions and other exploitation claims. Closeness and division into parts designed for livelihood, learning and meditation was the basic characteristic for all sorts of medieval gardens in our country.

During the foundation and development of medieval gardens, monasteries played an important role. After the devotees, the main occupation of the monks was gardening. The monasteries had their complete garden space in the form of a paradise courtyard that adjoined the church and was surrounded by a four-sided passageway. It was an analogy to Roman peristyle. There was a fountain or well in the center of the area, which was often divided into four squares. Healing herbs or flowers for the decoration of the monastery church—lilies, roses, peonies, aquilegias, irises, daffodils, and violas—were grown on beds. Medicinal plants and spices were grown on the area in which only the monastery head had access to. The cultivated plants served for healing purposes, for the kitchen, and for the preparation of wines and liqueurs. Unfortunately, due to the interference of the monasteries, these gardens have not been preserved in many cases.

Castle gardens were built inside the walls on a limited area. Because of their small size, they mostly contained medicinal plants, vegetables, and herbs for castle kitchens. The castle gardens were always fenced, and they were completed by pavilions, glories, or towers that were part of the perimeter of the castle walls. The areas of the beds were separated by metal or wooden fences, which delimited the raised beds. The sloping walls and the maze had grown in the late Middle Ages. In the middle, there was usually a water element, and around it, there were pewter benches that were covered with bower with climbing plants. The castle garden was later extended to the castle ditches, where the training areas and the playgrounds were created. The meadows beneath the castle were reserved for knights' tournaments, games, and behind the town walls, then festivities and gigs. Part of the castle gardens was forests and meadows which were reserved mainly for hunting. Medieval gardens or parts of them have specific names. The first part was called Viridarium on which predominantly ornamental plants were around the fountain or well. Vegetables and herbs planted on so-called Giardinum were separated by fences from fruit trees grown in pomerium and herbarium.

Medieval gardens were also built on narrow plots around burgher houses. This type of gardens had a simple layout, and the areas initially served to grow vegetables, spices, and medicinal herbs. Later, flowers and fruit trees appeared. The beds were elevated, and these were watered from well or water tanks inside the garden. Simple greensward benches were created for rest.

Complexes of gardens of several preserved monasteries, such as Zlatá Koruna, Český Krumlov, Vyšší Brod, or Milevsko, as well as a very rare preserved garden in the preserved castle complex Zvikov are the best example of the medieval type of gardens in the South

Bohemian region. Also, gardens in most of the castle complexes, including Český Krumlov, have the medieval origin.

3.1.1. The monastery gardens in Zlata Koruna

The monastery in Zlata Koruna was founded in 1263 by King Premysl Otakar II. The monastery was destroyed and burned several times, especially during the Hussite wars. Now, the garden included fruit orchards with apples, pears and plums, water elements, and at least 34 beds. In the garden under the abbey of the monastery, where the kitchen used to be, there was pergola, and at its farthest end, there was a refreshment house. In the records from 1720, the mention is made of two linden trees (*Tilia platyphyllos 'Laciniata'*) on both sides of the statue of St. Jan of Nepomuk, which is still in the monastery grounds. The Abbey Ornamental Garden was built in English style with a grass carpet of young clover and grass with ornately bound beds. There was also a small pond in the garden, for which the Abbey bought exotic goose, duck, and two swans. Exotic plants were grown in the greenhouse, and beside it, a fig house was built. In the decorative and vegetable garden, there were also small fountains and spacious bird house. In addition to the ornamental parts, the plant was planted and cultivated in the monastery, such as a mulberry plant used for silk production. The fragment of the black mulberry tree (*Morus nigra*), which is kept as a memorable tree, is still in the monastery grounds. The monastery also had a vineyard of 300 plants and a hop ground supplying an abbey brewery. At the time of the interruption of the monastery in 1785, there were three hop gardens, two kitchen gardens, ornamental gardens, and grassy orchards. In 1803, the greenhouse was abolished and later the gazebo. In the nineteenth century, the monastery's building turned into a silk factory, a pencil factory, a foundry, and a machine factory. The factory was here until 1909 when the building and the gardens began to be repaired. The restoration lasted until 1940.

The current appearance of gardens is only a small reflection of the state of their flowering. At present, the entire former monastery gardens are restored to its original form. The entrance to the monastery is now allowed by the gate from the village. On the sides of the statue of St. Jan of Nepomuk dominate the above-mentioned two large-leaved linden trees (*Tilia platyphyllos 'Laciniata'*). Another gate can be found in the courtyard, which is dominated by a large, majestic linden tree (*Tilia platyphyllos 'Cucullata'* and *Tilia platyphyllos*). The area in the courtyard is divided by paths, trimmed with beehives (*Buxus sempervirens*). Free lawns are complemented by the roses (*Rosa* Sp.) and the red yew (*Taxus baccata*). In the corner of the garden there are very old specimens of the dogwood (*Cornus mas*) and the ponderosa pine tree (*Pinus ponderosa*).

3.1.2. Gardens of Zvikov Castle

The unique preserved garden in the Zvikov Castle complex is divided into five sub-parts, according to the original purpose. The total area of the garden of 0.72 ha includes ornamental gardens around the Hlizova Tower, both courtyards and parks, as well as part of the utility garden. The royal castle was founded during the reign of Premysl Otakar I in the form of the Hlizova Tower and was extended to its present form after his death. After the death of the

Premyslid rulers, the castle came to the hands of the Rosenbergs, who were together with Svamberks, the last users to use the castle as a fortress complex. The Eggenbergs and subsequently, the Schwarzenbergs began to use the castle as an economic element and castle, and until then the only functional utility garden began to deteriorate. The restoration of the building was due to Charles III of Schwarzenberg, who, under the influence of Romanticism, let the dilapidated castle repaired, expanded to romantic courtyard arcades. Now, for the first time, the castle was also given a romantic ornamental garden.

At present, the entire garden area is situated on the south and southwest part of the castle. Usually, there are only grassy areas with growing specimens of deciduous and coniferous trees. Among the most significant individuals near the Hlizova Tower, there are mainly the common hornbeams (*Carpinus betulus*) and the linden trees (*Tilia cordata*), in the middle courtyard the overhanging specimen of ash (*Fraxinus excelsior* Pendula). The grown trees are complemented by flower beds in the former utility garden and climbing specimens of roses. The front courtyard and the parks area are reminiscent of the adjacent natural background of the castle, thus linking at least the visually adapted and natural part of the area today. Among the basic wood species, there are maples (*Acer platanoides, Acer pseudoplatanus*), linden trees (*Tilia cordata*), Douglas firs (*Pseudotsuga menziesii*), oaks (*Quercus petraea, Quercus robur*), beeches (*Fagus sylvatica*), red yews (*Taxus baccata*), and horse chestnuts (*Aesculus hippocastanum*).

3.2. Renaissance gardens

With new philosophical perspectives on the regular understanding of the world and life, new directions of gardens are emerging from the sixteenth to the nineteenth century. Gardens are transformed into unprecedented monumental gardens, or gardens and parks that return to rationality and simplicity and return to nature. Renaissance is referred as rebirth. In Renaissance understanding, life ceased to be the mere preparation of the soul for eternal life, and it changed itself in value. The classic Renaissance garden is characterized by its regularity, axial symmetry, and balance. Renaissance relies on the principle taken from antiquity, about the finality of space and the perception of material. Renaissance gardens relate to the motherland of Italy, and in other countries such as Bohemia, their concepts have expanded with a certain delay and a considerable degree of simplification. The main clues of the Renaissance garden include a rectangular network of rectangular paths, trimmed low fences alongside them, stone or ceramic pots of plants, walls of evergreen materials, the ground floor of a house open directly to the garden, and the so-called bosket, which is a densely planted shrub. The house was connected to the garden by a column gallery, providing a shadow and opening usually to the garden directly. At the house, there was a parter with more demanding floral planting supplemented with healing aromatic herbs. Private garden, which was close to the house, was separated from a representative part of the garden by fencing. Children could have fun here, and the garden served to nobleman for informal meetings. The character of these areas was mixed, and the area was divided into small beds, where flowers and vegetables were grown for cooking. There was also shady pergola to rest. At the end of the garden axis, special buildings were built like a teatron, a demanding fountain, or a casino. In the marginal part of the garden, there were situated tree nurseries, ponds, bird houses, or gamekeeper. The garden was still hidden behind the wall, but its connection to the neighborhood was important. It has been achieved by visibility through the walls to the city, mansions, and landscape. Part of the garden also consisted of orangeries, pavilions, loggia, aviaries, and arbors. In the Renaissance Garden, there was always a water element like a fountain, a spout, a waterwork, or a cascade. Most of these pieces were associated with sculptural decoration. The so-called grottos (artificial caves) were also popular, where natural materials such as lava, marble, clams, and mussels were used for decoration. The ground plan of the Renaissance Garden was based on the character of medieval gardens, mainly from its utility part. It had the appearance of a checker-board, because the straight, right-handed paths spread the area on square and rectangular patterns that were stained with evergreen fences. At that time, a huge number of plants were grown, which were often imported. That is why a flat floral parterre, acting like a colored carpet, appears around the houses. Coffee, lemon, orange, pineapples, and other exotic plants were grown in wooden or ceramic containers to move to orangeries, fig houses, pineapple houses, or greenhouses in the winter. For the amusement of the nobility, there were also premises for the breeding of exotic animals, especially birds and beasts.

One of the forms of the Renaissance garden is also the so-called mannerist garden. The mannerist garden is a Renaissance garden with subtle differences, even absurdities, from the end of the sixteenth century and the beginning of the seventeenth century. Water jokes and puns, gigantic sculptures, terraces, cascades, ramps, and stairs were the main features in this type of garden.

Now, for the first time, formal ornamental gardens are linked to the free landscape, although it is a unique phenomenon in a few places. This interconnection was carried out by the interconnection of deer parks with fencing and modified paths and structures located at intersection routes or at significant points of sight. The deer parks were used for breeding domestic game, which was hunted by the nobility by the hunts. However, the Renaissance and Mannerist Gardens remain mostly cut off from the surrounding landscape by fencing and hedges. The reason is the effort to create a space that is to be an idealized paradise without connecting to the outside world.

Examples of Renaissance-built or landscaped gardens in the south of Bohemia are the Gardens of Rosenberg family, such as Cesky Krumlov, Trebon, or the unique garden in Jindrichuv Hradec. A unique example of Renaissance gardens is the Kratochvile villa. Another example is the modification of the deer parks for game breeding and for hunting and recreational purposes. An example of such fields is, for example, extensive complexes around the castle of Blatna or the area around the Cerveny Dvur mansion.

3.2.1. Kratochvile villa garden

This manor Renaissance villa is inseparably linked to the Rosenberg family. The first mention of the local court dates to the fifteenth century, and it was owned by Jakub Krčín of Jelcany under the name Leptac. The year 1580, when Vilem of Rosenberg took the old fortress, has the biggest importance in the history of the villa and the garden. The fortress and the feast did not correspond to the representative needs of the powerful Rosenberg family, and so it was rebuilt into a generous Renaissance complex. Immediately in the years 1582–1589, the extensive

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reconstruction of the whole courtyard followed an elegant Italian Renaissance summer palace with a popular Italian Garden of Eden. The one-story house stood within the strictly regular layout of the garden. The villa and the garden and the related deer park represent a strange, closed world. The basic function of this unit was completely secular, as can be seen from deer park for game breeding and hunting. The garden was surrounded by a triple wall with bastions and a low commercial object with a tower over the gate. The garden is divided by two water ditches into the inside and outside garden. The interior water ditch with the drawbridge surrounded the summer house. The outside water ditch then encircles the main wall of the garden. In 1586, water games were formed in the garden, but they were not there for a long time. Garden with fruit trees, an herb garden, a regular ornamental garden, and, above all, a spectacular water ditch in the immediate vicinity of the villa are a perfectly clear symbolic representation of paradise away from behind the wall. Important fact is that the composition of the villa itself has never been fundamentally changed; basically, it remained in the late Renaissance conception until the twentieth century. Since 1981, the complex has been reconstructed, and its present status is a good example of a summer house from the Rosenberg age. The Kratochvile Summer Villa with the garden is today one of the most preserved Renaissance buildings of its kind in our country. Its unique atmosphere also competes with the noble much larger settlements. The garden has the shape of a rectangle, and it is surrounded by a wall with an entrance gate. Part of the fortification is the Chapel of the Birth of the Virgin Mary in the south-eastern part of the complex and farm buildings. The compositional arrangement has been preserved to this day without any significant changes. The rectangle of the garden intersects the main axis on which is the entrance with the tower, the stone bridge over the internal water ditch, and the entrance to the summer house. The water ditch is followed by a wide grass belt, formerly a gravel. Today, a simplified orchard is planted there. The rear transverse part of the garden is designed as a kitchen and herb garden. Significant tree species include golden cypress (*Chamaecyparis pisifera 'Plumosa Aurea'*), hanging ash (*Fraxinus excelsior 'Pendula'*), Kentucky coffee tree (*Gymnocladus dioicus*), and Japanese thujopsis (*Thujopsis dolabrata 'Variegata'*). The restored wall is interrupted by niches with seats or look-out windows. The garden on the island is made of two embroidery belts and a hemline around the central grassy area, with a repaired original circular tank. Shaped trees in ceramic pots evoke the original lining of the island. Nowadays, a black chokeberry (*Photinia melanocarpa*) is being grown in containers. In 1992, the ditch was restored, and the island character of the inner garden was redefined again. To the east of the castle, there is today a horse racetrack, surrounded by alleys of oaks (*Quercus petraea*), ashes (*Fraxinus excelsior*), and platans (*Platanus* × *acerifolia*).

3.2.2. Garden of Bratronice Chateau

Today, the unused chateau with the park area is an exceptional example of a Renaissance rural garden partially rebuilt into the late-Baroque Classicist French garden. The building has undergone the usual development typical for almost all rural noble settlements. On the place of the original small fortress from 1227, a magnificent Renaissance chateau was built in the style of an Italian between 1575 and 1603. Part of the castle complex was a perfectly fenced garden, isolated from the surrounding environment. Part of the garden at the beginning of the eighteenth century became an orangery for growing citrus plants, a kitchen, and fruit garden. At the end of the eighteenth century, the Renaissance style of the garden was partly transformed into a late-Baroque French-style garden with many water features. The chateau was completed with a polygonal terrace and a transparent east-west axis was formed, intersected by four oval shaped pools, which were always fitted at the crossing of the main axis with the perpendicular paths in the north-south direction. At that time, some exotic tree species were also imported according to the period custom. The chateau was practically inhabited by the descendants of the original owners until the end of the twentieth century, but today, it is not used and the garden and individual objects are not maintained. Nowadays, the garden is loosely linked to the east courtyard of the farm yard and headed by a Renaissance one-story mansion in the form of an Italian venetian villa with a mansard roof and a perpendicular chapel toward the chateau park. The ornamental garden is continuously adjoining the terrace in front of the south-eastern front of the chateau around the central composite axis. The garden is composed of three elevated terraces individually finished by a stone ledge. The edges of the terraces, as well as the entrance gates, are lined with the originally cut-ash trees. At the highest level, the terrace is unusually shaped into a polygonal shape. Of the original water elements, only two oval pools were preserved on the compositional axis. The stone furniture (table, chairs, or stone cones) is the interesting part, which has been preserved in the central part of the garden. The rest of the original equipment and constructions preserve only the remnants of the original Renaissance fence wall, which was partly changed during the rebuilding of the Renaissance garden to the Baroque-Classicist park. The planned interconnection of the garden complex with the surrounding wooded hilly landscape through views through individual composing and minor axes was the reason for rebuilding of the garden. The overall state of the park is neglected due to zero maintenance. The valuable specimens of grown oaks (*Quercus petraea, Quercus robur*), beeches (*Fagus sylvatica*), linden trees (*Tilia cordata, Tilia platyphyllos*), pine (*Pinus sylvestris, Pinus nigra*), and Douglas firs (*Pseudotsuga menziesii*) are the dominant features in the park. These are freely supplemented by the planting of juniper (*Juniperus comunnis, Juniperus horizontalis*), cypress (*Cupressus nootkatensis, Cupressus lawsoniana*), thuja (*Thuja occidentalis*), and a very significant golden rain bush (*Laburnum anagyroides*).

3.2.3. Garden of Cerveny Dvur Chateau

The first mention about the garden around the Cerveny Dvur dates to 1598. At that time, the so-called Novy Chvalsinsky Dvur was established by Petr Vok of Rosenberg, intended for the breeding of beaver, pheasant, partridge, and quail. The chateau, together with the hunting ground and the arbor, was founded in 1672 from the initiative of Princess Marie Ernestina of Eggenberg. During the reign of Adam Franz of Schwarzenberg, a gardener's house, a fountain, and water elements were built. Josef Adam of Schwarzenberg subsequently realized in the period 1748–1781 the construction of a nonpreserved sala terrena, the annexation of the southern wing of the castle, and extensive landscaping of the garden. The shape of the field is illustrated on a plan from 1754, which captures an area of about 30 ha, adjacent to the eastern court. Plans from 1762 to 1779 show the transformation of the deer park into the Baroque garden, in the form of a regular French garden of a trapezoidal floor plan bounded by walls.

The star-shaped road network, diverging from the central pool, architecturally divides the garden into closed bosquets. All roads, except the center, are lined with cut alleys. In front of the garden facade of the chateau, there is a rectangular area of the ground floor with a pool in the middle. The main composing axis led from the chateau through the parter and the pool. It was highlighted by distinctive water elements across the entire length of the axis. In addition to the common fountain, the garden was supplemented with a water cascade with a cave, a beaver pond, a canal with a poplar island, and other waterfowl tanks. In the period 1769–1784, beavers, Chinese pheasants, Bengali deer, and angora rabbits were bred in the garden. In the garden, there was a natural theater, a summer riding school, Schneckenberg, and later a Chinese and Dutch Summer Palace. The transformation of the Baroque Garden into the English Park takes place in the middle of the nineteenth century, under the prince Jan Adolf II. of Schwarzenberg, partly thanks to the great damage by the storm. First, the peripheral formal walls were removed. The area of the original garden was extended to the eastern and southern sides after the removal of the fencing walls in 1839 to the current area of 117 ha. Regular road network has been canceled. While the water elements on the main viewing axis were left, they were modified into less formal tanks. Although some former water elements were removed during the formation of the new natural landscape composition, the water remained one of the main compositional elements. Various new buildings such as Bazantnice for accommodation of seasonal guests, the so-called Svycarna for breeding cow of Swiss origin, a Pink gazebo connected by a shadowy corridor with a rose garden, and a chapel of the Holy Cross contributed to the creation of the romantic sceneries. In the 1950s, the summer houses were demolished, and artificial caves were abolished. The parter's area, situated in front of the garden facade and the chateau's terrace, retains its rectangular ground plan. It is divided into three square squares—a circular fountain remains in the center, with a circular flower bed in both external fields. The flower beds also form the edge of the grassy square fields. The castle complex was transferred to state ownership in 1947 and nationalized in 1949. Since 1966, a psychiatric hospital has been set up in the chateau, which is still here. An extensive 117-ha park was used only near the mansion, and maintenance was reduced proportionally with increasing distances. The back stands and meadows were covered with natural seeded vegetation, and the so-called Green Way completely disappeared. Even the objects of garden architecture were not properly used and quickly dilapidated, some of them were completely removed from the park, such asso called Slechtuv mill, Svycarna or, one of two Gatehouse buildings. The park vegetation is formed mainly by pines (*Pinus sylvestris*), birch trees (*Betula alba*), beech trees (*Fagus sylvatica*), oaks (usually *Quercus robur* and rarely *Quercus petraea*), hornbeam (*Carpinus betulus*), ash (*Fraxinus excelsior*), maples (*Acer pseudoplatanus; Acer platanoides*), elms (*Ulmus* Sp.), horse chestnut (*Aesculus hippocastanum)*, linden trees (usually *Tilia cordata*, rarely *Tilia platyphyllos*), larch trees (*Larix decidua*), alders (predominantly *Alnus glutinosa*), and spruce trees (*Picea abies*). There are also poplar trees (*Populus tremula*), willows (*Salix* Sp.) and black locust (*Robinia pseudoacacia*), but these trees are predominantly as seeded vegetation. Also, the shrubs could be found free in the park. These are mainly black elderberry (*Sambucus nigra*), spindle tree (*Euonymus europaeus*), snowberry (*Symphoricarpos albus*), hackberry (*Prunus padus*), meadowsweet (*Spiraea* Sp.), mock orange (*Philadelphus* Sp.), dogwood (*Cornus* Sp.), February daphne (*Daphne mezereum*), and dwarf periwinkle (*Vinca minor 'Multiplex'*). Solitaires and groups are projected against contiguous stands situated on the south side of the original Baroque part. These trees contain the oldest ones such as lonely oaks and linden trees aged 210 or more years.

3.3. Baroque and Classicist gardens

The Baroque garden is a typical formal garden. These gardens are the product of European art of the seventeenth and eighteenth centuries. Compared to the Renaissance garden, which is composed of individual regular parts, the Baroque garden combines these parts to create a dynamic whole. As well as Baroque architecture and Baroque garden art, it is directed to the infinite and unlimited space. For example, it uses a large, quiet water surface that allows mirroring of objects. This makes the garden for the first time more connected to the surrounding area and, through typical elements and sight axes, combines formal private space with an open landscape. Popular motifs in Baroque gardens were shells and volutes (conch wrap). The creation of gardens, architecture, and art uses mirror symmetry on the center axis. In Baroque, we distinguish two basic types of gardens according to the origin of the place, namely the Italian and French type of garden. The type of Italian Baroque garden originated mostly in very sloping terrains. In our territory, they have spread together with the following type of maniristic gardens since the end of the sixteenth century. Differences in terrain overcome terraces, staircases, and water cascades. Water is fed from mountain springs through a system of aqueducts, canals, and tanks. The use of architectural works is the characteristic feature and the foundation of the garden. The vegetation component of the garden then only complements architectural works. Some artists did not even avoid irregularities in the ground plan. In contrast, the French type of Baroque garden is considerably larger than the Italian type, and these gardens are usually only on a slight slope. The Baroque garden was characterized by a rectangle, oval, and ellipse shape, complemented by complex patterns and curves. This was manifested, for example, by embroidery (French embroidery) of cut fringes and areas of colored sands and gravel. Baroque art is full of movement and life. There is also a shift from the Renaissance chessboard layout to a distinct oscillation, not just the garden, but, as described above, the entire surrounding area. Together with the gardens, sets of economic buildings, pheasantry, deer parks, and communications lined with alley were included in the unified landscape concept. In this concept, even the whole landscape units were transformed. An example of such landscape compositions may be in the South Bohemian region of Novohradsko, Cimelicko, or Libejovicko. Thanks to the longitudinal and transverse axes, the visitor was surprised by the new elements while walking through the garden. The axes were often directed to the open landscape to form an endless space or to a significant point, usually a statue, a significant tree, a small building, or a water element, in some cases, a city silhouette or some building. This point is named "point de vue". Linking the garden with the landscape begins with the removal of the walls when the former types of gardens were rebuilt. These fencing walls have been replaced by grids and later by canals and hidden water ditches called "aha" so that the garden is optically linked with surrounding landscape backgrounds. The characteristic structure of the Baroque mansions had stable positions of the individual parts, namely the courtyard in the entrance part, the residential building (palace, chateau), the partitioned ornamental garden behind the residential part, the young fruit trees garden, and possibly also the pheasantry and the deer park. The shadows of the grown trees were replaced by long shadows of pergolas, and paths were lined with shaped formed trees. The main entrance to the garden was a terrace with a staircase. Other determining features of the Baroque Gardens are the presence of decorative vases, spectacular sculptures, riding halls, horse stables, theaters, artificial waterfalls, and water cascades and alleys. The establishment of small country mansions and noble settlements was typical for the time of the late Baroque. These were always supplemented by rural gardens and parks. Their origin was related to the fatigue of the pompous Baroque gardens of the French style.

Among the typical examples of Baroque gardening in the region of South Bohemia, there belongs undoubtedly the Český Krumlov Castle Garden, the Garden of the Lnare Chateau, or Straz nad Nezarkou chateau. Typical examples of the Baroque composition of gardens and their connection to the open landscape are the above-mentioned gardens and parks Novohadsko, Cimelicko, and Libejovicko in the south of Bohemia. Typical examples of small-scale rural Baroque settlements are valuable garden complexes around the rural settlements of Bratronice, Lcovice, Nemcice, or Tazovice.

In the eighteenth century, Baroque garden creation changed into a cooler classicist gardens. The gardens were geometric and strict. These returned to the ancient style of Roman and Greek gardens. Simplified composition, slender, noble detail, simple, uncompact area fulfilled the contemporary concept of nature. In addition to parks with numerous waterways, colonnades, greenhouses, and statuary arbors, smaller suburban parks were established. Even the sculptural works were trying to imitate the antiquity. The surrounding landscapes around the gardens were still being adapted. The gardens were characterized by a diverse set of small parters. Roses, perennials of one color or basic colors, were planted. Cast iron was a favorite material of classicism, which appeared both on the construction site and in the gardens. The classicist space is often revived by a regularly designed reception area with a restored terrace complemented by fountains, balustrades, and the flower beds. The selection of plants for classicist gardens has been greatly influenced by the increasing popularity of the collection of exotic and rare plants. At the turn of the eighteenth and nineteenth centuries, the gardens were complemented by romantic exotic objects and artificially created ruins. Classicism gradually disappeared for the romanticism. In the creation of gardens on the territory of Bohemia, two developmental stages of Romanticism gradually emerged: first, somewhat sentimental German Romanticism, which in the nineteenth century replaced to the English Romanticism. The German form of romanticism was reflected in landscaping and gardening by the incorporation of the originally classicist composition and antique elements that subsequently replaced the elements of the Middle Ages and Gothic. The gardens are divided into smaller, more intimate sections, complete with decorative historic buildings such as caves, hermitages, ruins, and other romantic buildings, often in country style. The Romantic Garden was a place of wide grassy landscapes with graceful features, with groups of trees set with the impression of a romantic natural scene. Many older gardens have been rebuilt during the Romantic era, or at least, the overwhelming walls have been bumped, and other lands have been joined that have been transformed in the spirit of the English Park. By the end of the nineteenth century, the gothic forms of architecture had been mixed with other styles such as Baroque and Renaissance, bringing a wide variety and richness of detail into landscaping. Historic flower parters have become the popular element of gardens. From the previous periods, the collection of exotic plants, which are mainly grown in clustered and isolated groups, continues to be popular. These tree species have often become the basis for future arboretums.

While the classicist direction of the South Bohemian landscape has not been much remarkable, one of the few examples of Classicist Precision Engineering and Garden Architecture can be, for example, the Dacice Chateau. Romanticism has been manifested in the South Bohemian landscape in many places. In the spirit of Romanticism, reconstructions of large complexes of castle gardens were made. Of noteworthy, levels and scale have been the romantic rebuilding of gardens in Hluboka nad Vltavou or around Nove Hrady. Romantic parks and gardens are very often associated with the redevelopment of noble settlements in the spirit of historical styles such as neogothic such as Orlik nad Vltavou, Rozmberk, Vraz, or previously mentioned Hluboka nad Vltavou.

3.3.1. Gardens of Lcovice Chateau

The Baroque country manor was rebuilt into its present form in the eighteenth century on the original foundations of the Gothic fortress. The original fortress was extended to a three-story Baroque manor house with three floors of arcades, the addition of the Little Chateau, and a polygonal chapel on the north side of the castle. The first rebuilding, which primarily brought the establishment of an extensive Baroque formal garden, dates to the mid-seventeenth century. Although it was a Baroque-style barrier-type garden, this garden was embedded in the surrounding mountain landscape and the surrounding landscape served as a backdrop for sightseeing. These views to the surrounding countryside were used mainly at the beginning of the nineteenth century when a terrace in the southern part of the chateau was built. This terrace has a unique view on the mountainous landscape of Vimperk surrounding. There were also small buildings built in the garden in the spirit of the fashion trend of the time, namely the octagonal summer house with a dome known under the name of the Holy Trinity Chapel and a pavilion called the Hunting Tower, which was completed until 1984 by a grotto. At the end of the eighteenth century, Lcovice is listed as a mountain chateau with an exquisite garden and a ditch carved into the rock. At the turn of the eighteenth and twentieth centuries, the kitchen garden, including a large greenhouse, was established to the ornamental landscaping garden. After 1930, the owner of the park also established a sports facility in the form of tennis courts. After the nationalization of the castle, the park was dilapidated and served as a background for the agricultural cooperative. Now, a fire tank was built in the park.

At present, the whole park area is integrated into the wooded landscape of the Sumava region. The chateau with remnants of ditches is surrounded by a loose landscaped park with grown trees, especially of domestic species. The free area is left only in front of the southern arcade facade, where the uncovered part serves as a viewing axis to the surrounding landscape. The axis pointed from the northern side of the castle to the octagonal Chapel of the Holy Trinity is an important preserved compositional element. The axis ends with a decorative rock with an oval pool. In the northern part of the park, the Baroque pavilion, the Hunting Tower, and the road network has been preserved to this day. This part of the park is completely wooded. On the southern side, under the terrace adjoining the arcade facade is still a utility garden with a small pond, island, and story orangery, also with an arcade corridor. In the lower part of the garden, the orchard was preserved.

3.3.2. Gardens of Dacice Chateau

The first mention of the new castle appears in 1591 relating to the construction of houses in the upper square of the town of Dacice. Oldrich Krajir of Krajka and the Italian master Francesco Garrof de Bissone were the architects of the castle. The four-wing chateau with a square courtyard was based on the type of north-Italian town palaces. The significance of the main northern wing was underlined by a palatial arcade loggia with Tuscan columns and square-orientated overhangs on the sides. The castle after the extinction of the Krajir family in 1600 often alternated the owner, it was burned several times, and only under the rule of Ostejn family of Mohuc, it was repaired. In 1809, the Ostein family died out, and the Dacice dominium was dominated by the Dalbergs. The latest reconstruction that determined today's classicist appearance relates to this family. In 1832-1833, the rebuilding was carried out under the guidance of the Viennese architect Karel Schlepse, who placed a monumental empire-shaped stairwell into the eastern wing, penetrating both floors. Salm family related to the Dalbergs was the last owner of the Dacice Chateau. They owned the chateau until 1945. The castle from the beginning of its existence was adjoined by an extensive garden, later by the park. The oldest appearance of the chateau park is not known, but it is assumed that in the seventeenth century, the surroundings of the chateau were modified in the spirit of the Renaissance gardens. On the pictures of Dacice from the middle of the eighteenth century, the garden arrangement of the chateau in the French style with regular beds, cut shrubs, stone vases, and arbors can be seen. The ornamental part was separated from the utility garden, which included a still preserved garden house. The eastern slope under the garden was also planted, where hops were growing according to the description. The park has undergone a major change under the Dalbergs in the early nineteenth century. Karel Dalberg asked in 1817 Michael Riedl, the chateau chancellor of the Austrian Laxenburg, to create a proposal to establish a park in the English landscape style. The architect took full advantage of the rugged terrain sloping from the chateau building to the southwest, including a pond in which the islet was built. Since then, some groups of pine trees (*Pinus sylvestris*), oak (*Quercus petraea*), linden tree (*Tilia cordata*), spruce (*Picea abies*), and alder (*Alnus glutinosa*) originate. Later connection west of plots, west of the pond has evaluated the park, which has not changed much since then. Because of the modification of the park, the chateau was rebuilt in 1831–1833 according to the design of the Viennese architect Karel Schlepse in the Empire style. There were many interesting species of trees that are no longer in the park including the Japanese sophora tree (*Sophora japonica*) in front of the chateau, the mountain pine (*Pinus uncinata*), the black poplar (*Populus nigra*), the linden tree (*Tilia cordata*), and the Eastern spruce (*Picea orientalis*). For the Dalbergs, an empire greenhouse, several gazebos, a Norwegian and Dutch cottage, a chapel, a boat dock, a tennis court, a bowling alley, and a shooting range were built in the park. Apart from the chapel, however, none of the buildings survived. After 1945, the castle was nationalized. Poor personnel, financial, and material security, however, did not allow a new management of the chateau after 1945 to ensure proper care of the park. The professional care of the park was considerably banned, and the park was devalued by many natural rising vegetation that damaged the tree floor and narrowed the viewports. The fenced area of the modern natural theater and playground on the eastern edge of the park, set in the second half of the twentieth century on the site of the former courtyard, and also hit the area of the park insensibly. After 1990, a plan for planting of park stands was elaborated, and it was gradually implemented. The chateau building is surrounded by lawn and sheared ornaments from the red yew (*Taxus baccata*). Huge Canadian hemlock (*Tsuga canadiensis*) and a large specimen of Chinese lilac (*Syringa vulgaris*) are dominant at the entrance to the chateau park. Behind the chateau, the park continues as natural landscape park. The left side of the central meadow is lined with a group of contrasting trees of redwood beech (*Fagus sylvatica ´Purpurea´*), huge fir (*Abies grandis*), European hornbeam (*Carpinus betulus ´Pendula´*), and maples (*Acer platanoides*) combined with more distant Douglas firs (*Pseudotsuga menziesii*) and Eastern white pines (*Pinus strobus*). Across the meadow, there is a path traced by pine forests. In the middle of the park overlooking the pond, there is still a chapel, the only surviving Dahlbergian building surrounded by a group of grown and young conifers. From the chapel, a view opens on the lower half of the park with a pond and a central meadow with a group of western thujas (*Thuja occidentalis*). Huge solitary spruce trees (*Picea abies*), exciting maples (*Acer platanoides 'Lacinatum'*) and overhanging ash trees (*Fraxinus excelsior* '*Pendula*') grow on the left side along the wall. Several groups of oaks (*Quercus petraea*) around the granary and the pond are the oldest trees in the castle park. Surrounding the pond is accompanied by alders (*Alnus glutinosa*) with ivy stands (*Hedera helix*). Despite the popularity of growing exotic plants at the time of the greatest flourishing of the park, no such plants are present, due to the harsh climate. It does not mean that there would be no nonnative and odd kinds of trees in the chateau garden. These include yellow horse-chestnuts (*Aesculus flava*), field maples (*Acer campestre*), Canadian hemlock (*Tsuga canadiensis*), tulip tree (*Liriodendron tulipifera*), ginkgo tree (*Ginkgo biloba*), thorny locusts (*Gleditsia triacanthos*), beech (*Fagus sylvatica pendula*), yellow leaved oak (*Quercus robur 'Concordia'*), and swamp cypress (*Taxodium distichum*). Yews (*Taxus baccata*) are the most common bushes in the park.

3.3.3. Garden of Chateau Cekanice

Cekanice is one of the rare representatives of Classicist architecture in the South Bohemian Region, although its former appearance dates to the thirteenth century, when a medieval fortress was there. It was later rebuilt in the second half of the fifteenth century into a Renaissance chateau. The reason for the present appearance of the chateau and the garden is the fire and the subsequent renovation by Jan Jiri of Helversen in 1785 into a contemporary classicist rectangular castle with an extensive courtyard lined with production and economic buildings. A covered rectangular terrace with a triangular shield carried by Dorian columns is the base of the composition in front of the chateau. The mansion and the originally far larger landscaped park were marked by the nationalization and subsequent placement of the social care institution. At that time, there was almost zero care of the park, and there was also a significant reduction of the park area to the current range of approximately 4 ha. At present, the garden can be divided into two separate parts. The first one is the already restored entrance part of the so-called honorary court, the area of the courtyard in front of the castle. This area is loosely linked to the open space of the chateau terrace. The height difference between the terrace and the courtyard is aligned with a stone wall with an upper terrace and arched stone stairs on the sides. The terrace was supplemented with stone vases in the Classicist style, of which only one was preserved in its original form. The six grown spherical maples (*Acer platanoides ´Globosum´*), supplemented by the undergrowth of creeping juniper trees (*Juniperus horizontalis*)

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and cypress trees (*Chamaecyparis lawsoniana*), are dominants of the courtyard area. The area of the courtyard is optically divided into two units lined in a classicist spirit with sheared boxwood (*Buxus sempervirens*). In the axis of the courtyard, there is a historically documented circular stone fountain, which has not yet been restored. A loosely established landscape park behind the castle is the second part of the garden. It was, as mentioned earlier, far larger. The park passes freely into the surrounding countryside and is thus a complement to the woody, undulating terrain. The composition of the garden also involved the gradual inclination of the terrain to the local pond system. The axis of the park is formed by a path that is surrounded by today's fully involved forests of predominantly domestic coniferous trees (spruce, larch, and pine) supplemented with domestic deciduous trees (ash, linden, oak, and beech) and several specimens of nonnative vegetation in the form of Douglas firs (*Pseudotsuga menziesii*). This woody area is today largely affected by native-seeded vegetation due to low maintenance of the park. In the central part of the park, the torso of Renaissance glory is preserved. The western part is then more open in the form of a meadow and a fruit orchard adjoining the vast pond area. The low-rise buildings that were built at the end of the twentieth century are now a part of the park. These will be removed as part of the reconstruction of the park.

3.4. Landscape parks

Large landscaped parks have a very exceptional position in the landscape of the South Bohemian region. These parks were conceived as a set of different park modifications, castle gardens, and deer parks. These parts together form a harmonic unit interconnected by paths, water elements, and sight axes. This part of the ornamental horticultural work has in many places determined the appearance of large parts of the countryside. The main representatives of these landscaping compositions include Novohradsko, Libejovicko, or Cimelicko.

3.4.1. Novohradsko landscape park

The entire landscape park is situated near the town of Nové Hrady with its dominant castle and chateau. The total treated area is approximately 60 km^2 and extends from the valley of Stropnice, through the Novohradske ponds to the undulating edges of the valley that passes to the Novohradske foothills. The basis of landscape park structure was the Stropnice River, and above all, the dams of ponds covered with oaks.

The foundation of the ornamental Renaissance garden in an elevated position outside the town by Vilem of Rosenberg in 1593 was the first significant impact on the landscape. The lack of space near the existing seat, today's castle complex of Nové Hrady was the main reason for the separation of the ornamental garden from the settlement. In 1630, during the reign of Buquoy family, this garden became the foundation of a formally arranged Baroque garden in the French style. The garden was characterized by many cut flower beds, sculptural decoration, greenhouses, fig house, and summer riding school. Besides the ornamental garden, there were also a kitchen and fruit garden and a utility water pool. The Baroque parter is axially symmetrical, and this axis of symmetry has become the basis of a generous landscape axis with a total length of over 8 km ended by a polychrome obelisk in Kapinos deer park. On the other hand, the ornamental garden related to a linden alley with an adjacent pheasantry, which was arranged in two star breaks. The transformation of a formal Baroque garden into a relaxed landscape park in a romantic spirit occurred already at the end of the eighteenth century. The main interventions were the transformation of the rectangular water reservoir into the current pond, the construction of a rock waterfall, the creation of part-meadows, and the planting of the linden rondel. In the eastern part of the park, according to the Versailles Hameau, a romantic village with a hermitage, a gingerbread house, and a small courtyard were built. At the turn of the eighteenth and nineteenth centuries, the Empire Castle was built according to the plans of the architect Franz von Werchafeld. A stone staircase was added to the southern facade, and the northern facade was rebuilt. There was a terrace with balustrades and a double staircase. This terrace was directly linked to the so-called Blue Salon, which is in a large risalit that may evocate a tent. This salon became the second end of the sighting axis, ending on the polychrome obelisk in Kapinos deer park. At that time, the waterfall in the park was canceled, and an islet with an access bridge was set up on the pond. The romantic village of French style was rebuilt in a fashionable English Gothic style. The Park suffered considerable damage after seizing the property of the Buquoy family after the Second World War. Economic and sports facilities were built into the park, and many woods and building elements were destroyed and damaged, including the complete destruction of a romantic village. At present, the park is again connected with the surrounding countryside, thanks to the cancelation of fencing from the past decades. In front of the southern facade of the chateau, there is a courtyard with grassed oval bed and a unique specimen of ginkgo tree (*Ginkgo biloba*). The most important part of the chateau park is connected to a part-louvred meadow in front of the northern facade of the castle, around the west-east composite axis. Parter meadow is surrounded by balustrades and is revived by the presence of an oval pool with ornamental vase. At the meadow and park intersection, there are many rare woods such as platane (*Platanus × acerifolia*), red leaved beech (*Fagus sylvatica ´Purpurea´*), *Thujopsis dolabrata,* or black locust (*Robinia pseudoacacia*). Linden alley created in the eighteenth century as well as the star arrangement of the pheasantry is still the base of the park. Even on the eastern edge of the park interesting and valuable woody species such as linden trees (*Tilia cordata, Tilia platyphyllos*), maples (*Acer platanoides, Acer pseudoplatanus*), oaks (*Quercus petraea, Quercus robur*), spruces (*Picea abies*), red horse-chestnuts (*Aesculus × carnea*), Douglas firs (*Pseudotsuga menziesii*), and beeches (*Fagus sylvatica*) can be find.

Under the chateau park, another part of the landscape park is connected to the plantation in the valley of the Stropnice river, namely Dolní Bazantnice in Udoli u NHradu, with a total area of 29 ha. However, this area is in a very poor condition, many plantings have been degraded by natural seeded tree species, and only the central meadow is regularly mowed. The area of the pheasantry was established as a fenced area in the years 1667–1670. The area was gradually expanded and upgraded until 1794, when the pheasantry was changed into a utility garden with greenhouses and fruit trees. The utility garden with pheasantry was abolished in 1836, when a decorative park was established from the part around the water surface, which became an integral part of Novohradsky landscape park. Fields emerged from the second part of the former pheasantry around Stipton. In the framework of the reconstruction of the utility garden into the landscape park, the area of the Bazantnik pond was enlarged, two islands were planted, the existing oak stands were supplemented with other trees, a cottage building was built from the gardener's house, and the whole park was furnished with benches. As mentioned above, only the central meadow was preserved in its original form. Other areas are overgrown primarily by native-seeded forest trees and young spruce trees. Oak specimens are the most valuable tree species. The building of the original Cottage was preserved, but all decorative elements on the facade disappeared.

From the landscape point of view, the most valuable area is the so-called Tercino valley in the floodplain of the river Stropnice in the cadastral area of the village Udoli u Novych Hradu. The total area of this most important part of the landscape park is 138 ha. The park is situated at the foot of Nové Hrady Castle hill to the gothic Cuknstejn Fortress. The park was founded already in 1756, in an open area from the current ruins of the so-called Blue House to Economic Buildings, which is no longer present today. In the first phase, it was an ornamental park with flowerbeds, ponds, and a romantic ruin in the form of brick arcades. This form of the valley was destroyed at the end of the eighteenth century after the great floods. After the removal of all the above-mentioned constructions, the part was transformed again into a grassy floodplain. Now, the valley was taken by the wife of the owner of the estate, Terezie Buquoy Paar, who had built many new buildings in the valley. At first, the Wenceslas Spa, the so-called Laznicky was created in 1788. It is an Empire Spa complex with two sidewalks and a main building enclosed by a fence and entrance gates. The spa bath was completed with a swimming pool, a fountain, and a decorative flower bed. A terrace, a small pond, and a greenhouse were set up in front of the spa. In the year 1803, a residential so-called Blue House was built against the Stropnice stream. Under the leadership of architect Ignac Fnoik, the park was transformed into the so-called Friendship Garden in the following years, and it was gradually completed by other buildings such as the Empire Gate, Hammer, Filemon's cottage at Gabriel's Pond, and the Pine Lobe composed of rare specimens of the Eastern white pine trees (*Pinus strobus*). In 1817, there were other buildings in the form of so-called Tonina cottage and Fisherman's cottage. High artificial waterfall with the height of the 720 m was built on the Stropnice River was the most important technical work. The development of the park was completed in the first half of the nineteenth century, when, apart from preserving the existing buildings, other romantic buildings were added, such as the Swiss House, Brezovy summer house, and there was also a reconstruction of Hammer and the house of a wheeler in the spirit of English rural architecture. In the last century, there was a significant degradation of the park. After 1991, the park was restored to its romantic appearance except of the Blue House, which was damaged by the flood and is now only in the form of ruins.

3.5. Modern garden styles

These large complexes, mainly from the nineteenth century, were completed at the turn of the century mainly by small-scale Art Nouveau gardens. It is based on the principle of negation of historicism. The main features are asymmetry, ornaments, linearity and continuous, often complicated curves. These gardens have large lawn areas and carpet beds, and there is also a large water area. In addition, the color of pavements, garden furniture, and pergolas often appears. Art Nouveau style appeared in garden architecture only for a short period of time. Art Nouveau gardens are connected almost exclusively with the newly built magnificent villas. These villas were often nationalized and devastated in the second half of the twentieth century, just like their gardens. In some cases, the gardens were rebuilt in new emerging avant-garde styles, such as Cubism or Functionalism. For this reason, only a tiny fraction of originally pure Art Nouveau gardens, such as the garden of the Hardtmuth Villa in České Budějovice, survived to this day. These gardens have returned to an isolated, precisely enclosed space that is not a developmental or interconnecting element from the point of view of the environment. This isolation is typical for all other types of gardens up to the present. Since the end of the nineteenth century, the creation of open park areas has been linked only to the urban environment, where urban parks were established. The first half of the twentieth century was further characterized by the rapid alternation of various avant-garde art styles, which were reflected in landscaping and horticulture, but rather in smaller areas and near villas in the urban environment. These are directions such as Cubism or Functionalism. Cubism consisted of spreading the object into simple geometric shapes and their subsequent folding. Cubism manifested itself primarily in family gardens where it touched not only beds and arrangements but also fences and pergolas. The woods were often spaced at regular intervals and cut. Garden trips are most often seen by triangles or trapezoids, which divide the garden into parts using a hedge, inside which was a lawn, a flowerbed, or a vegetable garden. On the other hand, a functionalist house or villa formed a garden with a single unit and was nonviolently connected to it by large windows and a winter garden or terrace. The main features of Functionalism are trimmed hedges, climbing greenery on the facades of the house, flower beds of austere shapes, and grassy surfaces. After the Second World War, residential settlements began to appear to a large extent, with the construction of the garden and urban greenery. Bohemia has been a gardening colony for many years since the end of the 1950s. Urban settlements and country houses set up settlements with a specific architecture of small garden buildings. In urban settlements, greenery has been formulated completely since the 1950s without any conception and knowledge of tree species. Approximately from the 1970s, a natural garden with an ecological approach, promoting the return to nature began to grow significantly. Private gardens are formed based on the owner's requirements and lifestyle. Gardens are formed by self-help and professional firms, both natural and formal, of varying size, public, private, and semipublic. Gardens are embedded in artworks or modern materials and technologies (optical fibers, LED lighting). Gardens are realized on both roofs and vertical facades. Today, we are returning to setting up gardens and gardens for utility function or dividing parts of gardens into various functions, such as utility, leisure, mostly supplemented by swimming pool, ornamental etc.

4. Conclusions

As can be seen from the above described characteristics of individual historical types of gardens and parks, including the examples, the position of ornamental gardens in the landscape has changed considerably over the course of history. The gardens of medieval castles and monasteries are the oldest documented gardens on the territory of the Czech Republic. Only few gardens of large monastic complexes, such as Zlata Koruna, Vyssí Brod, or Milevsko, have been preserved from that period in the South Bohemian region. The castle gardens did not preserve because of the frequent later breaks or destruction of the castles, except for the unique gardens in the Zvikov castle complex. Since then, practically until the onset of the Baroque in the seventeenth century, the ornamental garden was an isolated area near aristocratic and ecclesiastical settlements, and only slowly the surrounding landscape became the backdrop for views from enclosed areas of landscaped gardens. As the typical representative of this isolated "Italian villas" Renaissance style of gardens, we can mention the garden of Kratochvile chateau of gardens of other small Renaissance village chateaus built in the Renaissance period. There was only one exception—the hunting deer parks, which have related to the surrounding landscape background, especially with forest stands, even though the parks were fenced. Since the southern Bohemia was a very important area from the point of view of the noble families (Families of Rosenbergs, Eggenbergs, Schwarzenbergs, Buqoys etc.), hunting fields have been one of the most extensive examples of planned changes in the country since the Renaissance. The Cerveny Dvur Deer park, Old Deer park near Hluboka nad Vltavou, Deer parks near Nove Hrady, and many others are the typical representatives of such hunting fenced places. Since the time of the Baroque, the country's ornamental gardens have been open to their surroundings, and their authors have tried to blend the gardens together with the surrounding landscape, as much as possible. It does not mean, however, that these gardens were not the private inaccessible area of the owners of the noble settlements. Open landscape parks have become a phenomenon of the landscape, since then, and especially in the era of Romanticism. The creation of these parks meant the transformation of huge landscapes into an open informal garden. Various buildings imitating architectural styles and customs from different parts of the world have become an integral part of these parks. Ornamental gardens and landscape parks have also enriched rural landscape by a wide variety of introduced plants, including very exotic specimens. South Bohemia became besides the South Moravian region one of the most important places in the whole Central European region in the creation of such type of open landscape parks. We can mention the huge transformations of the large parts of landscape into the landscape parks as Novohradsko, Libejovicko, Cimelicko, and others. It is important to note that the Baroque and empire gardens of small rural mansions from this time also played an unimportant role in the creation of rural landscape in the South Bohemian region. From the time of Art Nouveau, the gardens have begun to be isolated, and today, they are becoming more and more closed as a private resting place for rural houses and mansions.

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Section 3

Sustainable Prototypes of a Contemporary Landscape Architecture

Chapter 5

Ecological Aesthetics: Design Thinking to Landscape Beauty with Healthy Ecology

Lee Lee-Hsueh

Additional information is available at the end of the chapter

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Abstract

Scenic aesthetic is the outcome of interactions between humans and landscapes, in general made people focus on landscape beauty. The ecological experience is generally considered an explorative process based on the knowledge of the ecology. One major underlying problem is many people have misconceptions about the relationship of scenic beauty and ecological function; thus, two parallel lines were emerged between the appreciation of landscape and ecology. *People's landscape aesthetic experience* leads people to change the landscape, subsequently ecological function. Ecological aesthetics could date back to the evolutionary theories. The aesthetic preference has changed through time and may reflect the public understanding of ecology, which provides a critical linkage between humans and ecological processes. Landscape aesthetic and ecological quality can coincide in some issues, such as the idea that visual variety in the landscape is stimulated by natural patterns and related to the incidence of biologically productive effects. The experience process and the influential factors of beauty in landscapes with healthy ecology were drawn out, and these result in benefits for good landscape with healthy ecology. Within the contexts and principles, the construction of good healthy ecology and sustainability can be achieved.

Keywords: aesthetic appreciative transaction, scenic beauty, ecological function, ecological aesthetics indicator

1. Introduction

People prefer beautiful, scenic views of landscapes with good ecological health; they tend to appreciate and enjoy this, and positive emotions are aroused. Besides the effectiveness of the aesthetic experience on positive emotions, the benefits of the ecological experience are also considered in this chapter. Landscape aesthetic has been studied for a long time, in both descriptive inventories and public preference models and in both the expert and perception-based approaches. These studies have revealed the interactions between humans and landscapes as well as the results on the affective and cognitive responses and the composition of landscape aesthetic characters.

These approaches generally accept that the aesthetic experience derives from the perceptual and judgmental process of landscape visual quality assessment. It is public knowledge that ecological quality is important for landscape appearance and scenic beauty; nevertheless, humans cannot directly sense ecological quality [1]. In general, pervious research based on evolutionary and cultural theories assume that high ecological quality is associated with aesthetic quality. These arguments have allowed people to emphasize multiple aesthetic benefits, especially the appearance of the landscape, while ignoring the actual link between landscape and ecological quality; thus, the effect of the ecological aesthetic on the appreciation of landscape aesthetic is often overlooked.

According to the concept of evolutionary theories, people view landscape as a habitat, and aesthetic pleasure is derived from the experience of humans seeking a suitable habitat. Meanwhile, the aesthetic experience leads people to change the landscape, and these changes affect environmental processes and ecological functions. Therefore, a gap exists between the human-dominated landscape design and the ecologist's work, indicating that ecologically sound landscapes may not be aesthetically pleasing. In turn, ecological services and aesthetic attractiveness are like two parallel lines. This is not merely due to human influences on most landscapes, but it is also due to the challenge of climate change and sustainable development. There is no time to lose in bridging this gap.

The relationship between landscape aesthetic and ecology should no longer be described within the environmental behavior models; this may lead to the human aesthetic preference, and ecological goals are not aligned. In reality, however, aesthetic preference is associated with scenic beauty and high ecological quality [2–4].

The study believes that people could provide a direct sense of the ecological aesthetic, including landscape aesthetic and ecological quality manifestation. Aesthetic preference was derived from biophilia evolutionary theories and has developed through the spatial construction of physical landscape characteristics. Ecology was influenced by these characteristic associations. People evaluate their landscape preference while judging ecological quality; thus, it can be agreed that aesthetic experience and ecological quality are in alignment with each other.

On this ground, it is suggested that the objects of aesthetic appreciation are included in landscape and ecology quality. Landscape and ecology are simultaneously examined when people admire the landscape to gather environmental information. Aesthetic value and behavioral responses are the common outcomes of the simultaneous examination of landscape and ecology. This reveals the conceptual framework of the ecological aesthetic experience, as well as the common characteristics and factors that indicate the aesthetically pleasing landscapes that have healthy ecology. That is to say, the common concept of human aesthetic appreciation is combined beauty with quality of landscape and ecology, that is, the nature of ecological aesthetics.

2. The linkage of landscape aesthetics and ecology

The idea that landscapes are perceived as aesthetically pleasing means that people are able to distinguish beautiful scenery from a variety of landscapes. Based on habitat theory of evolutionary hypotheses, people considered aesthetic preferences to determine whether the landscape was suitable for survival [5]. Ecological and aesthetically pleasing environments provide valued experiences that can improve a person's quality of life [6]. This implies that these types of landscapes were beneficial for both human and ecological well-being. Environmental changes and urban sprawl have caused landscape resources to be under attack; therefore, it has been advised that people appreciate and protect landscape resources whether for environmental aesthetics or ethics.

Environmental aesthetics has traditional roots in the seventeenth to nineteenth century aesthetics of nature [7, 8], which present the idea of positive aesthetics. These positions further developed views concerning the natural environment. Leopold's often quoted land ethic defined environmental aesthetics, which tends to preserve the integrity, stability, and beauty of the biotic community [9]. Thus, these positions were distinguished into two groups: labeled cognitive and noncognitive views. Recently, developments in environmental aesthetics have broadened from their initial focus on the natural environment to consider the human and human-influenced environment. Additionally, they extend to everyday life through the consideration of what is known as the aesthetics of everyday activities.

Philosophical aesthetics had major interest in art; by contrast, aesthetics of nature was neglected in the first half of the twentieth century. That revealed the art-dominated construal of aesthetics of that time. The aesthetic for the appreciation of nature was compared with art, but nature was messy and of less philosophical interest. Analytical aesthetics dominated the second half of the century, where empirical approaches emerged with a focus on scenic beauty [10]. These approaches were used in response to the public aesthetic preference for the environment and greatly influenced picturesque landscape. As with landscape aesthetics, a somewhat tangible value could be systematically analyzed and landscape qualities could be translated into formulas useful in landscape design and management. However, that field was thought to lack an adequate theoretical framework. The idea of a socio-biological aesthetic appreciation of nature was prompted, such as is the case in evolutionary theories. According to bio-evolutionary preference, the basic aesthetic preferences of *Homo sapiens* are argued to have evolved in order to enhance survival and reproductive success; this can be seen in the selection of certain landscapes based on survival needs, such as being able to see without being seen in savannah-like landscapes.

In spite of such reservations about the various approaches of environmental aesthetics, the importance of ecology in the aesthetic appreciation of nature is stressed due to increasing concern for environmental issues. With a new interest in the aesthetic of nature and its relationship with people and the built environment, "ecological aesthetics" has emerged in the last several decades [4, 7, 8, 11]. The root idea of ecological aesthetics originated from Aldo Leopold [9, 12–14]. Today, ecological aesthetics incorporate studies of the aesthetics of nature,

Author (year)	Content of ecological aesthetics
Carlson [8]	Ecological aesthetics linked the beauty of nature to ecological integrity and stability; endorsed by engagement and the over-arching value of the ecosystem's biodiversity and health.
Gobster [15–17]	The different aspects of ecological aesthetic elements, such as individual, landscape, human-landscape, and outcomes combine to gain a deeper understanding and appreciation of nature. This blends with landscape aesthetics and ecological management in order to determine how aesthetic and ecological values are perceived.
Gobster et al. [18]	Ecological aesthetics bound up the visual quality and a pleasurable landscape appearance of ecological processes. It is desirable for humans to take aesthetic pleasure from landscapes that embody beneficial ecological functions.
Hill and Daniel [19]	Aesthetic preferences for natural landscapes are mediated by affective processes and developed by natural selection during human evolution. Ecological aesthetics have brought landscape aesthetic preferences into ecological imperatives.
Jorgensen [2]	Compared to relying on static visual cues of scenic aesthetics, ecological aesthetic appreciation for ecological landscapes was founded on a more dynamic, polysensual, and active engagement with the environment, and based on an understanding of environmental functions.
Koh [20]	The ordering principles in nature and landscape, which are inclusive unity, dynamic balance, and complementary, are the base of environmental ecology design, as an ecological paradigm of aesthetic.
Parsons and Daniel [7]	Ecological aesthetic takes the biological principles of ecosystem management (biodiversity, sustainability, etc.) as given and then asserts that human environmental aesthetic preferences should be consistent with those principles.
Sheppard [21]	Seeks the sustainability of landscape aesthetics and ecology, reflecting upon a deeper consideration of the beauty of the ecological function and process. The idea of visible stewardship may be the common criterion for aesthetic preference and healthy ecosystems.
Toadvine [4]	Ecological aesthetics concerns the aesthetic appreciation of the world, including both the natural and built environment. Whether through phenomenological or cognitive approaches, it has espoused the different modes of aesthetic considerations of specific domains.

Table 1. The content of ecological aesthetics from different researchers.

including natural objects and larger wholes, both within nature and the built environment. Additionally, it involves the relationship between the aesthetic appreciations of good-looking landscape with healthy ecology. **Table 1** summarizes the content of ecological aesthetics as presented by various researchers. The common perspectives considered that ecological aesthetics is a linkage between landscape and ecology. People perceived the appearance of landscape as an experience of the landscape, ecological function, and management as a whole.

3. The shared sources of landscape aesthetic preference and ecological aesthetics

The visual enjoyment of natural scenery has been widely recognized by people's desire to see, live in, and visit beautiful places [18]. People have also changed the landscape in order to ensure a suitable habitat. In the spatial–temporal milieu of landscape, this response not only expresses

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Landscape	Ecological aesthetic attribute	Ecology	Source
Visual scale, viewshed size	Landscape room	Patch size	[3, 16, 19, 21, 26, 27, 30–33]
Unity of a scene; elements or patterns are easy to be organized and fitness to content.	Coherence	Ecosystem, landscape, land use, vegetation suitability for natural conditions	[20, 21, 23, 26, 27, 32, 33]
Depth of view, visual perspective	Openness	The challenge of invasion in larger openings, and may reduce diversity	[19, 30, 31]
Diversity/richness of landscape elements/ pattern	Complexity	Habitat heterogeneity, land cover diversity	[21, 23, 27, 32, 34–36]
The holistic view of closeness to natural state	Naturalness	The degrees of naturalness to ecosystem and landscape	[3, 7, 18, 21, 27, 31, 34, 36, 37]
Sense of order, very careful management	Stewardship	Balanced patch size distribution/ edge, unfragmented ecosystem	[18, 20, 21, 26, 27, 34]
Pattern/land use interfered, and not fit into context	Disturbance	A discrete event or force brings ecological pattern, habitat change	[16, 21, 23, 26, 34]
Diversity, richness, evenness of landscape patterns, characteristics or elements refer to spatial complexity/coherence perception	Diversity	The elements of biodiversity, richness, and evenness that influence how ecosystems function	[33, 35, 38, 39]
	Richness		[30, 33, 35, 38, 39]
	Evenness		[35]
The variety of landscape types that help with aesthetic attractiveness.	Pattern/land cover (on site)	Land cover has effect on biodiversity, ecological function	[3, 19, 33, 40]
Human activities can result in the decrease of landscape aesthetic and naturalness.	Land use (off site)	The intensity of human-dominated landscapes like constraint in ecological quality of landscape room.	[33, 40–42]

Table 2. The common attributes of landscape and ecology.

landscape preference but also shows people attitude about ecology. The foundational-related theories of above exposition are evolutionary theories [22, 23] and cultural theories [4, 11, 16].

Evolutionary theories have inferred that humans prefer the prototype of landscape that is “to see without being seen,” such as in savanna-type landscapes in which the characteristics of prospect and refuge are present. Furthermore, Kaplan and others, based on information processing theory, suggested the information preference matrix that tracked people’s preference of natural landscape [5, 23–25]. This matrix was made up of making sense (understanding) and involvement (exploration). The arrangement of contents in the natural setting provided an understanding and potential for exploration, that is, environmental information for people perceived landscape.

When environmental information is coherence that means the setting is orderly and easy to understand for people; that would make people considers the environment is more security. The contents were distinctive and easily identified, indicating legibility, in a landscape that helps people have a strong sense of orientation and memories about the setting. Complexity, which is the richness and diversity of the landscape, encourages people to explore it, thus moving deeper and getting more environmental information in the mysterious setting. This implied that the range of the setting was perceived by the human's vision; prospect-refuge theories also asserted that the opportunity to see while not being seen was determined by visibility, and was defined "landscape room." Landscape room is related to the size of the perceptual unit or visual scale [26–28].

People can only hold a certain amount of environmental information at one time; the coherence of the physical elements' arrangement in the visual field is conducive at fore-middle ground, while the topography, taller trees, etc., alter the visible field. Within the landscape, physical elements were abundant and located in the background; this created a complexity and encouraged people to go deeper to explore [24, 26, 27]. Landscape room is not only related to landscape preference but also concerned to the patch size of landscape ecology. Patch size affects the edge and core habitats and species [29].

Herein, the visible field is considered a key factor in shaping the spatial layout of landscape and ecology. The combination of different landscape physical elements and its locations have influences on aesthetic perception and ecological function. For example, the density of tree group affects visual penetration and whether people could catch environmental information easily or not. That also related to the challenge of invasion and the diversity of habitat. Landscape room after landscape room forms a sequence of landscape experiences, which also act as a matrix of landscape ecology structure. The common attributes of landscape and ecology are shown in **Table 2**.

4. Conceptual framework and indicator of ecological aesthetic

4.1. Conceptual framework of ecological aesthetic

Humans involved in the environment within the process of human-landscape and ecological interaction had created ecologically aesthetic preference. People not only perceived the appearance of the landscape but also the ecological state, when engaged with the environment. The content and form of the environment included the variety and structure of the landscape and ecological elements arranged within a landscape environment. Its composition affects the appearance of landscapes and ecological functions. Herein referred to as "the construction of landscape and ecological characteristics," it was furthermore divided into "physical elements" and "spatial layout." The process of the aesthetic experience and behavioral responses was described as transactional and contextual [1]. The former refers to the interaction and transfers that occur between humans and the environment; the latter refers to human behaviors that are shaped by the environment. These parts were assigned as "aesthetic appreciative transactions" and "ecological aesthetic experiences." Afterward, change is an outcome of the aesthetic experiences; executive management, therefore, has to be on the side of human well-being and environmental sustainability. The conceptual framework for ecological aesthetic experiences is shown in **Figure 1**.

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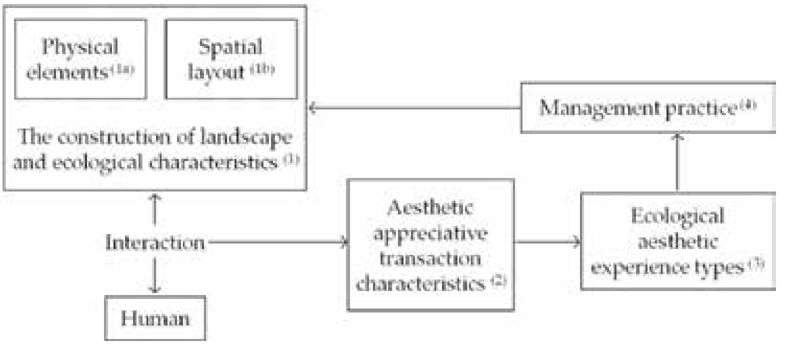

Figure 1. Model of ecological aesthetic experience process.

1. The construction of landscape and ecological characteristics. That is the spatial layout of the physical elements and would influence landscape preference and the structure of the ecological landscape in a landscape room.
   a. Physical elements. The composite modes of landscape and ecology elements have significant effects on aesthetics value and ecological functions.
   b. Spatial layout. The elements of landscape and ecology located at a landscape room.
2. Aesthetic appreciative transaction characteristics. People went into and sighted landscape room that was an interactional process between people and ecological landscape. Thus, people make sense of the environmental information, which refers to how they perceive the structure of a landscape room, and breed ecological aesthetic appreciative perception reactions.
3. Ecological aesthetic experience type. Once people comprehend the landscape room, next they would have different ecological aesthetic experience types. In this setting, people may or may not go deeper and get involved in landscape room.
4. Management practice. People modified and managed landscapes based on the outcomes of the aesthetic experience in order to build a suitable habitat and improve the landscape aesthetic.

4.2. The factors of the characteristics of the ecological aesthetics

The adaptable factors of each characteristic of the ecological aesthetic framework are shown in **Table 3**.

4.2.1. The construction of landscape and ecological characteristics

The construction of landscape and ecological characteristics consists of physical elements and spatial layout.

The physical elements are the eight common attributes of landscape and ecology, including vegetation, vegetable structures, vertical elements, water, edge, pattern/land cover, man-made

The construction of landscape and ecological characteristics		Aesthetic appreciation transaction characteristics
Physical elements	**Spatial layout**	
Vegetation	Landscape room	Coherence
Vegetable structure	Foreground	Openness
Vertical element	Middle ground	Complexity
Pattern/land cover	Back ground	Naturalness
Edge	Overall landscape	Diversity
Man-made feature/human activities	Surrounding environment	Richness
		Evenness
Water		Stewardship
Land use		Disturbance

Table 3. Indicators of each character of ecological aesthetic framework.

features/human activities, and land use. These factors commonly affect the appearance of the landscape and its ecological function. Edges are the boundaries of patterns or landscape rooms. Patterns are the various vegetation clusters or land covers in the landscape room. Land use is land development in the surrounding environment of the landscape room.

The spatial layout shows the physical elements of landscape and ecology allocated in an environmental space. One of the most important indicators in the landscape room is the perceptual unit of people, as it is necessary to sense and manage people. Other indicators are the foreground, middle ground, background, overall landscape, and surrounding environment.

4.2.2. *Aesthetic appreciation transaction characteristics*

Aesthetic appreciation transaction characteristics indicate the perception response while people enter a landscape room, gather, and deal with environmental information. This result has a major influence on ecological aesthetic preference and value. The indicator includes coherence, openness, complexity, naturalness, diversity, richness, and evenness.

4.2.3. *Ecological aesthetic experience types*

Ecological aesthetic appreciation was established based on the tangible value of landscape and ecology resources. The transactional process offers responses to ecological aesthetic experiences that result in a contextual state. Ecological aesthetic experience types may be emotional arousal, cognitive response, and behaviors including escape or approach, positive or negative emotions, legibility, mystery, and so on.

4.2.4. *Management practice*

Aesthetic experiences made people change the landscape and ecological function. This reveals people's care for and attachment to a particular landscape [43, 44]. Management practices

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therefore might establish the relationship between landscape and ecology and enhance the ecological aesthetic [7, 18, 19, 21]. Beauty perception would benefit the will of conservation; therefore, management practice is accepted by people [45]. Man-modified landscapes and respect for nature in certain contexts are well liked [43]. Stewardship is considered the outcome of management; disturbance is an unseemly spoiled landscape and ecology resource.

4.3. The appearance of factors for ecological aesthetic

The various groupings of common indicators of landscape and ecology are located on a landscape room. The spatial distribution is shown in **Figure 2**. The spatial layout of the physical elements includes the construction of landscape and ecological characteristics, where people enter, and the interaction between both. The process of human-landscape interactions rises interest in landscape and has aesthetic appreciation transaction characteristics, thus sprung ecological aesthetic value and preference.

According to prospect-refuge theory, which seems to consider the experience of ecological aesthetics in a landscape room, informational processing theory is a sequence experience of a succession of landscape rooms, based on evolutionary hypotheses. The construction of landscape and ecological characteristics falls into fore-middle-back grounds, in which landscape room after landscape room forms a sequence experience of ecological aesthetics. Combine those with surrounding environments to make up the overall landscape. As people go into landscape rooms and go deeper, they become enclosed in landscape rooms and the overall landscape, and the outcome of the experience of the interaction between both is the ecological aesthetic. The succession and number of patches were benefited aesthetic experiences [3].

If people go into, look at a landscape room, and appreciate it, they seize and comprehend the environmental information of the construction of the landscape and ecology characteristics.

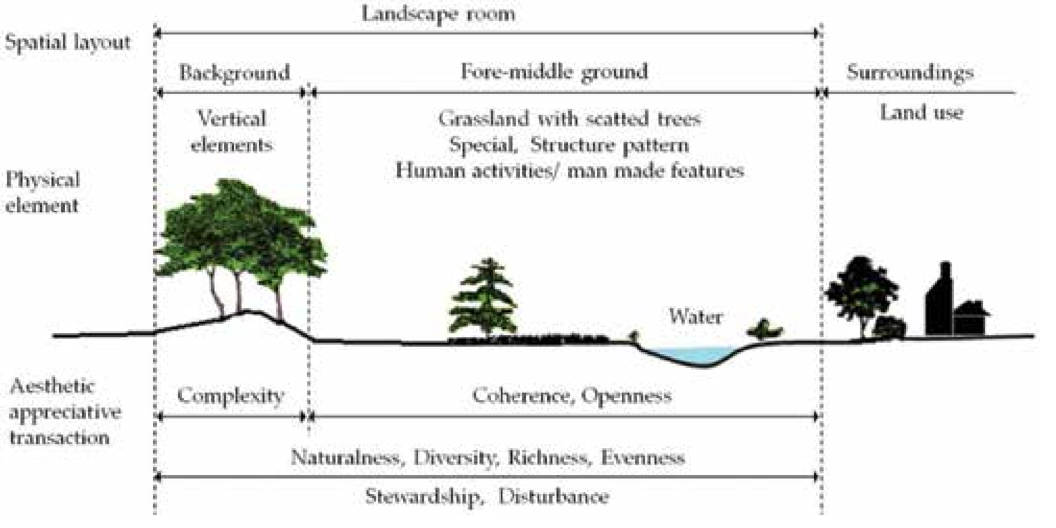

Figure 2. The conceptual scheme conveyed various indicators of landscape with ecology configured on a landscape room.

The relationship between the grouping of physical elements and spatial layout caused people to make sense of the landscape environment. In the species-rich grassland with scarce trees located in the fore-middle ground, people would hold that the environmental information was easy to understand. The visualized landscapes varied in structure in different heights of plants, such as meadow, hedge, and trees, making up patterns in which heterogeneity and diversity were perceived as scenic beauty [23, 42]. A type of setting possessed easier to understand and organized construction characteristics. People consider the setting as coherence and naturalness and show high ecological aesthetic value. Trees are refuge symbols, and the spaces between trees are prospects, according to the Appleton's habitat theory [46]. The various scenarios among landscape and ecological functions also indicate the structure of landscape ecology.

Kaplan and Kaplan [23] supposed that man-made features could drive landscape preference, so keeping the natural landscape free from man-made features is a better option. However, it was not possible to avoid man-made features, as appropriate man-made features would make people favor a place [47–49]; man-made features also relate to place attachment and place identity. For this reason, man-made features must fit the condition of the landscape and ecology and lay somewhere between the middle and background. The same consideration took place on land use and recreational activities.

Water is an important factor in landscape and ecology, as it causes positive perceptive responses and actions and results in habitat and species diversity and abundance. Waterscape was the preferred origin form due to its subtle influence of survival value, according to evolutionary theories. Bodies of water have ecological benefits, especially as a natural edge, that is, water-land ecotones in which the area is characterized by high biodiversity.

On the other hand, a degree of openness can be visually pleasuring, as this determines the opportunity to see while not being seen. Vertical elements, such as taller trees, topography, etc., lay on the background, and open land in the fore-middle ground has contributed to identifying the scale of viewshed. This characteristic of landscape and ecology construction would portray the setting as having complexity and encourage people to go deeper to explore it. Meanwhile, richness and orderly background are considered a key visual aspect for aesthetic preference. According to the informational processing theory [5, 23], an overly enclosed view limits the visual penetration and the ability to move around, which may make it difficult for people to find their way. However, the larger openings not only decreased mysterious perception but also had challenges of invasion and may reduce diversity. People generally prefer smaller openings over larger ones [16, 26, 30, 32, 50] and openings that are scattered over those that are concentrated [16, 50]. This involves an increase in patch heterogeneity and dynamic.

Whenever vegetation is allocated at fore, middle, or background in a landscape room, the diversity of plants is essential. This may cause variety in the visual landscape and ecological function. Richness and evenness are indispensable to the ecological aesthetic. The combination of the three indicators would ensure that the landscape room has coherence and complexity. The former's environmental information being easier to understand is also related to its legibility; the latter is out of respect to the mysterious. It also determines the action responses.

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Length of edge is closely related to gain size; this could be considered an aspect of landscape diversity and probably has ties with total viewshed area. Disturbance may cause change in edge length, affected edge, and habitat quality [29, 51]. The edge effects have impacts on visual variety and aesthetic value, which are also related to the incidence of ecological functions.

The spatial patterns of land cover types give rise to various aesthetic experiences [40]. Vegetative cover, human activities, and natural elements affect patterns of landscape, as well as aesthetic and ecological functions of landscapes [52]. Fragmentation in land cover has influenced core habitat and species quality and decreased ecological functions. This also caused visual landscape to lack coherence in the landscape room. Low-input land cover types may contribute to attractiveness of a landscape room, and yet less structures and homogeneous landscapes were less appealing due to a lack of complexity and mystery [23, 25].

Overall landscape is the landscape appearance of the landscape room. The overall appearance must reflect the aforementioned characteristics, so that it can better perform its landscape appearance and ecological functions. As a whole, the visual quality of the overall landscape concedes that the ecological aesthetic value improves with increasing diversity, naturalness, and natural appearance. A high affinity of a natural-looking setting is more favored and receives high aesthetic values.

Visual landscape aesthetic preference is based on biological and evolutionary principles [23], and beauty being in the eye of the beholder is shaped by cultural and contemporary environmental behaviors [16, 18, 30, 33, 53]. For various reasons, landscape and ecology management is carried out. People perceive the outcomes of management as either stewardship or disturbance. Stewardship, as a spatial expression of landscape, is orderly both visually and ecologically. Careful management ensures that landscape ecology maintains its dynamic, balanced state as an orderly process [20]. Stewardship also has an effect on human aesthetic preference [18, 21, 26, 27]. Instead, lacking careful management may lead to secondary succession that modifies flora and changes fauna.

Disturbance causes visual landscape incoordination, ecology disconnection, habitat fragmentation, and isolation. According to informational processing theory, understanding provides a sense of security. When disturbed, a landscape room was perceived as chaotic and disorderly. People may feel distressed and sense inaccessibility if they cannot comprehend the situation of the setting. Disturbance also leads to negative changes in the habitat quality in the long term.

Land use is a description of how a parcel of land is employed by people. Land use intensity of the surrounding environment revealed the police and consciousness of landscape and ecology. Surrounding land use of a landscape room may fit both landscape "needs" and public desires. The lay public may have different sensitivities to responses to the ecological aesthetic that may lead to the loss of development aesthetics for a wide variety of natural phenomena.

The land use of surroundings would change energy flows and nutrient cycles and invasive species in a landscape room, which would also have impacts on visual quality of the overall landscape. The land use of the surroundings must fit well with the landscape room. That means fitting and stewardship land use of the surrounding environment are important for the aesthetic and ecological function of the landscape room.

5. Conclusion

People really love and enjoy a good-looking landscape with healthy ecology; aesthetic preference was human transactions with the environment, as contextualized behaviors changed the landscape. Aesthetic preference for landscapes of relatively ecological quality is associated with behavior that is improved or protective of this resource. Aesthetic preference could be felicitously accommodated by evolutionary theories of the environment. Besides, cultural theories and contemporary environmental behaviors also influenced aesthetic preference. The cognitive and noncognitive (phenomenological) approaches focused on visual perception and preference, given the increasing attachment to the visual imagery and affective responses. These views revealed that the experience of ecology and landscape diverged. For example, ecological experience is all senses engaged, knowledge-oriented, active participation; the benefits are long term, and landscape is dynamic, living, changing and follows the ecological functions. Scenic experience is visual sense, perceptual, object-oriented, stimulus–response process; the outcome is mood change in the short-term, and landscape is static and inanimate. The two views were sure to split up, as ecologists and landscape architects engaged in different settings in general. Basically, the aesthetic experience may be supplied by memory or imagination, not only by present perception. Ecological aesthetic is the catalytic agent to sew together the gap between the scenic and ecological experience.

The previous studies were clarified; in that, human aesthetic preference was a blend of landscape and ecology. People appreciate and enjoy scenic landscapes. Landscape and ecology were combined, and the scenic appearance was the performance that landscape and ecological functions have in common. Some arguments that indicated the disjuncture of landscape aesthetic and ecological function in which humans cannot directly sense ecological quality can be refuted. Ecological aesthetic was based on evolutionary theories to assume that high ecological quality is associated with high aesthetic quality.

In some cases, aesthetic and ecological value may be inconsistent, and *r/K selection theory* can be quoted to explain this state. In ecology, r- and K-strategists play distinct roles in the ecological succession. Organisms that live in unstable environments tend to produce many offspring and reproduce quickly because the environment changed quickly, that is, *r*-selected species. By contrast, organisms living in stable environments tend to make few offspring, and in stable or predictable environments, K-selection predominates. The former meant that in an unstable habitat, the visual landscape may be messy; the latter may represent a mature habitat in which the landscape is orderly. The habitat of r-selected species may deduce the appearance of landscape as naturalistic, but not attractive; this was not the preference of the people.

This chapter indicates that high aesthetic quality is associated with high ecological quality, especially in the appropriate visual scale of a landscape room. Meanwhile, the experience process of ecological aesthetic and the common indicators of landscape and ecology were drawn out. The integrative ecological aesthetic standpoint and tools are improved to construct the good seeing landscape with healthy ecology.

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Chapter 6

Retrofitting Biophilic Design Elements into Office Site Sheds: Does 'Going Green' Enhance the Well-Being and Productivity of Workers?

Tonia Gray

Additional information is available at the end of the chapter

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Abstract

The use of biophilic elements in industrial design has become more commonplace as the benefits of natural environments show stronger links to positive health benefits and mental well-being. This chapter discusses the rationale, process and results of a study which examined the effects and long term impacts of biophilic design for site office workers. The research investigated the impact of incorporating plants, natural sunlight, prospect, ventilation, open spaces and windows to an office environment through retrofitting the design of a site shed. To examine the impact on productivity, stress and general well-being, this longitudinal study spanning over 2 years tracked the concomitant cognitive, social, psychological and physical benefits for workers. Within the first 3 months, data indicated a strong positive effect from incorporating green space to amend stress, enhancing well-being, fostering a collaborative work environment and sustaining workplace productivity. Through the course of the study, data continued to support these findings by indicating a rise in engagement with the design components and repeated evidence of workplace collaboration. In exit interviews, transference of greening concepts and accessibility to transform the workspace was discussed.

Keywords: productivity, well-being, biophilic design, natural elements, site office, collaboration, stress

1. Introduction

As we spend more and more time in traditionally designed office spaces, the need to address health, productivity and well-being in these spaces has grown [1]. Many modern companies are addressing an idea of 'going green' as it impacts their presence within the

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industry, but recently there has been a shift into focusing addressing the benefits that may result from greening within the workplace environment. This chapter outlines the practical steps taken to retrofit a tiny site office shed into a bespoke open plan office and the subsequent response from workers on how they experienced the design. The office shed is designed as a temporary space, however, for many workers who may spend most of their careers moving between them, it becomes a more long-term working environment. Through this step-by-step guide, our vision was to provide a tool to transform site sheds across the nation into more comfortable, productive and attractive workspaces for their occupants. Davidson [2] discussed that the design of a workplace can have a negative effect on the desirability of a job: "a third of respondents said that an office layout would affect whether or not they wanted to work somewhere". Through this vision, managers have the potential to heighten the quality of workplace environments. The effectiveness of this model was examined through four stages where person-plant interactions were tracked throughout the course of the study alongside the impressions and outcomes of those active in the workplace.

2. The research on nature within the built environment

Psychologists and environmental planners have been studying how people's health is affected by the presence or absence of the natural world in their immediate surroundings for almost two decades. A plethora of research documents how nature, especially sunlight and plants, can have a causal link to human well-being [3–19]. Biophilic design intends to enhance human well-being by fostering connections between people and nature in the modern built environment [20–22]. Despite the empirical evidence we have been slow to react because governments and business still think of biophilia as something esoteric or whimsical.

Given the noticeable positive health and productivity benefits upon workers, companies around the world are now examining ways to 'go green' within the four walls of their office space [23]. By incorporating the presence of natural elements into their workspaces, Davidson [2] reports that "greenery and natural light can boost workplace productivity by 6 per cent and increase employee well-being and creativity by 15 per cent". Views of nature outside the office or work area window have repeatedly shown that a natural view effects employees level of depression, frustration, and mood, with noticeable elevations in job satisfaction, patience, enthusiasm, and contentment [24–26]. Furthermore, the number of indoor plants proximal to a worker's desk correlates to productivity [27, 28]. Despite these compelling metrics it is perplexing that most corporate employers do not offer these simple amenities. To this end, Davidson [2] reveals 47 per cent of office employees said they have no natural light at their workplaces, while 58 per cent have no plants in eyesight.

Human-nature contact possesses a myriad of benefits and over the past 3 decades a growing body of research has been generated to provide testimony to these claims. For instance, Berman et al. [29]; Cha [30]; Dannenberg et al. [6]; Lewis [31–33]; Relf [34]; Shanahan et al. [35];

Ulrich [36–38]; Ulrich & Parsons [39]; and Verderber [40] have identified the following gains: stress reduction, improved mental acuity, creativity, healing, attention restoration, development of perceptual and expressive skills.

Elings [7] postulates there is a dearth of information about the people-plant interactions or the mechanisms behind nature therapy. Additionally, previous studies have produced inferior evidence-based research due to the methodological limitations of their research design. Biophilic design incorporates such features as indoor-outdoor connections, natural ventilation and materials, plants, extensive natural lighting, views to the outdoors, restored landscapes, courtyards, natural landscaping, water features and interior designs that mimic shapes and forms found in nature [41, 42].

According to acclaimed Harvard biologist Wilson [43–45] we are biologically drawn to nature. In industrialized societies, we spend on average 90 per cent of our time indoors in built environments, often in cities [13, 41]. These artificial settings seldom offer contact with nature or design based on natural principles. Biophilic design intends to enhance human well-being by fostering connections between people and nature in the modern built environment.

The enduring effects of plants and nature upon mood states of building occupants was examined in cutting-edge research undertaken by Burchett and colleagues [5]. Their groundbreaking research was the first empirical study to use universally validated psychological measures for evaluating the potential affordances of indoor plants. Worker productivity and the presence of plants correlates significantly [46] as well as lowering negative mood states and anxiety among building occupants [6]. Potted plants can improve indoor air quality for building occupants, but of particular interest, Burchett et al. [5] revealed that just one plant within the workspace can significantly enhance staff morale and simultaneously promote well-being and performance.

Furthermore, Burchett and colleagues' [5] seminal research investigated the benefits of indoor potted plants in reducing air pollution. A pivotal role was played by plants in minimizing volatile organic compound (VOCs) emanating from plastic or synthetic materials (such as furnishings, furniture, and equipment like computers, photocopiers), and CO_2 from occupants breathing. A causal relationship with enhanced cardiovascular health and mental acuity has also been found to be directly linked with air quality [47, 48]. The incorporation of green spaces in work sites is amassing extant research to support this area of inquiry and the 2-year collaborative project between Western Sydney University (Western) and Brookfield Multiplex (BM) was underpinned by these variables.

3. Methodology

A participatory action research design was adopted to ascertain the benefits of biophilic design within a site office upon workers. Data collection points in the 24 months of the study are displayed in **Figure 1**.

Phase 1:	Pre-implementation Interview with Sustainability Manager
Phase 2:	Qualitative data obtained from the recycling working bee post biophilic fit-out. Data was collected through interviews, observations and video anaylsis of site workers
Phase 3:	Qualitative data from in-depth interviews (n=12) following introduction of plants to office.
Phase 4:	Qualitative data from exit interviews at end of study

Figure 1. The qualitative data collection schedule.

3.1. Phase 1: preliminary interview for baseline data

In Phase 1, the study commenced with an interview with the Australasian Sustainability Manager for Brookfield Multiplex (BM), to gather detailed information about the rationale and raison d'être of the initiative. The questions were as follows:

- What was the impetus to get this innovative project off the ground?
- How important is the human capital in a work place?
- What support did you need from BM for this to happen?
- What is the sustainability message you want to impart at BM?

3.2. Phase 2: site office working bee: observations and interviews

Secondly, a Saturday working bee organized for site office workers, their partners, children and friends (See **Figure 2**). The primary intent of the exercise was to foster collaborative and group ownership of the project. Using elements of social capacity building and sustainable design, foremen were joined with apprentices and guided through innovative ways to up-cycle left-over materials freely found on their worksite which traditionally ends up as waste material. Workers witnessed first-hand how recycled office furniture and planter boxes can transform their site offices.

Qualitative interviews, observation and video footage were obtained during the working bee's proceedings.

3.3. Phase 3: site office interviews

Thirdly, 3 weeks after the working bee, researchers conducted onsite interviews with the workers (n = 12) to ascertain the initial impact of the biophilic design upon the workspace.

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Figure 2. The working bee and collaborative ownership underway in the pilot project.

Interview questions:

1. Demographics: (i) Gender and Age, (ii) Role or Position and (iii) Time spent in Site Office
2. Rate this office against previous offices you have worked in (score out of 10).
3. Do you think the design is beneficial in terms of health and well-being?
4. In terms of collaboration and co-operation, have there been any noticeable differences in the workspace?
5. Name three qualities that best describe "the vibe" of this workspace.

3.4. Phase 4: exit interviews after 24 months

Finally, 24 months following the introduction of plants to the office, researchers conducted exit interviews with four workers to investigate the lasting impact of the biophilic design in the workspace.

Interview Follow-up Questions:

1. Demographics (i) Gender and Age (ii) Role or Position and (iii) Time spent in Site Office

2. Summative comments surrounding workers' impressions of the office environment
3. Rate this office against previous offices you have worked in (score out of 10).
4. Name three qualities that best describe "the vibe" of this workspace.
5. So what is the long lasting impact/s and what would most like to take with you to your next workspace?

4. Findings

The initial data collection that occurred in the first 3 months was previously documented in Gray and Birrell [1]. However, to acquaint the reader to the preliminary findings, a brief overview is provided (Phase 1–3 below).

4.1. Phase 1: pre-implementation interview with Sustainability Manager

4.1.1. What was the impetus to get this innovative project off the ground?

BM is committed to delivering high performance buildings for our clients. By taking an evidence-based approach to building, we were seeing some great results in terms of productivity, health, staff attraction, retention, satisfaction comfort and so on. So I wanted to make sure we were doing it for our employees as well. With 80% of our staff in site offices, they were the most logical place to start.

4.1.2. How important is the human capital in a work place?

Very! Most of a company's spend is on their people and they are usually one of the most important assets as well.

4.1.3. What support did you need from BM for this to happen?

It just made business sense to invest in our people. So I got a lot of support both from upper management and the executive team, and more importantly, from the employees themselves.

4.1.4. What is the sustainability message you want to impart at BM?

If I can improve the workplaces of our people and help them be happier, less stressed or more productive in even just a little way, I think that makes the high performance site office worthwhile.

4.2. Phase 2: working bee findings

The use of the apprenticeship relationship reinforced team building and increased social engagement. Once up-skilled by the foreman, the apprentices were responsible for the construction of their personalized recycled planter box, choice of greenery and general maintenance for their plants. This process is outlined in **Figures 3** and **4** outlining the step-by-step stages.

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One unexpected finding of the working bee was the hidden benefit of intergenerational influence. Although unforeseeable at the commencement of the study, the children were both receptive and fully engaged in the activities on the day. The experience (see **Figure 5**) afforded many "teachable moments" for the young children to interact with adults. From the researcher's and parent's perspective, the intergenerational influence was a pleasant side benefit.

Figure 3. Steps involved in the working bee day.

Figure 4. Steps involved in constructing a planter box from recycled materials.

4.3. Phase 3: site office interviews

A breakdown of the demographics of the 12 participants and their workplace information is provided in **Table 1**.

Individuals were asked during interview Question 2 to rate (score out of 10), previous offices they had worked in against the biophilic office (see **Table 2**).

Data collected from interview questions 2–5 identified several emerging themes: the unique nature of this site shed (compared to other site sheds), sustainable workplaces and the transfer of learning (sustainable practices and ownership) from workplace to home, high performance workplaces, impact of external surroundings of working site shed, and the role and impact of 'green space' (specific plants) in workplace.

4.4. Phase 4: exit interviews 24 months later

Data collected from the exit interviews identified repeated themes from phase three: the unique nature of the site shed (compared to other site sheds), high performance workplaces, and the role and impact of 'green space' in the workplace. In addition to these themes, interviewees spoke about the lasting impacts of the biophilic design (transferability and how it

Figure 5. Success of the working bee including intergenerational impact with children learning how to pot plants.

Gender	Age	Role/position	Time spent in office
Female	25 years	Site Engineer	70%
Male	29 years	Services Manager	80%
Male	32 years	Project Manager	60%
Male	27 years	Site Engineer	40–50%
Male	32 years	Senior Site Supervisor	20–30%
Male	41 years	Site Manager	50%
Male	27 years	Foreman	20%
Male	22 years	Cadet	90%
Male	35 years	Contracts Manager	99%
Female	25 years	Site Secretary	100%
Male	31 years	Design Manager	95%
Male	31 years	Contract Administrator	90%

Table 1. Snapshot of the demographics of respondents.

affected productivity). As in Phase 3, the respondents were invited to rate the current office against their previous site offices (see **Table 3**) to ascertain the sustained impact of a biophilic office over 24 months.

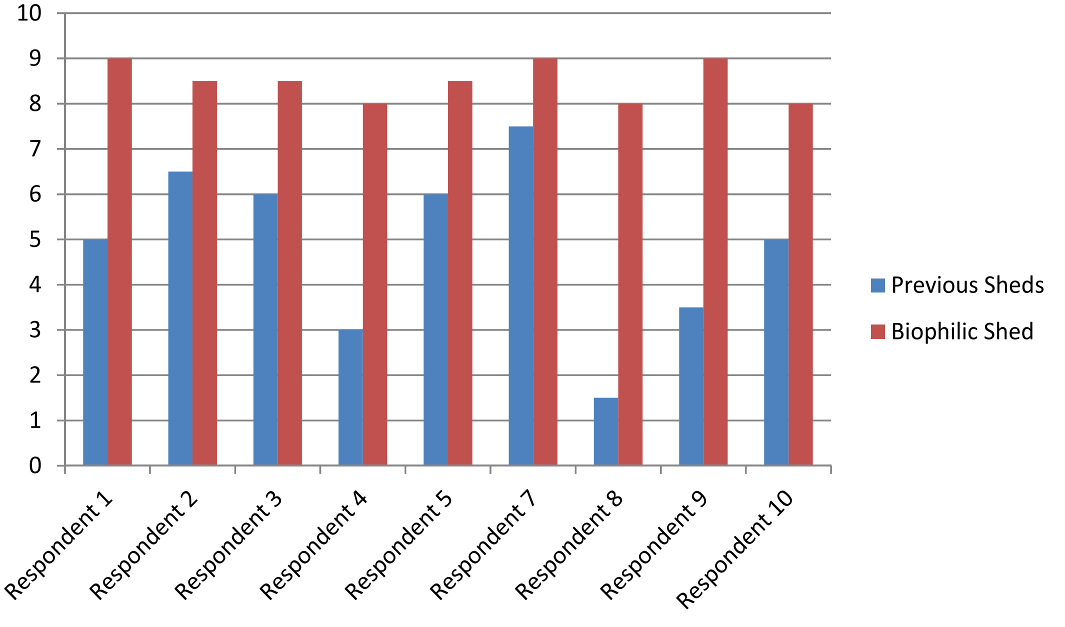

Table 2. Rating the biophilic office shed against previous offices worked in (score out of 10, 1 = poor, 10 = excellent) NB respondent 6 was a new team member (midway through project) so their data was excluded.

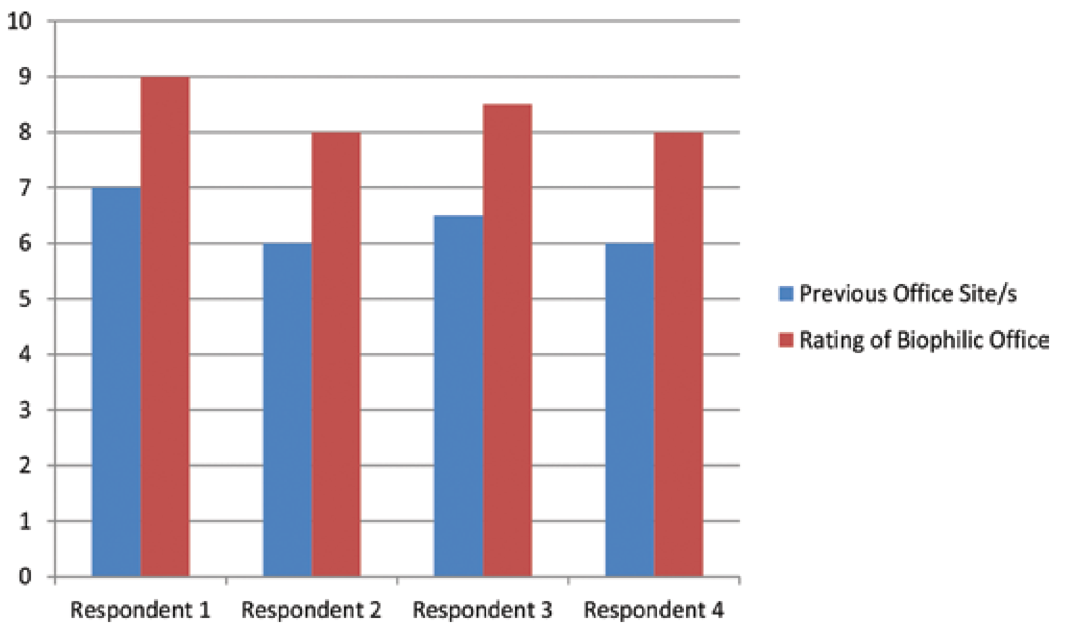

Table 3. The sustained impact and rating the office space against previous offices worked in, after spending 24 months in biophilic site shed.

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5. Emergent themes

Emergent themes are inductive approaches to qualitative research and are obtained from research on participants through the process of thematic coding. For the purposes of this chapter, three emergent themes will be addressed: high performance workplaces, the impact of plants and biophilic design in the workplace, and social dynamics in the workplace.

5.1. High performance workplaces

The site office, although deemed to be by its very nature transitory and temporary, is in fact the type of workplace setting that workers and managers inhabit serially over their working lives; although the site may be temporary, the workers are permanently in similar structures. Most respondents noted an overwhelming positive difference between previous site sheds and the present one.

Notably, the qualitative data uncovered the following comments:

> *"It's an 8 or a 9 [rating out of 10] definitely the best office that I've ever worked in"*

> *"…my last site is at say a six or a seven…this one at an eight or a nine."*

Comments such as 'aggressive', 'stark surroundings', 'sterile environment' and 'stale kind of environment' typified the responses associated with previous site offices. Many comments related to a changing 'vibe' within the office:

> *… most site offices, they're fairly cold, harsh, walled sort of environments, and that's not the sort of environment that's conducive to really collaborating well and creating an relaxed atmosphere.*

> *"My last job, no one really went to the office. There wasn't a good vibe in the office."*

In contrast, many viewed the biophilic site shed as increasing social capability. Several workers referred to the 'gentler feel' of the place, and one also highlighted the 'softening of social interactions' in the site shed. These included more communication between younger and older workers, as well as between the more and the less experienced members of the team:

> *If you're in an open area you feel as though everyone's on the same level, where you can walk past and just have a conversation and ask questions.… I come back to the office and you know, I'm looking for an answer first from someone. And I find that this office gives me an opportunity to speak to different people. I'll just walk past someone, and I'll think to myself, maybe I can ask this person. Because you get an opportunity to see people in their open area and you're not, in an office, or kind of restricted.*

The newly designed open plan arrangement suited this type of increased social interaction, as well as the range of smaller meeting places:

> *I came from a previous site where our site shed was quite limited, and there wasn't really a lot of room to kind of set up and have an area to work. There was more room – that was definitely a bonus.. It was, yeah, very different. We also didn't have a lot of meeting rooms, so a lot of the conversations where we didn't want to make a lot of noise, we would walk outside and talk on the phone.*

The open design and accessibility to co-workers was reported as a factor of enjoyment for those coming to work. Friendships and teamwork were repeated long-term themes from those experiencing the open plan design:

> *I think it definitely made it a more enjoyable place to be compared to other offices I have been in and worked in. I have definitely been in offices where I avoid going there. Here, it's a good environment here. Everyone gets along. [W]e've got good people here and the office, the way it's set up, it allows you to communicate.*

A repeated theme for workers involved the utility of the open concept design and its ability to ignite an organic space for collaboration. A change in the workplace atmosphere along with improved collegiality was evidenced in the interviewees comments. Many noted spontaneous collaborations occurring on a frequent basis which was noticeably absent in other sites. These productive collaborations expedited problem solving across teams:

> *There are opportunities here in the office where they can grab someone, ask a question… the problem can be solved in five minutes rather than let the problem be ongoing for a couple of days before they bring it to the attention of the design team.*

Workers remarked on the barriers created by walled offices and closed doors and how these obstructions were minimized by the open concept design:

> *It's been good for me personally because you get more involved in conversations. Where I was sitting, as a general foreman you've got the site manager and then there was a foreman, there was a grad, there was an engineer. Just so many different people…Everyone starts collaborating a lot better which I think has been great. I would recommend this office now to anyone.*

Some participants found those increased interactions distracting, but these reactions were in a minority:

> *Personally, I haven't got the best attention span anyway, so with everyone talking, especially, I'm in the design hub so there's a constant flow of people coming in and asking questions. … A lot of what I do is reading reports and trying to knuckle down and get design done… I can't focus because there's seven different conversations, and everyone asks you, because you're sitting there and its so open plan…*

The mutually beneficial nature of the space was also recognized by the same person:

> *I think collaboration in this job has been good, and a lot of that's been because of the way the office is set up. … we review something in the meeting room and get the screen up, or we do at design art, so that's been good. Yeah, I think it has been good, quite a good collaboration.*

Ease of communication was also a benefit for this worker and the layout was described as both efficient and effective:

> *Reason being the design is an open plan so people can hear other people talk. You know what's happening around the site, and then you just bounce off ideas off each other.*

When revisited during the exit interview, one participant highlighted the efficiency he felt that had resulted from the previously mentioned collaborative workplace design:

> *The way it's set up. You have the design manager sitting with the project engineers. They always work together which is good…the layout is efficient…it's just an open plan.*

In addition, during the exit interviews, one worker spoke about how implementing a biophilic workspace made a statement for the economics of the situation and what kind of impact it made to have the company invest in the workers:

> *I think what it probably did was break the culture somewhat in the company for wanting to spend the smallest amount possible on an office space. I think maybe it's opened a few people's eyes. They're saying it's probably worth spending a relatively small amount of money – in the context of a 150 million project – to spend a bit of extra money on making the office a good place to work in. I think it's been money well spent whereas traditionally you wanted to spend as little amount of money as possible because it was considered 'dead money'*

Another worker echoed feeling a similar impact:

> *The company invests in us all really well. That's why everyone does their job so well and completes it on time. It's good to look after your clients but very important to look after your employees because they are the ones doing all the work.*

Individuals spoke of the site shed as a 'happy environment': One worker commented on their observations of the interpersonal dynamics:

> *I think it's a happy project team, it's a productive team. Everyone works well together. Everyone likes coming in to work. Again, lot of different factors for that but having a big nice office that's roomy enough for everyone and comfortable to be in doesn't hurt.*

One worker continued to express the positive differences that they experienced in this site shed as compared to previous sites:

> *The team there was different. We went through a lot of people. The turnover was quite high but here, I don't know, I've just enjoyed it more.*

From natural lighting, furniture made with natural materials, white painted walls and carpet, to open windows and hearing bird sounds, all of the interviewees pointed to different positive attributes of the unusual biophilic workspace. Accounts from the qualitative interviews also suggest that this space increases social capacity and collaboration, and may lead to gains in productivity.

5.2. The impact of green spaces and biophilic design in workplaces

One of the primary goals of the study was to better understand the impact of natural elements upon workers. In particular, the researchers wanted to gauge the perceived benefits of biophilic design elements in the workspace. The dominant effects seemed to fall into two categories: esthetic appeal of the green office space and emotional bonding with nature

The esthetic appeal of the green office was described with words such as: 'positive vibe' 'relaxing' 'calming' and 'natural'. When asked about impressions of the office, many users described a dominant feeling rather than a physical description:

> *Immediately you notice something different because it's got that 'vibe' … kind of secluded away. \ you don't really know what to expect, and then you walk in, .. it is modern and relaxing. I'm not sure what words to use, but it's different in a very positive way.*

In terms of the 'greenness' of the site office, this interviewee does speak specifically about these qualities, however, the plants are mentioned overtly:

Yeah, … you see plants, and you're just, you know, it's different. You don't feel as though you're indoors the whole day, if that makes sense.

Interestingly, the disbeliever acknowledges the greenness in some way may contribute to the transformed working environment:

Look, I'm a bit of a skeptic to be honest with you, … But I was actually surprised when we did all the plants, because it actually, it is good. And it does make, it does create a better vibe within the office.

When prompted further about the impact of the 'vibe,' he explained:

I'd say 'energetic' would be one word: relaxed, calm, enjoyable.

All interviewees were overwhelmingly positive about the plants and how they were impacting on the work site:

You know, our subbies [subcontractors] come in and have a meeting with us, and they go, geez, where did you get all the plants? I don't think it's going to have a negative impact on anyone who works here, that's for sure.

In the same vein, another articulates:

Look, it reduces stress and fatigue and stuff like that, but I think not knowing, it probably does. … I may not directly know that it's making me feel a lot better, but you walk in and it doesn't feel like your standard office.

Based on the previous evidence, it is clear that workplaces matter to workers who inhabit them, perhaps more so to those who inhabit temporary spaces such as site offices. Despite issues of who waters the plants (which appears to be a gendered issue!), the plants themselves contributed to a transformed working environment:

I suppose it kind of reminds you we are in a living environment… We're working long hours though; I'm sure it does help though, just not being such a stale kind of environment… Anything that's natural, anything natural that's I suppose growing and changing every day.

During the exit interviews, workers reflected on the lasting impacts of the biophilic design:

"The deck has been good, having the space out the front, the big lunch area. The greenery has been good."

"[A] more happy environment, very green."

"The well-being of the office seems really good."

One participant reflects on the lowered stress levels they experienced during their time in the site shed:

I've enjoyed work, I really, really have. Even my wife said it to me. My last job I was very, very stressed out at this stage in the job and she said: "Here you're not".

Another reflected on the significance of the biophilic design:

I think it definitely made it a more enjoyable place to be compared to other offices I have been in and worked in. I have definitely been in offices where I avoid going there.

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Many of the onsite workers initially experienced individual attachment to plants on site. Stories of plants being personified with names and characteristics were shared during the interviews, as well as a sense of ownership and comradeship toward each worker's individual "desk buddy":

> *Mine was a bit of a struggler. It was a battle of mine. It went to the big nursery in the sky but it will be remembered.*

Others commented on high stress levels in their previous job, and made reference to the site office plants in a favorable context:

> *But I do enjoy having them [the plants] now; I think it's really nice. I'm not super- stressed at the moment. I'm in one of my calmer cycles, so I don't know if that's down to the plants, or whether that's down to just where the job's at. I like them.*

By the exit interviews, however, individual relationships were mentioned less often by interviewees. The lasting impacts from the emotional bonds were related more to the overall feeling and environment that the plants set up in the office, speaking about the overall green environment and the office having a 'vibe'. Accounts from the qualitative interviews report lower stress levels and positive well-being.

6. Discussion

6.1. High performance workplaces

One intended goal of this study was to investigate the effect of biophilic design on worker productivity. Through gathering data over the course of 24 months, the researcher can report the biophilic design contributed to a site of productivity for workers at the site shed (see **Figure 6**) where the lingering benefits still remained. The biophilic elements of this retrofitted site shed that showed up the most in data were the desk buddies themselves and the open concept design.

6.2. Greenery

Lohr et al. [45] state the presence of plants having positive correlations with worker productivity. Interaction with nature has been shown to boost mental productivity [29] and provide increased venues for attention span as well as lower stress levels. Participants acknowledged the green additions to the workplace as accompanying factors to inspiring creativity. One participant commented on previous offices emitting a "sterile environment" while this retrofitted shed felt more "alive" and "energetic" in comparison. These parallels between an "alive" and "energetic" environment were supported through a rise of engagement with the biophilic elements in the office.

The use of natural spaces softening an environment was reinforced in the way workers reported largely on the open concept format creating different 'vibes' within the workplace. Many reflected on improved mood states and heightened desire to work and be engaged with those in their workplace as compared to previous site sheds. Interviews at the summation of the study

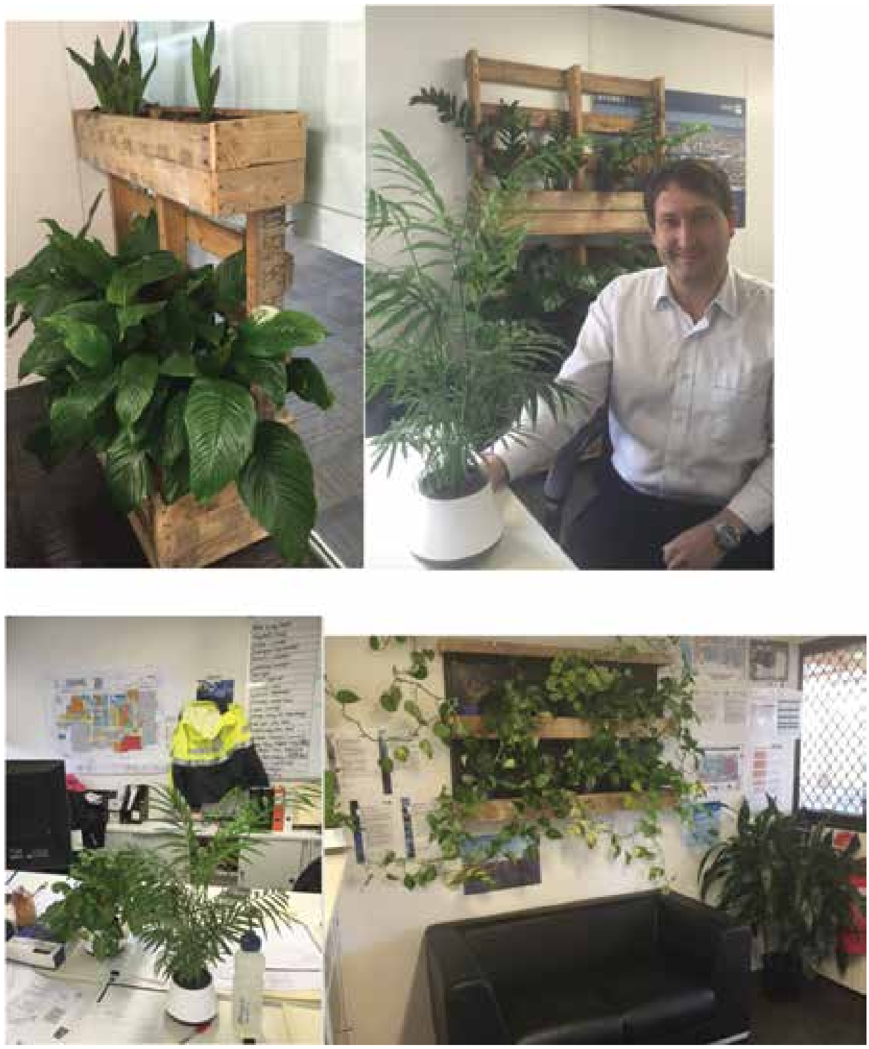

Figure 6. The site office site transformed by biophilic design.

indicated repeated incidents of workplace collaboration occurring at the site shed. Participants reported that these instances of collaboration were unique to the design shed and space.

Notable enduring impacts reflected upon in the exit interviews were the open space concept providing a viable space for collaboration and team building within the workplace. Dannenberg et al. [6] reported large reductions in negative mood states and levels of stress among building occupants. The biophilic design evokes use of space and an open concept method that intentionally strives to foster human-nature relationships in a built environment. These softer environments allowed workers to thrive and experience the mental benefits of a relaxed vibe within a workspace.

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As a result of the renovated space, employees were able to deconstruct barriers that previously existed in both formal and informal hierarchies of office members. An increase in neutral spaces provided a setting for what participants described as "spontaneous collaboration". The-step-by-step workshops designed for the creation of desk buddies allowed participants to contribute to the space and fostered a sense of accountability in the outcome.

6.3. The impact of green spaces and biophilic design on well-being

Biophilic design exemplifies the interaction between people and natural elements, not limited to and including use of space, greenery and access to natural light. The benefits of nature on well-being are highlighted in the literature. Retrofitting the office space with biophilic elements provided access to natural elements for office workers.

By the end of the longitudinal study, the 'desk buddies' introduced were reported to be 80 per cent still flourishing in the workplace although looked after largely by the caretakers and less by the workers. The desk buddies had initial interest and high attention by workers before absolving into the general green space of the office by the end of the project. From the initial introduction of plants, to the time the temporary workers disbanded, there was a shift in focus to the ambiance and environment rather than specific plant relationships. As specific plant relationships were absolved into the overall greenery in the office, the foreignness of greenery in a work environment lessened and workers were engrossed more in the overall ambiance and comfort of the space. This ambiance produced a softer environment for workers as a contrast to the harsh and sterile environments of previous sheds.

Many workers highlighted the simplicity in the approach and design, and commented on the biophilic workspace as a feasible concept to transfer to other site sheds they were being assigned to. The step-by-step model was an asset for transforming the site shed into a more energetic and productive space for the workers and also facilitated accountability and a relational aspect for those who had worked on the design. Workers in the site shed felt that having a hands-on element to the retrofit made it more genuine.

7. Conclusion

This study provided a long term investigation of the effects of biophilic design on worker productivity and well-being. The ongoing qualitative interviews offered an insight into the study at different stages of development. Historically, site workers have been assigned 'temporary, match-box' sized offices for the duration of construction projects [48]. In this landmark study, aspects of open plan design and green interior spaces were purposely infused into the newly devised bespoke office site. Within the literature, there has been little documentation of a longitudinal study and its long term effects on workers. Occupants clearly support the newly introduced biophilic design elements to enhance collaboration among workers, improve morale and mitigate against stress. Early data trends from this study suggested resounding approval by office workers for the newly introduced biophilic site office and were supported by the follow up and exit interviews highlighting lasting effects for those workers. We can confidently report that biophilic-designed site offices are linked to social benefits, including cooperation and mentoring, and to positive psychological effects, such as improved work satisfaction and higher morale. Not only were workers viewing the site shed as a place where work needs could be met, they actively thrived in the environment that was created through the unique design.

Applications for this study include the transferability of these flexible, multi-use spaces and their role in increasing productivity and collaboration. This was recognized in the opportunities for spontaneous collaboration and transcending levels of authority in the neutrally presented space.

The enduring impacts of this study recognize the trends of the multi-faceted human-environment relationships. This study enhanced worker well-being, productivity and performance by establishing long term exposure to a more biophilic workplace. The 2020 model provides a step-by-step model for which to outfit workplace environments with biophilic design. An unexpected positive outcome of this study was the opportunity to increase the skill level of workers to accomplish similar greening outcomes in their own backyards, homes or future workspaces. The outcomes of this focus group illustrate potential for accessible biophilic workspaces that can be self-designed by workers and contribute to the ongoing well-being of staff. This was a focus group study – the first to be initiated, and more confirmatory studies are needed in various contexts. However, given the consistency of positive results among the workers surveyed, it would be advantageous to recommend indoor plants should be a standard fixture in temporary (and permanent!) workplaces.

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Chapter 7

Modular Green Roofs in Urban Ecospace

Elena Korol and Natalia Shushunova

Additional information is available at the end of the chapter

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Abstract

This chapter essentially starts with green roof systems in an overview of the green building industry. Various green roof systems, traditional green roof structures, and innovative modular green roofs are also examined. The advantages of these systems are delineated. Likewise, the most important green roof technologies, the factors that impact the decision to choose roofing system, which are recommended for adoption, are discussed. The greatest value of installing modular green roof systems as a successful solution for urban ecospaces is also explained here. Green roof benefits and values are considered as well as important advance on sustainable development of landscape planning and design of the environment, including modern green infrastructure elements. This study analyses both traditional green roof structures, co-called green roof “pie,” and innovative modular green roof systems. Finally, the influence and impact of green features on green building development and standard documents required and related issues are examined.

Keywords: modular green roof system, urban ecospace, innovative green roof technology, green roof “pie”, livable ecosystems, green building development

1. Introduction

In high-density urban areas, quickly installed modular green roof system gains success and has a high potential in solving problems such as the lack of urban space, green areas. Modern park-like design of green roof creates great well-being areas in urban ecospace. These innovative systems consist of the green roofs with the integration of supported integrated solar and wind energy collecting and converting devices and including an irrigation system. Many studies provide evidence for the benefits of the modular green roof system in urban green space with microclimate differences. The big cities hold several environmental challenges: they occupy 3% of the land surface, host 50% of global population, consume 75% of natural resources, produce 50% of the global waste and emit 60–80% of greenhouse gases (GHG) [1].

Modern green roof technologies are seen as a key strategy to improve urban development, the environmental quality, sustainability and livability of cities. Smart progressive technologies in green buildings such as green roof and green wall systems have multiplicity aspects of a modern eco-style house, forming a living, breathing ecosystem for healthy urbanites. The modular green roof is increasingly dynamic part of the ever-growing green building sector. These coatings form a modular living system on the roofs of large commercial and office buildings and residential buildings. This paper reminds us that research regarding roofing ecosystem provided by the urban landscaping needs to be translated into robust and practical tools for changes in urban planning and management. The modular green roof system is a technically advanced design solution erection of roofing, as well as innovative technological solutions with a number of functional advantages and the ability to integrate devices that convert solar and wind energy-solar panels, LED-lamps, micro wind turbines as known as wind generators.

The sloped modular green roof system is used adjustable supports to the desired height and construction of communications, network hose for watering, that provides quick and easy access to staff to monitor the status of the waterproofing layer. The stormwater retention is also particularly important in big cities where it is difficult to manage the water free flowing off impervious roof surfaces during a storm. The adjustable leveling structures allow the bottom of the modular tray to be adjusted with respect to underlying roofing structures. It should be noted that other surfaces could be covered, including horizontal surfaces that form part of building structures: terraces, patios, decks, and ledges.

2. Key benefits of green roof systems

Green roof system with modular trays is better than the conventional green roofs. The advantages of pre-planting modular trays before traditional green roof structures with green roof "pie" are more easier to place on the roof structure, improved esthetics, incentive using in maintenance as well as security procuring. The modular green roof system is a technically advanced design solution of roofing, as well as innovative technological solutions with a number of functional advantages and the ability to integrate devices that convert solar and wind energy-solar panels and micro wind turbines. Modular trays are equipped with drip irrigation systems to create a microclimate zone directly above the roof of green building. The research describes modern green roof system that consists of the green roof modular pots with a big variety of configurations and integrated devices (**Figure 1**).

Widely, there are great positions on the benefits and improvements of green roof system in urban space. Key benefits of green roof systems are following:

- Green roof installation provides energy savings. In London, a building services manager revealed that the application of a retrofitted green roof on a building had reduced the

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Figure 1. Modular green roofs in urban ecospace.

need for cooling/heating in the floor beneath. If the green roof had been installed as part of the original design of the building and the ability of the green roof to reduce cooling and heating requirements had been known, there would have been a big potential of energy efficiency of buildings. The energy savings both in heating and cooling are maximized underneath the green roof. The positive impact of green roof system on the energy performance of the buildings becomes more evident and noticeable.

- Mitigation of the urban heat island (UHI). The vegetative layer of the green roof reduces the harmful substances in the air due to the absorption of carbon dioxide CO_2 and the release of oxygen. The green roof system neutralizes a significant amount of dust and harmful gases. According to researching of [2] spirit on the green roof is much cleaner and contains 37% less sulfur dioxide (SO_2) and 21% less carbon monoxide (CO). The green roof additionally moistens the air, increase the longevity of the roof structure several times (3–4 times).
- Reduction of noise level up to 8–10 db. The soil is capable of absorbing the lower frequencies, and the vegetation is high, also the layer of soil cover is fireproofing, in case of fire, the soil layer will prevent its spread. Acoustic is cataloged as one of the major factors in the built environment quality.
- Versatile installation schemes and types of the green roof system, an improved method for roof covering. Protection of the roof membrane against extreme temperature fluctuations, UV radiation and physical damage from maintenance period, greened roof can double the material life.
- Lightweight, modularity, and modern park-like design of green roof system with reversible interlocking means that easy and quick to install, dismounting and maintenance.

- Effective water flow runoff management of green roof systems, that provide water supply be special hydroponics system, including automatic watering system, pipes, and ducts for water transfer (**Figure 2**). The Australian water sensitive urban design (WSUD) is now increasingly used internationally, and strong collaboration is between champions in the United Kingdom and New Zealand [3].
- Plant diversity and multiplicity of modules comprise different configurations, sizes of diameters and heights that allow to use both intensive and extensive roof greening structures. The plants are selected according to the specific geographic zone and climate characteristics and green roof type such as extensive, semi-intensive and intensive roofs. And it shows interest in installation of this biggest variant of green roofs and their geographic applicability, which is available in many regions. It is important in selecting, that plants have fluence on the roof's performance and its tolerance to drought, wind, light, shade and pollutants. According to some studies, the extensive and semi-intensive green roof types are currently used a narrow spectrum of plant species due to their relatively harsh growing environment which includes shallow rooting depth, high wind stress, and fluctuating substrate temperatures. The low-growing plants may include a wider range of plant species such as *Arenaria montana*, *Arenaria balearica*, *Arenaria* s*agina subulata* "Aurea," collectively referred to as "Shortgrass Meadow Plantings." As another example, the vegetation could include another mixture of vegetation such as *Sedum acre* "Aureum," *Sedum album* "Coral Carpet," Sedum spatulifolium "Purpureum," *Sedum spathulifolium* "Cape Blanco," *Sedum spurium* "Green Mantle," *Sedum spurium* "Red Carpet," and *Sedum kamtschaticum* "Variegatum" (collectively referred to as "Desert Succulent

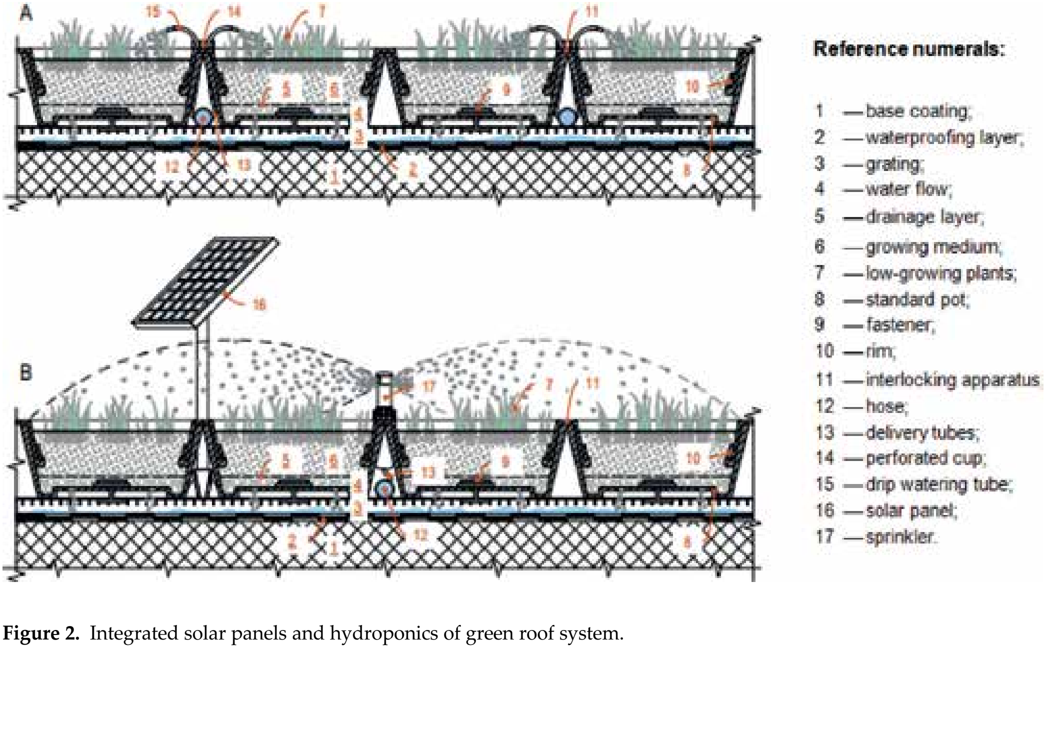

Figure 2. Integrated solar panels and hydroponics of green roof system.

Plantings"), *Sedum spurium* "Summer Glory," collectively referred to as "Desert Succulent Plantings," "Albertiana Conica," *Picea pungens* "Globosa," *Picea pungens* "Glauca Prostrata," and others. Additionally, there can be joined other grasses, herbs, and mosses.

Typically plant cultivation manner is to supply nutrients through "soil". Alternatively, plants modules could be supplied without vegetation, for example, with only the growing medium or non-soil growing medium. This technique is so called "hydroponics" method. Hydroponics is a subset of hydroculture, using mineral nutrient solutions, in water, without soil, so thus giving the plants the maximum amounts of both nutrients and air to the plant root. According to it, fillings of plants modules presented plenty of solid growing medium, such as gravel, expanded clay, shingle, growstones, pumice, rock wool, perlite, vermiculite, coconut fiber, rice husks, thatch, straw, sand, or the like. In study [4] the impact of two substrate components assessed: brick particle size and a polyacrylamide gel additive, living mulch on the growth, physiological and visual health of newly established green rooftops during 25 days of extreme drought, and this study shows that coarser particle size substrates can significantly improve the drought tolerance of plants on green roof.

The alternative embodiment of the modular green roof system, illustrating modular pots of different configurations with various fillings and using the adjustable leveling device on a sloped roof is shown in **Figure 3**. The waterproofing layer is placed on the rooftop deck. Then adjustable leveling devices are installed on the waterproofing layer and fixing the standard pots to the grating assembled on the adjustable leveling devices by elongated fasteners. Further, it takes place the installation process of the standard pot with successively filling of drainage layer, growing medium and low-growing plants and alternatively fixing to the grating is by inserting fastener using centrally mortise. The interlocking apparatus penetrate into the modular pot with a rim until it clicks. In this case, roofs having slopes is 1,5 to 3%, which allows water flow, resulting by the irrigation water or rainwater to percolates vertically through the growing medium of the standard pots and further to drain away freely on a

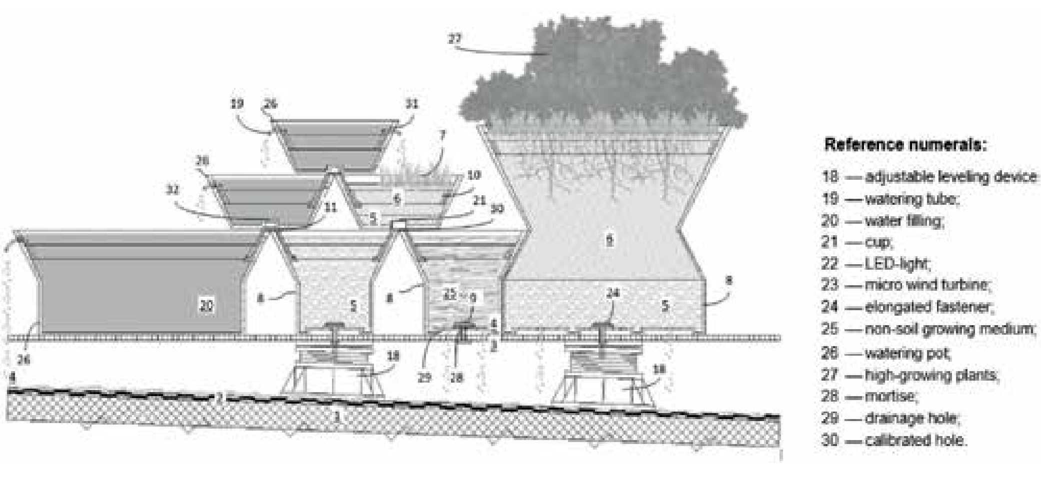

Figure 3. Cross-sectional view of the green roof system with adjustable leveling.

surface of a sloped roof. The water flow passes through drainage holes that in the bottom of the standard pot. The water flow from watering tubes, which passing through diametrically opposed outlets in the side surface of the pot, supply both the standard pot and watering pot with water filling. Additionally, the modular pots can be installed on each other forming the multi-level system using the calibrated hole inside the standard pot on interlocking apparatus, which covered by the special cup. In the same manner protuberance inside the watering pot is adapted to install it on each other on interlocking apparatus.

Typically plant cultivation manner is to supply nutrients through the soil. Alternatively, standard pot could be supplied without vegetation, for example, with only the growing medium or non-soil growing medium. This technique is so-called "hydroponics" method. Hydroponics is a subset of hydroculture, using mineral nutrient solutions, in water, without soil, so thus giving the plants the maximum amounts of both nutrients and air to the plant root. According to it, fillings of standard pots presented plenty of solid growing media, such as gravel, expanded clay, shingle, growstones, pumice, rock wool, perlite, vermiculite, coconut fiber, rice husks, thatch, straw, sand, or the like. The wide choice of the growing medium and moreover using the "hydroponics" method provide advantages over the prior art in that it consequently significantly reduces the pressure on the environment in view of the fact soil is not renewable.

The original modular design is another advantage of the modular green roof system. This allows you to cover the surface of any configuration with various forming parts, for example, ledges rounded and cropped corners on rooftops, edges of pools, fountains and many others. The interlocking apparatus is provided with a lighting system that in form of, for example, solar lamps and LED-lights. This can illuminate the environment as daylight and it is likewise spectacularly viewed at the night time. Modular green roof system provides esthetic benefits and serves as a major amenity for building occupants as these "landscaping and living roof" gain in prevalence and popularity. So, using alfresco aquarium is integrated in modular green roof system element of urban space together round-curving lines of balcony edges added more esthetic value to roof view. It can easily fit into the design with arched vaults and similar objects.

Modular green roof systems are provided favorable well-being conditions for living in the new and recreated rooftop projects of residential, public and commercial buildings, trade and office centers. Furthermore, these systems could be used partially in the country houses space as landscaping system to promote healthy conditions. With the combination of build-up energy-effective devices, such as "Smartflower," which is also completely automatic, there is formed interflow impersonation of the modular green roof system. It directs its solar modular fan on a surface area of 18 m^2 towards the sun and begins producing electricity by device dual-axle sun tracking, the fan moves reliably along with the sun throughout the day. Thus, 1 year of use the "Smartflower" system equals 4.000 kWh—the average complete annual consumption of a central European household [5].

In comparison with the static rooftop systems, the unit starts earlier in order to produce the exact amount of needed electricity. It consistently maintains the electricity supply and even uses the energy from the last sun rays efficiently enough to cover early evening electricity requirements (**Figure 4**).

Figure 4. Energy-effective devices build-up in modular green roof system.

The present roofing system is to be solved various problems of roof covering by making inexpensive, little expenditure of labor and waste-free assembling based on the principle of building kit. This future-oriented green technology is developed of the urban spaces of tomorrow from the viewpoint of a wide range of sustainability aspects and supports the development of integral solutions from a systems perspective. The unique configuration of the system with an unusual combination of architectural and esthetic design solutions gives a beautiful appearance to the urban areas and also allows to use methods of landscaping on living roof. The green roof technology includes the apparatus to integrate a plurality of special roof covering elements with aspects of energy collecting and converting devices.

The essence of this innovation solution is the fact that covering surface on the building roof is covered with special modular trays with vegetation that fixed to the gratings by engagements. Modular trays are equipped with irrigation and drip irrigation systems to create a microclimate zone directly above the roof of the building. While the green roof covering modular device must be observed and control the green roof installation process.

For the study of green building in the evaluation of building energy performance and thermal comfort, the methods of modeling by the WUFI®-Software are used (**Figure 5**). The object of the study is a flat green roof covering of 100 m^2 with a slope of 1.5−3.0%, located at a height of up to 15 m with a base of reinforced concrete slabs.

2.1. Green roof installation quality according to the green standards and green roof code

The installation process has the following steps:

- The correct and consistent installation process of the waterproofing layer and its compliance with the project specification. Proper installation of irrigation systems and drip irrigation, and matching their capacities and an operating mode with the required parameters in accordance with the provisions of the Green roof standards, called also Green roof Code, that consist of special requirements for the device, and the rules of acceptance of control.
- Quality control of the roofing and grating mounting processes. According to the map of quality control processes have to be controlled. It should also be noted that the performance

of work report of the roofing system installation must be carried out in the general journal papers or special journals of the installation process on the forms that considered in Russian requirements. To date, the most widely accepted standard among the leading green roof suppliers is the German FLL standards, the landscaping, and landscape Development Research Society. This standard is generally recognized as the benchmark for green roof installation quality. According to the German FLL standard, a successful green roof system must basically replicate nature and consist of the protection layer, drainage and filter layers, growing medium, appropriate components for vegetation and irrigation.

Big cities are adopting new building codes that incentivize adoption of innovative technologies in modern buildings. The green construction industry is moving fast, together with a growing trend for Green Building Rating Tools. The green roof systems, which installed on different types of buildings, can put you on the right track to earning the highest BREEAM, LEED, DGNB or HQE certification ratings. Building certifications such as Leadership in Energy & Environmental Design (LEED) provide for certain tax credits of the green roof using and benefits for building owners.

Some implementations of the present invention. It pursues sustainable performance objectives while giving substantial importance to the life cycle analysis on a building scale and to the impacts of a project on health, comfort and the environment by using green roofs. The Department of Environment in Malaysia has been provided the water quality standards, practiced

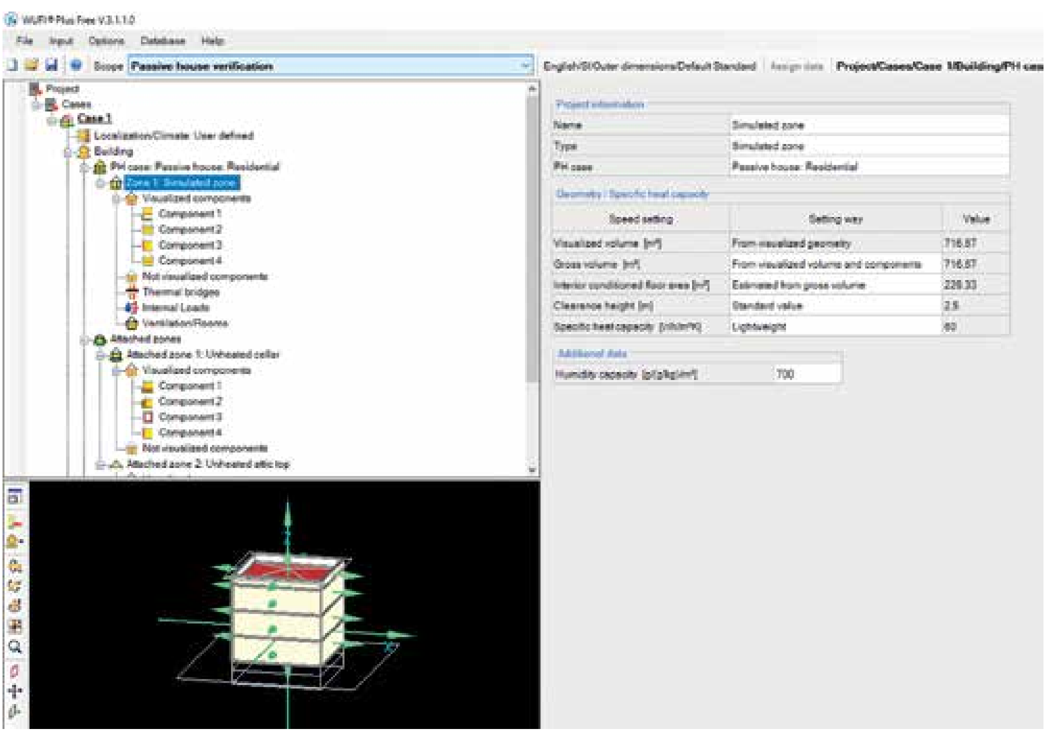

Figure 5. Evaluation of green building energy performance.

water quality standards for green roof installation. According to standard NWQS, there are six classes of water quality (I, IIA, IIB, III, IV, and V) and this classification is based on a descending order of its best quality to the worst quality [6]. The rainwater quality parameters are estimated by soft computing technology like adaptive neuro-fuzzy inference system.

Following the same pattern, the Karlsruhe Performance Rating System rates green roofs according to natural categories. These functions, which assigned a weight based on its importance are as follows:

1. Type and depth of soil used (Soil)—15%.
2. Impact on climate due to evapotranspiration (Climate)—15%.
3. Type and variety of vegetation (Flora)—30%.
4. Impact on zoological biodiversity (Fauna)—30%.
5. Average annual stormwater retention (Water Balance)—10%.

The sum of the weighted rating for each of the five functions is used to compare different green roof systems and stipulate minimum requirements.

2.2. Analyses of green roofing structures

The device of the green roof means the creation of structurally complex systems with vegetation and soil mixture placed on the waterproof membrane, with the integration of irrigation systems, as well as devices that convert solar and wind energy.

The green roof principles that exist today are manufactured in Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau (FLL) landscape industry organization in Germany. "The Guidance on planning, execution and the maintenance of green roofs"—version of FLL on English language. This document covers design, construction and maintenance of green roof systems, with detailed sections on stormwater considerations, requirements for the plantings, growing medium, drainage and requirements for all green roof "pie" layers. It also provides information on testing some components of the green roof. The green roof represents a multilayered structure and consists of several layers: a vegetative layer, a soil substrate, a filtering layer, a drainage system, a layer of waterproofing and a layer of thermal insulation. According to the standard TGRCS – Toronto Standard "Construction of green roofs," the green roof "pie" is shown as a multi-component structure (**Figure 6**).

In this chapter, each layer is examined for the analysis of the selection of the material of the roofing system and its features. The materials used for the construction of roofing surfaces must meet the requirements of the current standards in the field of standardization and green roofs types: intensive, semi-intensive, and extensive roofs. The vegetation is selected individually according to the climate conditions, the roof location and the thickness of the growing medium. Often, mosses, lawn grass, wildflowers and mountain vegetation are chosen for the green roof covering, since such vegetation is not whimsical to specific climate and regional conditions.

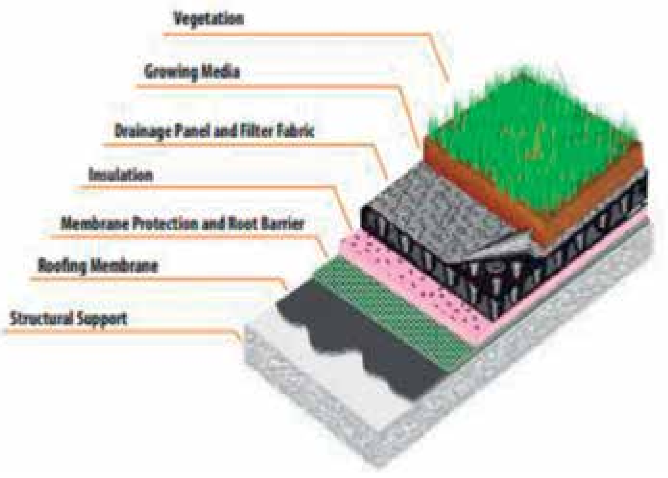

Figure 6. The structure of the layers of the green roof "pie".

The growing medium is usually soil substrate or natural soil. Reduce the weight of the layer can effectively be due to the addition of loose fillers (peat, sand, and unlimited additives). The soil depth is selected in accordance with the type of green roof: intensive or extensive types.

As a filter layer, a nonwoven material is used—geotextile. In this study, the analysis of the two most popular methods of bonding—needle piercing and thermal calendering—is given. According to the roofing technology, the thermally calendered geotextile is stronger for tearing than needle-punched. Thermally bonded geotextile, unlike needle-punched, has the property of high wear resistance and excellent tensile strength. The material is resistant to the effects of ultraviolet rays and aggressive media, such as atmospheric moisture, acids, alkalis, bacteria or fungi.

The drainage removes excess water from the soil. In the drainage layer, polystyrene pellets are used. The most resistant materials for the anti-root layer are fiberglass, membranes made of synthetic material are also used. In case of green roof modules, the growing medium is separated from the drainage by a permeable geotextile fabric which is responsible for blocking soil penetrator. Research considered the wider multiple solutions both Sustainable Urban Drainage System (SuDS) and Green Infrastructure (GI) as management solutions containing natural elements and estimate their physical interdependencies with other city scale infrastructure, in parallel to this the interactions between the various agencies responsible [7].

In UK practice, Sustainable Urban Drainage Systems are configured as a sequence of stormwater practices and technologies used to drain stormwater in a manner of replicating as closely as possible the natural, pre-development drainage from a site, consistent with the previously-described principles [8].

The function of the waterproofing layer is to protect and prevent water and moisture from entering through the structure inside the building or onto external walls. As a waterproofing layer, a bituminous polymeric material should be used, laid in several layers:

- polymer waterproofing membranes on bitumen (EPDM) basis with anti-root protection, environmentally friendly material; or polymeric waterproofing membranes on a synthetic (PVC-membrane) basis with anti-root protection with life cycle up to 60 years;
- additional copper or aluminum foil layer to the membranes;
- liquid rubber;
- polyethylene film.

If the roof is flat, then the waterproofing is arranged with a slope of 3–5% to ensure the necessary flow of water. It is recommended to make a heat-insulating layer of foam glass or pearlite sand. Also as a heater apply extruded polystyrene plates and mineral wool. The thickness of the insulation of the coating is established by calculation, taking into account the heat-insulating properties of the remaining layers of the coating.

The design of the intensive green roof differs from the extensive type. Insolation is located not on the bottom, but on the top of the waterproofing membrane, which protects it from mechanical damage. In this case, the required angle of inclination of the roof for the device of the green roof is 5–8°. With an increase in the slope of the roof more than 12°, it is necessary to arrange transverse locks: wooden planks, geogrids or cassettes, which will hold back the soil. With the use of devices that prevent soil from slipping, planting of greenery on roofs with an angle of up to 45° can be established. In modular green roof systems, the basic element is a tray that quickly and easily mounted in a single covering. This system can be used on roofs with a slope of up to 20%.

These recommendations are given for choosing the most energy-intensive and economical structure of the green roofing system. A detailed analysis of the multilayer material structure and labor analysis of the green roof installation is presented the main features of using greening systems on roofing structures.

In some studies, it is noticed that in Finland forests represent an iconic national landscape and novel green spaces meeting the needs and preferences of urbanites are considered increasingly important to produce livable urban environments.

3. Conclusion

Nowadays smart solutions of green roofs are becoming more and more popular in recent times for their ecological, technical, economic benefits and esthetic qualities. Successful urban planning is including network of natural and semi-natural areas that integrate green roof systems into natural constructed urban environments. In the meantime, existing green roof technologies can be expensive to purchase and labor-intensive to install. This research is aimed to contribute to sustainable future-oriented solutions for the complex problems of urban areas to create livable ecosystems. The renovation project of roofing structures includes apparatus and method for green roof system to install on a rooftop on the residential, government, public and commercial buildings, trade and office centers. Modular green roofs in urban ecospace is an emerging trend in green building development. Innovative energy-efficient green technologies will bring a great benefit to the ecology and help to relieve the Heat Island Effect, in light of growing concerns about climate change and greenhouse gas emissions (GHG). Eco-trend of Modular green roofs refer to rejuvenate and rebuild the nature. Although this study has made several advances in predicting benefits of green roof systems, and it has to move further on work pertaining to green roofs, there are several areas that will require further researching.

The relevance of the research topic is determined by the need to develop an effective, economically progressive technology for the device of inversion roofing systems by landscaping. With increasing density of development of urbanized areas, technologies of construction of exploited roofing coatings are of particular importance. Existing technologies for roofing coverings do not allow you to perform the required amount of work of adequate quality and are characterized by low productivity, as well as high labor costs. The predominance of green plantations on the coverings of buildings and structures contributes to the formation and development of new urban space, improves the environment, reducing emissions of greenhouse gases into the atmosphere. Total reduction of greenhouse gas emissions by 52.3 million tons CO_2 by 2020 characterizes the increase in the level of environmental safety of the city.

The modern modular technologies in the construction of roof coverings with landscaping systems are the most effective solution, as the labor intensity of technological processes during the installation of roofing systems with landscaping systems is reduced compared to traditional types of roofs, and functional development is provided for the exploitation of the roof. Innovative solutions in the creation of engineering systems are the devices that convert and store solar and wind energy on the green roofs of buildings and structures. At present, energy has received serious prerequisites for development, so green roofs with the integration of renewable energy sources are key elements on the path of innovative development of green building technologies both in Russia and abroad.

In Norway, approximately 90% of individual housing projects are equipped with roofs in operation. At the same time, landscaping systems are actively used on roofing in the United Kingdom, Denmark, and The Netherlands. The leader in the field of green building technologies is Germany, the "Green capital" of Europe, where the standard of quality of the device of green roofing on buildings has already been developed and applied. In the earliest researching [9], measurements in Germany conducted in 1984 revealed not only reduction in maximum surface temperature but also temperature amplitudes reduced by half due to green roof installation. Furthermore, adding green roofs to urban environments provides eco-restorative habitats and affords unique protection from traffic noise in the city (**Figure 7**).

Modular green roof systems in urban ecospace are becoming increasingly important part of the green building renaissance. Modular green roof constructive system is regarded as the most effective solution of innovative approaches and techniques for green design and construction. Trying to find the optimal system of a green roof, this system is to be solved various problems of roof covering by making inexpensive, little expenditure of the labor and waste-free green roof assembling based on the principle of building kit. The unique configuration of the system with an unusual combination of architectural and esthetic design solutions gives a beautiful appearance to the urban areas and also allows to use methods of landscaping on

Figure 7. Green roofs as eco-restorative habitats in the city.

living roof. Given the increase in urbanization worldwide, the impact of urban green spaces on future generation have aim to save our Green Planet and bring great benefit to the ecology by develop green building technologies. This future-oriented green roof solution is appreciated by potential investors because implementing this system can improve a company's competitiveness and bring multiple economic profits and great environmental benefits.

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Chapter 8

Improving Traditional Spate Irrigation Systems: A Review

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Additional information is available at the end of the chapter

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Abstract

Although the spate irrigation system is an ancient practice, it is only in the past very few decades the system has undergone little modernization interventions. However, these interventions were mostly in the aspects of heavy investment in the sophisticated head works for improving flood water diversion efficiency. In many cases, the modernization interventions were not successful due to various problems such as heavy sedimentation, high flood, disturbed local water distribution rules, or the new designs were not coherent with home-grown practices. On the other hand, successful improvements incorporate less labor intensive and relatively permanent structures with the advantages of conventional systems without considerably altering the approach of the spate irrigation practice. Thus, in this chapter, the techniques of improving traditional spate irrigation systems were reviewed. Farmer-implemented improved traditional spate irrigation systems: flow diversions; canals and control structures; management of sediment, field water, and soil moisture and agronomic practices; reactive water rights and distribution rules were assessed. Therefore, this chapter helps as a reference material for teaching, training and research activities, and it plays a great role in the efforts of sustainable spate irrigation systems development, rehabilitation and management programs.

Keywords: bed bars, flood diversion, intakes, sedimentation, soil moisture, water rights

1. Introduction

Spate irrigation is being practiced in dry-land regions for food security and livelihood improvement. Spate irrigation was defined by [1] as "a resource system, whereby flood water is released through generally dry wadis (ephemeral streams or seasonal rivers) and transmitted to irrigable fields." According to Ref. [2], spate irrigation is a scheme redirecting flash floods from the river bed using conveyance structures (canals) to bunded fields situated at a certain distance from the water source.

The broad definition of the spate irrigation system as provided by [3] is "an ancient irrigation practice that involves the diversion of flashy spate floods running off from mountainous catchments where flood flows are channelled through short steep canals to bunded basins, which are flooded to a certain depth." According to Ref. [3], floods are usually flowing for only a few hours with substantial discharges and with recession flows lasting for only one to a few days. The spate irrigation depth could range from 0.2 to 2 m [4]. Subsistence crops, regularly sorghum, are cultivated using moisture stored in deep alluvial soils after one or more spate irrigation [5].

Flash flood irrigation has been practiced since 70 centuries ago as a main means of survival and income source for the poor in dry-lands [6]. It is being practiced in Latin America, Central and West Asia, the Near East, North and the Horn of Africa [5]. Even though spate irrigation is an ancient practice, it is still the least documented, understood and studied [6]. As a result, no exact data are available for the global spate irrigated area. However, the estimation is about 2.0–2.5 million hectares (10^6 ha) by [7] and 2.6×10^6 ha by [6].

The estimation has become difficult because the spate irrigation has no much consideration by development organizations as that of irrigation from permanent water sources, and the change of spate irrigated area from time to time [6, 8]. In many countries, the spate irrigated area is stable, in North Africa declining, but rapidly expanding in the Horn of Africa, especially in Ethiopia and Eritrea due to settlement in large low land areas [5]. However, there is huge spate irrigation potential globally [7].

Spate irrigation has many advantages in dry-lands. For example, a study conducted by [9] showed a significant increase of barely yield under spate irrigation in Gareh-Bygone plain, Iran. The short duration floods diverted from the dry wadis could be used to irrigate pasture/forest land, recharge groundwater, fill drinking water ponds for human beings/livestock, control flood and conserve biodiversity [5, 10].

According to Ref. [11], flood water spreading in Gareh-Bygone plain (Iran) facilitated spate irrigation of rangeland and groundwater recharge. This reversed migration of communities who have left the area due to groundwater depletion. An artificial recharge of the course grain alluvium area in Iran is a rational option to building large dams. Spate irrigation contributed groundwater recharge and mitigated agricultural drought in Tunisia [12].

Even though spate irrigation has a number of benefits, it is prone to high risks and uncertainties such as too little or no flood water, structural damage by exceptionally large floods and sedimentation of canals and fields [13]. Spate irrigation is special from perennial irrigation in several cases as it requires unique approaches and skills that experts are not all the time conscious [5].

However, the spate irrigation system has been the subject to inappropriate modernization interventions on head works, canals and distribution structures. These interventions, in many cases, were not successful [4, 14, 15]. The modernized spate irrigation system was failed to irrigate the anticipated area in Wadi Laba, Eritrea, due to improper approaches and design assumptions used in modernization, the modern designs disturbed the home-grown water allocations and rules, culvert sedimentation, wrong use of scouring sluice and breakdown of breaching bunds [4]. According to Ref. [16], improving spate irrigation effectiveness by the modernization of the distribution and diversion structures of Makanya catchment spate irrigation system (Tanzania) is not feasible because of high sedimentation. As an alternative, investment in the conjunctive use of groundwater was suggested by [16] as it employs little involvement, minimizes the scheme disruption, and hence it maintains the existing water management rules.

From experience, the best successful improvements incorporate less labor intensive and relatively permanent structures with the advantages of conventional systems without considerably altering the existing approach of the spate irrigation practice [2, 5]. Hence, slight improvements to conventional structures with minimum modifications to locally used canals and water rights are ideal [2]. In general, to improve the traditional systems, the technology adopted should be easy for construction and friendly for maintenance, and the materials used must be inexpensive and locally available.

Therefore, the objective of this chapter is to examine techniques of improving traditional spate irrigation systems. The existing gaps in spate irrigation systems were reviewed, summarized and suggested for improvement. This strengthens any sustainable spate irrigation system development, rehabilitation and management efforts aimed at improving food security and livelihood in water-scarce environments.

2. Classification of spate irrigation systems

The three types of spate irrigation systems based on infrastructure are traditional intakes and canals, improved traditional systems, and modernized systems [5].

2.1. Traditional intakes and canals

The two types of traditional intakes are spur-type deflection and bunds that are constructed crosswise the flood channel in flatter plain areas. The construction of diversion is uncomplicated and temporary. Pictures and more explanation for these intakes are available in Ref. [5]. Traditional intakes use only local materials and indigenous skills and might have made possible irrigation to be continued for several years [17]. The location and layout can easily be adjusted to suit the changing wadi conditions as traditional intakes are very flexible and low cost.

On the other hand, the major drawbacks of traditional intakes are their continual requirements of a high amount of labor, and brushwood and tree materials to maintain, reinforce or rebuild intakes that are broken or washed out by huge spates [5]. Hence, the improvement of traditional spate irrigation systems is required to minimize the stated drawbacks.

2.2. Modernized spate irrigation systems

Modernized systems are generally identified for their durable and hard diversion structures built diagonally in wadis such as a weir, the sluice gate, intake, main canals and retaining walls [14]. Pictures of modernized schemes are available in [2, 14]. Much of these modernization interventions seen in the last three decades were focused on improving the efficiency of flood diversion [6]. In large schemes, any conventional intakes were replaced with single concrete diversion weirs having sluice gates to remove sediment. In newer schemes, steep canals and sediment control structures are constructed for reducing sedimentation. Nevertheless, increasing diversion efficiency using a single modern/permanent structure at one location can alter the existing distribution and access to spate water between upstream and downstream farmers and causes conflict between them [5, 6].

2.3. Improved traditional systems

Improved traditional spate irrigation systems are farmer-executed upgradings such as spillway and flow throttling arrangements near close to canal heads and flow distribution and drop structures in the main canals [5]. Water regulating structures can also be included in the canal and field systems, simple rubble masonry or gabions can be used for diversion, and in some areas, earth-moving equipment (bulldozer) may be used to construct diversion bunds.

3. Improving spate irrigation systems

3.1. Main challenges to improve spate irrigation systems

As spate irrigation systems are located in remote and forgotten areas where there is deep-rooted poverty, they face substantial problems: absolute lack of support systems; sustainability of systems is susceptible during a series of drought years when framers are forced to migrate; little support to agronomy in spate irrigation with little research and international sharing of experience; inequity described by significant inequality or usually intricate tenure relationships that obscure local collaboration and reasonable water allocation; political or policy invisibility; and inappropriate approaches followed in the past such as modernizations with heavy investments in sophisticated head-works which were no longer functioning in many areas [7].

3.2. Ways to improve spate irrigation systems

Methods of improving spate irrigation systems include: improving the existing traditional diversions, guaranteeing improvements do not affect traditional water distribution rules; avoiding a high flood and sedimentation damages to command area; improving water productivity, and soil moisture management and conservation; improving field preparations, seed treatment, and use of improved seed; early planting and targeted use of agrochemicals; introducing new crops; and an appropriate crop selection for spate irrigation [5–7].

In addition, promoting local agroforestry; improving drinking water facilities in spate areas; improving land and water tenure, issuing individual titles where they do not exist and codifying or reviewing water rights so as to minimize conflicts and accommodate new realities such as intense use of groundwater and the need for recharging; working on the bigger picture: improving access roads to spate-irrigated areas, general amenities and market facilities and integrated water resource management are ways to improve spate irrigation [7].

Improvements to spate irrigation systems must be designed so as to reduce the labor required to maintain intakes, improve the control of water within the distribution systems and minimize the capacity of large floods to damage canals and fields [2, 5, 6]. Their design must ensure that they can cope with frequent and sometimes large changes in river beds; improvements must recognize and respect the established system of water rights, priorities, and amounts. It is not advisable to replace the traditional spate irrigation systems with the modernized ones or to implement the modernized ones in new projects. Hence, improvements in the traditional spate irrigation techniques should be made as it was briefly discussed in the following sections.

4. Improving traditional spate irrigation systems

4.1. Improving traditional spate diversion structure

The three types of improvement to diversion structures are intakes (diversion structures), canals and regulating structures, and wadi (seasonal or Ephemeral River) training structures [5]. There are different types of diversion structures which depend on resources available for construction, farmers' preference, and site conditions. These are more long-lasting diversion spurs with breach/overflow parts; improved diversion bunds including the use of fuse plugs and bed bars; controlling flows admitted to canals including natural orifice control or gated intake structures; rejection spillways; and a combination of the above [5]. A typical layout of improved intake is shown in Ref. [18].

Based on cost and local conditions more durable diversion spurs can be constructed from reinforced concrete, rubble masonry or gabions on a deep foundation [2]. Improved bunds can be constructed using earth moving machines. A more permanent weir has to be designed with overflow section and energy dissipation structures. Pictures for improved traditional bunds: diversion weir with a stepped downstream face and diversion weir with breachable bund are available in [2, 5].

It is also possible to use a concrete-faced traditional weir with improved downstream scour protection, and abutments extended with gabions. The durability of different diversion spurs was evaluated by [19] as shown in **Table 1**. The improved gabion diversion spurs are the most long lasting (durable) as they require less maintenance.

Type of material used for diversion spur	An average number of reconstruction required during a usual spate season
Traditional Wadi bed material and brush-wood	2–4
Stone	0–1
Gabion	Can last up to 5 years
Source: Haile [19].	

Table 1. Durability of traditional and improved gabion diversion spurs in Eritrea.

Gabions are preferable to a concrete wall that could fracture and fail where the ground is liable to subside [20]. Moreover, gabion maintenance is manageable by farmers. Sorghum production showed an incremental of about 100% (from 2000 to 4000 kg/ ha) and 75% (from 2000 to 3500 kg/ha) in Hidmoand Urkudi, and Adiharemli and Wudet areas, respectively in the Aba'ala plains of Ethiopia by improving flood diversions [20].

4.1.1. Intakes

The designs of intakes and gates can be affected by the type and characteristics of spate flows and sediment concentrations. It is advisable to have open intakes rather than the gated ones as the gated intakes are difficult to operate with high floods coming at unexpected hours. For example, wide open intakes as introduced in Ethiopia might be suitable [15]. The farmers' perception for the main cause of the structural failure of modern spate irrigation systems in Raya Valley (Ethiopia) is narrow intake and canals, less angle of intake deflection, and the existence of the sluice gate as many floods can be lost while scouring sediments under the sluice gate [14].

The interventions on intake width and deflection angle can increase irrigated areas. For example, a study conducted by [14] showed that improving the intake deflection angle from 120 to 150° for 3-meter wide intake, the intake width from 3 to 5 m at 120° deflection angle, and the intake width from 3 to 5 m and deflection angle from 120 to 150°, can increase irrigation area by 21, 81, and 100% respectively [14]. However, these interventions in the deflection angle and intake width did not result in any significant reduction of sediment deposition at the intake. An intake with 5 m wide and 150° deflection angle was suggested from the design point of view; however, a detailed cost–benefit analysis was recommended to be done to make a final decision [14].

An example of the improved entrance to canal formed by two conical stone structures, with a circular base diameter of 3–4 m was shown in [2, 5]. The stone abutments were built by excavating a circular foundation of 2 m deep, lining the abutments with large stones and filling the gaps with smaller stones. The center of abutment structures was filled with small stones and cobbles. The height is usually 2–3 m, and the side slope ranges between 35° and 40°.

4.1.2. Rejection spillways and bed bars

The use of rejection spillways in improved systems is to regulate the flows of floods diverted to canals. It is constructed normally in the first 100 m of the canal, as a side spillway, for easy return of excess water to the wadi (dry river bed) [5]. The spillway depth should be 0.5 m below the canal bank. The spillway section length could vary with many factors such as the geology of the site, the cost of construction, and the degree of safety required. Stones, grasses, and branches can be used to stabilize the spillway sections.

A bed bar is a buried wall with its top at, or slightly above, wadi bed level. It is used to avoid the lowering of the wadi channel adjacent to the canal intake. A mass concrete which can be cast into dug out ditches is the best material for the construction of bed bar [5].

4.2. Improving traditional canals and water control structures

This comprises changes in canal design and the installation of new or improved water control structures. These structures can be grouped into five: check and drop structures, flow-splitting structures, flow spreaders, the field offtakes, and in-field structures. Many of the water control structures used in improved spate irrigation systems are similar to those used in conventional perennial irrigation practice. However, the dimensioning of spate canals does not follow classical irrigation design.

4.2.1. Improving traditional canals

In spate irrigation systems, the objective is to divert the maximum possible amount of water during the very limited duration period of the spate flood to reach as many of the fields as possible. Hence, the discharge capacity per unit irrigated area of intakes and canals of the spate irrigation system must be 10–100 times larger than that for perennial irrigation [5]. When improving or extending spate canal systems, the following points must be taken into consideration: (i) improving existing canal networks can give better water control and overcome some disadvantages of the field-to-field water distribution system, but may require a change in the way that water is distributed; (ii) spate irrigation relies upon water application carried out as quickly as possible; (iii) farmers' prior agreement to proposed changes and their full understanding of the implications for water allocation and distribution are essential for sustainable changes; (iv) where canals are performing reasonably satisfactorily, the design of improved canals should be based on the existing slopes and cross-sections and supported by survey data. Velocities in the canal network should be maintained as close as is possible at a constant level throughout to ensure high sediment-transporting capacity and to minimize deposition in the canals; (v) in flatter areas with alluvial soils, scour damage should be avoided through implementation of regime theory, selection of appropriate canal dimensions and slope, the division of flows and the provision of controlled intakes and embankments and associated bank protection works.

Improved/ remodeled Rod-Kohi conveyance system in Pakistan has increased the reliability of flood water flow, which eventually provided the most favorable moisture level at each diversion point. As a result, the wheat yield (kg/ha) increment was 19–27, 43–62, and 57–68% at the head, the middle, and the tail reaches, respectively, as compared to that produced before spate improvement [21].

4.2.2. Check and drop structures

Although spate diversion from canals with a series of earthen embankments/bunds is easy, the frequent reconstruction of the bunds is labor-demanding and maintenance is hard while water is in the canal. As a result, farmers always demand better control structures when schemes are being maintained or improved. The best alternative means for this case is by providing an intermediate design of combined check and drop structure [5]. This encompasses a drop structure, combined with an earthen embankment for heading up the flow to convey it onto a series of fields. This type of structure is observed in old traditional spate schemes with considerable drops between fields.

4.2.3. Flow-splitting structures

These structures are constructed on main or secondary canals where flood flows were traditionally shared proportionally among groups of farms or where it is necessary to reduce flood flows in canals to smaller/more manageable discharges [5]. It is good to design flow-splitting structures in close consultation with farmers and build them from local materials using gabions or dry stone pitching.

One approach used in Eritrea for splitting flow was to provide a tough flow division structure, built from gabions to split huge flows into two channels. This structure also provides a durable hard point that farmers can use to anchor temporary diversion bunds that can be adjusted from spate to spate to control the allocation of lower flows. An excellent picture of this gabion flow splitting structure is available in Ref. [5].

5. Improving sedimentation

Spate irrigation is as much about sediment management as it is about water management [5]. The sources of sedimentation in spate irrigation systems are mostly floods from mountainous catchments. The sediment transport load of these floods is commonly up to 5% and in some wadis can exceed 10% by weight. This is at least twice that occur in many perennial irrigation systems. Coarser sediments reduce the flow rate of the flood by clogging intakes and canals. The levels of command areas also gradually increase overtime by field sedimentation.

The command area level rise during the design life of the project has to be considered when improved spate diversion weirs and intakes are designed and constructed [22]. Because the upstream command areas are closer to the wadi and hence irrigated more frequently, they are usually affected by high sedimentation rates. On the other hand, sedimentation rate is lower in downstream command areas as they seldom receive water [5]. For example, sedimentation rates were from 8.3 to 31.6 mm/year in the upstream and from 5.2 to 8.6 mm/year in the downstream fields of the Sheeb spate irrigation scheme (Eritrea) [22]. **Table 2** shows the average sedimentation rates of different spate-irrigated fields.

The command area rise from an upstream field is estimated from the following Eq. [5]:

$$\Delta h = n^{*} d^{*} c/(1.4^{*} 10^{6}). \tag{1}$$

where: Δh = annual rise of upstream fields (m); n = number of yearly spate irrigation; d = irrigation depth per irrigation (m); and c = concentration of sediment by weight (ppm).

New intakes and canals have to be designed to cope with changes in wadi bed and/or field levels rising up to 50 mm/year [5]. In spate irrigation systems, the settling basins are not best options, and designing canals with non-uniform slopes and sections can improve the performance of Fokisa modern spate irrigation system in Tigray (Ethiopia) [23].

The following measures has to be considered when new diversions are proposed [5]: (i) in order to maintain the irrigable command area, estimates of the rise in command levels expected over the design life of structures (>25 years) should be developed and used to design weirs, intakes, and water control structures. (ii) Intakes associated with permanent raised weir structures should be provided with effective sediment sluices that are designed to be operated during the very short periods when flood flows exceed the diverted flows. (iii) Where intakes are not associated with permanently raised weirs, the provision of bed bars and breachable bunds, built from local materials, on top of the bed bars provides an improved intake that works in a similar manner to sediment management in traditional systems.

The scheme	Annual rise rate (cm/year)
Wadi Laba, Eritrea (Measured 2003/2004)	Upstream fields 1.0–3.5
	Middle fields 0.8–2.0
	Downstream fields 0.5–1.2
Wadi Laba Eritrea (Long-term estimate)	3.0
Eastern Sudan	1–3.9
Baluchistan mountain systems	>5.0
Wadi Zabid	Upstream fields 2–5

Source: Haile [1].

Table 2. Typical rates of sediment deposition.

6. Field water management and soil moisture conservation

The impact in crop production due to improving soil moisture conservation and managing field water allocation is at least equal with that of improving water supply [2]. Therefore, field water management and moisture conservation have to be integral components of spate irrigation improvement endeavors [6]. Their efficiency is affected by many factors: the nature and kind of field water-sharing arrangements; soil water-holding and infiltration capacities; the mode and timing of tillage and mulching practices; irrigation turns and gifts; water distribution rights and rules; and design, operation, and maintenance of field bunds.

6.1. Field water distribution methods

Field water sharing is regulated by water rights and rules in operation at the time and follows the following principles: flood water must be spread rapidly to avoid flood vanishing in low-lying areas; shared flows must be manageable to avoid erosion and gully formation; and large and sufficient water must be guaranteed for downstream areas in short period of spate flow availability [5]. The two common spate water distribution practices are:

i. Practices in command area water distribution: field-to-field distribution or individual field distribution; and

ii. Sizing of the command area: extensive distribution or intensive distribution.

6.1.1. Field-to-field water distribution/ individual field off takes

In most cases, there are no tertiary and secondary canals in field-to-field spate distribution systems. Hence, the entire flood flow in a canal is diverted to a group of fields divided by an earthen bund that blocks the canal. After irrigating the upstream field, water is released to the next field by cutting downstream field bund. This process continues until all the fields are irrigated [2].

The other option to field-to-field water distribution system is to provide fields from field inlets on secondary canals (controlled systems) [5]. This individual field intake is the norm in Pakistan whereas field-to-field systems are common in Yemen and in the Eastern Eritrea. There is a possibility of having these two systems in one scheme. **Table 3** shows the comparison of field-to-field and controlled systems.

It is recommended to implement a field-to-field water distribution system with a compact (smaller) command area under the single intake and single canal [6]. This type of distribution system rapidly lets huge amounts of flood water to fields within a short period of time spate is available. In Yemen and Eritrea, about 100–200 ha (divided into five blocks of 20–40 ha) are irrigated by one intake. Overflow structures such as simple stone pitched and concrete orifices (with stilling basins) have to be used to minimize field bund damage during excessive water application. Pictures of intakes and stone reinforced overflow structures in Pakistan, and stone-pitch overflow control structure in Tihama are available in Ref. [6].

Field-to-field irrigation	Individual field intake/controlled systems
• No land required for secondary canals, but possible damage to growing crops during second or third irrigation	• Land is required for secondary and tertiary canals though at the end of season canal beds are sometimes cultivated
• Smaller floods later in season are not diverted because upstream plots are cultivated	• Large gated flow control and division structures and field off-takes with a high flow capacity are needed—expensive
• In-field scour on the lands results from the breaching of downstream bund	• Gated control structures make it possible to divert water at any time in contravention to agreed water rights. This is not usually possible on a field-to-field system where diversion to fields is achieved using bunds constructed across canals.
• Smaller floods do not reach tail-end plots	• When plots are large, lack of leveling will create uneven irrigation
• The timing of breaching can be a source of conflict.	• Group water supply is not vulnerable to breaking of individual field bunds
• Damage of upstream field bunds may jeopardize flows to lower areas though compulsory maintenance is often regulated by local rules/laws	• Sedimentation in canals affects their ability to provide water to the tails

Source: Lawrence [2].

Table 3. Advantages and disadvantages of distribution methods.

6.1.2. Extensive or intensive water distribution

This method differentiates whether irrigation is distributed widely or concentrated in a narrow area at field level. Single irrigation is universal in extensive systems but two or three irrigations before cultivation are possible in compact/small area. The crop yield from two or three irrigations in a small area is more than two or three times that of single irrigation from a large area [1, 24]. This evidence was obtained from spate irrigation of sorghum crop in Yemen and sorghum and maize crops in Eritrea.

Therefore, compact area favors second irrigation, and promotes cooperation and investment for bund maintenance and land preparation before irrigation, because of a higher predictability of the spate irrigation system [5, 6].

6.2. Field water application and the importance of field bunds

According to Ref. [5], the height of field bunds is low where spate water supply is frequent and plentiful, normally in the upper fields and they are relatively higher in areas where spate water supply is erratic. In high field bunds of 2–3 m, water can inundate a land for long period and hinder timely tillage and land preparation, and are also not easy to maintain. Moreover, high field bund incurs high construction, maintenance, and operation cost to the poor, and consumes their time. Since the spate system is uncertain, its failure to provide the investment return may discourage farmers' future commitment. Therefore, according to Ref. [6], maximum field bund height limit was set to be 1 m.

Some of the techniques of improving field spate control and distribution are properly leveling field bunds to ease overflows over a long stretch, excavating a shallow trench downstream of the bund to distribute overflowing water over the total width of the field, the strengthening of spillway arrangements, and enhanced field gates [5].

6.3. Soil moisture conservation and improved agronomic practices

As crop yields can be hardly lowered by soil moisture deficit, moisture conservation is as important as water supply in spate irrigation. Techniques of soil moisture conservation in spate irrigation systems include soil mulching; mulching and intercropping; pre- and post-irrigation tillage; breaking soil crusts; practices of combined sowing and plowing; and encouraging the burrowing action of insects and crustaceans [5, 6, 25]. Crop yield can be increased by a factor of 1.5–3 through improved soil moisture conservation. For example, in Eritrean, sorghum yield was increased by 2 t/ha by practicing improved soil moisture conservation techniques such as mulching, pre-irrigation, and combined tillage and sowing [6].

Several cropping strategies have been developed by farmers to survive with the risks in spate irrigation. They grow high drought-tolerant local varieties in spate irrigated areas. Some of the major subsistence crops grown include sorghum, millet, pulses, and maize. After sufficient subsistence crops have been harvested, farmers usually grow cash crops like sesame or cotton [5].

According to Ref. [25], pre-irrigation plowing showed to be most effective in improving sorghum yield as compared to post irrigation plowing (**Table 4**). About 4 t/ha of sorghum yield was obtained in Eritrea where the combined sowing and tillage practice were used [26]. But, sorghum yield varies from 1 to 1.5 t/ ha in spate irrigated areas of Yemen and Pakistan where the combined practices are not implemented [26].

According to Ref. [27], the pre-sowing spate irrigation depths for the optimum wheat yield of 3448 kg/ha under spate irrigation would be 30–45 cm (September–July) in Pakistan. Pre-sowing depths of less than 30 cm and greater than 45 cm have resulted into the lowest wheat yields of 3302 and 3098 kg/ha, respectively. Farmers of Eritrea estimate that a person who has his own bullocks would be able to harvest a yield of 30–100% higher than another who does not own bullocks [5]. Because, with one's own draught animals, one could plow fields and

Land preparation	High floods ($2.4\ m^3/s$)	Medium floods ($1.6\ m^3/s$)	Low floods ($1\ m^3/s$)
Pre-irrigation	4.29	2.14	0.86
Post-irrigation	2.25	1.07	0.43

Source: Avelino [25].

Table 4. Sorghum yield (t/ha) for gash agricultural spate scheme, Sudan.

repair bunds after every irrigation, thus vastly increasing soil moisture retention. Therefore, investments in infrastructure may be complemented by programs to ensure a better stock of draught animals.

From the most comprehensive assessment of yield in the spate irrigated and non-irrigated farm, wheat yield increased from 4 to 13 t/ha; barley from 7 to 12 t/ha; teff from 3 to 6 t/ha; haricot bean from 6 to 15 t/ha; and maize from 3 to 10 t/ha [28]. This shows that under spate irrigation, yield increase is significant for all crops.

Spate irrigated agronomic research that have to be studied and disseminated to farmers are: drought-tolerant and high-yielding varieties; improvement of inter-cropping systems, seed banks establishment, improved crop storage to minimize post-harvest losses, improved soil moisture conservation and management practices; and the integration of home-grown and technical knowledge with the scientific one [5].

7. Water rights, distribution rules, and managing inequity

7.1. Water rights and water distribution rules

In spate irrigation systems, water rights are expressed as "reactive water rights" as they express granted asserts and tolerable practices in a changing and unpredictable situation rather than quantifiable rights to a natural resource, as in perennial irrigation systems [2]. Water rights and rules help to establish water allocation rules in new systems, discover prospects for improvement in enforcement and revision of water rights, and consider new circumstances and how they affect distribution rules and avoid unplanned shortcomings of the anticipated changes [5].

Conflicts are spring to arise in the absence of agreement on water rights as spate irrigation being new in many areas. The results are sometimes dramatic. For example, the conflict on the Weida River in Konso (Ethiopia), where more than 200 persons were killed over a water dispute between investors and pastoralists, is an evidence for this [5].

As concluded by [29], tribal area systems working without state involvement in Punjab (Pakistan) have developed successful local irrigation managing institutions based on social and ecological significances to guarantee sustainable self-leading resource administrations. In contrast to this, the state interference in indigenous irrigation systems undermined collective action and distorted equity in access to traditional irrigation rights in state-managed areas in Punjab.

Rights and rules are also important to adapt to changes in the wadi morphology/courses and flood canals [2]. Codifying water rights and rules in documents can serve as a basis for clarifying disagreements [30]. The enforcement of rights and rules can decline, but the rights and rules become worthless without enforcement by local leaders, organizations, or government institutes [28].

The repertoire of water distribution rules was described by [2, 30]. In the Wadi Laba (Eritrea), the rule states that regardless of its location, the type of crop grown in it, and the social and economic status of its owner, a field is allowed a second turn only after all the other fields that are entitled to irrigation (in line with the rule on demarcation) have received one turn [29]. This rule has, however, some practical shortcomings. In Wadi Tuban, Yemen and Rod Kanwah, Pakistan, the rules limit the access to second turns only to the most important subsistence crops such as wheat in Pakistan and red sorghum in Yemen [30].

7.2. Managing inequity and uncertainty

In spate irrigation, a certain degree of inequity between upstream and downstream users—between and within systems—is inevitable. Ensuring the command area that is not too enlarged can alleviate this. A smaller command area will make it more likely for farmers to have two or more floods, which can highly increase productivity as crops are no longer in the "stress zone" [15].

According to [31], for example, in Bada (Eritrea), a number of mechanisms to reduce inequity in water distribution are: first is the prevalence of the permanent channel network that avoids water that is concentrated excessively in the upper reaches, as is the case in a field-to-field irrigation. The second set of rules that modify the difference between upstream and downstream fields are the restrictions on second turns and the practice of distributing water to the driest fields first in times of water scarcity.

8. Summary and recommendations

8.1. Summary

In this chapter, the needs for and ways of improving traditional spate irrigation systems were reviewed in detail. Spate irrigation is the science and art of diverting floodwater from dry river beds or seasonal rivers and using it for crop or pastures production, water supply for human and livestock, groundwater recharge, and tree plantation. To maximize the productivity of drylands with high spate irrigation potential, traditional systems of spate irrigation has to be improved. In this case, farmers should be consulted and involved using their indigenous knowledge in the planning, design, and implementation of improvement works. The modernization interventions which fail to consider these, in many cases, were not successful. On the other hand, the best successful improvements incorporate less labor intensive and relatively permanent structures with the advantages of conventional systems (technical and social aspects) without considerably altering the approach of the spate irrigation practice.

Hence, the improved spate irrigation systems must be designed so as to minimize the damage of canals and fields by large floods. These systems must guide and split flood flows, rather than constrain them, avoid excessive sediment load in spate irrigation systems and ensure that suspended sediments should not be deposited in the canals. Their design must also ensure that they can cope with recurrent and occasionally big changes in river beds.

In addition, spate irrigation improvement packages should adopt a field-to-field water distribution system with compact (smaller) command area under one intake and one canal instead of an individual field water distribution system; limit maximum number of irrigation turns to two; limit field bund heights to 1 m; opt for water rights and rules that entitle downstream fields to the more frequent small and medium floods, thereby ensuring equity in both water quality and quantity; optimize soil water holding capacity and infiltration rate through pre-and-post irrigation tillage, combined tillage as well as soil mulching; and grow drought tolerant local variety crops.

In spate irrigation systems, it is not advisable to have gated intakes as they are difficult to operate with high floods coming at odd hours; hence, open gates are recommended. In spate irrigation systems, the objective is to divert the maximum possible amount of water to irrigate as many fields as possible during the very limited period of the spate flood availability. Hence, the intakes and canals must have a much larger discharge capacity per unit area served than would be the case in perennial irrigation schemes. The deflection angle of the intakes should be minimized to reduce sediment entrance. The design of the canal command levels needs to take account of the likely rise in field levels (due to sedimentation) during the design life of the proposed improvements to the canal intake.

Water rights in spate irrigation should be “reactive water rights” since they describe agreed claims and acceptable practices in a changing and variable environment. A certain degree of inequity between the upstream and downstream user and conflicts can be minimized when water rights and rules are enforced. Farmer-managed spate irrigation systems are more sustainable than those with much government interference.

In conclusion, the review investigates that the science and art of spate irrigation is the least understood, the least researched, and the least documented. Therefore, this review chapter helps as a reference material for teaching, training, and research activities and would play a great role in the sustainable spate irrigation system development, rehabilitation, and management work.

8.2. Recommendations

The following gaps were identified from the review. Spate irrigation is yet different from conventional irrigation in many ways. In spate system, farmers are interested in diverting a large amount of flood. In this case, a large amount of sediment could get into canals and irrigated fields and spate structures could also be damaged. Therefore, optimal design of spate irrigation systems which both maximize the amount of water diverted and minimize structural damage and sedimentation problems is required. Spate irrigation is also the least researched and the least understood among irrigation engineers, managers, and the users, and the least documented. Moreover, spate irrigation is not yet a part of the curriculum of many academic institutions. Hence, in order to exploit the available spate irrigation potential for food security and livelihood improvement, the following are suggested for the improvement of traditional spate irrigation systems:

- Capacity building and experience sharing programs on successful and improved traditional spate irrigation system, are required for professionals, practitioners and farmers, agro-pastoralists, and others who involve in spate irrigation development. In this case, technical or engineering aspects (design of intakes, canals and command areas), soil and water management, agronomy, water rights and distribution rules, environmental and institutional aspects of spate irrigation should be attended to the trainees.
- Incorporating separate spate irrigation courses at higher educations.
- Farmer-based on-site research such as (i) the impact or combined impacts of field bunds, pre-irrigation and post-irrigation tillage on soil moisture storage, and crop yield, and (ii) different short duration, drought and flood tolerant, and high yielding crop, orchard or tree varieties.
- Research on optimal design of improved traditional diversion structures, canals, and canal structures that maximize the amount of flood water diversion and that minimize the structural failure and sedimentation problems. For example, the effect of improved traditional intake size on sedimentation of traditional improved canals, fields, the size of the irrigated area, and cost-benefit analysis associated with improvements, etc., are not well studied.
- Research on social aspects of spate irrigation is as important as technical aspects (for example, water and land distributions, spate use and rights, the participation of irrigators in the spate irrigation development and management).

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Section 4

Landscape Architecture Around the World (Case studies)

Chapter 9

Natural and Cultural Landscapes in Atacama Desert: Between Tradition and Innovation

José Antonio González-Pizarro and
Claudio Galeno-Ibaceta

Additional information is available at the end of the chapter

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Abstract

Climatic conditions modeling the landscape of the Chilean northern region are examined, along with how they could model different strategies to be inhabited by various demographic contingents in time. These experiences have persisted in the different geographic spaces of Atacama Desert, from the Andes at an elevation higher than 2000 m.a.s.l., going through the intermediate depression between 2000 and 500 m.a.s.l., to the coastline panorama. In the various shades of the desert climate and the experiences of several populations, life styles and spatial conceptions were posed in terms of their cosmic dimension from a deterministic view and pragmatic apprehension to a contemplation-like view. These conceptions between man and the landscape have assumed different relations of technology use, natural and energy resources, and a constructive-architectonic design in Atacama Desert, which have remained as monuments in the Chilean southern space.

Keywords: landscape, desert, nitrate, Antofagasta, Andean

1. Introduction

The large extension of Atacama Desert in Antofagasta region includes different geographic areas with desert climate variants that define various landscapes. According to Köppen's classification, on the coast, we find a coastal desert climate with plenty of clouds and high humidity but without rain. A characteristic of this presence are the *camanchacas* (fogs) enclosed by the hills of the Coast Cordillera. If we go up to the east, between 1000 and 2000 m.a.s.l., we find an intermediate depression and a regular desert climate with other characteristics such as high thermal fluctuation between day and night, clear sky, and absence of rain. Farther to the east, and higher toward the Andes, we find a marginal high desert climate, present at the

Andes foothills over 3000 m.a.s.l., with rainfall that fosters steppe growth. Finally, we find a high steppe climate with rainfall in summer that reflects vegetation and certain surface water currents ([15], pp. 214–221).

These climatic features, added to a rugged topography, have defined natural landscapes with distinctive characteristics. Every human action must have faced the desert. The difficulty to transform a natural scenario into an inhabitable space has been subjected by two factors: one of them, water supply, either through groundwater or the access to the main surface water current (Loa River) and the second one, the necessary road connectivity with the Pacific Ocean or transboundary Mediterranean cities (Bolivia and Argentina). Closeness or distance to port settlements in the moorland posed different views about space, nature, and landscape.

We must indicate that Atacama Desert became part of the Chilean landscape during the second half of the nineteenth century, when nitrate exploitation began in this territory. It was a dissonant landscape compared to the one that characterized Chile, with forests, rivers, and lakes [33]. From being a *boundary* between Chile and Bolivia, the desert arose as a *frontier* region where the whole desert landscape showed the known and what remained as unknown. In this sense, the desert landscape caused tension on what John Agnew called "landscape ideals" inside the national territory, thus opening other "sites of memory" for the country's modern times [2].

We must keep in mind that the concept of nature is an abstraction about which different cultures have had distinct views. Whiston Spirn ([64], p. 251) pointed out something that is proven in the desert, "There is always tension between the autonomy of nonhuman features and phenomena and the meanings we ascribed to them".

The knowledge about its relief, with the attribution of names to its geographic features, from the language of its pre-Columbian inhabitants (in Quechua language, Lascar and Llullaillaco volcanoes; in Kunza language, Licancabur and Panitri volcanoes; etc.), and in modern times, by Chilean geologists, mainly Francisco San Román [53], named them as Cordillera Darwin, Sierra Vicuña Mackenna, Sierra de Almeyda, Volcan Lastarria, etc., to honor these great men of science and Chilean liberalism. This action of the word on the nature gave shape to Atacama Desert toponymy. And this meant man's o*rientation*, the second step for perceiving the landscape. The designation, by means of language, began to fill the void of space with content, distinguishing what nature exhibited itself before their eyes. It was the step from "feeling lost, a shipwrecked in things", *otherness*, to forming "an idea about things", *self-absorption*, even acting in the world, Orteguian *action*, where the ultimate meaning is the need to think to survive ([49], pp. 30–31). Heidegger reminded us that it is our speech that leads to man and, in the archeology of the old locution in his language, indicated us that to construct means to inhabit: "we inhabit, as we are the inhabitants" ([25], p. 203). Inhabitants of the Earth, where everything is nature: the material world where "human beings are included and excluded" ([66], p. 233).

At present, it is considered the so-called "affordance theory", developed by James Gibson, links the environment to human behavior, or as Heft (cited by Ward Thompson [61]) describes "perceptible properties of the environment that have a functional significance for an individual", which makes it possible for certain mental constructs—certain prototypes—to approach us to understand landscapes.

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2. Landscape in time and space in Atacama Desert

Anna Whiston Spirn has argued that an appropriate reading of nature and its landscapes—both native and cultural—requires considering the interconnections of air, water, earth, life, and culture to understand these contexts [65]. Pre-Socratic thinkers such as Empedocles affirmed: "of all things, four are the roots. Fire, Water, and Earth, and ether's boundless height" ([18], p. 67). For the Greeks, ether was the pure air on the mountains. The essential elements that make us understand landscapes, as highlighted by Gaston Bachelard with air and water, make imagination flow over our environment.

In this context, it is where the different views developed with time struggle, regarding the space we are concerned about. Visions not only contain the man-nature relationship, but also certain paradigms that still survive [13, 20, 24]. Landscape will not only reveal to us as different approaches to the world as it is, but also as we would like it to be, because the landscape "is both the phenomenon itself and our perception of it" (Wylie, cited by van den Brink et al. [59]).

(a) The cosmic-sacred dimension linked to the belief systems of the region's native peoples, to the world view. There is an inflection from an ecological optics considering the construction of a smaller place, which is nature, inserted in a cosmic framing. This hieratic dimension means to of assume the space in connection with tutelary gods, is animated by a symbolic rationality. The passage of man through steppes and ravines opens paths that melt with the earth itself. In the landscape of the Andes foothills, they become high altitude shrines located on the top of high peaks. It is a space where resources are not an absolute dominion to humans. The balance between river beds, agriculture and herds, and the sustainability of human presence, is the primordial axis of the cosmogony that animates this view about nature and landscape.

The priest Gustavo Le Paige was a passionate scholar who studied the archeological sites on the high peaks of great "Salar de Atacama" and reached some conclusions:

> *"(…) despite the scarce cultural evidence about Inca settlements in this region, we are impressed by the fact that Incas imposed their religion of high peaks, showing that, along with the administration of Atacameña zone, they were concerned about establishing their own religion. / We believe that only priests went up to the summits accompanied by a few assistants to offer ceremonies to the sun, which included burials of offerings under the platforms (…)* ([29], pp. 38–39)."

(b) The naturalistic-deterministic dimension brings together a view that lies exclusively on the earth's surface. It is to prove that the dominant landscape—the desert—is the synthesis of adversity for man. It is possible to oppose nature to a technique that can exceed negativity for a civilized life. Searching the entrails, in the deepest part of the barren land, mineral resources that may compensate life inconveniences and investment risks. It is the deliberate construction of an artificial landscape precarious for man. A disruption against nature. Looking at the desert and its flat, dry, and luminous landscape from an instrumental rationality. The primordial, the virginal nature is not respected. The native is altered by what is strange to the landscape: industrial plants and machines. The determinism of every mining cycle, that is, abandonment, *desertus,* when human presence ends, changed the landscape into a heterotopic space [14]. A sample is ghost towns such as Pampa Union or the large number of abandoned nitrate cities in different cantons, or geographic areas, in the whole region.

San Román masterfully described the convergence between the common sense of desert man and the technical knowledge about space. On this elasticity of space he stated:

> *"The long stretch of Chilean territory running from the rough Huayco valley to the nitrate pampas where Loa River flows, including between both extreme boundaries the whole Chilean breadth extending from the Pacific coast to the Andes crest, makes up what was properly considered as Atacama Desert until the beginning of the present century. This designation has been restricted more and farther to the north as the general progress and mining discoveries populated or made exploration accessible to those territories, founding towns and creating industries in them; but, as a mere geographic title and above all, as an the meaning of an arid zone and production exclusively due to the mineral kingdom, tradition and customs still preserve that name for the whole region that embraces two Chilean provinces nowadays, Atacama and Antofagasta"* [53].

(c) The pragmatic-utilitarian dimension helped strengthen instrumental rationality in all its dimension. The landscape does not only make up an object for its purposes, but the look about it extends as a reading of total lordship. Everything must be at the service of man's economist view: its mining resources, the flora—the *llareta*—as an energy source, and water use, exceeding the quotas and turns of the tributaries destined to the agriculture of the native peoples. The space is transformed into its nature. Each human settlement has the purpose of getting the greatest amount of resources from the space in the shortest time. It is a predatory view about the environment. There is no an esthetic view but usefulness regarding the landscape. The metaphor of man's transitoriness materializes in places—where man builds—in the middle of the desert. The railroad, telegraph posts, train stations, and asphalt roads, emerge as the new nature superposed on the wasteland. The ruins from the abandonment of these constructions, by depopulation, reflect the visual contamination of this rationality.

Oscar Bermúdez, the great nitrate historian, drew a synthesis of the human passage and the unalterable of natural space. He could not forget his own pampa experience:

> *"The geographic environment of this region, at first gave rise to the life forms of primitive cultures able to adapt there and, even, prevail in the environment. There the Spaniards spent centuries trying to unwillingly endure their solitude and the difficulties imposed by the large distances. Later, an industry was established, the soda nitrate industry […] but, neither the old populations, nor modern nitrate and copper industrialization have changed the desert landscape at all"* ([7], p. 19).

(d) The contemplative-ethical dimension constitutes a combination between ecological awareness and the sense of native beauty. Damage to the landscape entails, as a reaction, an ethical, and esthetical reflection about human action. It is a view that intends to enquire about unknown landscapes and look for corners in nature that allow to measure eutopian places, assigning indigenous ethnic groups and their locations as "good places", where happiness can still be found ([26], p. 16). Places and corners of the landscape, where the contemporary tourist believes to live in the plenitude of its authenticity. In this sense, the writings of native essayist and poets suggest a view about the nitrous pampa, associated with nitrate human epic, highlighting the manly quality of the indomitable desert.

In 1945, it was Montandón who was dazzled by the landscape that connected the pampa with the oases of the Andean foothills, highlighting what could be perceived by every eye alert to the beauty of the natural and the potentialities of a heritage that began to be unveiled:

"The traveler who goes through known routes or heads towards the mountain ranges in Chile's northern region stops to observe relics and historical sites that awaken his curiosity and sensitivity. Open doors over the past, the emotional state that intends to appear there has different origins. It is the mute presence of Tiahuanaco-Atacameño adobe masses burnt out by the desert sun. It is in the oases of the 'unknown pampa', the humility of those little churches, genuine product of this rustic colonial art. Parallel 22° 30': two places lost in Salado River valley, tributary of the river Loa: Aiquina and Caspana. At the edge of rocky paths carved by nature, strange stone rooms emerge, defended by themselves in their inaccessible heights… the Pucara de Lasana, an important town and also a fortress… houses have windows and doors, the first shown in the American architecture… A road connect Calama and Chiu-Chiu, a sleepy town receiving desert winds from four sides; the construction of its delicious and old church dates back to 1557" ([36], p. 48).

The writer and poet Andrés Sabella conjugated the meaning of the desert as an inalterable space observed by man, unperceivable in the infinite nature:

"Open pampa… It is not possible for anything to hide to the eyes of death. On the grounds are the traces of the hardest time. And in the firmament, the sun breaks down into a furious laughter full of fire… The clouds slide, far away, timidly. The sky opens into a beautiful blue-lost smile. The sky of the pampa is the lovely cap of a pond that is not convenient to show in excess. At night, the stars swell with light and stay low… The earth is dry. A grey of forgetfulness escapes through the cracks. And the desert remains flat, smooth, macabre" ([52], pp. 19–20).

Faced with this multiform desert landscape, human action has been manifested in the paradigms mentioned. Some of the demographic segments have left imprints in the wasteland: since the Hispanic indigenous syncretism of the foothills settlements, combining the indigenous *talatur* ceremony singing, the airphonic instrument of the *sicuri*, the Marian procession and the sound of the bells [31]. Both invoking the perpetuity of time must impregnate inhabited places.

Since the mid-nineteenth century, we can observe the dual effort of the pioneering inventiveness with that of man stocked with technology. The intuition of dreaminess that surrounds man and landscape into only one. A dialectic relation is appreciated, manifested in giving ore discovery the utopia looked for and at the same time trying to transform aridity by means of a creative designation. Benjamín Subercaseaux was able to capture this last connection:

"In the pampa, and also on the mountains, geographic names indicate the thought and stages of the efforts made in struggling for life… some names reveal the anguish of explorers and adventurers: Misleading Pampa… and the permanent concern about water for these hoarse throats: White Waters, Good Waters" ([57], pp. 100–101).

The landscape of the nitrous pampa was populated with places, in a Heideggerian sense. The relief was disrupted by shovels and iron bars until the nitrate crust (*caliche*) appeared. Mining camps broke up the continuity of soils. Later, mechanic tools arrived together with constructions to shelter machinery and housing for pampa men. Despite this, the desert kept its demarcations, yielding men portions of the coast. On the coastline, places were built, which would remain with man and where nature and culture would live together.

From the ports, man extended his material culture to the hinterland. He did not always run over nature. He reflected, as Ortega and Gasset asked, to operate in its construction. He posed himself the dilemma of adapting human inhabitability to the proper materials (mud, adobe, cattail, and straw) or introducing a rupture in construction elements (Oregon pine for housing and railroad ties, cement, steel structures, etc.). In the same way, he offered an innovative answer for the climate such as the control of solar radiation, thermal oscillation, scarcity of water resources, and energy. Architect Glenda Kapstein examined transversality of architecture in the deserts of the region, from 3000 m of altitude to sea level and identified "intermediate spaces" as a strategy and operation of human adaptability to these contexts [27]. Man started changing the means of transport and their adaptability to the natural environment: caravans used colonial paths; stops in pre-Columbian tambos or infrequent oases in the pampa; later, he introduced techniques invading nature: asphalt roads, highways, railroad networks, and airports. The technological innovation claimed by J. Schumpeter became the destructive creation, beneficial for mining production, but devastating for nature and human life.

The landscape, even in its natural and cultural contents, encloses a historical construction, that is, a social construction collecting the sensitivities of each epoch: a "way of seeing" that makes it possible the fair appreciation of the landscape in its twofold connotation. On the one hand, what is sterile, uninhabited, the desert, can be "rediscovered" as a space for "existential re-encountering" between solitude and the universe [23]. Or, on the other hand, the introduction of varied elements in urban construction has been able to direct the search of its own imaginaries: the need of parks, avenues crowded with trees, squares, gardens, orchards, and the farms known as "quintas", would be evoking not only immigrants' landscape, but also the link with life in the water/green equation. Lewis Mumford once pointed out the pretension of naturalizing the urban. This relation of crossed landscapes is also related to the inhabitant of the space. Lynch [30] referred to the image of the city mediated by paths, edges, landmarks, nodes, and districts revealed from the experience of the body in a space, involving that each inhabitant establishes an orientation compass in the cultural organization, in the settlement order. The recognition of order bases the image of the urban landscape, gives meaning to space and finally relates its identification with the city.

Natural landscape was the most appreciated image by literature to build the nitrate epics: the nitrate pampa or the categorical desert. The struggle between man and nature was built as a metaphor not only of the magnitude of this adversity—quite in the perspective of an answer to the challenges of adversity in the historiography of Arnold Toynbee—but also in the history itself between the subject of the gear of the technique and its fight for redemption before nitrate capitalism. Sabella represented the culmination of both allegories [22].

The places were those that gave a greater meaning to the spaces. The link of natural landscapes to places shows the distinction in the desert geography. Foothills cemeteries were erected according to the world view, the ancestral belief of Atacameños impelled them to create *gentilares*, sacred places in the infinite desert, while those Christianized used the lands around to colonial churches, as in Chiu-Chiu.

Toward the intermediate depression, the pampa and nitrate mines shared a dichotomous western vision: death spaces distant from those of life. However, the coffins and wooden crosses fused with the pampa, while corpses kept their structure intact due to the salts and the nitrate of the soils. The need of "perpetuate" the memory of those who "traveled to the beyond" made *pampinos* keep their cemeteries visible by means of paper or metal flowers. The desert makes possible coffins and memory equity. It is a panorama that can be appreciated before that much luminosity of the wasteland plain.

In the cities, death rounded up in cemeteries where the stratification of civil life continued: family pantheons, mausoleums of foreign colonies; individual niches stacked on thick cement walls whose tombstones evoke his life; individual graves in the soil, whose signs disappeared with time; common graves for anonymous men and women. A Latin tradition that has accommodated to "Memory Parks" where death dissipates in the frenzy of present life, under trees, and grass. Again, the heterotopia of spaces makes itself present.

And, it is precisely the absence of the symbol of life—the water and the greenery of the landscape—what is emphasized in those places established in the rural spaces of the pampa and coastal cities. This non-native landscape, artificial but real, has reflected certain aversion to what the desert means. The landscape design—as written by Whiston Spirn [62]—does not only express our conception of nature, but also the place of human beings within nature.

The landscape of the oases, centennial villages, transhumance and Andean volcanoes, agriculture and water tributaries, has constituted space and places that have been re-signified in time. A peaceful life in them, mysterious and exotic, could be glimpsed by explorers in the nineteenth century: places that were out of history, where time had stopped in their town arteries; later, it was discovered as a magnet offering urban man an existence far from noise, the desired rest, another way of trying a life style [31]. At present, it offers a landscape esthetics, where the authenticity of the natural co-exists with the artificial of its urban life. It can be say that it is a landscape thoroughly open to a polyphony of interpretations, where the native ancestral shows itself with the Spanish colonial seal and the accents of republican modernity. Norms from old times about property and water converge with foreign preceptive ideas that speak of how to build in order to respect inherited heritage. Whiston Spirn [63] referred to a movement esthetics and change of multiple visions: "This aesthetics engages all the senses, not just sight, but sound, smell, touch, and taste, as well. This aesthetics includes both the making of things and places and the sensing, using, and contemplating of them".

It is relevant how, in the case of San Pedro de Atacama and its surroundings, at the Andes foothills itself, natural and cultural landscapes have been able to reconcile an esthetics that speaks of a certain cultural hybridism, where native people have been able to retake the dominance of their space (places of great archeological and monumental importance such as Tulor village, *Pucara de Quitor*, and Moon Valley natural sanctuary, among others) and how the foreigner has encouraged changes in his habitat (hotels that recover the traditional architecture with designs of high sophistication as well as restaurants of gourmet gastronomy) and the State has built a mixture in the whole landscape (authorizing the construction of the great radio telescope ALMA—Atacama Large Millimeter Array—in Chajnantor plain, surrounded by the ceremonial centers of Atacameño people). Again, we are in the presence of the value that words have for creating new realities, altering the impressions about the original landscape.

The town of San Pedro de Atacama was declared national monument (typical zone) in 1980 because "it represents the valuation and rich expression of an oasis village of pre-Columbian and Hispanic roots, making up an archaeological center internationally well-known" [9]. The State has recognized the existing biodiversity, creating *Los Flamencos* National Reserve and creating *Nature Sanctuaries*, where the prototypes of the Andes geography are considered: the "Cordillera de la Sal" and its "Valley of the Moon" highlighted by its geomorphology [9, 35]. In this way, the most contemporary orientations about landscape have been understood, such as the one from the European Convention, posing that this is a fundamental part of individual and collective well-being and a cultural identity component ([61], p. 45).

The latter was also observed in the nitrate landscape. To change the stereotype of desert landscape, the one on the surface, tangible and real, unveiling had to operate, exposing the occult, revealing the other truth—as Heidegger teaches—the one with soda nitrate and copper resources. It was a space where utopian community ideas practiced were embodied in their plans that delineated the camps of workers and employees, following the impulse of the settlements of the Industrial Revolution ([16], p. 19). The new landscape did not only change nature, but also man's behavior. "A life style in the desert" was forged, assuming the adaptability/innovation with space elements. It was intended to change space aridity by introducing water supply technology: solar plants in 1872 and, later, at the brink of the twentieth century, Sloman dam to control Loa River course. To distinguish these points in the space, each place or nitrate mine had a reference meaningful for companies, their inhabitants, and the whole region [10]. It might be said that nitrate towns—the same as Chuquicamata mining camp—were the greatest and pioneering efforts in the pampa to conduct an urbanization process in the desert space. Paraphrasing Doreen Massey (cited by [56], p. 162), men and women generations in these camps did not only construct the social forms of these places, but also gave them a special meaning. All this built a unique landscape worldwide, connected to what Oscar Bermúdez named as "Shanks Civilization".

Changes in exploitation techniques and the new realities of the world commerce derived that globalization have been reflected on the pampa landscape. The new copper era meant the alteration of human landscape. The miners no longer belong to the region. C*ommuters* have disrupted the landscape because their lack of roots in the space has meant the provisory of mining settlements, what architect Eugenio Garcés has called "copper hotels" or "dwelling machines" [17].

Artists have reflected the world that vanished with time, as most nitrate industrial cities, describing the most visible of them in the landscape: their high chimneys or the utopia of the green in its squares, as appreciated in the paintings of Chela Lira, Carlos Contreras, and Waldo Valenzuela. Paintings rescued the last vital shreds of the meaning of cultural landscape in the desert space.

3. Vernacular and pre-Columbian landscapes: conservation and perception

Bodini, in his study on the population of northern Chile in 1968, distinguished three large areas: the Andean zone including the foothill and high plateau areas; a pampa zone including the different pampas of the central plain and part of the Coast Cordillera; and a coastal zone characterized by seaports ([8], p. 49). In addition, he pointed out studies on "plenty of groups around Andes salt lakes and foothills oases".

The architecture historian Ramón Alfonso Méndez in his composition of the Chilean historical process of architecture, began his journey with the manifestations of northern Chile deserts. Following the conquerors' route, from Cuzco to Mapocho, "as the Inca horizon vanishes in the vast aridity of Atacama", more rustic constructions were identified: *pucarás*, sanctuaries, and terraced fields. Human groups associated with these principles occupied the desert edges, Changos on the coast, and Atacameños in Atacama puna and foothills valleys. He defined the former as "expert fishermen" who lived in constructions made of seal fur supported by cactus trunks or whale ribs. The latter were "farmers, cattle breeders, good traders, miners, and textile manufacturers" who had inherited an "interesting architecture of rough stones roofed with herbs", using a technology that collected "forms and techniques from Andean millenary cultures". They had also developed "terrace fields and artificial irrigation" and also the pucarás, big complexes defined as defensive cities such as Lasana, Quitor, and Turi, built with an organic design and strategic localizations allowing them the domain of the environment and their own agricultural areas ([34], p. 2).

Despite the large desert pampa, both borders developed at the same time and with certain connections. Lautaro Núñez, in his study on the pre-historic agriculture of the southern Andes, from Atacama Desert coast, establishes links with the foothill oases. Identified evidence (quinoa, vicuña furs, spear-thrower, and throwing darts) reveal that coastal populations must have temporarily moved to Andean environments for collecting and hunting. About the correspondence between the coast and the Andean world, he manifests:

> *"(…) it was a serious mistake to consider the non-ceramic occupations of the coast without relating to similar populations located on the interior of the coast. These concepts of coast and Andean region are not valid for a narrow country where mobility for early micro-environmental advantages was a distinctive feature (…)"* ([43], p. 123).

This mark of landscapes with their inhabitants, natural environment, remained inalterable for a long time, we could say, unknown for most people. In 1907, caravans or expeditions were organized in Antofagasta to visit these sites and villages.

A journey in the first half of the twentieth century, from Antofagasta to Toconao, indicated the contrast between modern life, industrial, noisy, and feverish in its economic activities, and an ancestral life, with motionless constructions, peace and silence, centered on its activities of old times. Foothill towns description fused with a landscape calling contemplation. The visitor narrated in 1936:

> *"We have arrived there through lonely roads; we have not even been accompanied by the infinite rows of posts supporting vibrant lines, link of life to distance… Nothing discovers life for us. Life is hidden in the ravine. Around three hundred inhabitants live there. There is peace, much peace above all. Because Toconao inhabitants are only concerned about their orchards, that are their life. These inhabitants identify themselves with their trees; they know the age and history of each of them. Thus, when an engine vibration or the sound of a horn is heard, a shake of suspicion runs through the modest population"* (cited by González-Pizarro [19], p. 18).

In 1944, Luis Armando Sepúlveda tried to register these sensations by stamping: "But this desert, distressing for people from the south (…) is a yellow grey stark desert, where not even a blade of grass, neither a bird show, in many leagues around, any sign of life" [55].

In the mid-twentieth century, Roberto Montandón permanently published about northern Chile, addressing settlements, ruins, and landscapes, but he particularly dedicated to the constructions of the eastern Atacama Desert margin. In May 1945, he published the first of many papers about northern architecture in the journal "En Viaje". In "Reliquias históricas de Chile" he gave evidence of the colonial and pre-Columbian legacy of sites on both ends of the country. In the north, he addresses towns such as Ayquina and Caspana, from the ruins still existing in their perimeters, Chiu Chiu and its colonial church, Lasana Pucará, and San Pedro de Atacama, and the presence of Incas and conquerors, their church and town hall. Surrounding the Great Atacama Salt Lake the under snowy summits we find Toconao with its old bell tower, its characteristic orchards, and maize plantations, defined as "Atacama Puna Garden" ([36], pp. 48–49).

The syncretic forms of Andes architecture, emerging from the encounter of the Spanish with the Andes native man are revealed in colonial churches. Lautaro Núñez, a remarkable archeologist on the area says, "Missionaries had to struggle against strange cosmic visions and so many unexpected ritual practices…the cult to the nature of waters, soil fertility, objects with powers such as those of 'old saints' and those small idols of the protecting world of birds and animals…The first rectangular chapels with a door and a half-arc altar rather looked like Inca 'Kallancas'…with their typical slanted roofs and seats shaped as 'poyos' or lateral stone benches, following the only model that remains in Old Peine Town" ([45], pp. 11–12).

Montandón deeply examined the relations between society, desert landscape, and architecture in long writings published in chapters. The first one was "Oasis en el desierto de Atacama" (May, June, and August 1948). In this case, the historical dimension becomes relevant. Oases were vital for colonial routes and the Great Atacama Salt Lake was a huge geographic framework with life orbiting around it, "as if this dead extension had wanted to be surrounded by mankind". The three main axes of the Atacameño world were Calama, Chiu-Chiu, and San Pedro de Atacama. Their presence at the center of the Andes made them become a node that established links with Tiahuanaco and other bordering cultures. Evidently, the presence of water creates places, "The oases marking out the eastern desert from north to south, from old Lasana Pucara near Chuquicamata, to Tilomonte, on the southernmost end of the Great Atacama Salt Lake, occupy river bank grounds, the most irrigated by Loa, Salado, and San Pedro rivers, their villages corresponding to the names of Chiu-Chiu, San Bartolo, Vilama, and San Pedro de Atacama. Calama is also benefited by the waters of Loa and Frontera rivers. But this desert capital has swapped its condition as an indigenous old town due to its important function as a strategic crossroad with its road network and international railroad" ([37], p. 50).

Due to the water in the creeks at the foot of great hills and volcanoes, settlements were also established on the east margin of the Great Salt Lake: Toconao, Socaire, Peine, and Tilomonte. To the interior of Chiu-Chiu, in what is called Alto Loa, we find Ayquina, Toconce, and Turi, among others, also with their Pre-Hispanic remnants.

About the architecture of Chiu-Chiu and most of these settlements, he explains: "From the stray currents of the river running at the foot of the hillside and the clay of its margins comes the mud that covers its roofs and the adobe bricks of the walls. House walls are made of cut stone from neighboring cliffs and strong frames made of carob trees sustain the heavy roofing. The narrow shadow of some pepper trees projects over the dusty street and lengthens beneficially over the naked soil of inner patios" ([37], p. 50).

A longer writing on the architectonic historical understanding of Christian temples in the Andes area was published by Montandón in 1951, with the title "Iglesias y capillas coloniales en el Desierto de Atacama". Chiu Chiu building is still the most appealing and original for the researcher, but he also studies the constructions of Toconce, Ayquina, Caspana, Conchi, San Pedro de Atacama, Toconao, Socaire, and Peine in depth. As a synthesis, he manifests, "In Atacama Desert, we find again that sober architecture distinguishing the highland chapels of northern Argentina and the Highlands: simplicity, austerity, farm tastes of highlands and we would like to look for architectural continuity between the functional structure of cunza constructions and the simplicity of these chapels erected at a few steps from the pucara. Their modelling incorporates them to the tutoring and disturbing desert landscape, as no other construction could. It is as if their builders had intuitively penetrated the infinite greatness of harmony laws, which also transfigures humility" ([41], p. 22).

A Pre-Hispanic construction that particularly conquered Montandón's attention was Lasana Pucara. On the road from Chiu Chiu to Lasana along Loa River canyon "stone ranches and cultivated land" with maize and alfalfa were observed. Pucara architecture did not have to be compared with big Inca works, rather the particularities of its modest architecture had to be identified. He says, "The strategic sense of Atacameños manifests itself in the location of their pucaras. They choose easily defendable places and take care of water supply, an essential element. So, it is in this way how the fortress-towns of Lasana and San Pedro de Atacama [Quitor] erect on elevated places, whose rocky side walls look over the river. (…)" ([38], p. 43).

The pucara was characterized by its organic expression, in profound harmony with nature, by its scarce symbolism and monumentality. For Montandón "these ruins reveal a thorough concept of town, with its organization and its functional and defensive demands". The researcher also made a careful description of their "primitive architecture".

> *"We could speak about Lasana, of constructive rationalism due to the functional use of space and the subordination of the whole structure to a determined goal that we could call defensive housing; a tight set of houses supporting each other, accommodating their construction maps to the uneven terrain; it is the terrace-town where rooftops, watchtowers, and steps hang as stone waterfalls. Narrow passages for internal circulation, wall remnants at the outer perimeter of the pucara, and its access previously through just one narrow entrance contribute to give more importance to this defensive function whose construction is perfect (…)"* ([39], p. 17).

In defining a Pre-Hispanic Atacameño architectonic panorama, three types of housing groups are defined: A. The open town, non-defensive, and without a perimeter wall; B. The pucara or fortress-town with houses built close to each other, densified, mostly located "on a land elevation and surrounded by a wall"; and C. The tambo or inn on the road, used for trips, with pens, houses, and vigilance venues ([40], p. 55).

The main mountains and volcanoes, the high summits around the Great Atacama Salt Lake hold ceremonial structures on their tops, called high sanctuaries. For the inhabitants of these great spots and for other Andes cultures, the big tutoring mountains watched their lives and determined nature cycles. Mountains talked with each other and determined the fate of human beings. One of the first to investigate these constructions on the summit and their goals was the Belgian priest Gustavo Le Paige, who lived in San Pedro de Atacama since 1954 till his death.

According to the priest's studies, the summits had been occupied by Incas, although he also affirmed that there could have been previously occupied by other cultures and later by Incas. Le Paige could prove that constructions for cult in the sanctuaries were called "huacas". These were mainly stone walls on the summit floor.

His explorations led him to ascend several of these summits, as he explains in a series of drawings and descriptions published in a paper in 1978, the main one being Licancabur Volcano, together with Pili, Pular, Yariques, Colorado, Miniques, and Quimal Hill. Apart from huacas, offerings such as small dressed statues, firewood, and fireplaces were found on most of these archeological sites ([29], pp. 36–52).

> *"(…) This region is the space where Atacameño culture developed, the summits mentioned above being worshiped by the new religious customs of the Inca Empire. These summits were used for worshipping the sun, but the firewood remnants found allow supposing that they made signals as a means of communication (…)"* ([29], p. 38).

At present, explorations on Andes summits have concluded that there are sanctuaries in most of them, which are part of network extending throughout Collasuyo, for example, the high Llullaillaco (6739 m.a.s.l.) on the southern end of the Great Salt Lake.

In living together between tradition and modernity, the domestic architecture of San Pedro de Atacama, Lautaro Núñez has made the balance between the convergence of the natural and cultural. "Patrimonial housing that must be taken care of and studied thus captures the calling of the inner life of San Pedro neighbors within the walls. Then, when opening the front door, this 'disembarking' is picked by the hallway. Here ends the open space of the sun or the luminous streets and you enter the reign of neutral light; then, the inner patio inside after the solemn passage under the adobe half-arc that gives hierarchy to the 'tunnel' of the hallway. Inside the house, you finally gain the elements by playing with the sunset and the shadows, at the service of the acts of sleeping, eating, looking, loving, doing, keeping, and waiting. Acts always willing, where customs have prefixed them and where housing-truth has indicated" ([44], p. 249).

However, time gave rise to the arrival of new changes. Some villages realized that their isolation, customs, and architecture offer moments of "authenticity" to the foreigner. All this has made patrimonial and cultural tourism flourish, altering daily life, while the natural impenetrable landscape opens before other eyes. These changes resulting from the globalization process have affected the relation of man to the landscapes observed.

The Spanish anthropologist, José Luis Anta Félez, points out about this alteration of the landscape, "In this way, all the elements get together to create a reality where the 'foreigner' and 'adventurer' tourist finds a symbolic space to project all his interpretations of exotism and continued primitivism…that has not existed and neither can actually happen in an Atacameño life adjusted to a vital reality limited to a desert and a planned country like Chile" ([3], p. 20).

4. A brief image of northern towns: between nature on the maps and the rediscovery of indigenous traces

In pre-Columbian and colonial times, the presence of water determined human settlements. In this way, rather Atacama Desert borders were inhabited (except for the winding course of Loa River), the eastern one to a greater extent; then, the foothills due to the water coming from the high summits of the Andes; and in the western border, the encounter of Coast Cordillera with the Pacific Coast, thanks to the scarce springs produced in the geography facing the coast clouds.

The neighbors of old Antofagasta, from the nitrate period, used to walk along the coast. Sometimes, a mound of seashells called their attention. Later, archeology determined a Chango fishermen settlement. Some coastal towns emerged between the coastal fogs with the legend/reality of the construction of coves that gathered the native people from the coast. Changos and some Camanchacos, as José M. Casassas Cantó, a Spanish historian exiled as a republican, named them, called the attention to regional ethnic history in the 1970s.

The first inhabitants of Cobija, Tocopilla, Antofagasta, and Taltal were indigenous or native people from the coast. Settlements were drawn on desert spaces located between the mountains and the rocky sea [11]. In the case of Cobija, indigenous presence dates back to 1581. It is documented that 400 indigenous dedicated only to fishing lived on this site. So, "the cove was a permanent dwelling for fishermen tribes" ([6], p. 3). The document indicated that the presence of tap water springs around enabled them to settle in this place, even since some pre-Columbian times. Then, a chapel to indoctrinate indigenous people was built during the Hispanic domination.

> *"(…) Cobija served as an entrance port to sub-Andean valleys during the colony, being visited, particularly in the 18th century, by French merchants who imported their goods to sell them in Chiu Chiu and San Pedro de Atacama. The road from Cobija to the hinterland reached the margins of Loa River and continued edging the river until arriving at the indigenous villages of Calama and Chiu Chiu; from here, it went straight north to Santa Bárbara to then go into Alto Perú"* ([6], p. 3).

Later, founded by Bolivia as Puerto Lamar in 1825, it had two configurations. The first one was recognized on a French map in 1852. It consists of one street of about 550 m on the east-northeast axis, with houses on both sides, parallel and quite close to the coastal border. These images of one street with houses on both sides can be observed in a well-known Mauricio Rugendas's drawing, as a register of his passage through Cobija on December 1, 1842 ([28], p. 62). It shows a street going up and, on the background, the high hills of the Coast Cordillera. After the 1868 and 1877 tidal waves that swept away the linear town by the coastal border ([6], p. 5), the city gradually occupied the highest part of that coast with a chessboard-like design slightly rotated (to the east-northeast axis), with a central space for the town common and a new temple. The ruins of the constructions, foundations, and basements, still remain and allow understanding the urban structure of practically three vertical and four horizontal blocks.

Cobija was an articulating enclave for exploration operations on the Atacama Desert coast; in some way, a nineteenth century equivalent to San Pedro de Atacama strategic mission on the foothills settlements and routes.

In the early twentieth century, Isaac Arce could collect several utensils from a series of indigenous cemeteries on Morro Moreno, which was populated by Changos ([1], p. 13). The isolated peninsular character of this mountain, and also its height, let it exposed to sea fogs, allowing flora and fauna development (it is currently a National Park) and the emergence of tap water springs known due to navigation routes. Its singular shape of a lying body with permanent clouds on its summit, an important part of the sea horizon of Antofagasta city, inscribed it in the urban imaginary of this port city.

Some of the expeditions that explored the archeological sites of the hinterland and the coast were conducted by the French Eugéne Sénéchal de la Grange and Georges de Créqui Montfort in 1902 and 1911, and also Germans such as Max Uhle and Otto Aischel. The landscape of the desert and the coast fed European and North American museums with archeological pieces [21].

On February 13, 1924, an article published in *El Mercurio de Antofagasta,* written by an author whose pseudonym was Ognirg, argued that before Antofagasta, around the bay, there was an indigenous village, particularly on the site occupied at that time by Nitrate Agencies (currently occupied by Antofagasta Hotel). It indicated that the remnants found there gave evidence of primitive constructions (whale bones buried vertically) and vestiges of utensils domestically used. So, it may not have been a cemetery, but an indigenous settlement ([48]: s.p.).

At present, together with local vestiges from nineteenth century miners, pre-Columbian settlement data have been found in Antofagasta City, at El Trocadero sector, as a big seashell deposit and cemetery of sea collector groups.

The northern writer Salvador Reyes liked to emphasize that, "Antofagasta, like all northern towns, was not founded by a conqueror. There was no ceremony, the wind did not make royal flags wave, neither the sun crashed 'on the hard edges of weapons'. These towns were born from the impulse of miners who walked through pampas, beaches, salt lakes, and creeks without ever surrendering to fatigue" ([50], p. 79).

The relation between coves (an aquatic form of the coastal border), the coastline (the limit between the border and the water) and the border topology (the border shape) is essential for understanding the decision of a chessboard-like design. From the first designs of coastal cities in Antofagasta Region, a common generality is observed in all urban structures that are, in one way or another, facing north. This configuration is favorable mainly because they face bays protected from the southeast currents by some kind of geographic element. The chessboard-like design by the border will be oriented, in some cases, to configure a network parallel to the water borde, with the necessary foundational docks extending over the sea. In other cases, they rather responded to territorial geometric congruences.

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In the initial case of Cobija, we have seen that its second design was chessboard-like, slightly inclined to the east-northeast, rather following the form of the border topology and the coastline. In Tocopilla, the design implementation on the topography was more rational, a decision not following the topography, not aligning with the coastline, rather placed practically in 45°. This inclination has several positive aspects: the prevailing wind enters streets and blows to the southeast axis and, blocks received sunlight on all its sides all the year through.

In Mejillones, the initial design and then the re-foundation were oriented north, toward the bay, conditioned by the coastline shape and border topology.

In Taltal, the map responds to the narrowness naturally produced between the topography and the protected bay; the initial grid faced the sea and the docks extended over it.

The case of Antofagasta is singular; it is a 45° design in front of the southern border of a small bay, design decisions being not casual. This can be observed in "Plano Jeneral del Puerto de La Chimba" or Antofagasta from January 20, 1873, drawn by Adolfo Palacios. It expresses the encounter of the organic nature of the border with the rationalist geometry of the chessboard-like design. On the other hand, in this Cartesian structure, the first design of the railroad route along settlement streets appears, drawn by the influential British engineer Josiah Harding.

The map contains, in its caption, an explanation of the 41 main urbanization entities. Due to water scarcity, 10 of the remarkable sites were machines to absorb water, located along the sea border since they were supplied with sea water.

The first urbanization designs emerged due to closeness to mines, not because of Indian Law precepts. However, despite of the fact that everything occurred more intensively in the nineteenth century, its indications were followed, with rational chessboard-like designs emerging from the docks and industrial areas.

In the beginning, the urban landscape of coastal towns revolved around their ports. Although these relations supported by transportation could be cataloged as functional, they also made up an urban image since several of the main buildings were connected to this space of docks that received travelers and immigrants through the entrance to the city and the desert. In this sense, the density of docks, cranes, quays, boats, and large iron boats, their sea facade crowded with horizontal constructions, were its welcome face. There was a city at sea.

These port cities forged commercial networks mainly organized around the railway; so, hinterlands of mining cities, known as cantons, were structured, for example, and, from north to south: El Toco, Central, Aguas Blancas, and Taltal. As Bodini pointed out, they formed isolated networks which were later connected by the longitudinal railway.

The only way of operating in these desert sites was through technology and knowledge from the Industrial Revolution. Cruz Larenas indicated that one of the first operations for beginning the foundation of Antofagasta was the installation of a water-distilling machine ([12], p. 83). A few years later, water supply had improved, from Quebrada La Negra and La Chimba, water was carried in mules, while from Morro Moreno, water not apt for human consumption was carried in big boats. The water consumed by the population came from condensation machines on the coast and innovative solar evaporation plants in certain settlements in the desert.

About technological development deriving from global interests in mining exploitation in Chile, Astaburuaga pointed out, "Nitrate richness also contributed to do programs elaborated or dreamt of for a long time: the railway itself, the introduction of new cultivating systems, the inauguration of hydraulic and industrial engineering works, the presence of scientists and technicians who made plans, described and sized the country due, not insignificantly, to the country's economic transformation in the second half of the past century, thanks to that fountain of richness. It allowed objectively establishing a good number of coordinates that had not settled in the Chilean land yet" ([4], p. 11).

In general, nineteenth-century foundations continued using the chessboard-like design in Tocopilla, Mejillones, Antofagasta, and later in Cobija and even Taltal. The urban configuration based on the chessboard-line design network reveals a rationalist sense of settlement organization. On the one hand, Indian laws, in this case referring to the logics of urban configuration ([51], p. 18) and, on the other hand, Paris urban changes led by Haussmann from 1852 to 1870 were a model to follow around the world, at least in their hygiene criteria.

In this way, foundation using chessboard-like geometry in in the context of colonies has, on the one hand, a functional orientation, from both the viewpoint of the regulating design and the implementation of basic services. But, what was the meaning of continuing founding with the orthogonal grid in the second half of the nineteenth century, in the context of independence from new American republics? Richard Sennett identified a nature-linking strategy in using the chessboard-like design, "(…) in the modern age, the framework design seems to have been a plan for neutralizing the environment" ([54], p. 282).

5. Monuments of a disappeared cultural landscape

From 1903 to 1913, around Baquedano and Sierra Gorda villages, in the area called central or Bolivian canton of the nitrate mines, 21 of them were built using Shanks technological development. It was the period of the greatest industrial activity in the region with the biggest demographic concentration in Atacama Desert. At the end of the 1920s, most nitrate mines had disappeared and their remnants stayed as mute testimonies of the landscape history and culture. Andrés Sabella, in the most formidable novel about nitrate, **Norte Grande**, described the situation of ghost nitrate mines, "The smoke of that nitrate mine was a ghost lost beyond the sky. There was now, in its venues, a heavy tree grid of loneliness: loneliness of sun absorbed in itself and stubborn, of winds that seemed to escape from a certain devilish industry, of the strong smell of an abandoned house, of years of urine, of invasive iodine. What a small city without a heart!" ([52], p. 137).

A piece that gave meaning to the landscape of these port cities was a big steel construction resulting from the development of Industrial Revolution engineering in the second half of the nineteenth century, the viaduct built over the sharpened gorge of Loa River, in parallel 22 of the Atacama Desert, near Conchi village, at the old 298 km of the Antofagasta-Bolivia Railway.

Conchi viaduct crossed 244-m long and rose over 102.6-m high at its greatest elevation. Its construction started in May 1887 and began operations in February 1888 for *The Antofagasta (Chili) and Bolivia Railway Company Limited* (**The Engineer** 1889c). It must be clarified that this work was part of the constructions made jointly by Compañía Huanchaca and Compañía de Salitres and it would connect the mines in the south of Bolivia with Playa Blanca smelter in Antofagasta port.

Once erected, it was recognized by *The Engineer* as the world's highest viaduct in 1889.

In brief, the American-type viaduct typology would be a continuous upper vortex of beams supported by a series of horizontal triangular prisms.

Some regional guides early recognized the value of this engineering piece and included descriptions of its construction. The pioneering **Guía de Antofagasta** from 1893, created by Mandiola and Castillo, indicated that the bridge was "one of the world's most remarkable" and showed it as a grand construction and unique experience travelers had to be attentive to.

> *"(…) This bridge also is particular for being a magnificent modern engineering work. It is built on smelted iron columns resting on the bottom of the creek, whose base licks Loa River waters. Several years of train traffic without undergoing a big loss of balance warrant their safety, after repeated tests for inauguration. Travelers stop to contemplate this truly marvelous construction; and not just a few tourists have paid it special visits, despite its distance from the coast, greater than 300 km away"* ([32], p. 7).

The journey from Antofagasta, going through the viaduct, became a fundamental route for communicating the Pacific coast with Bolivia. The circuit was potentiated by the construction of Northern Longitudinal Railway from 1910 to 1913, which connected all these isolated networks. During this process, in 1910, Antofagasta-Bolivia Railway published a guide to inform travelers. There they referred to the viaduct, "(…) At km 298 – immediately on the eastern side of Conchi railway station – we arrive at Loa viaduct, one of the world's most interesting engineering structures; the elevation of the viaduct rails is almost 10,000 feet above sea level, while its height over Loa River water surface running under it is 336 feet or greater than twice the height at which the train crosses Forth bridge over Forth fjord. The viaduct is a quite elegant steel structure with six entangled beams over an 80-feet span each, clearly sustained by steel trestle towers" [58].

The viaduct, as a technological expression, is a sound representation of the spirit of that time. It conjugates several factors: the challenge of technology in terms of calculations and simulation, construction development as to pre-making and assembly, and the urgency of communications in connection with economic interests, but undoubtedly, one of its main contributions is its rigorous hook with the desert geography, as if it were a prosthesis which, with its categorical artificiality conceived a new form of consonance with the sublime expression of Atacama Desert geography.

The town of Pampa Unión was appointed a sanatorium in the plain desert in 1911. It became the great emporium of nitrate mines, challenging *pulperia* monopoly. Its fate stayed linked to the disappearance of nitrate mines using Shanks system. Its wall remnants, nostalgic publicity, and desert streets speak to us about the efforts of a town. The amount of people sheltered by the mines and towns, now ghost towns, was registered in their cemeteries, "In the inmensity of the pampa, modest crosses interrupt the view of the horizon. Tombs ordered in rows and framed with wooden fences burnt out by the sun or made of metal to make them more lasting, remind the traveler of the life that existed in all those towns…The present view of a pampa cemetery is a window to the past. The amount of tombs allows us having an impression of the town magnitude" ([46], p. 101).

6. Chuquicamata and a piece of modern life in the desert

In its 92-year, Chuquicamata comprised ephemeral villages that smelted with its beginnings, such as Punta de Rieles, "where all railway branches ended", and Banco Drummond, a town of stone houses where metal was bought. Possibly, the only Chilean mine whose operations were decided from a distance of more than 1500 km: the government headquarters in Santiago on May 18, 1915 [42].

The industrial city or company town displayed in Atacama Desert. It seems that the challenge posed by the adversity of the environment made the construction and experimentation of formal ideologies as a modern city more rewarding. Although there are detailed and well-known studies on nitrate network cities, the main one being the study of Eugenio Garcés, in terms of the rationality of urban form and desert landscape, the icon has been Chuquicamata copper-mining camp. A copper city contemporary to nitrate industrial cities such as Chacabuco, in this case impulsed by North Americans, the Guggenheim.

From 1912, a new industrial city began to be built on the north of Calama. The first design was an organic structure for foreigners, but the workers' city had a 45° complex chessboard-like design giving evidence of the knowledge and rationality of the first decades of the twentieth century, with the maturity and experience of the nineteenth century. The camp grew and one of the biggest investments made by the Company was the modern Roy Glover Hospital. This building was a reference in terms of organic architecture oriented to health, designed by New York architects with Chilean specialists as consultants, Fernando Devilat and Frank Fones. It was a building located on an elevated site between the workers' new camp and the gringos' old camp, which defined sensitive experiences from the middle of Atacama Desert.

An interesting account revealing a corporeal view was that of nurse Graciela Toro (well-known as a writer and poetess) who points out that after graduating as a nurse, she worked at the hospital for 10 years, the first moments being "puzzling": "(…)Day shifts used to continue at night. Work was excessive and overwhelming; personnel was not enough. Jumping from sleep to wakefulness was an order, an exercise that had to be done" ([60], pp. 18–19).

Graciela Toro said that a nurse's work was generally a dignifying job, but working in Chuquicamata was "twice as beautiful" and also "heroic". She had to live in the nurses' residence. Her account is extremely corporeal. She does not refer only to her wakefulness state, but also to dressing, sounds, and air which, even in the new location of the hospital, was contaminated by the industrial area.

She learned how to use anesthesia machines and bought books for improving her knowledge. "One night, during an operation, I passed out. I was hospitalized for anemia. I had several transfusions. I was very thin and seriously ill. (…)". When she returned to work, she could feel the hospital with greater sensitivity.

> *"I returned to work. As it became more intense during night shifts, I used to go down to my apartment which was in the same building, at different hours; two, three or five o'clock in the morning. In this way, I began to discover the overwhelming grandeur of the desert and its amazing beauty. There was something strange in its geological quietness of caressing and lonely muteness. Roaming around the hospital nestled between mountains, the wind seemed to drag a message from the bottom of time. It was a magic world that wrapped me! The curious form of the hills had different color shades every day, which suddenly illuminated with fantastic irradiations. Then, silent, astonished but alert, in the same way I entered – on tiptoes – the operating room, I entered the world of poetry (….)"* ([60], pp. 22–23).

7. Preliminary conclusions

The desert landscape can be contemplated from the senses. You can hear the silence of its pampa and the wind revolving in its creeks, but also the noisy brokenness of its urban development. It can fill our smell with the mild wind of the sea and the products of its fertile ocean and feel the advance of contamination. The sight can be crowded with distances that betray man's loneliness and vicinities that do not always accommodate to nature adversity. To the eye view, the technique of photography was superposed. Initial curiosity was followed by the scientific representation of the landscape. Company towns changed their environment, first by prospecting, then by exploiting. Magnanimous companies such as Chuquicamata erected mountains of residues; the nitrate companies also did it, but at the level of human work. A great part of the first nitrate cities have disappeared, dismantled; the most modern are partially preserved, but many are ghost towns, traces of sunsets. Port cities still suffer from the conflict with mining around their ports. Some foothills towns have been scorched by tourism. Culture has changed. The desert is resistant, but also conserving; mankind traces remain and will remain. The desert Philippi [31] visited is radically not the same. Le Paige's San Pedro de Atacama is another one. Montadón's observations are still on-going. The borders are not such any more, they have blurred, and Atacama Desert vanishes with the unmeasurable human whirlpool [47].

As far as man continues his adventure for trying ways of adapting to the desert—as it continues in the Andes foothills—and nature keeps on showing itself tough and untamable, never a full stop will be put to this dialectic relation between culture and nature.

Mario Bahamonde, one of the main narrators of the north, already said so, "The soil came slowly and entered trhough his eyes, meanwhile steps resonated in the head…But he had to continue walking because the only imperative in his life was arriving. Where? Arriving… arriving. If there were a road, at least, maybe an old trace. But, what! In the end, all the pampa was only one way…Arriving!" ([5], p. 7).

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Chapter 10

Rural Landscape Architecture: Traditional *versus* Modern Façade Designs in Western Spain

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Lorenzo García-Moruno

Additional information is available at the end of the chapter

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Abstract

In any rural area, ensuring both architectural quality and preservation of rural characteristics must be a goal of building design for sustainable environments. Imitation of traditional building techniques and use of natural materials are trendy again in landscape architecture of rural areas in Spain. This is especially visible in architectural design of façades of new building. However, there are few researches that focus on analyzing the visual effect of this new architecture in landscape integration. In regards, this chapter explores visual quality impact of a façade based on their complexity degree. The aim was in particular to identify visual preference patterns in ornamentations with stone or wood of novel rural buildings. New architectural styles from an experimental rural area of Mediterranean basin are chosen for this purpose. Here, 15 secondary housing images were used to evaluate the visual preference of different façades: traditional vs. new archetypes. During the measuring process, scientific design theories of façade complexity were considered. Seventy-five observers scored images selected using a five-point Likert scale, and results were analyzed by appropriate statistical tests (Cohen's "d"). Surprisingly, as a main result, the simple use of natural materials is not enough to guarantee the design quality of a façade.

Keywords: architectural design, façade complexity, sustainable development, architectural heritage, visual preferences, esthetic characteristics, public participation, landscape planning

1. Introduction

A wider space between secondary residences is a growing requirement especially in rural tourist areas of the Mediterranean basin [1–3]. Ensuring both architectural quality and preservation of the rural landscape for sustainable environments must also be considered as a second homes' requirement to satisfy [4, 5]. The use of materials, quality, right colors, traditional techniques of construction, and/or designs of façades with coherent complexity must be taken into account for that purpose. Traditional materials help in imitating traditional styles, but the use of wood and stone material is not ever enough to achieve the desired visual quality [6, 7]. Inadequate legislation is a part of the problem, and improvements in transfer of scientific knowledge to professionals involved in urban and rural management could be a part of the solution [8]. The vague and subjective recommendations were found in most European legislations of sustainable rural landscape planning [9], which might be avoided on the basis of data from research studies. However, few scientific studies are available in regard to visual preferences and façade design.

Surface properties are the primary sensory characteristics affecting visually the appearance of the façade of a building [10–12]. Colors, materials, or windows and doors have a stronger impact on façade quality than the own volume of the building or its silhouette [7, 13–15]. The existence of a hierarchical size scaling among main openings (i.e., doors and windows) and textures (i.e., colors and materials) is important for the coherent understanding of a building [16, 17]. Since simplicity generates "gaps" on the visual reading of a building, it leads to psychological discomfort, and results in an unpleasant outcome, simple façades violate this hierarchical downscale [18]. A scaling based on gradation from large scale (formal) to fine scale (stylistic) elements is, therefore, recommended for improving the visual quality and acceptance of a building [19]. Intermediate-scale elements comprise what is known as ornaments, and are essential for the coherent scaling of a façade [20]. The scaling of sizes into large, intermediate, and small elements has been quantified as a function of the total length of the façade [21, 22]. The visual theory of "*septaves*" [23] classifies components into three levels: "part of the façade", if the component's length is within the range of 1–1/7 of the façade's length (large scale: 1st *septave*); "ornament", if in the range of 1/7–1/49 (intermediate scale: 2nd *septave*); and "texture", if in the range of 1/49–1/343 (small scale: 3rd *septave*). Door and window trims, cornices, and plinths fall in this theory into the consideration of ornaments. Ornaments and textures (2nd and 3rd *septaves*) represent the amount of visual details of a façade. The number of visual details increases the complexity of the design, and complexity has a demonstrated weight on acceptance [15, 23]. However, complexity is also affected by the novelty/familiarity of the details and by their level of organization within the façade [24].

Many studies attempting to find a correspondence between complexity and visual acceptance have been already performed. Most of them recorded a linear-positive correspondence [25–27], but the others found just up to a certain threshold and identified an inverted U-shaped correspondence [28, 29]. The architectural style (traditional vs. modern buildings) and the profession of the observer (architects vs. the other professionals) could have a significant influence on differences of response. High levels of complexity seem to be accepted better by architects than by the general public, in special for modern architectural styles [25, 30–32]. Traditional architectural styles achieved a better acceptation of complex patterns among the general

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public [33–36]. However, some researchers have found a threshold point in complexity above which the visual acceptance was impaired in all cases, irrespective of professions or architectural styles [24, 37]; so, the controversy remains open.

This paper attempts to explore aspects of the visual quality of a facade based on their degree of complexity for sustainable environments. Exploring how the size, amount, and arrangement of materials and ornaments may affect visual perception of a façade was the basis for the methodological design. The aim was in particular to identify visual preference patterns in ornamentations with stone or wood of new rural secondary residences for sustainable environments, taking mainly into account the new regional development of architectural styles of some rural examples of a Mediterranean environment (Casas del Castañar, Jerte Valley, Spain). The design of masonries imitating traditional styles often employs artificial stone coatings in which visual quality has not been evaluated in scientific studies. A threshold point in acceptation of the complexity derived from the use of these materials would be expected. Comparing the visual effect of traditional and novel techniques for arranging these materials on the façade, since the organization of visual details is expected to influence acceptance. Novel designs find often problems with the current regulations, but they are increasingly demanded in many rural areas of Spain. This chapter was structured first presenting "Materials and methods" section arranged in four parts, which is particularly tested in the proposed case study area. In the "Results and discussion" section, the results from the method application are discussed. In the last section, the "Conclusions", summaries considerations obtained from this approach and describes suggestions for future research.

2. Materials and methods

2.1. Pilot area and architectural styles

The pilot area selected for this research was Jerte Valley in north of the autonomous community of Extremadura, Spain. It is covering the area of 375 km^2 and occupying the space (X: 252,262, Y: 4,443,772, Datum: WGS84/UTM 30 N). The Jerte Valley mainly bases its economy on agriculture, particularly on Cherry crop. The Cherry crop phenology has led to a growing rural tourism, and as a result thereof, to an increase of buildings linked to ecotourism including the construction of second homes. Unfortunately, an illegal residential sprawl has taken place in most of the 11 municipalities of Jerte Valley and their neighborhoods [4, 38, 39]. Casas del Castañar was selected as a municipality for the study on the account of the quality of its rural landscape and of the urban expansion noticed in recent decades despite the population decreasing (see **Figure 1**). It was additionally selected because of its recent legal planning review performed after year 2000, although legal texts do not seem to be based on technical or scientific planning requirements from the point of view of visual building integration.

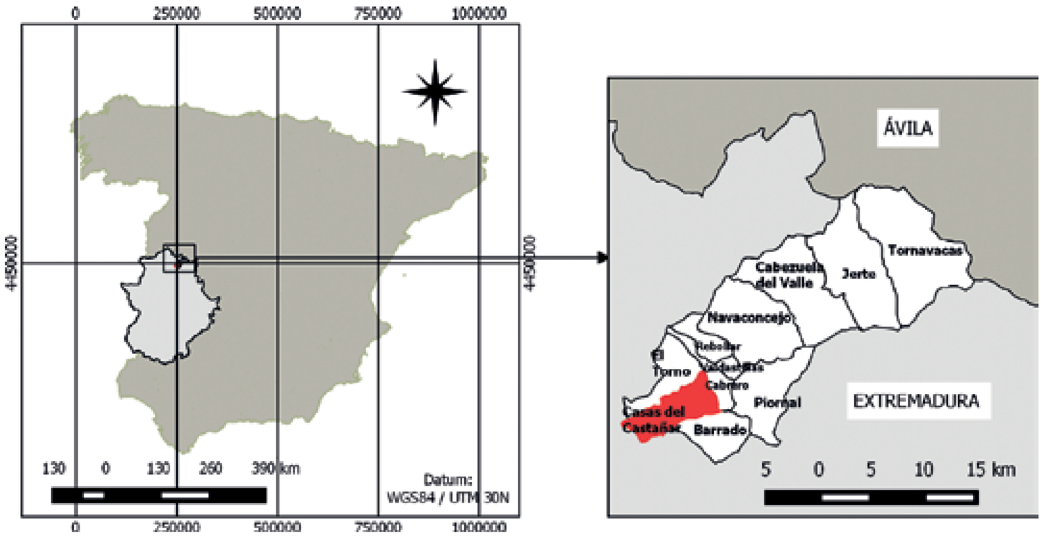

Figure 1. Geographical location of the pilot area.

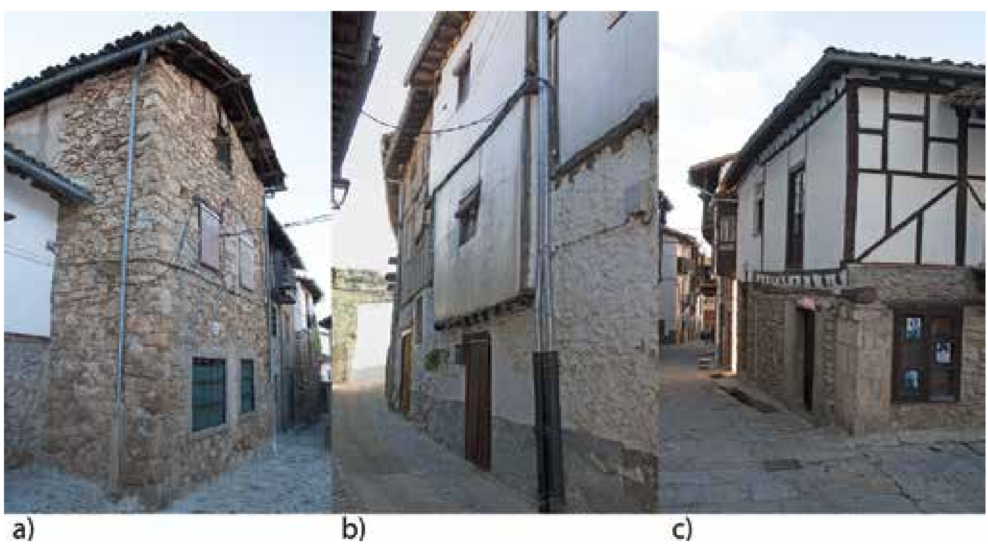

Figure 2. Traditional mountain Mediterranean second homes from the pilot area: (a) stoned second home; (b) half-timbered second home limed on the upper floors; (c) half-timbered second home visible on the upper floors.

The traditional mountain Mediterranean second homes were chosen for the purpose of the study. Two main examples of this style exist: stoned and half-timbered second homes. Wood framing has been traditionally destined to the construction of the upper floors away from moisture and xylophages, using the masonry for the lower floor as the mainstay of the entire building. Framing is limed in some second homes and is visible in others, generating a greater visual complexity as shown in **Figure 2**. Most new buildings of the experimental area did not face any review of the design process because of their illegal conditions. In contrast, other buildings do not exactly match traditional esthetics that matches a legal status (see **Figure 3**). An inventory of the new buildings developed in the study area during the last decade was made by the means of geographical information systems (GIS) and ortho-aerial photographs, and cases with limited accessibility or visibility from main roads were excluded from the subsequent fieldwork. Examples of buildings displaying stone cladding and wood details imitating traditional types were recorded, and a set of three secondary residences was finally selected for the investigation. Only two-storey buildings were considered in this study. Selection criteria included two main requirements: similar volume and height of the building, and an adequate visible angle for image capturing (see **Figure 4**). Pictures were taken as necessary to record the highest amount of building details, since perspective does not influence the analysis [40]. Images were captured in sunny days of spring and early summer, and negative conditions such as rain, excessive cloudiness, fog, or midday sunlight were avoided [41, 42]. The observation line was kept as perpendicular as possible to the façades [33].

2.2. Visual stimuli and experimental design

Three sets of five façade simulations based on three secondary residences selected and on five different façade treatments were prepared. This work generated 15 pictures for evaluating visual stimuli (see **Figure 5**); this is an adequate number of pictures per interviewee, for

Figure 3. Examples of novel second home styles in the area of the study: irregular pattern of stone shingle distribution (house on the left) and wood framing imitation on the upper floor (house on the right).

Figure 4. Original images of three secondary residences selected for the study.

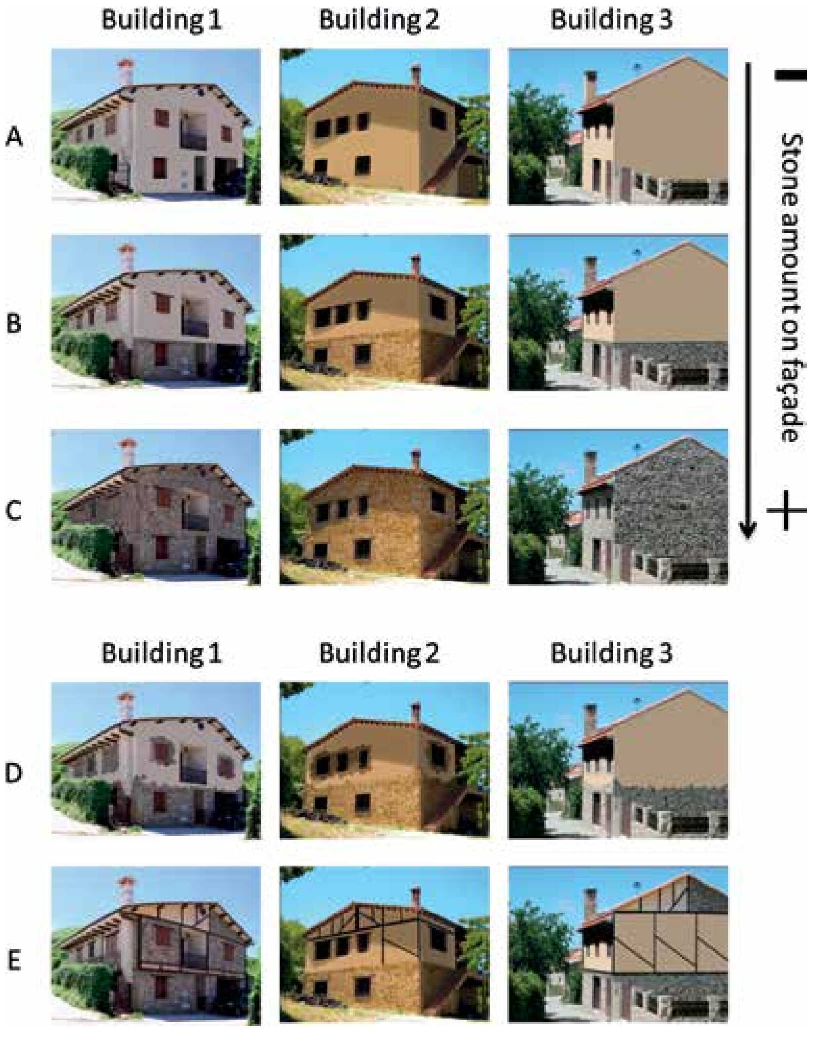

Figure 5. Scenarios and individual images used in the survey. A-C cases represent an increase gradient of stone cladding. Cases D and E represent respectively: new trends of ornamentation in stone and traditional stone and timber framing.

guaranteeing a correct visual attention until the end of a questionnaire and for achieving consistent results [15, 24, 32, 43, 44]. Adobe Photoshop TM CS3 was used for image processing. Use of both real pictures and photo-simulations for the purpose of the investigation is supported by prior studies [45–48]. Façade treatments represented two visual proposals as follows:

- First, a gradation of traditional stone cladding (image sets A–C) was ranging from null (set A, the lowest complexity) to total (set C, the highest complexity) coating. Image set B was the intermediate proposal, and displayed the plinth of stone cladding characteristic in traditional houses. The objective of these image sets was to evaluate how variation in complexity based on differences in stone amount on the façade may affect visual preference.

- Second, a novel trend in façade ornamentation was developing at present in the region (image sets D and E). Image set D displayed a stone cladding of intermediate complexity that does not match the traditional design. Image set E imitated the traditional stone and timber framing, and displayed an intermediate to high complexity. The objectives of these two sets of images were: (1) to guess if a similar number of stone cladding may reach the same pattern of hedonic response irrespective of the shingle pattern distribution (comparison of B and D); and (2) to test how the novel trends in combining stone and wood on façades in imitation of the traditional style affect visual acceptation (comparison of B and E).

2.3. Participants and survey procedure

Image sets were shown to 75 participants recruited in the University of Extremadura, Spain, who freely agreed to collaborate the study. Among them, 39 participants (18 males and 21 females) were students and professors of architecture or other technical careers related to landscape. Thirty-six (18 males and 18 females) were students and professors from other university disciplines. The average age of the respondents was 29.17 years old (18–48 years old), and they were classified into three homogeneous groups: (1) undergraduate students from morning course (18–24 years old); (2) undergraduate students from evening course, and postgraduate students involved in master programs (25–33 years old); (3) professors (35–48 years old). All participants had never seen before the buildings shown and did not recognize the image sets as familiar to them. They were requested to fulfill a questionnaire form consisting of two parts. The first part collected demographic and educational data from the participant, and the second part involved the evaluation of the image sets. Every image was evaluated in terms of preference on an ordinal scale of five-point Likert test, from very unpleasant = 1 to very pleasant = 5. Bipolar rating scale was selected from previous researches, since semantic differential scales have been already used successfully to measure hedonic tone [27]. Images were presented at random order and image size (10 × 15 cm) was large enough to appreciate details.

2.4. Recording of results and statistical analysis

People's preference is variable dependent, and its ordinal character allows a continuous analysis of the data [49]. Mean values of preference were calculated for each photograph. Original building (OB) (1–3), type of Façade treatment (FT) (A-E), gender (G) (M-F), age (A) (1 = undergraduate, 2 = postgraduate, 3 = professors), and educational background (EB) (architects and engineers (I)/others (II)) of the participants were the independent variables (factors) of the study. Mean preference ratings were analyzed by a MANOVA factorial design: (2 (G) × 3 (A) × 2 (EB) × 3 (OB) × 5 (FT)). The latter two variables had a repeated measured analysis within subjects; gender, age, and educational background data comprised an analysis between subjects. The standardized mean differences for preference between levels of façade treatments and buildings were expressed as an index calculated from Eq. (1) as follows:

$$d = \frac{(\mu_1 - \mu_2)}{\sqrt{mse}} \quad (1)$$

where μ_1 represented the mean of preference responses for a level of a factor, and *mse* (mean square error) estimated the total error expected for a sample in the repeated measure analysis of variance with the total stimuli presented (15 images).

3. Results and discussion

The index "d" aforementioned is very useful not only to estimate the effect size of the differences found between two levels of a factor, but also to compare and discuss the results from different studies. In statistics, an effect size is a measure of the strength of a phenomenon. In the current study, it indicates not only if two pictures are significantly different, but also by how much are different. The contrast, for instance, between second homes with a plinth of stone cladding and without stone coating estimates how much significant improvement the stone presence in a partial covering would have; moreover, this possible effect can be numerically comparable with other researchers by using the index "d". For Cohen's d, an effect size up to 0.2 might be a "small" effect, around 0.5 a "medium" effect, and 0.8 to infinity, a "large" effect; $d > 0.2$ is accepted as good threshold for distinguishing significant from nonsignificant visual differences in environmental impact assessment [50]. Finally, the sample size ($n = 75$) is assumed as good enough since, at least, leads to detect effect sizes over 0.2 at significant thresholds of power analysis [$(0.75 = 1-\beta$; $\beta = 0.25)$; $\alpha = 0.05$] [51]. For more information about this index, it can be consulted [52].

3.1. Preliminary results of MANOVA

Similar patterns of a five-point Likert test were found in the responses obtained in spite of small nonsignificant variations between the observers. Females and participants unrelated

Source	SS	df	MS	F	Level of significance*
Gender	0.014	1	0.014	0.003	0.957
Educational background	6.420	1	6.420	1.330	0.253
Age	1.945	2	0.972	0.202	0.818
Gender × educational background	0.076	1	0.076	0.016	0.901
Gender × age	5.011	2	2.506	0.519	0.597
Educational background × age	8.655	2	4.328	0.897	0.413
Gender × educational background × age	6.280	2	3.140	0.651	0.525
Error	303.999	63	4.825		

Significance level was set at 0.05.*Neither social variables nor interactions among them presented significant effects (alpha < 0.05) on dependent variables (participants' responses).

Table 1. Results from testing between subject effects by MANOVA.

with landscaping sciences scored images higher than males and architects or engineers, but the differences lacked statistical significance (see **Table 1**). In addition, there was no interaction among these variables and the original buildings (OB) (1–3) or the façade treatments (FT) (A-E).

In relation to façade complexity, a consensus in the hedonic tone was also recorded among participants from prior studies. Akalin et al. [24] mentioned that gender and profession had an influence on preferences, but interactions between social variables and complexity were also not found. In contradiction, no main differences concerning profession were found in a prior study [37], except for some relative differences observed between architects and other observers but they occurred only for high levels of complexity. Data obtained from participants were also considered globally in the present study, and only original buildings (OB) (1–3) and the façade treatment (FT) (A-E) were analyzed in terms of preference. Data analysis from repeated measurements on single participants (within-subject analysis) showed a real influence of these variables (OB, FT) on responses, as well as that they interact in a two-way manner (see **Table 2**). Thus, participants did not equally accept the five proposals of façade design presented in the three building cases.

Source	SS	df	MS	F	d^1
Building case (1–3)	61.59	2	30.80	38.34*	0.6
Error	101.21	126	0.80		
Façade treatment (A–E)	54.78	3.5	15.67	10.2*	0.4
Error	338.33	220.35	1.54		
Building case × façade treatment	18.279	8	2.285	6.380*	0.3
Error	180.502	504	0.358		

*Significant differences (alpha < 0.01) were found on participants' responses in function of the architectural variables and their interactions.

[1]Cohen's d > 0.2 indicates that these differences are visually important [50].

Table 2. Results from testing within subject effects by MANOVA with Huynh-Feldt correction.

3.2. Preference for stoned façades based on the amount of shingle (image sets A–C)

Mean of participants' Likert test regarding stone cladding increased from minimum (A) toward intermediate (B) complexity irrespectively of the second home presented. In addition, standardized mean contrast showed that the differences were significant at the 0.01 level, with an important effect size (d > 0.2) as shown in **Table 3**. The rating decreased for maximum façade complexity (C), although such decreasing was statistically significant only for building 2 (see **Table 3**). Therefore, the results showed an inverted U-shape correspondence between the degree of façade coverage and the people preference (see **Figure 6**). This was demonstrated for building 2 and suggested by results for buildings 1 and 3 as shown in **Figure 6**.

Building case	Level of shingle amount	Mean	d	F (1.74)	Level of significance
1	B (middle)	3.65	*0.602*	47.687	1.47E–09*
	A (absence)	2.96			
	C (high)	3.53	*0.497*	14.671	0.0003*
	A (absence)	2.96			
	B (middle)	3.65	0.105	0.714	0.4010
	C (high)	3.53			
2	B (middle)	2.97	*0.384*	14.049	0.0004*
	A (absence)	2.53			
	C (high)	2.53	0.000	0	1.0000
	A (absence)	2.53			
	B (middle)	2.97	*0.384*	16.664	0.0001*
	C (high)	2.53			
3	B (middle)	3.31	*0.500*	41.138	1.19E–08*
	A (absence)	2.73			
	C (high)	3.17	*0.384*	8.773	0.0041*
	A (absence)	2.73			
	B (middle)	3.31	0.116	0.818	0.3688
	C (high)	3.17			

MSE = 1.314 (with Huynh-Feldt correction).*Significant differences were found when comparing pairwise of scenes from top to bottom (alpha < 0.01). These differences also achieved an effect size above 0.2 [50].

Table 3. Standardized mean contrasts for visual response in function of the stone cladding amount (A–C comparisons by pairwise of scenes from top to bottom). *d'Cohen italic* values represent those mean comparisons reached statistical significance differences with strong effect size.

While façades of building 2 were coated with limestone, building 1 and 3 were coated in granite, and such difference in the nature of materials might have influenced the results. Granite masonry is common in the traditional Mediterranean mountain houses of Extremadura [53]. Since the less familiar a façade is, the worse the Likert test may result [24], limestone could have been recognized in the present study as an exotic material by observers, in special at high levels of cladding. Thus, they would have been easily linking granite to the traditional usages of the region as shown in **Figure 1**. During an informal interview performed after the survey, some participants manifested, indeed, some annoyance about the stone's color of building 2C in comparison with buildings 1C and 3C. This late information was not part of the investigation, but suggested that the nature of the stone could actually have influenced the results. The color of materials can turn the buildings into more striking and less preferred [7, 14].

In conclusion, traditional partial stone coating (image set B) achieved the highest level of acceptance irrespective of the stone type (see **Figure 6**). Whether the type of stone and the color affect significantly facade's assessment will be investigated in future studies.

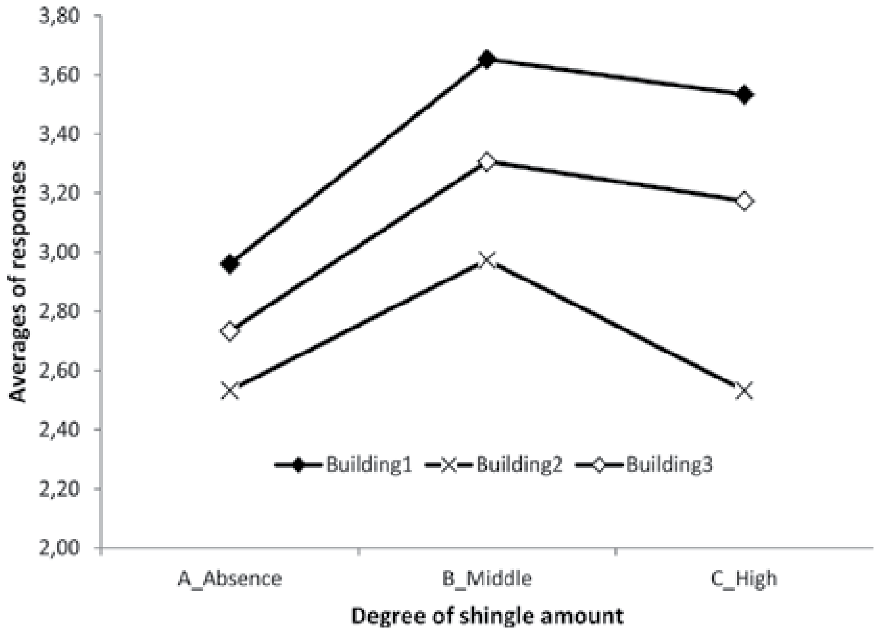

Figure 6. Mean values of Likert test as a function of the amount of shingle on the façade. A significant trend of inverted U-shaped was found for building 2, but not for buildings 1 and 3.

3.3. Preference for stoned façades based on the shingle pattern distribution (image sets A, B, D)

Similar amounts of stone coated the façades of buildings in B and D image sets, but D scenario received a significantly worse evaluation than B scenario as shown **Table 4**. In addition, irregular distribution of stone shingles (D) recorded the same results than the lack of stone coat (A) after statistical analysis for significance (see **Table 4**). Visual improvement of a façade requires, therefore, something more than the simple addition of stone.

The perception of a pattern depends on how visual information is presented and how it is organized [17]. Scaling coherence is a fundamental component of the structural morphology of forms, and is presented in façades from most traditional architectures. It involves a nested visual hierarchy of scales based on the arrangement of formal (openings) to stylistic (details) elements in structured patterns. Complex and ordered patterns display a tightly organized and large information content that looks coherent to the observer. Chaotic forms display, on the other hand, large amounts of uncoordinated information that may exceed the brain's processing capacity, turning the façade less familiar to the observer [18]. This is the most likely explanation for the low rating achieved by visual proposals presented in image set D, where the randomization of the boundaries of the stone baseboards did not follow either coherent or familiar design patterns. Such presentation disorganizes complexity and impairs human comprehension [36]. At the opposite extreme, small scales were removed from façades in image set A, which minimized the complexity of forms. The structure of both of the above extremes (A and D) lacked cooperation of hierarchical materials and

Building case	Arrangement of shingle pattern	Mean	d	F (1.74)	Level of significance
1	B (regular plinth)	3.65	*0.462*	13.303	0.0005*
	D (irregular plinth)	3.12			
	A (no shingles)	2.96	−0.140	1.245	0.2680
	D (irregular plinth)	3.12			
2	B (regular plinth)	2.97	*0.427*	19.093	3.9E−005*
	D (irregular plinth)	2.48			
	A (no shingles)	2.53	0.047	0.136	0.7130
	D (irregular plinth)	2.48			
3	B (regular plinth)	3.31	*0.541*	21.796	1.32E−005*
	D (irregular plinth)	2.69			
	A (no shingles)	2.73	0.035	0.08	0.7780
	D (irregular plinth)	2.69			

MSE = 1.314 (with Huynh-Feldt correction).

*Significant differences were found when comparing pairwise of scenes from top to bottom (alpha < 0.01). These differences also achieved an effect size above 0.2 [50].

Table 4. Standardized mean contrasts for visual response in function of the stone cladding pattern (A, B, and D comparisons by pairwise of scenes from top to bottom). *d'Cohen italic* values represent those mean comparisons reached statistical significance differences with strong effect size.

impaired the rating by observers in comparison with proposals from image set B (see **Tables 3** and **4**). Scenario B was simulated by following traditional techniques of structural arrangement of materials. Such techniques are the result of centuries of observation of nature are intimately related to mathematics [19], and optimized the visual comprehension in the present study.

In conclusion, arrangements related to mathematics and presence or absence of patterns in the surroundings influence the ability of the human brain to grasp concepts relying on patterns. Chaotic patterns on a façade become impressive but unfamiliar, and are less likely accepted by ordinary people. The characteristic, intimate relationship between architecture and mathematics in most traditional designs is broken when materials are inappropriately arranged on a façade, and this rupture has a negative impact on visual acceptation.

3.4. Comparison of preference for half-timbered façades vs. partially stoned houses (image sets A, B, E)

Half-timbered façades (image set E) scored as high as the stone claddings presented to participants for buildings 1 and 2 in image set B, but not so for building 3 (see **Table 5**). Actually, images of building 3 in scenario E were scored as poor as the corresponding images in scenario A (see **Table 5**).

Building case	Façade with stone plinth/wooden framing	Mean	d	F (1.74)	Level of significance
1	E (stone and wooden)	3.52	−0.113	0.7990	0.3800
	B (stone plinth)	3.65			
	E (stone and wooden)	3.52	*0.489*	11.882	0.0010*
	A (only painted)	2.96			
2	E (stone and wooden)	3.12	0.128	1.721	0.1937
	B (stone plinth)	2.97			
	E (stone and wooden)	3.12	*0.512*	14.902	0.0002*
	A (only painted)	2.53			
3	E (stone and wooden)	2.80	*−0.442*	10.897	0.0010*
	B (stone plinth)	3.31			
	E (stone and wooden)	2.80	0.058	0.171	0.6809
	A (only painted)	2.73			

MSE = 1.314 (with Huynh-Feldt correction).*Significant differences were found when comparing pairwise of scenes from top to bottom (alpha < 0.01). These differences also achieved an effect size above 0.2 [50].

Table 5. Standardized mean contrasts for visual response in function of adding a wood framing on the upper floor (A, B, and E comparisons by pairwise of scenes from top to bottom). *d'Cohen italic* values represent those mean comparisons reached statistical significance differences with strong effect size.

Materials and surfaces are selected in traditional architecture mainly based on structural, functional, and climatic considerations, and stylistic factors are considered of secondary importance. Wood has always been a significant element because of its flexibility, ductility, and strength. It enables a lighter and cheaper construction, setting up wide interiors and large external openings, in special on upper floors [54]. Materials and structural subdivisions create architectural scales by themselves that can be intensified through moderate intervention [36]. Setting these materials together is not, however, enough, but the achievement of a coherent whole via hierarchical and structural organization of the materials is required. This requirement was fully achieved in the past by half-timbered traditional buildings, and this building technique evolved over time into a style [55]. Combination of horizontal and vertical elements (wooden beams) with diagonal elements (wooden braces) diversified structural complexity in adaptation to climate factors or in satisfaction of local traditions, achieving an almost perfect cooperation between the scales of the elements on the façades. After centuries, these buildings have kept esthetically readable and recognizable, and represent often by themselves the identity of a culture. Examples of this style in the European setting are found from the ancient Roman world until present [3, 31]. Partial stone claddings and wooden timbers are currently arranged into the façades just for decoration purposes. Decorative arrangements imitating as much as possible the traditional patterns evolved from the former structural roles of these materials would be expected to optimize the visual coherence of a façade. Images of buildings 1 and 2 from image sets B and E were prepared in agreement with this idea, while the pattern of distribution of timber elements presented for building 3 in image set E was not. The results obtained in the present investigation (see **Table 5**) supported the proposal.

In conclusion, the agreement between novel proposals and traditional styles does not depend only on the quantity of critical common features, but also of their quality, i.e., of their complexity [55]. A feature consists of the sum of materials and the hierarchical cooperation, the functionality, and the structural patterns of distribution of these materials. Different combinations of features yield different expressions and different levels of perceptibility. The stylistic features represented by proposals from image set B achieved a satisfactory and understandable complexity in all cases, while proposals from scenario E were visually weaker and less satisfactory for building 3, despite of presenting a similar quantity of features than the rest.

3.5. The influence of large-formal elements in façade complexity: void-to-solid ratio

Theories based on cooperation among façade's elements in hierarchical scales also take into consideration the influence of large elements, like windows and doors, on the visual integration of a building (1st septave). However, most prior studies analyzed façade complexity only in terms of the small elements (2nd–3rd septaves). Void-to-solid (VTS) ratio is defined as the ratio between the area of the façade covered by openings and the area of the solid wall. The optimal ratio for buildings of two floors has been estimated in the range of 0.3–0.4, and ratios less than 0.2 have been found unsuitable in terms of visual acceptance [13].

Main façade VTS ratios of buildings 1 and 3 ranged between 0.26 and 0.27. Although out of the optimal range, these values were very close to the lower limit and were not expected to impair or influence significantly visual acceptance. However, building 3 was significantly less preferred, on average, than building 1 (see **Figure 7**). Similar colors and the same type of stone

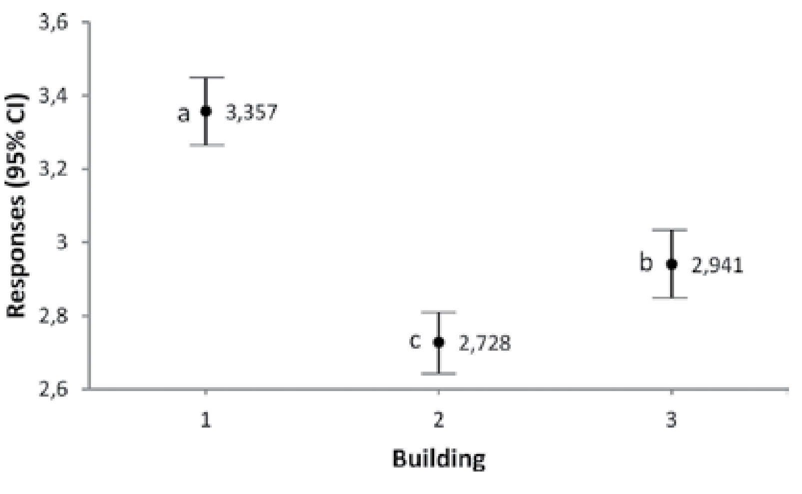

Figure 7. Mean values of Likert test as a function of the building shown. Significant differences at alpha <0.05 are given (Bonferroni test of post hoc comparison).

(granite) were used in both simulations, and the results might perhaps respond to the absence of openings in the secondary façade of building 3 (VTS ratio = 0 vs. VTS ratio = 0.15; buildings 3 and 1, respectively). Building 2 obtained the lowest average scoring (see **Figure 7**). The type of stone might have had some influence, but the different pattern of arrangement of windows could have also been important. Windows in building 2 were arranged on the middle-left of the façade, which left a wide solid space on the right side that likely modified the perception of the building's volume.

4. Conclusions

A partial stone coating of the façade limited to the lower floor is the best option for both granite and limestone coatings, and is better accepted than nude façades. Arrangement of the stone must keep harmony between the scales of the elements and the esthetic result. Irregular arrangement is worse accepted than the traditional plinth of stone ($-0.54 < d < -0.43$). Full coating is risky, in special when the stone used does not account among the usual in the region. The structural and functional meaning of a building must also translate into the esthetic result, and the tradition teaches the way to follow. Half-timbering provides visually understandable and esthetically accepted results on a façade, but the orientation and arrangement of the beams must never be random. Optimal visual acceptance is reached by imitating the patterns evolved from the original function of the timber coats in traditional architecture.

With these considerations in mind, imitation of traditional half-timbering does not present significant visual advantages or disadvantages, over imitations of traditional plinth of stone (B). However, if half-timbering misses the traditional style, visual acceptance becomes worse than for a regular stone plinth ($d = -0.44$). Cost–benefit considerations suggest that avoiding timber-frames may result less risky and potentially more successful for visual acceptance. Both the amount and the arrangement of openings may likely influence the perception of façade complexity, and the issue will be taken into full consideration in future studies. Additional studies involving different types of stone claddings, alone or in combination with other materials like bricks or ceramics of different colors, could also enlighten better correspondence between façade's complexity and visual acceptance for sustainable environments. In the meantime, transferring the results of the present study to sustainable rural planning activities may help to improve the current guidelines and regulations for building design in the region studied, and perhaps in other Mediterranean areas.

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Chapter 11

Evolution and Dynamics of Fractal Growth of the Urban Green Spaces in Seville (Spain)

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Additional information is available at the end of the chapter

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Abstract

Like urban growth, the increase in the area of urban green spaces can be described using fractal design, a measure, of the dynamic evolution of public space of leisure and recreation of the citizens, associated with the growth form of the city. Throughout the history, the city of Seville has been a good example of sustainability and eco-design in spite of the enormous physical transformations carried out both in the city center and in the periphery. In essence, the evolutionary process of the city is both technical and social giving rise to a landscape that is transformed and remains. In this work, from the evolution of green area per inhabitant from 1842 to 2016, a prediction model capable of characterizing the changes of fractal dimension associated with the growth of Seville is proposed. This prediction model can be used to estimate the growth rate of the fractal dimension, and therefore to reveal the spatiotemporal process and pattern of Seville growth. Especially, the model lays a foundation for researching the correlation between urban form and urbanization and for developing the theory of spatial replacement dynamics.

Keywords: Seville, green areas, fractal growth, eco-design, sustainability

1. Introduction

Environmental sustainability, defined as the set of policies and processes aimed at maintaining an adequate level of development that does not jeopardize existing natural resources, is a complex concept, since it depends on the criterion chosen to determine when a certain level of development does not jeopardize the survival of existing resources in a geographical space [1]. In this regard, and considering the scope of the city, it may be interesting to highlight the dual relationship between the functioning of the city and the sustainability of the city ecosystem, due to the great diversity of areas (industrial, residential, commercial, recreational, etc.) that coexist.

From the point of view of eco-design, and according to [2], this dual relationship reveals the use of certain amounts of environmental resources, which must be transferred through a series of eco-efficient strategies implemented in the initial phase of the urban development project.

According to [3], the relative growth of urban population in the city of Seville has been 11.75% between 2002 and 2012, which has led to a continuous transformation of the traditional agricultural landscape in order to create new urbanized zones. This constant growth has led to the exhaustion of the agricultural resources supplied to the rural areas that have been absorbed by the urban fabric, resulting in an incessant migration from rural to urban as a result of the rapid and consequent economic growth that existed from 1970 to 2007 [2]. This, which can be seen as an advantage from the point of view of growth and development of the Andalusian capital, can become one of the main obstacles to maintaining the current sustainable and eco-efficient urban development (SEUD) in Seville. The existing migratory balance in the city of Seville should not be forgotten, which although low, 2.69% between 1981 and 2011 [2], is important in the total count as a result of the fact that from 2012 the migratory balance is negative up to and including, 2016 [4]. In this regard, [5] specifies that policies aimed at improving the problems of mobility, sustainable development, quality of life, urban competitiveness and strategic marketing constitute a new frame of reference.

Several studies have analyzed the urban expansion of the city of Seville. According to [2], from the formal point of view, the growth of Seville has an irregular and radio-centric form, which counteracts the eastward development trend of the city and turns the basin of the former Guadalquivir river into the backbone of its plane, from where the best urban landscape perspectives are offered, both in its historical areas, as well as in those most related to the port or to the northern part of the metropolis. On the other hand, [6] specifies that the growth of the city is influenced by the development of the social differentiation of Seville in both the Southwest-Northeast direction as in East-West direction, occurring outside these two directions the emergence of a series of islands scattered throughout the territory, with its own social character independent of contiguous urban sectors and that has its origin in the local and particular dynamics that give rise to its development and colonization.

Then again, and based on the study carried out by [7], the city of Seville is transforming part of the typical pattern of Mediterranean city, based on compactness and drastic countryside-city separation, for a more decentralized one. Initially, the confirmation of the metropolitan model at Seville city resulted in the materialization of suburban cities, around the central city, with a high index of building density, which housed a significant part of the industry. At the same time, most of the tertiary functions remained in the central area. This imbalanced model demanded a significant mobility of the population, due to the necessity of the center-periphery displacements for reasons of work and of satisfaction of great part of the personal services.

Currently, the new model of activity dispersion across the Sevillian territory has generated increasingly complex urban structures that require the articulation of more and more disconnected and fragmented spaces. The decentralization of equipment and companies (universities, technological, and business parks, etc.), although tending to compensate for the deficits in the periphery, predominant in the previous model, increases the demand for mobility, which has meant the need to build an extensive network of roads and urban highways throughout the territory, to which must be added the construction and expansion of the Seville metro.

On the other hand, and as is well known, the process of occupying urban spaces, associated both the spatial and temporal dynamics of city morphology, has given rise to a progressive adaptation of design rules by local governments in order to adjust to the needs of use and enjoyment of citizens [8].

Then again, and according to [9], the process of urban growth, as well as that of its associated green surface, is related to the shape of the city, ecology and urban system, variables that have to be taken into account when choosing the model to be used to predict the fractal dimension of green areas over time. In this sense, one of the models most used to date is the logistic model [8].

Although the analysis of land use changes (LUC) as well as the assessment of urban sustainability in the city of Seville has been treated to a greater or lesser extent, less attention has been paid to the study of the growth of urban green spaces (GUGS). In fact, hitherto, there is no work that focuses on the city of Seville. For this reason, in the present chapter, the main objective will be to use, jointly, statistical and urban data to obtain the aforementioned relation (LUC vs. GUGS) and, explain the reason that causes the city of Seville has an evolution and dynamics of its green spaces that resemble a logistic model.

2. Study area

The city of Seville, throughout its history, has undergone a continuous transformation, which has allowed it to adapt in a systematic way to the evolution of the times but always maintaining the base of the pre-existing city (**Figure 1**).

After the conquest of Seville by the troops of King Fernando III in the mid-thirteenth century, the scheme of Muslim city is maintained with narrow streets and domestic architecture overturned inland. The density of the buildings decreased as we moved away from the oldest area, with huge gaps mostly occupied by orchards. This structure will be maintained for several centuries as a result of the fact that the new settlers were inferior in number to those expelled [9].

In the sixteenth century, another great transformation of the city took place with new ideas about the monumentality of the buildings, their perspectives, widening and straightening of the streets, as well as the incorporation of squares destined to the development of economic, political and social life. According to [2], the strong population growth, in this century, had the consequence of silting the urban perimeter up.

As a result of various calamities (earthquakes, epidemics, and floods), there was a notable population decline in the middle of the seventieth century, which led to the transformation of many places destined to housings and plots in vacant spaces and orchards, especially in popular neighborhoods to the North of the city. There was no change in the external appearance

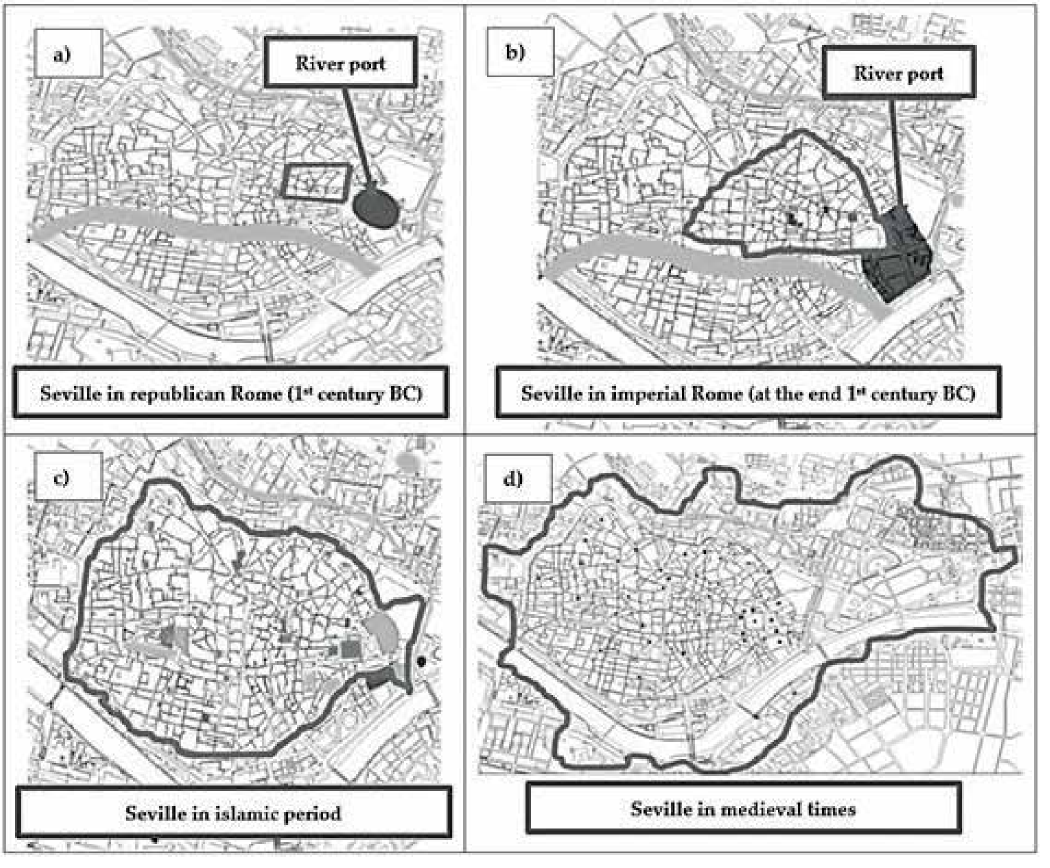

Figure 1. Evolution of Seville throughout history.

of the city. In fact, in the eighteenth century the existence of the urban plot of the seventieth century gave rise to a congestion of that one, making the transit through the metropolis very difficult.

The first third of the nineteenth century was very important for Seville to raise the quality of life of citizens were made urban reforms aimed at the beautification of the city, such as improvements of promenades and gardens, reforms of La Alameda de Hércules, the Cristina Gardens or the Las Delicias Gardens. This was followed by the economic growth of the city as a result of the promotion of the port and the establishment of the railroad, which led to an expansion of the city in a diffuse way with the demolition of walls, mainly due to the existence of a global urban project that allowed the connection between the different independent plots that were formed.

During the first third of the twentieth century, there are few reforms of the urban center that were taking place as a consequence of the Universal Exposition of 1929 was being developed, which meant an expansion of the city Southward. On the other hand, Eastward an expansion takes place through the roads that arrived at the city, which went across to empty zones (plots) for arriving at the neighborhood of Nervión, being this the first transformation of rustic land in urban of true importance in area (for this reason in 1940 there was a substantial increase in the urban green area per inhabitant (**Figure 2**)). Then again, in the North, several nuclei had begun to appear, lacking the minimum urban services (El Fontanal, La Corza, etc.), which gradually became part of the city.

From 1960, there was a decline of the historic center derived from the appearance of new neighborhoods, such as Los Remedios, which caused the displacement of the more well-off classes to these new areas; the real state pressure suffered by the historic center as a result of the disappearance of historic buildings; and the expulsion of the poorer classes to the periphery.

Later, with the preservation policy of the historic center, which has been maintained during the last years, as well as with the 1992 Universal Exposition [2, 10], a requalification of urban endowments were achieved that reached the eastern part of the city, as well as a considerable improvement in urban and interurban communications both by road and rail, offering a neo-city vision, totally adapted to the possible changes that may arise in the future, that offers the visitor an endless number of displacement possibilities, shopping centers, green areas, leisure places, monuments, etc. Currently, and due to the construction of new communication infrastructures (bike lane and metro), as well as the architecture sustainable management in the urban fabric of Seville, the city is combined in a complex framework of overlapping, giving rise to an urban landscape that adapts to the socio-economic moments prevailing in each era, and that remains throughout time.

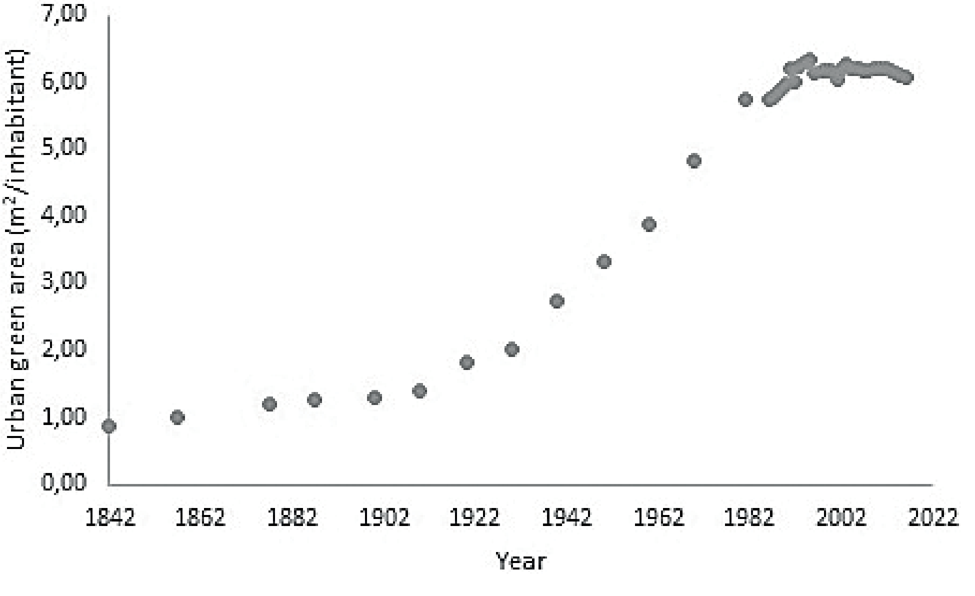

Figure 2. Evolution of urban green area of Seville from 1842 to 2016.

3. Fractals and logistic model

As is well known, fractal designs preserve many aspects of natural landscapes by ensuring that the spatial scaling of the landscape is built [11]. In this sense is interesting to specify that Euclidean geometry, trigonometry and calculus are the tools that are generally used to model natural phenomena. In a broad sense, models are described in terms of points, straight lines, circles, parabolas and other simple curves. Thus, points of zero dimension, one-dimensional lines and curves, two-dimensional plane figures such as the square and the circle, and three-dimensional bodies such as cubes and spheres make us see the world as we understand it up to now. However, some phenomena, such as the growth dynamics of urban green areas, are best described by a dimension whose value is not precisely a whole number (0, 1, 2, …), in other words, it does not correspond to a Euclidean dimension. This value (1.1, 1.12, …, 1.35, …, 2), then, corresponds to a fractal dimension.

According to [8], the function of a measurement or parameter rest with a comparison of values (including year-to-year comparison and one-to-one comparison). Therefore, by comparison of fractal dimension values of different urban green areas in different years, we can reveal the spatiotemporal information about green areas evolution from a city as a system. In this way, evolution and growth of green areas can be associated with spatial dynamics of city morphology.

On the other hand, it is known that the measure of a system has both an upper limit and a lower one, so that the growth of the measure (urban green area) will have an S-shape, called sigmoid function, as long as the speed of growth of the system is not uniform.

Currently, in whatever city around the world has a level of green spaces ranging from 0 to 1 (or 0–100%). As a consequence of the fact that growth of green areas is based on two-dimensional maps, the upper limit of fractal dimension will be 2 ($D_{max} = 2$) while the lower limit will have a value equal to 0 ($D_{min} = 0$).

As a result, and using the logistic model, the sigmoidal growth of urban green areas can be described, according to [12], by Eq. (1):

$$D(t) = \frac{D_{max}}{1 + A \cdot e^{-k \cdot t}} \tag{1}$$

In Eq. (1), the time "t" is the difference between the year in which we want to obtain the fractal dimension and the initial year of the time series, "D(t)" is the fractal dimension at the "t" moment, "A" is the quotient given by Eq. (2), "D_0" is the fractal dimension corresponding to the initial year of the series (1842 in this case), and "k" is nothing other than the original growth level of the fractal dimension of the series corresponding to the variable analyzed.

$$A = \frac{D_{max}}{D_0} - 1 \tag{2}$$

4. The case of Seville

In this work, an exhaustive bibliographic search was carried out in order to find a time series, broad and significant enough, to be able to infer the fractal dimension of the green areas corresponding to the city of Seville (**Table 1**), based on the existing relationship between the surface of the large parks and gardens of the Sevillian city and, the total area corresponding to all the green areas of the city up to the end of 2016 [13]. In this sense, and due to this surface is related to the number of inhabitants of the municipality of Seville, the information provided by [2, 14, 15] was very useful.

The growth trend of fractal dimension values, from 1842 to 2016, was modeled by the logistic function (Eq. (1)), and the logistic pattern of this variable is presented in **Figure 3**.

The logistic patterns of fractal dimension growth of green areas of Seville, for the period 1842–2016, is presented in **Figure 3**, and the logistic model obtained is shown in Eq. (3).

$$D(t) = \frac{0.9654}{1 + 0.0482 \cdot e^{-0.0156 \cdot t}} \quad (3)$$

The goodness of fit is about $R^2 = 0.9378$.

Year	Dimension	Year	Dimension
1842	0.921	1995	0.9653
1857	0.9283	1996	0.9652
1877	0.9355	1998	0.9651
1887	0.9340	1999	0.9649
1900	0.9268	2000	0.9648
1910	0.9226	2001	0.9646
1920	0.9379	2002	0.9645
1930	0.9432	2003	0.9644
1940	0.9535	2004	0.9642
1950	0.9585	2005	0.9641
1960	0.9612	2006	0.9639
1970	0.9634	2007	0.9638
1981	0.9648	2008	0.9636
1986	0.9650	2009	0.9635
1987	0.9651	2010	0.9633
1988	0.9652	2011	0.9631
1989	0.9653	2012	0.9630
1990	0.9653	2013	0.9628
1991	0.9654	2014	0.9626
1992	0.9653	2015	0.9625
1993	0.9653	2016	0.9623
1994	0.9653		

Table 1. The fractal dimensions growth of urban green areas of Seville metropolis (1842–2016).

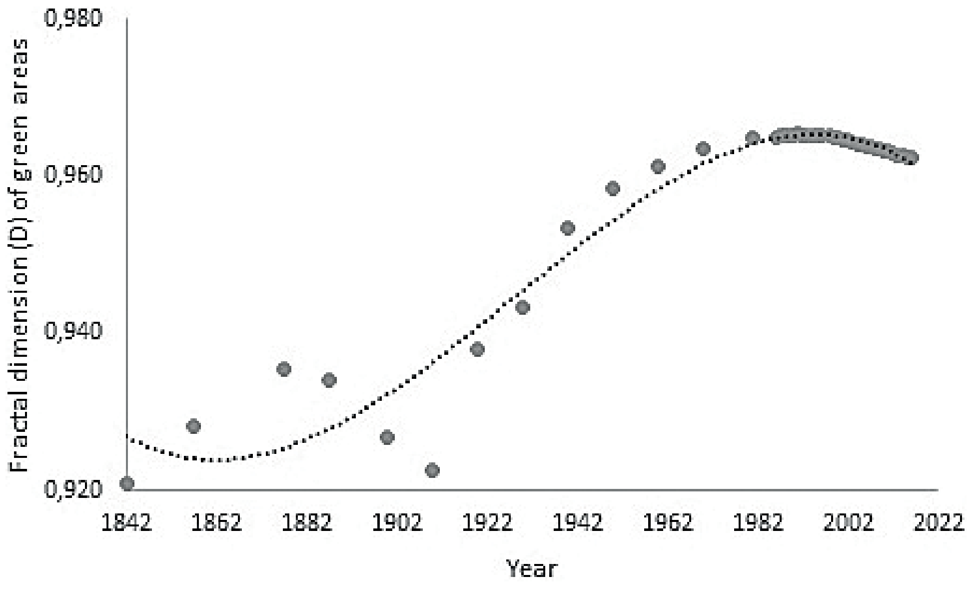

Figure 3. Logistic patterns of fractal dimension growth of green areas of Seville (1842–2016).

The results can stimulate new thinking on when and where an urban green area fractal is.

In urban green areas of Seville, the estimated value of the capacity parameter "D_{max}" is less than the Euclidian dimension of the embedding space and, therefore, is acceptable. Besides, the goodness of fit for urban green areas of Seville seems to suggest a proper fractal dimension estimation, so that can be inferred that the size of the study area has been adequate. In this sense, it is important to specify that in this study was defined a fixed study area whose advantage is that the fractal dimension values are more compatible for year-to-year comparison. However, and according to [12], for a fixed study area, the fractal dimension values of initial stages can be underestimated, while the dimension values of terminal stages can be overrated.

According to **Figure 3**, it can be seen that the maximum speed of fractal dimension growth appeared in 1930 when the city size is about 230,000 [2.01 m^2 of urban green area per inhabitant (**Figure 2**)]. This is very important due to do not differ from the speed of population growth.

On the other hand, special attention must be paid to 1995, since it is when both a greater green area per inhabitant is reached (6.34 m^2/inhabitant) as well as the greater number of inhabitants of the city (about 720,000). Otherwise, the greatest value of the fractal dimension, D_{max} = 0.9654, is observed in 1991 (6.21 m^2/inhabitant and about 705,000 people) as a consequence of that all the green infrastructure corresponding to the 1992 Universal Exposition was about to be finished. This suggests that when the population size reached about 705,000, both more buildings as more urban green spaces appeared in Seville so that the urban LUC became more intensive than ever.

In general, these LUC, and according to [2], can be observed using remote sensing images, as a consequence of industrialization processes (**Figure 4**).

In relation to the growth of the urban green area, it should be borne in mind that, in social terms, the annex and diffuse urban growth would imply greater social segmentation, as well as an upward trend in housing prices, which would make more difficult the accessibility to housing. As a result, Seville can be defined, to date, as a compact city where the incorporation of the environmental variable in new urban design and development projects is facilitated, being, therefore, eco-design a key element in urban policies of the Sevillian city since the beginning of 1990.

Hitherto, in Seville, squares, gardens, parks (**Table 2**) or urban forest play a fundamental role in the environmental and biodiversity of the city, as well as being spaces for strolling, relaxing or leisure. At spatial planning level, they are part of its structure and symbolize a balanced and eco-designed city environment, where the building is cushioned by natural spaces.

As is known, the development of non-Euclidean geometry has given rise to the construction of an endless of new models based on fractal dimension.

Actually, logistic models of fractal dimension growth can be used to explain the process of urban green spaces evolution and predict the results of city development where green areas fractals are concerned. In this sense, logistic parameters can be used as an assistant criterion,

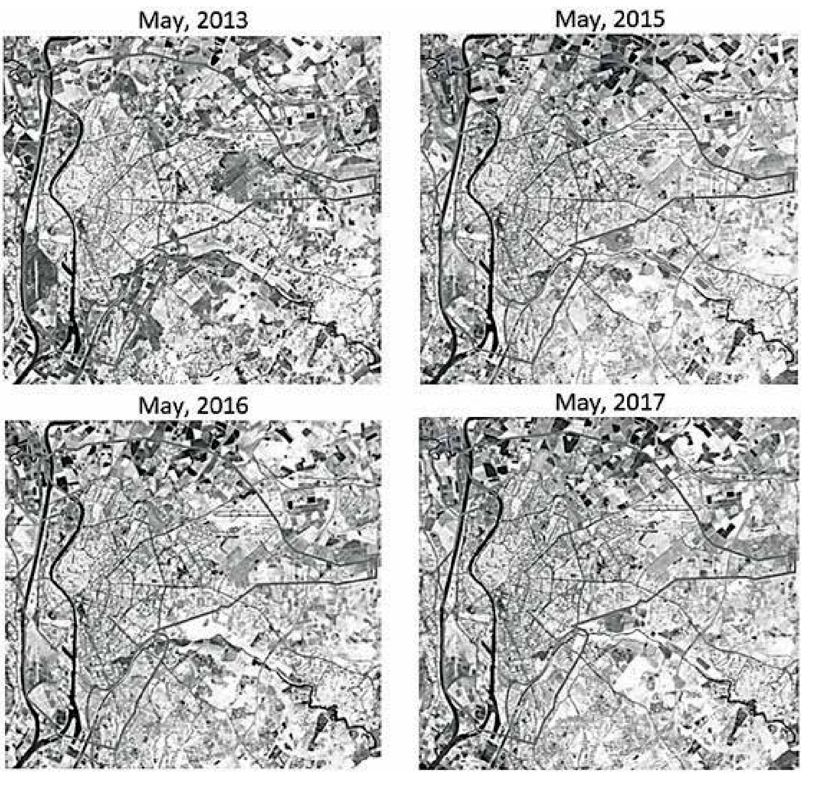

Figure 4. Landsat 8 LC satellite images showing the false color bands combination (764) to see urban areas in mid-May in recent years in Seville.

Name	Dated as a public park in	Area (m^2)
Parque Guadaira	2014	24,000
Parque Vega de Triana	2012	180,000
Parque de Los Bermejales	2010	135,000
Jardines de La Buhaira	1999	350,000
Parque Infanta Elena	1998	35,000
Parque José Celestino Mutis	1997	45,000
Jardines Prado San Sebastián	1997	58,384
Jardines Torre Los Perdigones	1997	20,294
Parque del Alamillo	1992	480,000
Parque de San Jerónimo	1992	148,677
Jardín Americano	1992	140,000
Parque Amate	1987	316,800
Parque Miraflores	1987	940,000
Jardines Federico García Lorca	1987	9240
Parque de Los Príncipes	1973	108,000
Jardines de Chapina	1969	39,760
Jardines de Villa Luisa	1925	5700
Jardines de Catalina de Ribera	1898	18,250
Parque de María Luisa	1893	340,000
Jardines del Valle	1866	10,554
Jardines de Murillo	1862	8500
Jardines de Cristina	1830	8100
Jardines de Las Delicias	1829	54,250
Jardines del Real Alcázar	1500	60,000

Table 2. Area of the main parks and gardens of Seville.

that is to say, if "$D_{max} > 2$," can be inferred that the study area is too small, and it will be necessary to define a larger study region in order to find a proper urban green area fractal spectrum over time. Moreover, if the lower limit value of a fractal dimension, "$D_{min,}$" can be obtained appropriately, it will be possible to make a space-time diffusion analysis for the urban green areas of the city.

On the other hand, urban green spaces evolution is associated with urbanization processes [2, 12]. According to [2, 5, 8], the intra-urban green areas growth process reflects the flow of interurban population to the city. In Seville, this process took place from the beginning of the 1980s until the mid-1990s, leading to a radio-centric growth of the metropolis and those satellite municipalities (Montequinto, Dos Hermanas, Alcalá de Guadaira, and Camas among others), besides its associated green areas, which are located a few kilometers from the Andalusian Capital.

5. Conclusions

The city of Seville has an average annual temperature about 19°C, that along with its average precipitation of 533 mm, concentrated between the months of October and April, as well as its nearly 2900 hours of sunshine per year, make it one of the main places of tourist visit around the world, not only for its climatic conditions, but also for its great monumental offer, urban green areas and restaurants among others.

In addition to the advantages offered by the parks and gardens of the city, the urban transport network allows tourists to move at low prices to the monumental areas or to the historic center. It cannot be forgotten that in the historic center of Seville there is an island of heat, although the pre-existence of narrow streets and high-rise buildings, give rise to a temperature decrease of a couple of degrees, enough to allow tourism on hot days.

The growth dynamics of the urban green areas of the metropolis has been a reflection of the diffuse growth of the city, giving rise to a series of disconnected areas with the central urban nucleus that little by little have been incorporated by the city, making possible the increase of demand for mobility and the appearance of new transport infrastructures, which has allowed Seville to be increasingly sustainable and eco-efficient.

On the other hand, the fractal dimension growth of urban green areas of Seville can be described with logistic models [16–20]. Besides, the uses and significance of the logistic models of fractal dimension, for spatial analysis of urban green spaces growth, can be specified in five main points:

a. Logistic models can be used to estimate the past missing fractal dimension values and predict the future unknown fractal dimension.

b. These models can be used to estimate the peak value of the fractal dimension growth rate.

c. The models can be applied to analyze where an urban green space fractal is.

d. Logistic models make a possible new approach to researching urbanization processes throughout the green areas dynamic of the city.

e. Finally, by means of the models, can be researched the spatial replacement dynamics of urban green areas.

For everything specified, and according to [21], for an adequate SEUD in Seville it would be necessary to take into account, increasingly, the importance of urban industrial polygons, as well as the design of their associated green areas, since their correct integration in the urban fabric of the city can lead to the plausible use of more open spaces, in addition to other facilities and infrastructure oriented to the community.

In relation to this, the application of the prevailing theories about the city of the twenty-first century and the processes of social agreement, which help the configuration of an urban scenario with new rules of use and design of urban green spaces, are the points to take into account in order to achieve the consideration of urban green landscape as a legal argument for local development, eco-design, social welfare, and the improvement of the quality of life of citizens within the framework of sustainability criteria [22].

Finally, it very important to emphasize the fact that green areas urbanization tends to generate fractal structures should, of course, incite reflecting about the underlying socio-economic processes.

Multi-scale concepts may also be of interest on the micro-scale of town sections (parks and gardens). Instead of rounding up the boundaries, fractal-like outlines of residential areas may be imagined: the consequent lengthening of the outline lets more house-owners benefit of the situation (urban green spaces enjoyment) on the edge of the settlement which seems to be rather appreciated.

When interpreting the results it becomes obvious that a fractal approach to urban green areas patterns helps us to make evident that green spaces patterns follow a particular type of spatial organization, despite their irregular aspect. According to [20], besides the purely descriptive approach, fractal modeling allows illustrating important features of these patterns and seems to provide a new approach for managing the consequences of the new lifestyle, which tends to claim good access to different kinds of both urban and rural amenities, and at the same time helps to reduce the risks of a diffuse sprawl which tends to weaken the environmental quality and to generate increasingly traffic flows.

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Chapter 12

Renovation Spaces in Heritage Districts: The Reviving and Renovation of Culturally and Historically Open Spaces in Islamic Regions

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Additional information is available at the end of the chapter

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Abstract

The study depends on a spatial orientation to open urban spaces in heritage cities for potential investment opportunities after eliminating the garbage and ruination. Spaces such as alleys must take their role to host everything from live music and dinner on candle lights to traditional games gatherings under colorful traditional sculptures to highlight historical values at the alley, where spaces transform into emerging and effective public places creating public awareness. Thus, these spaces, such as streets and alleyways are transformed to a creative district block that is enriched with arts, architectures, fashion shows, restaurants, coffee shops, music, museums, shopping stores, commercial agencies and tourist offices, theaters, galleries, cultural houses, libraries, and all entertainment means. Moreover, sustainable transportation devices which do not use regular engines in any form and do not pollute the heritage spaces can be used to replace regular engines to take care of the environment. The regulation of power usage is important to make people able to discover the hidden beauty in these cities behind the buildings, whereas these spaces can attract tourists toward the city to accomplish a sustainable urban scope.

Keywords: recreating spaces, renovation, heritage, roads

1. Introduction

Heritage district forms one of the critical regions due to its traditional, cultural, and historical values in the Arabic and Islamic world and the Middle East, a rich land for these heritage areas widespread from north to south and from east to west, that shape a private form within the urban fabric. In the urban heritage areas, all the housing units formulate one integrand unit, formed into one adjacent mass. On the other hand, the opened spaces working on disrepute of the urban create for a vital ventilator {through an inner courtyard considered as a social core}.

Despite its uniqueness, many mutual characteristics and features appear in these cities through time, different factors from the heart of social life and its traditions, beliefs, and needs of its life demand, and environmental circumstances that all combined to construct the Islamic and Arabic cities to draw the outline and features of the social life on its architecture gave it a special and unique language.

2. Study vision

It contains the schematic characteristics of the spaces, roads, alleyways, and public spaces with human scale that suit the heritage elements and essential components in urban fabric structure. It includes buildings, pedestrian walking axes, open space landscape, and streets in traditional and heritage cities with architectural and planning characteristics. It is crucial for academics to confirm that the elements of cities from the Islamic world and Middle East represent large fields for those heritage districts and spaces, transform it from a negative to positive image through investment and display in a form that releases the potential powers in it and change it into spaces that support the evolution ([1], p. 12). In addition, it improves the quality of life with concentration on building environment development while paying attention in all aspects of urban fabric by distinguishing its theme (characteristics) and concentrating on the roads, streets ways, and its gradient from public to private ([2], p. 65):

- Using narrow and zigzag ways within the urban fabric.
- Division into urban scene and optical elements.
- Organic and zigzag street planning.
- The hierarchy take into consideration of the urban fabric characteristics such as function, scale, and privacy.

The architectural and heritage characteristics and features of the city ([3, 4], p. 55):

1. Organic.
2. Hierarchy (moving from central plaza to the main roads, then to the semipublic roads, then to the private roads in pedestrian blocks and finally to private alley for group dwellings than to a dead-end alley (cul-de-sac).
3. Enclosures by a positive response to the human requirements through creating a buildings.
4. Adjacent: buildings were close to each other and less exposed to the surroundings.
5. Human scale: through compatibility, human characteristics and environment depends on human scale.

6. Flexibility and adaptation and horizontal extension.
7. Geometrical rhythm.
8. Form and function.
9. Abstraction mechanism and symbolic strategies.
10. Unity and diversity.
11. Directionality and axial.
12. The beauty through achieving functional utilization and formal beauty.

This study focused on the status of (studying space circumstances in heritage alleyways) Baghdad to explore transformation of the alley to available space and mention the rich architectural pact of the city ([3, 4], p. 58), because the alleyways present a significant clue in the history of cities and buildings and reveal details on building constrictions and urban spaces and its cultural use with its economic and social history. However, even home life was in it, there will always be these significant details of buildings that provide a window through the history of ancient cities with not only just an abstract space but also alive lasting districts ([5], p. 22).

The study tries to create a full life space in the cultural and civilization city—Baghdad—and all the same heritage cities. Baghdad alleyways have the supper ability to recruit its available in these spaces like a front yard for the whole urban society that can be operated and invested in benefit of the public interest, and the value of urban experience depends on pedestrians ([6], p. 73). Moreover, because of the alleyways volume with unique features, we can create a unique environmental experience for pedestrian way from annoying transportation in modern cities ([7], p. 98).

This small zone shrinks and expands from time to time imposes an intimate feeling, the monotony of the pedestrian, where it can create surprise element. Renovation Spaces in Heritage Districts: The Reviving and Renovation of Culturally and Historically spaces… 501 [5], p. 25. it acquires importance from the nature of the journey and gave a full impression about the cities and its history. where it can be clearly observed through the building characteristics and nature ([7], p. 85).

The study aims to display the relationship between courtyards that represent the importance of it. Moreover, the outdoor space represented by roads forum and nodes by space adaptation for many and different usage or rehabilitation to achieve the development in heritage district by McClusky [6], p. 103:

- Existence (subsistence) means the optimum use of natural resources that exist in the heritage districts which is a form of conservation.
- Precedence in the select useful field for the nation (educational, cultural, …, etc.).

The previous types represent the sustainable development of a heritage

- Economic factor.
- Environmental factor.
- Social factor.
- Political factor.
- Morphology and city planning.

It came with social, economic, environmental, and political motivation; space can be under strict division like service burying areas that lead to health and garbage issues (epidemic, garbage, crime), narrow space, and environmental considerations to explore the space and its rehabilitation ([5], p. 46). By concentrating on a specific space or an element to display its importance above the other space that the study focuses on or on one side of it, we can apply the space rehabilitation in heritage cities into two directions ([6], p. 32).

- Quotation (formal): trait as contemporary, cloning, and forced in.
- Fundamental (essential): combined content, configuration, and function.

The nature simulation in urban fabric heritage includes ([3, 4], p. 41):

- Studying future system in the design.
- Ecological system (climate).
- Adaptation methods.

Site topography within the urban fabric ([7], p. 42):

- Harmony between shape and context.
- Colors.
- Nature utilization.
- Power resources.

Briefly, we can classify urban fabric content in the urbanscape for Islamic city in to: **urban structure and urban spaces**.

3. Urban element functions

This building has excellent value within the traditional urban fabric of assignee unity or within the urban commotion in the overall context ([5], p. 26). These buildings include the central mosque which occupies a central location in hears of the city in the central coda junction that connects between it and the city gates, markets, schools, and traditional houses ([7], p. 25). Each one of them is distinguished by its architectural particularity features within traditional fabrics; the study will illustrate (clarify) each one of these structures down to the residential area that includes multiple spaces.

3.1. The religious elements "mosque"

The mosque is the educational, cultural, and legal center and space to perform social activities besides ([3, 4], p. 93). Its fundamental function is lingoes entity which makes it earn a considerable importance reflected in its central position and domination on urban fabric composition. The most important feature of the mosque is its axis, which is oriented toward AL qibla. This orientation can be found in Arabic and Islamic cities, so that the mosque becomes an extension to the expansion and orientation of the buildings, roads, and paths even if it was far away from useful geometrical data ([5], p. 84). Moreover, the mosque is considered the dominant element in an old city, which can create a respectable skyline city by the dome and mosque minaret that exceed the mosque height, (uses as an extra space). For prayers in super-hot days, the ablution spaces (media) toilets, and some stores in one of its corners, and it has mostly a big plaza in front of it ([1], p. 84).

3.2. The commercials elements "markets"

It has an essential value in Arabic and Islamic city which has a significant role in the formation of the urban fabric and one of the critical branches in city development. The markets value appears in economic, social, and political life in the city. The commercial streets and markets are the leading characters of Arabic and Islamic cities: they are spread from central regions of the city as a connected network from alleys that gradually expands, then into a narrow way into the secondary markets; therefore it is similar to the alleyways and public streets of the city in scaling ([7], p. 52). The linear or irregular shape or markets have a profound effect in the Islamic and Arabic city, and the commercial streets in many types covered and uncovered, narrow and organic, pedestrian transportation roads. With particular care in design for creating a significant role in the streets function ([5], p. 91). Mostly, markets were completely covered, and shops have been distributed on both sides such as merchants and workers' shops connected with many spaces covered and uncovered, where networks are widespread ([6], p. 21). Usually, stores and bazaars are linked to the commercial markets (suq) as supporting units, for business trading ([1], p. 24). Commercial streets and bazaars lay in very dense and urban entangled fabric from surrounding buildings. The commercial streets are the only significant element in Arabic city; so, we can consider it as a cultural heritage. The arcade is the most critical element of the bazaar and an active binder for religious, educational, commercial, industrial and entertaining spaces, and the shop (mahal) is its constructional unite. A fundamental element in bazaar formation and the group of shops is a direct trade market ([1], p. 67). The bazaars (khan) have its significant role in urban functions. Its importance is gradually sorted as its location, function, size and architectural style ([6], p. 193). Bazaars and buildings for different functions, as within the urban fabric, are divided into two parts due to its function ([5], p. 62):

- Marketing bazaars for storage, workshop within the industrial, and commercial core of the urban fabric.
- The other type is a hotel—bazaar (khan) which it can be used for lodging (habitation), these khans usually has an inner courtyard.

3.3. The residential elements "houses"

Traditional housing units that form the significant part of the urban fabric, about two-thirds, consist of many feature dwelling units, and its characteristic features are as follows:

1. Each district has its character and maintains its unity and homogenous fabric based on many foundations as religious, social, and personal basic (each tribe combined into one or more district ([3, 4], p. 55).
2. Its organization prevents the merge between districts, where every district is self-sufficient.
3. Architectural form for the residential unit, the form and construction of the dwelling, is an image to reflect climatic, environmental, technological, cultural, available construction material and social life of the family ([1], p. 21). Dwelling units provide a suitable household for the Islamic society in Arabic city. Therefore, these units have features and characteristics such as inward-looking, architectural, and ecological treatments that the courtyard provides.

3.4. Streets network

Streets planning standards are very accurate for each detail and cannot be all pointed in this area because they are branched down to the human behavior in the streets ([6], p. 35). The street width determines the necessity of its function, such as the main street in Basra is 60 arms width whereas the main street in Baghdad is 50 arms. Secondary streets were determined 20 arms width, and the minimum road width was 7 arms; the most important features of the roads planning in Arabic and Islamic city are ([5], p. 39):

1. Using narrow and twisted streets that are integrated with the urban fabric of the city.
2. Dividing the view into the deferent scene to avoid the boredom.
3. The streets are usually organic and in zigzag and irregular form to achieve privacy for inhabitance.
4. The traditional city has a hierarchy particularity for streets whether in function, scale, or privacy which leads to apparent differences in streets' scale.

5. The cul-de-sac street where they increased in a residential district to provide privacy.
6. The external roads which came from outside the city ended with the city wall which organizes the process of entry and exit.
7. The roads divided in privacy scaling to main roads as a semi-public space related to social activity for the public, condition as a semipublic or semi-private, spaces and alleyways as a semi-private related to the residence.

4. Urban spaces

An efficient urban space represents a factual extension to the three-dimensional world around humans; such space represents a place for human gathering that is not only a physical place which occupies land in the city but also a significant, philosophical, spiritual, natural, and economic attempt ([8], p. 112). Therefore, space is materialistic enclosure connecting buildings and considered as a vessel to contain human activity, and is formed by intellectual and humanitarian concept that presents human interaction with the natural and cultural environment. The urban spaces distinct with features and characteristics such as gradual and containment represent features and characteristics of heritage fabric ([7], p. 53).

From here, the importance of urban spaces stands out in Arabic and Islamic city as an essential part of information of urban form and heritage fabric in the city. From many studies that have been done within the Islamic city about the roads, it can determine the net movement in gradual levels as:

The first level forms the spinal essences for street system determined by main streets which combine the main gate of the city with each other, and with the city center, where central activities are located and combined with main roads that lead to other cities and villages. The city contains few numbers of these roads and one of them represent the central axis to the city center ([9], p. 57). **The second level** represented the main roads that combined adjacent buildings to the residential district or through them and linked directly with first level streets ([5], p. 175). **The third level** signifies secondary roads that serve the district within residential neighborhoods usually used by inhabitance of the neighborhoods or people who connect with them from another district; some points of this level show some commercial and service activities that are specified for neighborhood services ([10], p. 51). **The fourth level** represented by dead and alleyways (cul _de_ sac) leads to the specific dwelling, which assimilates a transition zone between semipublic and private space in the dwelling. These alleyways connect with the three levels and the alleyways length is usually between 9 and 140 m. This level has an essential role to reduce permeability to the private space ([11], p. 212).

Upon what has been mentioned above, we can divide urban space in heritage cities into (**Figures 1–4**):

Figure 1. Old Arabic cities.

Figure 2. Old Arabic streets.

A. external space

- Main streets
- Secondary street
- Sub streets
- Alleyways
- Large squares (plaza)
- Small squares (plaza)
- Patio
- Nodes and road junction
- Permanent markets (bazaar)

B. courtyards

- Inner courtyards
- Secondary courtyards

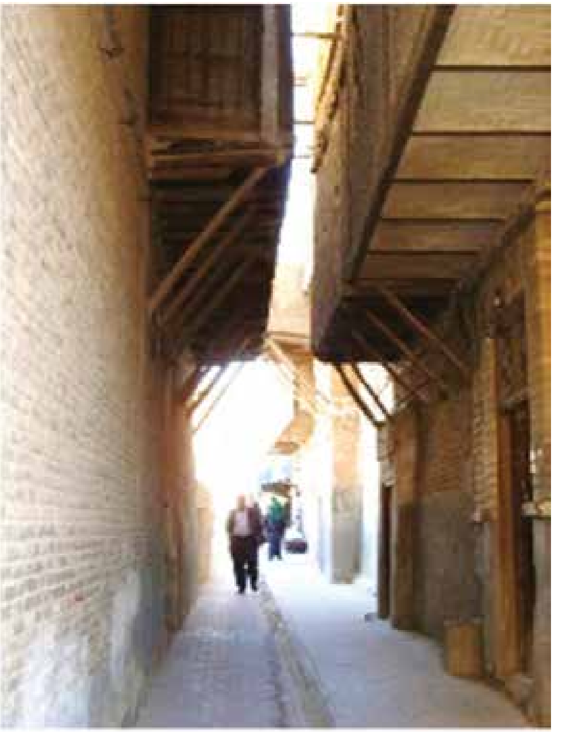

Figure 3. Old Arabic roads (Zuqaq).

Figure 4. Alrasheed street in Baghdad.

5. The relation between traditional regulation and space formation in heritage district

A traditional building, that has a regulating architectural pattern, which reflects the urban heritage spaces, such as a house with two facades on two streets. The main house door set on the private streets with less pedestrian and the buildings with high noisiness or pollutions functions such as ferniest, carpenters workshops blacksmith workshops …, etc. They are placed away from the city ([12, 13], p. 63). In the beginning, the city construction was ruled by these regulations where the houses were designed with inner courtyard from one story to two stories. Architecture was characterized by:

- Simplicity
- Form intelligibility (clarity)
- Proportionally
- Harmony
- Human scale

The courtyard in the dwelling (house) is an open space to the sky, centering the house or on one side of the house, which can be considered as living space, most of the human activity can be translated into a rectangular space shape or a square space shape; sometimes, it takes different volumes and shapes to perform variety of functions; the courtyard in terrace is usually in one corner and is surrounded by an arcade which is higher than the courtyard. The arcade ceiling usually consists of stone arcades or cross stone vaults ([14], p. 163).

These corridors considered as an inner porch overlooking the courtyard, on the ground floor level, represents a terrace (veranda); the whole arcade is connected with the chamber ceiling, which is sometimes decorated with ornaments that are represented an Islamic decoration ([14], p. 163). Besides, there is another courtyard near the kitchen, bathrooms or toilets; some houses may contain a private yard for farm animals and that depends on the owner's richness and the family members which are mostly a combination of many subfamilies, such as the grand father and his sons, brothers, and grandchildren; some of them use a coal store for the stove or furnace which is illustrated in design philosophy of traditional house in the Middle East ([14], p. 163).

The courtyard functions:

1. Include the internal circulation horizontal and vertical movement in the traditional house.
2. Achieves the esthetic aspects in its architectural elements within decoration and the used material.
3. Achieve the healthful aspects which are the only air source to ventilation and lighting for the other inner spaces.
4. Achieve the social aspects, to be used as a private space for a family gathering to achieve social activities. In deferent occasions, the lobby is a suitable space for the family.
5. Considered as a service space for many activities and services such as food preparing, laundry, bathrooms, and toilets.

Figure 5. Traditional house in Syria.

6. Achieve and organize the connection between sky and earth through space perspective during day and night as a spiritual and psychological connection with the sky.

7. It achieves environmental sustainability and helps to soften the temperature inside the house. Cold air layers gathered in the yard during the night and together with greenery and water help to reduce the ambient air temperature during the day. Fountains and basins are used in different shapes and sizes.

8. The patio overlooks at the balconies called the "Al-Tauhous," which is open to the guest's reception. The terraces on the upper floors face the north to benefit from the cold wind and take on a more private character called the "seat."

9. As the concept of esthetics in the spaces where the concept of esthetics interferes in the formation of spaces through the use of local building materials and balance the human thought with the concepts of utility and beauty and the benefit of beauty, and as the impact of the movement in the formation of spaces and the relationship between public and private space in the heritage cities (**Figures 5** and **6**).

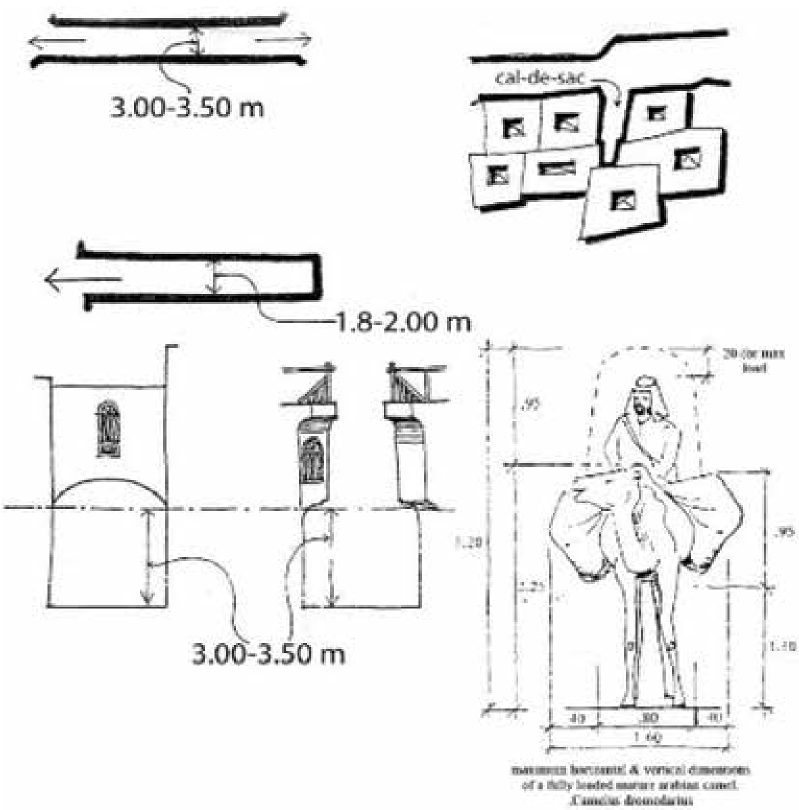

Figure 6. Arabic traditional roads details.

6. The relationship between the interior and exterior

The relationship between the interior and exterior and the transition between them from spaces are characterized by high enclosure and solidarity of the internal environment. The most important character is represented by the middle courtyard, which is the micro-social environment, and its entry is broken for security, environmental, and social considerations, and the gradient of privacy and access to the external environment and its paths called Alleyways ([5] p. 129).

The alleyways are one of the most marginal areas, where the spaces between "here" and "there" are at its best to serve the movement of the buildings surrounding them. Moreover, at its worst becomes the dark and even dangerous spaces, sometimes seen by the city's residents as a dead space ([3, 4], p. 88). In the eyes of specialists, however, it has a great importance that the negative space occupied by the alleyways is not dead at all; it is only in a deep sleep waiting for a new birth of something new and a function that serves its surroundings. In cities where real estate is rare and costly, the alleys are being reclaimed, revitalized, and reused through rehabilitation. The rehabilitation in heritage areas is one of the best ways to preserve it ([5] p. 129).

It is rehabilitated and recultivated. New spaces can make societies safer, cleaner, and more prosperous. The ancient and heritage cities areas are always in the changing process in the size and nature similar to the human being grows, and ages when change functions and become damaged and vanity. This necessitates looking at their problems from time to time and dealing with them. The Urban renovation is one of the ways to deal with these problems. The Urban renovation is being taken in the development of new areas outside the cities rather than the reconstruction of regions or districts in which they are already faded ([5] p. 193).

The need for a more comprehensive urban renovation has emerged. The maintenance and rehabilitation of the old dilapidated areas are defined as a decisive influence on the development and improvement of the urban environment by organizing a massive scale of the existing city areas according to present and future requirements regarding urban life ([10], p. 85). Including comprehensive replanning of land, conservation and rehabilitation of areas with urban problems are consumed without attention to its historical location and heritage value ([14], p. 42). In another definition, it is a process of changing the urban environment of the city, through which the old structures and service lines are improved or rebuilt, which are not compatible with the contemporary time to face economic and social changes. Districts are used at the end of the useful life of areas of urban fabric over time because ([3, 4], p. 71):

- The structural form of the building blocks deteriorates due to aging.
- Due to the rapid and often uncontrolled urbanization process and the changing lifestyle, many buildings have become inadequate even if they are highly functional.
- Staggering population inflation and the consequent increase in demand for housing within the city to obtain a better quality of services and the corresponding technological development that helped to find structural patterns to replace previous patterns.
- The process of rehabilitating heritage spaces and investing in different functional patterns that meet the needs of the people according to current time style, so that rehabilitation and investment are the best ways to preserve buildings and heritage spaces.

7. Rehabilitation policy

It is expressed by upgrading existing buildings to an acceptable level. It is the most common method to date. It includes the improvement and development of the areas through the partial demolition of some buildings, the reconstruction of new buildings, and the development and repair of others. Here, most of the urban structure has been retained with the addition of open spaces, but this may make fundamental changes in heritage spaces ([1], p. 24).

The focus on the rehabilitation policy as an important principle in the urban renewal in terms of social, economic, and urban rehabilitation processes have become very important urban processes at present time because urban transformation has affected the urban fabric of the old areas due to the neglect and the lack of maintenance and migration of owners and can be adopted in areas where the buildings are partly deserted "and is characterized by the unavailability of open spaces and green areas and lack of organization and congestion ([10], p. 75).

Rehabilitation can be defined as a process whereby the built-up areas are improved according to a comprehensive plan that deals with the intensive development of certain types of land use. This process includes reducing population density and land tenure, removing and identifying dilapidated buildings, and providing essential services, health facilities, and preservation of property ([2], p. 100). It can be defined as the process aimed at improving the physical structures that suffer damage in some parts and lack of essential services and social services. It also means the procedures for treating old areas at the beginning of the phase of conservation, which maintains a large proportion of the good or repairable and reused physical structures, are adapted to meet contemporary requirements in order to rebalance those areas and ensure their continuity and relevance to time ([3, 4], p. 13).

Rehabilitation means a series of works through which areas, spaces, and buildings are improved through repair or development while preserving the parts of the building and its elements that carry outstanding historical, architectural, or cultural values through the ages that have passed since its building. Memory and mental and physical and materialistic presence mean finding a new function for the building so that it can be utilized and exploited, while at the same time ensuring its continuity and preserving it. The principle of rehabilitation can be adopted in areas where buildings are partially deserted, lacking internal spaces or green areas, and are highly organized, overcrowded, and underserved. They are concerned with raising the urban and environmental level of the urban fabric, heritage spaces, or even distinctive architecture ([11], p. 39).

8. Levels of rehabilitation

There are multiple levels of rehabilitation, which may be either a single building, a group of adjacent heritage buildings, or a heritage corridor in case of a group of buildings that represent a connection between one area and another, the rehabilitation of the entire heritage area in case of a complete area represents the urban heritage, which includes buildings and heritage corridors. Accordingly, we can illustrate levels of rehabilitation as follows ([14], p. 71):

8.1. Rehabilitation of building (building and location)

This approach in rehabilitation is the rehabilitation of the building or the group of buildings in their physical existence, so that the product is a new construction that physically either entirely or partially interferes with the building or the historical site and as a result of the rehabilitation process, dialectical relations between the past and the present occur, such as, the return of missing parts for a particular building, or the adding new parts to the building or site containing a number of historic buildings ([1], p. 92).

The process of a building rehabilitation itself leads directly or indirectly to the revival of the urban heritage surrounding it, and the degree of this process depends on the importance of the building and its role within the urban fabric and the importance of its function, which revives the building ([3, 4], p. 120).

8.2. Rehabilitation of a group of buildings (urban fabric)

This approach is concerned with the rehabilitation of certain aspects of the building or the group of buildings so that the output appears in new buildings, a link between the old and the new, and may have a certain type of physical relations of a particular style, and the rehabilitated side enters into new relationships within the new buildings and its previous relations. This rehabilitation process of a group of buildings represents the revival of urban heritage fabric and restores its function ([2], p. 11). The rehabilitation is based on two main aspects:

The first aspect is to revive the function of the building or the heritage fabric. The function may be outdated and it used to suit the needs of that era such as the traditional craft markets or planning for a new function that responds to the requirements of that era and works on attracting people to the fabric or heritage site because this outdated function was unable to attract people and revive the old fabric ([9], p. 63).

The second aspect is the preservation of the building or the heritage fabric and the preservation of its distinctive identity and the work to revive its heritage, and it represents the heritage aspect of the rehabilitation process.

8.3. The benefits of rehabilitation

The continuity of the historic building yields many benefits to society, such as ([5] p. 82):

1. **Urban benefits**: it works to improve the urban environment in which the inhabitants of the old areas live and to make it a safe and healthy environment that is suitable to the human by improving the style of uses and providing infrastructure services.
2. **Social benefits**: people and cities preserve their identity and social ties.
3. **Cultural benefits**: preserves art, architecture, and monuments.
4. **Economic benefits**: provides employment opportunities for residents of the old areas and creates centers to attract economic activities in those areas by encouraging investors and owners of capital and reuse of the existing building is more economical than demolition and reconstruction.
5. **Environmental benefits**: the old buildings are more environmentally friendly, because the traditional materials that were built from them, like clay, are natural materials that do not harm the environment.
6. **Benefits of preservation**: and maintaining the reconstruction of buildings through their function.

9. Mechanisms of rehabilitation at the individual or urban levels

9.1. Infrastructure system

The infrastructure is a system of facilities and techniques worthy of attention during the process of rehabilitation of urban spaces and heritage units, which provides users a sense of comfort. The system works as fully integrated with the rest of the components of rehabilitation to meet the requirements of spaces in terms of comfort, convenience, and requirements of security and safety ([14], p. 49).

It can be described as a set of interconnected systems and networks that represent physical and incorporeal aspects, societal needs, goods, and essential services. The physical infrastructure includes the social, economic, cultural, entertainment, and sports aspects that are necessary to provide an organizational structure, development, and sustainability of successful and productive societal systems ([14], p. 94). These include primary and secondary services, which are educational and cultural services, health services, entertainment services, works and public roads water, sanitation services, rainwater, solid waste management and treatment, energy services, green infrastructure, telecommunications services, transportation and security services, which are move as follows:

1. **The transportation of these systems' services moves vertically and horizontally on two levels:**

   - The level of individual buildings, where rehabilitation can be done by hiding the small parts within the walls, and the vast parts require allocating channels to contain them vertically ([5] p. 37), while technically small ones can be hidden within the floors while the large parts require false ceilings to hide. In some rehabilitation projects, it is difficult to enter such services because of the difficulty of manipulating the structure or because of the high economic costs associated with providing such spaces for putting this kind of services. Some interior designers rely on the means of transportation of these services to appear in pleasantly decorated courtyards in an interior environment ([14], p. 81).

   - At the level of the public spaces (external), rehabilitation is a complex operation and at the same time, it is expensive regarding materials and needs a long time as it is the first and necessary step in any process of rehabilitation of traditional spaces ([3, 4], p. 45).

2. **Electrical and communication services**

   - During the day, these sources of lighting work with natural lighting ([5] p. 44).

   - During the night, the artificial electrical lighting is effective in the lighting of the indoors and outdoors and for other purposes that may relate to the exterior of the building and monuments and different signs at the level of private and public spaces or for the purposes of movement or display at the level of public spaces ([5], p. 44).

   - Electrical equipment and installations: These include electrical protection devices, circuit breaker, wiring systems and cables, which deliver electrical power to all building devices, as well as, other electrical systems of the communications system, firefighting, and elevators of different spaces [5].

3. **Health services**

   This includes the supply of drinking water, irrigating, and the water pipe system within these spaces. Other systems may be added, such as water purification and desalination, especially water for conditioning and pumping systems, as well as, water's drainage services [5].

4. **Sewerage network**

   The restoration of the sewerage system, as it is often destroyed or severely damaged, and the rehabilitation ensure the preservation of the safety of the buildings, which promotes their sustainability in a proper manner and reduces the expected and probable destruction caused by damage and deterioration of the network, and in addition to what affects the spaces, especially the streets due to the damage of tiling and paving, and what is reflected on the rest of the services and activities that have an effect on the overall effectiveness of the urban spaces and the inability to represent them in an appropriate manner that achieves the greatest ability to invest these spaces and activate them according to what is planned (**Figures 7–9**) ([6], p. 88).

Figure 7. Sewerage network.

Figure 8. The lighting.

Figure 9. The transport services.

5. Transport services

The importance of dealing with transport within the public spaces and streets is a matter of concern because it has a significant impact on the effectiveness of these spaces. The first step to be taken is to cancel and prevent traditional means of transport to pass into the

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heritage spaces because they cause pollution, damage, and confusion of the complete rehabilitation and development. The use of nonpolluting transport means that rely on electrical energy, such as, electric cars and vehicles, as well as, traditional transport means, such as, horse-drawn carts and various types, sizes and shapes of bicycles that give esthetic and nontraditional touches, which enhances the recall of the collective mental memory of the place and thus supports the material and physical memory and adds to the human soul of joy. This requires the use of various kinds of barriers (the fixed and moved ones) that allow the wheels to pass when necessary (the apparent and hidden ones) with modern forms that add elegance and beauty to the spaces and works to restrict the traffic in general, which allows at the same time the service vehicles such as cars for the transport of materials and goods to some shops within heritage spaces, as well as, garbage truck for cleaning and transport, emergency cars, ambulances, firefighting trucks and other necessary vehicles to sustain life within these heritage spaces ([5], p. 82).

6. **Agriculture**

   The rehabilitation of spaces requires putting monuments, development, and creation of the requirements and making green spaces that suit with the capacity and importance of some places and panting them in different ways to achieve many aspects, firstly, esthetic, psychological, and environmental comfort [5].

9.2. Materials and quality of details

The use of local materials such as bricks, stones, marbles, and woods can be the used in modern building technology. Nowadays, many things have changed, as many different methods and styles of production materials in the stores. Building's materials play an essential role in creating visual homogeneity and contrast between heritage buildings and adjacent modern buildings. Building materials are an essential element to the sense of belonging to the surrounding environment ([8], p. 94).

Because the essential issue of the building is façade which reflects many properties such as texture, color, and its suitability for reflection and absorption of light. The designer's task is to know the characteristics of the surface and the properties of the used materials and their techniques and the ability to form the elevation mentally with their materials and colors. The materials cannot be visualized unless you see it to be used in many buildings or models. The expression of architecture and raw materials, which are used in construction is the privacy of the place where the cities were built at that time ([10], p. 34). Robertson confirmed that the change in the use of materials leads to change the characteristics of the urban landscape of the heritage areas. This change has not only occurred in the architectural style but also has weakened the sense of locality and identity, thus weakened the local architectural character due to the development of transportation and communication, which helped to use global materials instead of local materials that have particular traditions, but the impact of local materials remains strong in promoting privacy and identity ([12, 13], p. 54).

The use of nonlocal materials has led to the diversity of architectural forms according to these materials; they are distinguished by different properties from traditional materials, due to their different properties and nature, and thus led to visual and expressive changes that were not previously familiar with local architecture, especially in color and texture. The buildings were characterized by smooth texture and flat surfaces in the 1950s, 1960s, 1970s, and 1980s representing the orientations of global architecture. The harmony between architecture and society in previous eras belonged to the fact that the society possesses and absorbs the techniques of that era. This society produces these techniques and is not an emergency case ([3, 4], p. 23). The details and their quality sometimes play a more important role than the building materials themselves, as the presence of uniform details in adjacent buildings gives greater flexibility in making changes in color, materials, texture, the height of the building, etc. Moreover, the difference in the quality of details is related to the movement of the viewer and speed ([9], p. 69).

Use of the smallest architectural vocabulary for details: The composition is achieved through the use of repetition, which is determined by the use of structural materials and colors, in addition to the selection of one shape and one material ([12, 13], p. 54). The use of the highest architectural vocabulary for details: The visual formation composition is obtained through the highest use of elements and architectural details, which represents the nature of the individual who moves inside the complex and the simplicity to analyze the information within (**Figures 10** and **11**) ([12, 13], p. 54).

9.3. The floors

The floors are the link between the buildings and between the spaces. It also represents the surface between these elements in the urban landscape, as well as, being a place for walking and waiting for pedestrians and cars. The floors have two primary purposes ([3, 4], p. 145):

- Functional purpose: Multiple models of behavioral patterns, pedestrian movement; waiting; seating, children's play yard, or traffic.

Figure 10. Materials and quality of details.

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Figure 11. The effect of agriculture.

- Visual purpose: Floors work as an esthetic element to connect the various buildings and determine the space confined between them as a space of rest or movement of pedestrians and cars.

9.3.1. Characteristics of the shape of the floors

The shape of the floor surface is one of the most important characteristics that affect the overall structure of the building and the urban landscape. The difference in the surface shape of the floor occurs as a result of the difference in the relationship of the surface level of the ground with the horizontal level, as well as, the ground level's location with regard to level of view, gives this difference in the forms of floors, for the level of view the following cases ([10], p. 86):

- Floor with level of view
- Floor below level of view
- Floor above level of view

Each of the previous cases expresses meanings and feelings and works to form the relationship between the place and the human; it can be divided into two basic types: horizontal floors (one level) and floors (multi-level) ([10], p. 63)

9.3.2. Horizontal floors

The most important features are:

- Less specific to organize and arrange the elements in different ways whether free or regular ([1], p. 116).
- The sloping or curved floors of the outer spaces are more impressive and distinct than the flat horizontal floors where the limited vision range makes discovery more difficult ([1], p. 117).
- Ease and freedom of movement on the horizontal floor, especially when changing direction while moving or visually, as well as, easy to control the vision both in moving objects around us, and vision of moving things ([1], p. 118).

The problems of flat floors, especially if extended, are visual boredom, especially when the urban landscape lacks apparent attractions ([1], p. 118).

9.3.3. Multilevel floors

They are divided into the following types ([12, 13], p. 54):

- Simple slope floors.
- Floors with a steep slope.

9.3.4. Treatment of floors surface

The nature of the used materials in the construction of the floor works on giving the final appearance and can be confined to ([12, 13], p. 111):

- texture
- color
- divisions

9.3.5. Floor texture

The texture helps to determine the type and speed of movement. The flat concrete floor helps to increase the speed of walking, while the rugged floors oblige the person to move slowly. The materials should be chosen with an appropriate texture, and thus it is necessary to choose materials with a texture that suits the type of movement whether fast or slow with attention to the safety factor in the design of the texture of the floor. The floors are divided into two parts depending on the texture ([3, 4], p. 94):

- Floors with a soft texture.
- Floors with a rough texture.

9.3.6. The color of the floor

The shape, proportions, relationships, and characteristics of architectural elements are greatly influenced by the color of the floors. The choice of flooring colors should be subjected to some of the essential considerations ([12, 13], p. 54):

- Although light color values help spread light, however, they do not fit with dust, dirt, and footprints.
- Floors with dark colors, unsuitable, where footprints appear more pronounced, so the most appropriate colors are those with light gray values.

9.3.7. Floor divisions

Divisions affect the identification of movements, facilities, and different possibilities. The movement on the ground is determined by the movement of the receiver in an innate manner between the buildings, and the extension and homogeneity between the elements, and these divisions can be inspired by the spirit of the place ([12, 13], p. 68).

The floors play an essential role in the process of understanding the urban landscape within the heritage spaces, achieving visual pleasure, surprise, directing attention to famous buildings, breaking the visual boredom, creating a state of diversity and suspense in the urban landscape and connecting building blocks visually.

9.4. Trees and plants

Trees and plants play a significant role in organizing the urban landscape within the heritage spaces as one of the natural phenomena of nature that captures the human admiration and enchants them in their renewed colors with the seasons of the year, beauty, diversity, and natural effects that bring pleasure to person.

The design of urban landscape is a work of art when its elements are properly organized in an esthetically pleasing composition. Plant and tree designers are influenced by site characteristics and architectural elements when designing outdoor spaces and green spaces ([7], p. 57). When designing, it is necessary to consider the following elements and characteristics: identify lines accurately on the site, form, texture, color, scale, proportions, and unity. Moreover, taken into consideration the characteristics of the used architectural elements, such as walls, fences, walkways, outdoor terraces and all other elements, they cannot be separated from the esthetic and functional considerations of plants. All elements are taken to form a whole homogeneous, just as the melodies form musical instruments in a homogeneous unit within the symphonic band to produce an enjoyable vocal output ([2], p. 90).

In addition to the elements of design, consideration must be given to the functional characteristics of plants, such as the work of visual and physical barriers, climate control, and reduction of soil erosion ([12, 13], p. 76). The artistic influence of external spaces is experimented in a variety of ways, so that the viewer usually interacts with the event by passing through these spaces and taking a position through, around, above, and under its elements, which creating diversity through the vistas emergence and its disappearance.

The esthetic pleasure of the senses remains and is compatible with the function and the physical environment, since the green elements (plants) have a set of characteristics that contribute to the formation of the landscape of the external urban spaces, and these characteristics are the form, texture, and color. These properties also contribute to find line, mass, diversity, repetition, balance, and assertion. Moreover, they are important to consider the final size of the growth of plants compared to the space to be occupied and then its relationship with the size of a human and the rest of the elements and buildings within the surrounding. The importance is in the following (**Figures 12** and **13**) ([12, 13], p. 76):

1. Linking buildings visually and closing spaces between them, as well as, optical connection between buildings and the site.

2. Determining the features of spaces and streets.

3. Achieving privacy through its work in defying vision.

Figure 12. Using plants in re-habitation places.

Figure 13. The floors.

4. Protecting from wind, dust, and heat of the sun.
5. Confirming the moving and visual axes in the direction of the viewer.
6. Framing the vision toward the crucial scenes.

7. Creating variation in shape, color, and texture with buildings.
8. Achieving visual integration with adjacent blocks.
9. Achieving visual diversity through changing and moving shadows, as well as, changing colors throughout the year.

9.5. Street furniture

All elements of the street reflect the importance of visual impact on the importance of functional, which is as considered one of the primary components and the critical scene of the city and its streets ([3, 4], p. 75). The formational components play a role in the urban planning process which works with the surrounding buildings to unite the place, as they are components with elements such as booths, fountains with their sizes, fountain basins, flowers, and stationary street furniture ([7], p. 83).

It is worth to mention that there are no specifications and fixed determinants of street furniture and they are different according to the street and its characteristics from one country to another, but in general, there are essential customs that must be taken in the selection of street furniture; they are ([5] p. 100):

- **Scale**: The dimensions of street furniture and the area it contains.
- **The site** for the viewer: achieving the best esthetic and visual properties and serving the visual angles of the scenes. In general, the used colors are neutral to the most of the elements unless the function requires the opposite of it, and the finishing materials and the methods of connecting the elements to the different surfaces of the street are essential to create a feeling of belonging to the street scene as a whole. Street furniture can be divided into:

A. Signs

They are symbols or signals placed in specific places to convey information to street users. These marks are classified as follows ([12, 13], p. 76):

1. **Identification sign**: these are the signs that carry information that defines the type of activity or function and its names, such as, private building, stores, etc., and represents the most critical type because of its remarkable presence in the commercial streets ([2], p. 90).
2. **Directional signs**: it relies on the use of signs (arrows) to direct road users to event sites and services, such as traffic signs ([2], p. 90).
3. **Orientation signs**: they are signs that represent information regarding the time and venue of the events of different types ([12, 13], p. 76).
4. Prohibitory and warning signs.
5. **Official notices**: they represent precise information in general that requires signs of the significance of the following ([2], p. 90):

- The simplicity of expression and using signs instead of letters as much as possible.
- They have standardized forms including the fixation method.
- Their dimensions are commensurate with their function or the importance of their information.
- Be visible through the day and light at night.

The uncontrolled use of signs and identification of various activities in the streets of the city make the receiver to feel confused and also distorting the urban environment of the street ([5] p. 100).

B. Lighting

It has been used for street lighting, areas, and open spaces since past for safety and lighting, and can be classified into two types ([2], p. 90):

1. General lighting: such as fixed poles for streets, squares, and traffic signals (controlled).
2. Special lighting: the lighting of buildings and trade exhibitions.

It should be noted here that the poor distribution of poles in the streets of the city reduces the importance of the scene and the effectiveness of its use.

C. Pedestrian roads

The design is influenced by standards related to the quality of the used materials and colors. It is preferable to use bright colors because they do not fit with the open places where the footprints appear. Therefore, it is preferable to use nonslip gray piles. In vast areas, appropriate patterns and layouts are made to minimize boredom due to the large areas which they lack in the Arab heritage cities while they exist in the western heritage cities, such as the Plaza in the cities of Roman and Agora in Greek cities (**Figures 14** and **15**) ([7], p. 83).

Figure 14. Sings in streets.

Figure 15. Lighting.

D. Seats and sitting places

Sitting places represent one of the essential components of the street, and their shapes are affected by the nature of the used materials, and must have standard specifications related to the dimensions of the human body, and must be located in places away from traffic so that people can enjoy ([12, 13], p. 76), rest, and observe the various events, as well as prefer to be shaded by a number of sun shades and shading facilities to protect people from various weather conditions ([5], p. 100).

E. Plant containers and trees

It is essential to define spaces and achieve containment; also, plants and trees have value and an esthetic and symbolic importance through their psychological and visual effects. Trees and plants with their various sizes, bodies, and colors give a sense of joy ([5] p. 100), vitality, activity, and psychological comfort to the street users. Also, it improves the image of the urban scene by organizing its sites parallel to the street or in front of the ruined buildings or places with undesired scene, as well as it provides shading and a protected environment for street users, and the choice of plants and trees in the street depends on ([7], p. 83):

1. The characteristics of the street and its harmony (shape, color, and texture) which fit with surrounding components.
2. Performed function.
3. The appearance during the stages of growth and seasons of the year.
4. Their symbolic value.
5. The required maintenance costs.

Figure 16. Seats and sitting places.

Figure 17. Plant containers and trees.

F. Bus stops

These components, play an important role in giving a distinctive character of the place or street, where they must be the used and structured the street outline based on the right

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foundations and in harmony with the character of the urban scene to be distinctive sensually and visually ([5] p. 100). The most important characteristics and productive relationships can be confined to achieving the state of continuity and harmony between the buildings and the rest of the elements that provide the overall picture of the urban scene. It should be noted that relations are not constants ([5] p. 100), but are subjected to change, and the ongoing budget that requires the designer to take into account depending on the location and its nature and physical characteristics, and these relations are classified as characteristics in two directions (**Figures 16–18**):

1. The first direction: it is the relationship and control that contributes to the process of creating homogeneity, harmony, and continuity of the visual context of buildings and adjacent blocks to achieve a visual structure which is coherently visual and compatible with each other and with all ([5] p. 100).
2. The second direction: it is the formal relationship and esthetic addition that achieves visual and psychological pleasure, where they play a role in creating a formal expression and giving a coherent urban image to adjacent buildings with the other elements (complementary parts of the structure of the urban scene) ([12, 13], p. 76).

Figure 18. Pedestrian roads.

Figure 19. Landmarks.

G. Landmarks

There are useful components in the streets, squares, and spaces of heritage that sometimes give a personality of the place (the area sometimes takes the name of the landmark or vice versa); some examples of these components are gates, monuments, and clocks or the transfer of distinctive trees in their qualities or ages and other components ([12, 13], p. 76).

The journey within the heritage spaces can be an indefinite experience ([7], p. 83), lacking the sense of place and time if the structure of the place is clear and transparent, where the vision can be achieved from different locations, and this helps the traveler to guide his behavior in the environment and heritage spaces ([2], p. 90). The landmark can achieve this function in different ways, and the landmark can be appealed to the field of vision to guide the road and then disappears and reappears as a visual reference to guide precisely to the road, and in other cases, the precise construction within the field of vision is essential by seeing within different trips and in various ways helps to gradually build the mental image of the viewer in the heritage spaces ([5] p. 100). Some buildings, such as the mosque, the church, and other religious buildings, are located in a clear location, for example, on the top of the hill and they can be seen from different roads and locations and guide pedestrians and vehicle riders to know the road in heritage spaces and environments (**Figure 19**) ([12, 13], p. 76).

10. Conclusions

1. The most important policy in the revival of heritage areas is the rehabilitation by preserving those heritage areas with their fabric and buildings or to restore them to a proper form that harmonizes with their identities regarding materials and design and then reoperating these heritage spaces in a way that achieve benefits and preservation.

2. The heritage spaces are spaces with different functions and activities that are overlapped with each other, such as, cultural activities, tourism, entertainment, marketing, commercial,

etc., which necessitates to find different strategies and mechanisms to promote these functions in order to achieve higher efficiency, benefit, development, and higher investment in those spaces that is appropriate to the aspects, such as architectural, esthetic, utilitarian, economic, cultural, social and entertainment in those heritage spaces.

3. The use of sustainable means of transportation which does not consume fuel and does not cause pollution, such as horse-drawn carts, electric vehicles, and various bicycles, as well as, walking in the heritage spaces that would strengthen the connection of individuals with the place and the achievement of social aspects as well as the promotion of spatial affiliation and feeling the spirit of the place, which adds joy, pleasure, and a sense of psychological comfort in the tours.

4. The occupancy of heritage spaces in several functions, whether esthetic, cultural, social, economic or environmental, increases the effectiveness and performance of these spaces positively and supports and promotes the principles of sustainability and development, which are essential goals in the contemporary architectural and urban planning trends.

5. The revival and rehabilitation spaces in the heritage areas require the creation of points of visual attraction at the level of squares, green spaces, and spaces using the Landmarks, which gives heritage areas their identity and true privacy.

6. The style and diversity of covering the streets and spaces that are included in the heritage fabric harmoniously are one of the most critical points that give attractiveness and add contemporary esthetic touches that increase the effectiveness and glamor in heritage spaces.

7. The open spaces in the heritage fabric can be revitalized through the rehabilitation of these spaces to include green spaces, simple playgrounds, fountains, individual bodies of water or landmarks, as well as, monuments and statues.

8. The rehabilitation act of furnishing the streets and spaces in traditional areas and heritage spaces plays a significant role in their revival: ticket booths, food booths, ice-cream booths and seats; and even lighting lamps, if chosen in a distinctive and appropriate way with the heritage, may play a significant role in attracting tourists.

9. The revival of heritage spaces requires consideration, attention, and importance to be given to them by taking into consideration the proportions of what is added to the new fabric so that it does not lead to losing the importance of those buildings and heritage spaces as those spaces and buildings are the targets of rehabilitation.

10. It is necessary to pay attention to landscaping and adding green spaces in most heritage areas. It creates psychological comfort and gives points of attraction, as well as, the transfer of some trees of formal or age distinction makes them attractive points, also being landmarks within the heritage spaces.

11. The adoption of the rehabilitation strategy for heritage spaces enhances the functional, visual, and spatial integration and correlation within heritage spaces on the one hand and between the cities as a whole on the other hand.

12. By using mechanisms in the rehabilitation strategy of spaces, the coherence between the parts and components of the heritage spaces is developed and rehabilitated.

13. The revival of heritage areas through the rehabilitation of spaces with religious, spiritual, and educational characteristics, such as, mosques, churches, and schools, works in turn to preserve the spiritual and cultural aspects of these areas.

14. The revival of heritage areas in general and alleys in particular achieve general visual form.

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Chapter 13

The Relevance of Vegetation Series on the Maintenance and Sustainability of Public Spaces in the Southwest Iberian Peninsula

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Additional information is available at the end of the chapter

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Abstract

City and countryside, by their mutual dependency, constitute a unique system, which is the basis for the development of a global landscape. This interaction is far from the country being simply the city's food supply. The interaction should be reinforced through ecological corridors allowing the biodiversity movement that guarantees the landscape identity. In this regard, life's standards are strictly related to the landscape quality. Moreover, landscape biophysical features determine the vegetal potential and consequently their uses and techniques adopted by man toward his territorial settlement. Contextually, two Iberian case studies have been selected and analyzed from a multidisciplinarity perspective, aiming to determine how vegetation series may influence the maintenance and sustainability of urban green spaces. Bearing this in mind that a landscape architecture project is dynamic and considering the fourth dimension: time—mainly regarding the vegetation development, creating new volumes and spaces-considering their natural evolution, a deep knowledge of the plant material is seen as a critical factor for a sustainable landscape planning at several levels.

Keywords: biodiversity, geobotany, landscape identity, native vegetation, sustainable planning

1. Introduction

Plant material is the main tool for landscape construction used by the landscape architect, so, in-depth knowledge about it will necessarily express the quality of the project [1]. Thus, it is up to the landscape architect to plan the territory regarding human's necessities, considering landscape identities. With this in mind, the phytosociology knowledge is pivotal as an auxiliary science [2], which is critical for the understanding of the evolution and establishment of native vegetation typologies among territories [3].

In this regard, the Mediterranean Basin represents one of the *hot spots* of biodiversity at a global scale [4], with a rich endemic flora. So, it should be highlighted that the Iberian along with the Micronesian Islands represents more than 50% of the European floristic diversity providing a large range of plant materials possible to use in public green spaces.[1]

Nevertheless, renowned landscape architects—i.e., [5–8], among many others—have demonstrated concerns regarding the adaptability of plant material to edaphoclimatic local features—plant selection and their landscaping potentials for a particular territory. During modernism, where the ecologist movement had a greater expression [1], a smooth interventionist mindset shift occurred, leading to a higher artistically and scenic approach. Such changes reinforced by the work of [9], included the following concept: "a Garden is a masterpiece, it is not done, it is created from the existent."[2]

Recently, several questions have been raised regarding a sustainable resource management and city's sustainability [10, 11]. In this regard, should be highlighted the case of reducing of fossil fuels and promoting new energy sources — renewables. In this regard, the reducing of costs in urban territories—such as the reduction of urban green spaces and their water management—is one of the major's challenges to achieve sustainability and the so-called smart cities [12].

In the present work, two case studies have been chosen where a model of climatic vegetation series and their replacing steps is presented. Each series is set targeting topics such as synchorology, community, bioclimatology, dynamic, and essential bioindicators for each replacing step—where each one builds up about those surfaces several climatic vegetation series.

Afterward, geographical and phytosociological knowledge is applied regarding Iberian landscape architecture projects—where an analysis is performed aiming to obtain a well-adapted floristic set concerning local edaphoclimatic features. Thus, the plant material chosen should be considered not only at the level of plastic and ecological features, but also regarding a set of functions to be performed (by the plant material) in the landscape configuration and design.

The study consequentially intends to demonstrate how multidisciplinarity fosters a better project as well as increasing the city's sustainability—considering the interactions of phytosociology and landscape architecture [3].

2. Vegetation series: methods and principles

The vegetation cover of Iberian Peninsula is far from its pristine state [13, 14], when it was dominated by the *Querci* [15]. The anthropic action in these areas is mentioned as far back as

[1]Piet Oudouf, in one of his travel over the Mediterranean, listed plants in the United States of America, a typical grassland of the Mediterranean world – the *Stipa gigantea* Link. Still, it is not used in Mediterranean gardens. In the same line lies the case of the *Narcissus scaberulus* Henriq., living spontaneously only in Mondego's Riverbanks, which has been carried to Central Europe where it is valued as an ornamental species.

[2]Also, Raposo-Magalhães (2001) highlights the relevance of well-known ecological features of native vegetation for an integrated landscaping intervention. So, biogeography should consider fostering an increase in the landscape identities.

before the 8th century BC [16]. Since then, man has been changing the landscape for his own benefits, shaping multifunctional landscape patterns, multiple production areas, particularly for cereal culture (ager), grassland (saltus), and forest (silva) [1].

In the beginning, clearings have been developed in existing woodlands in order to create grazing areas for cattle [15]; furthermore, arable areas of agricultural production have also arisen. Thus, a heterogeneous landscape should integrate principles and practices of protection, production, and recreation [10], ensuring their sustainability. Nevertheless, with the population growth, there is a considerable tendency for the separation of "rural" and "urban space"; still, it should be taken into account that the landscape must be understood as a whole [17] through the concept of global landscape—where city and country depends on each other, being part of the larger system [18]. Such link must be reinforced by the *continuum naturale*, allowing the movement of urban biodiversity and contributing to the balance and territorial stability [17]. So, interventions in public spaces must have unifying elements, in order to avoid distortion of place features or lose the *genius loci* [19].

The best extracted information about the natural vegetation cover of each territory is provided through vegetation series (or *sigmetum*). This concept consists of a set of plant communities in different stages, occurring in a homogeneous physical space [20]. These communities could present a reverse or progressive dynamics depending on their maturing state [21]. Vegetation series is always associated with the head of the series, which corresponds to the maximum development, also known as potential natural vegetation, and often compared to their pristine state [22]. However, when anthropic action ceases, the vegetation growth depends on local soil and weather conditions, during a certain period of time, until it reaches floristic stability. The identification of a specific plant community—that is repeated on some territory in ecological and floristically situations—allows the application of specific SIGMA methodology[3] aligned with the phytosociological inventory, intending to describe a new vegetable association ("syntaxon") [23].[4]

Consequently, phytosociology science has developed a system of associated interpretation, analyzing the relationships of several geographical series of contiguous vegetation [24]. The *geosérie* or *geosigmetum* is the basic unit of geography and phytosociology, which represents the set of contiguous series of steps, or a mature determined topographic unit (typically a set of situations in ridge, half a hillside and valley) within the same biogeographical unit [21] (**Figure 1**).

Climatic series depend only on the direct precipitation of rainfall in a specified location, while the edaphic series are the result of peculiarities of soil and topography morphology, which in time are divided into edaphoxerophile—dry areas with weak water retention in soil—and edaphohygrophile—depression relief areas that receive waters from upstream, usually associated with waterlines [21]. Through this, each type of vegetation can add different series of potential vegetation, as is the case of the west Iberian territories, where the edaphohygrophile vegetation consists of an alder wood (*Salix* spp. and *Fraxinus* spp.).

[3]SIGMA: Station International de Géobotanique Méditerranéene et Alpine.

[4]This concept was first introduced by Flahault & Schroter in 1910, at the Brussels Botany Congress and since then, the association came to be regarded as a basic unit of vegetation, contributing to the advancement of phytosociological science.

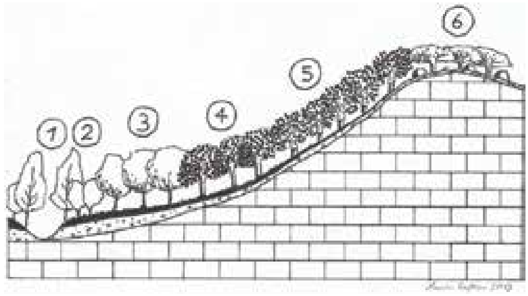

Figure 1. Representative scheme of the predominant series on the Iberian Peninsula. Edaphohygrophile vegetation: 1—*Alnus lusitanica*, 2—*Salix atrocinerea*, 3—*Fraxinus angustifolia*; Climatic vegetation: 4—*Quercus broteroi*, 5—*Quercus suber*; and edaphoxerophile vegetation: 6—*Quercus rotundifolia*.

Several landscape architects have contributed to the appreciation of native vegetation cover [2, 3, 7–9, 21, 25]. A growing attention for ecological issues has contributed significantly to the development of the identity of the landscape and of the intrinsic characteristics of each location. Serving as proof, the property of the Foundation project McConnell in California (designed by Peter Walker and Partners in 1978) where several degraded areas of dry and wet environments were recovered using the native perennial herbaceous.[5]

Relevant phytosociological concepts for the interpretation of vegetation series on landscape, such as a schema type for vegetation development during a period of 40 years (**Figures 2–6**), were prepared by the landscape architect Gilles Clément [7], representing an awareness of the evolution of the vegetation series in space and time. This methodology evidenced the importance of knowledge of plant landscape architecture dynamics, where each figure can resemble a vegetable, belonging to the association, in this case, vegetation series.

Shrubs—of greater longevity and lower maintenance and fewer costs for the garden—can be found spontaneously in areas of higher development of vegetation cover, belonging to banks or replacement steps, closer to the potential woodland formations. These are typically dominated by dry plants and also considered as *maqui scubland*—i.e., A*rbutus unedo, Rhamnus alaternus, Myrtus communis, Viburnum tinus, Prunus spinosa*, among many other species. However, the soil erosion in some areas of the Alentejo Region has hindered the natural regeneration of these plants, due to the scarcity of deep organic substrates. Under sun exposure, it forms communities of shrubs—away from the hood, belonging in the study area to classes of *Cisto-Lavanduletea* and *Calluno-Ulicetea*. However, these plants show higher growth rates, forming woody shrubs in few years, leading to a high propensity of wildfire events.[6]

Most of the literature review analysis regarding vegetation series was made through the work of [26], which gathers the majority of vegetation series existing in the Iberian Peninsula.

[5]Also the garden of the Calouste Gulbenkian Foundation in Lisbon has undergone some changes in the used species.

[6]For example, the *Lavandula genus* if not pruned, in a few years may, shows an aged appearance—leaves only at the ends of the branches, decreasing the ornamental interest. This behavior may be explained by the remote replacement steps from the ancient woodlands—that aim a rapid supply of organic matter to the soil, in order to allow the establishment of a more demanding plant regarding soil (during the mature stage).

Figure 2. Year 0. Derelict landscape with some prime-colonizing herbaceous [7].

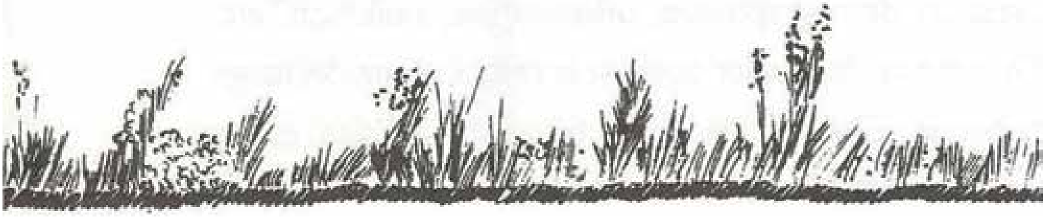

Figure 3. Years 1–3. An agricultural soil—after the abandon, leads to a meadow; otherwise, is preceded by a pre-meadow of bryophytes [7].

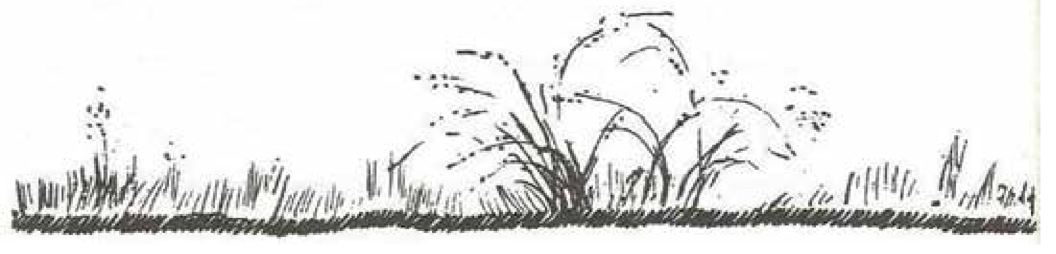

Figure 4. Years 3–7. The meadow is occupied by scrubs—mainly thorny [7].

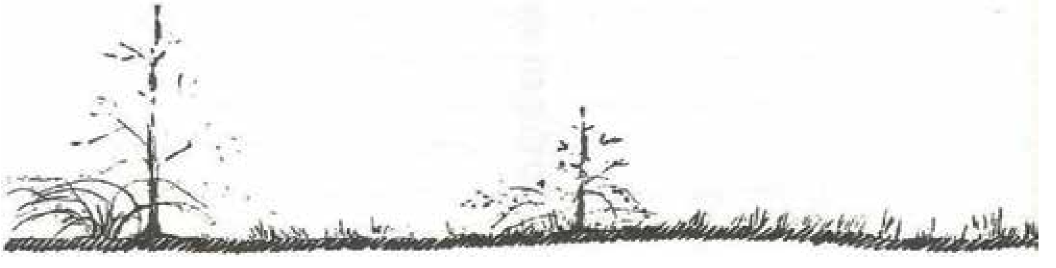

Figure 5. Years 7–14. The grassland area increases in relation to the grassland. Small trees start to emerge [7].

Through the knowledge of territorial potential vegetation, it was possible to propose a set of plants that are well adapted to and most suitable for different soil and climatic features. Phytosociology can thus be used in different project phases. At a first phase, the bioindicator plant can be used as an interpretation tool, providing information related to the study area—i.e., the potential vegetation series and its perturbation state, existing substrate type,

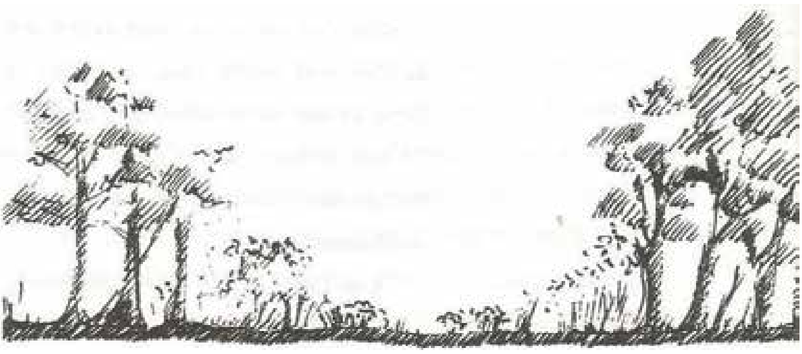

Figure 6. Years 14–40. The tree shade inhibits the growth of the shrubs that at first protected them [7].

and thermoclimatic. In the proposal phase, and based on the abovementioned conditions, it is possible to propose a set of plants based on the different associations of vegetation series identified, through the consultation of phytosociological inventories.[7] Faced with a set of plants well adapted to local edaphoclimatic conditions, it is now easier to select them suitably according to their functions and their morphological, chromatic, and aromatic features and in different aspects such as volumetric, texture, time, and duration of flowering, color, aroma intensity, among many others.

3. Mediterranean flora and vegetation: a brief description

Mediterranean flora is quite unique, it adapts to dry and hot summers and relatively cold and damp winters, predominating evergreen trees and shrubs, resisting in the dry and hot periods through the dormant and numerous morphological adaptations [27]. It is typical of Mediterranean vegetation, i.e., thorny bushes with reduced leathery leaves and covered with varnish on top or at the bottom, as strategies to prevent the water loss during the warm months [27].

From a historical perspective, the several geological events and climate changes—particularly during glaciation *eras* allied with long periods of low temperatures, and also increased precipitation periods—indorsed the offset, and subsequently, the adaptation of a great number of plants. Through successive adjustments over time, some of these plants have become endemic in these areas. One of those examples is the case of *Juniperus navicularis* dating geologically to the Pleistocene [28], whose genetic ancestors, due to their morphological similarities, thought to have belonged to *Juniperus oxycedrus*.[8]

From the five existing macrobioclimatic classifications on Earth [29], the Mediterranean macrobioclimate is the one that offers greater diversity of bushes. These territories are characterized

[7]At this stage, it is still important to distinguish typical “deep soils” substitution stages, usually of superior ornamental interest and greater longevity, from “eroded soils” plants, some of them colonizing plants with less longevity.
[8]Species still present in the Tejo’s International Natural Park and in Douro’s Valley.

by a perennial vegetation, where the deciduous elements only appear in the waterlines. Regarding to landscape, vegetation is dominated by oleasters, oaks and cork-oak forests, and other oak marcescent/leaf, distributed according to the mesological gradients. Even small changes in topography originate differentiated conditions that interfere in the vegetation dispersion patterns [30]. In the southwest Iberian territories, the dominant vegetation is made up of *Quercus suber* and *Quercus rotundifolia*.[9] According to Caldeira-Cabral [2]: “The Portuguese flora is characterized by the beauty and color of its flowers, finding your height above all in spring and autumn.”

The four main replacing stages of these vegetation series are based on: preforest bushes, groundcover vegetation, heliophiles bushes, and perennial groundcovers, which changes depending on the degree of anthropization and land use. The first stages of replacing these *Querci* formations are represented by preforest bushes of *Ericion arborea*, usually dominated by *Arbutus unedo*. As a second step of replacing, appears a *lategraminetum* dominated by *Stipa gigantea* that remains through the extensive grazing. Soil degradation promoting the appearance of heliophiles bushes dominated by communities of *Calluno-Ulicetea* and *Cisto-Lavanduletea*, where most of the plants belong to the genera *Lavandula, Cistus, Ulex, Stauracanthus, Erica, Pterospartum, Halimium,* and *Thymus*. In advanced replacement steps, the therophytic meadows referring to the *Tuberarietea guttatae* class appear.

4. The southwest Iberian context

The *herbaceous stratum* and due to the existence of a well-defined dry and hot season during the summer—reaching high temperatures—the meadow dries on the final of the spring season and perennial plants spend summer in a vegetative rest state, conferring them no vitality. Aiming to overcome this scenario, lawns and meadows are irrigated; however, water costs are quite high (especially to municipalities), aiming to keep the *herbaceous* cover always green [31]. So, from a sustainable perspective, it is totally discouraged to support these irrigation costs for several months. On the other hand, the shrub *stratum* offers a large range of plants and also provided the possibility to create different floristic aggregations, through different morphological features that plant material presents in these territories.

In landscape architecture, different spaces are designed through shrub and tree *stratum*, where the relationship between “full and empty forms” two basic components for defining the space. Only through such synergy—with volumes and their respective limits—these types of space appear [1], among them are

- *Closed space*—defines what is occupied by dense vegetation, both at the tops of trees levels and massive woodland species;
- *Open space*—characterized by the lack of vegetation or by the form of coating, such as clearings lined with meadows or lawns. However, limited by the distance;

[9]Also, *Quercus broteroi* and *Quercus pyrenaica* are possible to be found in mountains or valleys.

- *Unlimited space*—the boundaries are so apart that the user does not *feel them*;
- *Punctuated space*—contains a number of elements scored in open space, where they can be made up of trees or bushes;
- *Compartmentalized space*—an open space consisting of vertical planes, made by trees or hedges alignments.

Trees are the structural elements in the landscape, where their *grandeur* and number contribute to unify the spaces. Their value increases with age and many of them exceed the lifespan of most buildings [32]. The density of trees, the height of their cups, and the leaf typology (persistent/deciduous) contribute through light filtration to create different ambiances in the space. The large trees are superlative to define the structure and serve as open space framework [6]. When they are used separately, it creates focal points increasing their value in function of their size, shape, and color; on the other hand, when used as bushes scenario (with all of their elements developed), it is able to comply with its protection functions, production, and recreation [33].

The shrub *stratum* volume also influences the brightness—mainly due to their smaller dimension, standing between the tops of the trees and ground [32]. In fact, some elements have bush features (resembling geometric shapes), i.e., *Teucrium fruticans* similar to a semi-sphere. Shrubs are responsible for defining most of the limits, enabling to create volumes of physical and visual restraint. On the other hand, the *herbaceous stratum* provides open spaces—i.e., lawns or meadows. However, some of them with higher presence are used in compositions along with shrub elements. The case of *Stipa gigantea* (typically Mediterranean) is one of the plants used and suggested by [34]. Climbing vegetation can act as ground cover. Nevertheless, when supported by these structures, they are able to create barriers as shrub stains or integrate shade structures.

In open spaces, and using different *strata* of vegetation cover, four limits of typologies can be defined such as:

- *Permeable boundary* can assume variable degrees, requiring the opening of small spaces that will ensure and determine the permeability degree through regularities and irregularities of those spaces. This limited typology ensures some visual permeability, but not necessarily physical.
- *Closed boundary* is defined as a mass of dense vegetation, can be materialized, mainly, by the shrub *stratum*, forming visual and physical containment.
- *Open boundary* is characterized by small elements. In this way, there is a free pedestrian circulation with considerable load capacity and visual range.
- *Open contained boundary* consists of low-sized elements (bushes whose height does not exceed the *eyeline* of the user) constituting only a physical barrier [1].

The shape can be worked with various purposes—referring to the lack of two-dimensional objects—and the seizure of the form is made through the outline. In isolated elements—in extreme weather conditions, as in mountain areas or coastal that is exposed to strong winds—the vegetation can assume different configurations. In other cases, the form is crafted in order to create sculptural forms; thus, the relevance of a given element into the space is proportional to their dimension.

In Mediterranean flora, it dominates fine texture plants and occasionally spiny plants. High temperatures allied with the low precipitation patterns during summer are reflected by several plant modifications to these conditions [27]. Fine textures are typically of heliophile plants such as *Halimium calycinum*, while coarser textures are verified in prewoodland vegetation, such as *Viburnum tinus* and the *Arbutus unedo*. However, the composition based on texture has greater sense in small areas, where it is possible to capture such details. In larger areas, the scenic space apprehension does not focus on texture; in fact, it gives priority to vegetation masses of shape and color.

There is a greater diversity of plants and blooms in shrub and *herbaceous stratum*, so their association will be pivotal to a well-visual reading and understanding of the space. However, the color should play a supporting role regarding species form [8], despite being the main reason why people are interested in plants. There are several possible colors to conjugate from the plant material; therefore, treatment has been an object of study to determine the best chromatic association [35].

In a considerable color diversity scenario, there may be a reduction in the seizure of each one of them, due to the phenomenon of *contagious* with neighboring colors, where there are three main ways to deal with color [35]. In the case of working with the same textures, a more attractive combination can be used, such as *Nerium oleander*—with pink flowering and its variety *Luteum Plenum* with yellow flowering. Red is one of the most used colors for rhythm and punctuation of spaces, due to strong contrast with green patches [8]. The yellow can also become strong when used in excess; nevertheless, when used in transition areas can emphasize that *passage*. Therefore, it is easier to combine large numbers of light colors, than strong colors. For example, pink is easily combined with other colors, can also function as a connecting element among other colors—red and white, white and blue, or blue and violet. Blue is used to give a sense of depth on space, placed on the rear or on the edge of a planting area [8].

The result of any intervention in landscape must respect the following principles:

- *Unit* is set to the apprehension of space as a whole and not as a set of interventions carried out separately and without any links between them. Each intervention should be framed in a space with certain features, which define the character of the place. Thus, the plant material can be the main contributor to this spatial unit, where the principle of dominant species has great use potential.
- *Simplicity*—a principle that aims to facilitate space apprehension through a balanced composition without great exuberance and, therefore, easy to visually read.
- *Diversity*—is implicit in all nature where there are a number of different ambiances, given by color contrast, texture, the relief, plants, and light/shadow [2, 36].

A planting plan that explores contrasts and differences between vegetation plastic features (volume, shape, texture, and color) are occasionally the best compositions, concerning: clarity, distinctness, and unity composition [35]. Still, space designs regarding plant material should be based on nature principles, as noted in the phytosociology pools (**Table 1**), where there is a set of dominant and less dominant plants.

In these phytosociological stages, underlies the unit, given the dominance of *Arbutus unedo*, since they high coefficient of presence. The simplicity is present in the similarity between different chromatic shades of yellow, making the apprehension of space easy. The contrast arises at the level of vegetation textures and the chromatics of some blooms. Although some of these species have flowers humble, the chromatic contrast arises, naturally, through the red and purple flowers.

Altitude (m)	345	555	295	425	115	370	85	380	460	375	**Flower chromatography**
Orientation	E	—	E	NW	N	SW	N	SE	NE	NW	
Surface (m^2)	100	60	100	200	100	100	100	50	150	100	
N° of species	21	20	27	24	19	24	10	23	24	22	
Ordinal number	1	2	3	4	5	6	7	8	9	10	
Species features											
Arbutus unedo	4	5	5	4	3	4	4	4	4	5	
Erica arborea	.	1	3	2	2	2	3	2	2	2	
Ruscus aculeatus	.	.	1	1	3	2	+	2	2	3	
Cytisus grandiflorus	+	2	2	1	+	1	.	.	.	.	
Daphne gnidium	2	2	.	1	1	.	.	+	.	+	
Osyris alba	2	.	.	.	+	1	1	+	.	2	
Rubia peregrina	+	2	1	.	.	.	.	+	+	1	
Quercus rotundifolia	1	.	.	1	3	.	.	1	1	.	
Pistacia terebinthus	.	.	2	1	2	.	.	1	+	.	
Phillyrea angustifolia	.	.	.	1	1	.	.	+	2	.	
Hedera hibernica	.	.	+	.	.	2	.	.	.	3	
Quercus suber	.	.	.	+	1	.	.	.	3	.	
Lonicera etrusca	.	.	.	1	1	.	1	.	.	.	
Asplenium onopteris	.	.	.	.	.	+	.	+	.	2	—

Presence ratios: 5—of 100 at 75%; 4—of 75 at 50%; 3—of 50 at 25%; 2—of 25 at 10%; and 1—of 10 at 1% e + —lower than 1% or punctually.

Table 1. *Cytiso grandiflori-Arbutetum unedonis*, inventory pool (adapted from [37]).

http://dx.doi.org/10.5772/intechopen.73169

At texture level, the presence of *Cytisus grandiflorus* with finer texture in opposition to *Hedera hibernica* with a coarser texture should be noted. The diversity is also demonstrated in this study, due to a large number of species—a typical feature of Mediterranean territory influence.

5. Case studies

The present work analyzes landscape architecture projects located in territories with similar bioclimatic, but presenting considerable differences on substrate features. So, it is possible to emphasize the importance of soil in plant material choice and their adaptation to edaphic local conditions. Contextually, the latest and most representative projects in Alentejo were selected, as they share the most ecological conditions with Mediterranean climate. Following this, projects with the most variety of exotic plants were taken into account, in order to present a contrasting sample with a high level of native plants.

The project's choice went through to identify representative areas with a certain type of substrate, such as sedimentary sands, in Vendas Novas project, and the limestones of Estremoz—internationally known by providing high-value ornamental stones for building construction (**Figure 7**).

Contextually, it will be presented as the potential climatic vegetation series for each case study. In the case of plants with a lower growth or nonadapted to local features, it will be

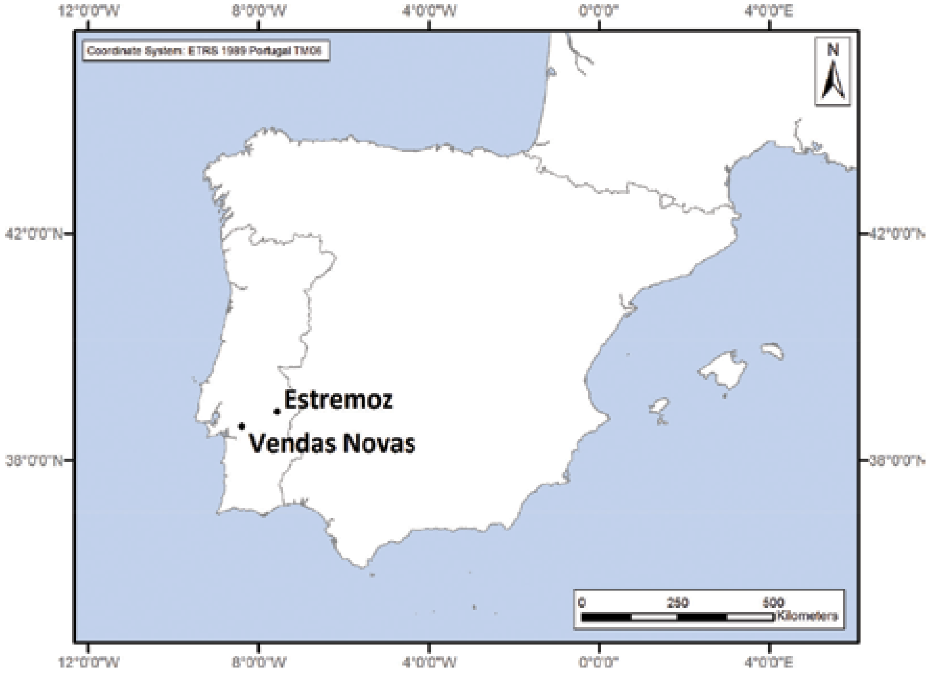

Figure 7. Geographical location of projects in the Iberian Peninsula.

carried out as a proposal with a set of plants based on the vegetation series analysis, aiming to be well adapted to local features and promote a sustainable urban green space.

5.1. Results

5.1.1. Vendas Novas

Taking into account the purpose of the study, the following project has been selected: "Urban section coincident with EN4 between the Largo's João Luís Ricardo roundabout and the access to EN251-1."[10] The project is located near the railway line in the east entrance of Vendas Novas, corresponding to a narrow stretch dimensions approximately 1 km × 10 m long.

The city of Vendas Novas, from a geological perspective, lays on siliceous psammophilous substrates, belonging to the sedimentary basin of the lower Tagus. Regarding bioclimatic features, it is thermomediterranean subhumid. At an ecological level, it fits a climatophile characterization, and at a biogeographical characterization, it is on the Ribatagano-Sadense sector. Bearing in mind the scenario mentioned above, a potential natural series of such territories is constituted by native *Quercus suber* agglomeration—the *Aro neglecti-Querco suberis Sigmetum*.

For this project, which has an area of about 1 acre, 70 different plants have been chosen: trees (10), shrubs (30), herbaceous (27), and climbing plants (3)—all of them are native. Some of the plants have adapted well to the local features, such as *Cupressus sempervirens* and the *Juniperus* spp., while others, even with irrigation have shown some difficulties in development. On the other hand, the irrigation inhibited the development of some plants, particularly the ones with dry features, as is the case of the *Thymus serpyllum*.

It is possible to verify that the grass compound used on the project demands high water to maintain the green tone during summer periods, as it is located on Mediterranean clime. If compared to temperate climes, grass does not need such amount of water, as the precipitation distribution patterns are more homogeneous during the year, decreasing the maintenance costs [32].

Through the use of native vegetation, it is possible to reduce the maintenance costs of these areas and also keep some landscape identities such as volume, form, texture, or chromatography of plant material. Furthermore, reducing the number of plants may contribute to a larger unity and spatial integration. Even with the apparent adaptation of some plants to local features, all of them are irrigated daily. By assumption, if the irrigation is cut off, a large amount of these plants will change their behavior, leading to reduced growth or even to their loss, particularly in the summer period.

Taking into account what was assessed, *Quercus* agglomerations are seen as a possible solution for a proper vegetation series selection. These woodlands, inserted into the *Quercetalia ilicis* class, are dominated by *Quercus suber* and elements such as *Smilax aspera* var. *altissima*, *Rubia peregrina* subsp. *longifolia*, *Arum italicum* subsp. *neglectum*. The first step for replacement should be composed by bushes such as *Arbutus unedo*, *Erica arborea*, *Phillyrea angustifolia*, *Daphne gnidium* from the association *Phillyreo angustifoliae-Arbutetum unedonis*. After their disappearance, other typology of vegetation should take its place, such as the *Erico australis-Quercetum lusitanicae ulicetosum welwitschianii*. Furthermore, in considerable relief areas—where the soil is well preserved—it is pos-

[10] EN is the acronym for National Portuguese Road.

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sible to find a community dominated by *Cytisus striatus*. Still, regarding deep soils, perennial grassland of *Euphorbio transtaganae-Celticetum giganteae* emerge, aligned with *Herniario maritimae-Coryne phoretum matitimi*; however, this last one should need some "degree" of perturbation to emerge and prepuce [38]. Along with the soil erosion comes the *Thymo capitellati-Stauracanthetum genistoidis*, but still, further North, the *Halimium verticillatum* [39] could also emerge. The farthest replacement step from the vegetation climax is composed of a *Corynephoro macrantheri-Arenarietum algarbiensis* annual grassland.

In **Table 2**, it is possible to contemplate the proposed plants for the project, evidencing a significant number of flowers during spring; this allows some margin for the chromatographic features of the plant material.

5.1.2. Estremoz

The city of Estremoz is 448 m above the sea level—where the oldest geological substrates of the district of Évora are present, dating back to the Precambrian. The soils are complex and may vary by a few meters—in a spatial perspective—consisting of limestone rocks, basic, metamorphic, and acidic, with basic rocks being predominant. Regarding bioclimatology, Estremoz is inserted on thermo-Mediterranean subhumid layers.

Due to the significant soil erosion, climatophile-dominant series (on the regional landscape) are *Rhamno laderoi-Querco rotundifolia Sigmetum*. In the geography, a large and "nocive" anthropic presence can also be observed that is mainly catalyzed by the inadequate agricultural and forestall techniques, causing soil erosion, which allied to low precipitation patterns promote heliophile vegetation and dry vegetation (**Table 3**).

Description	Main replacement steps	Bioindicators
Woodlands	*Aro neglecti-Quercetum suberis*	*Quercus suber, Smilax aspera* var. *altissima, Rubia peregrina* subsp. *longifolia, Arum italicum* subsp. *neglectum*
Maquis scrubland	*Phillyrea angustifolia-Arbutetum unedonis*	*Arbutus unedo, Erica arborea, Phillyrea angustifolia, Daphne gnidium*
Broomland	*Erico-Quercetum lusitanica*	*Quercus lusitanica, Erica scoparia, Ulex australis* subsp. *welwitschianus*
Bushes	Community of *Cytisus striatus*	*Cytisus striatus*
Perennial grasslands	*Euphorbio transtaganae-Celticetum giganteae*	*Celtica gigantea, Euphorbia transtagana, Armeria pinifolia, Arrhenatherum album*
Groundcover	*Hyacinthoido transtaganae-Brachypodietum phoenicoidis*	*Brachypodium phoenicoides, Hyacinthoides vicentina* subsp. *transtagana, Avenula sulcata* subsp. *gaditana*
Scrublands	*Thymo capitellati-Stauracanthetum genistoidis*	*Stauracanthus genistoides, Halimium halimifolium, H. calycinum, Lavandula lusitanica, Thymus capitellatus*
Perennial grasslands	*Herniario maritimae-Corynephoretum maritimi*	*Corynephorus maritimus, Anagallis monelli* var. *linifolia, Sesamoides spathulifolia*
Annual grasslands	*Corynephoro macrantheri-Arenarietum algarbiensis*	*Corynephorus macrantherus, Loeflingia baetica* var. *micrantha, Malcolmia triloba* subsp. *gracilima, Coronilla repanda*

Table 2. Main replacement steps and bioindicators of *Aro neglecti-Querco suberis Sigmetum*.

Description	Main replacement steps	Bioindicators
Woodlands	*Rhamno laderoi-Quercetum rotundifolia*	*Quercus rotundifolia, Olea sylvestris, Jasminum fruticans, Lonicera implexa*
Maquis scrubland	*Myrto communis-Quercetum cocciferae*	*Quercus coccifera, Myrtus communis, Pistacia lentiscus, Pistacia terebinthus*
Broomland	*Retama sphaerocarpa-Cytisetum bourgaei*	*Retama sphaerocarpa, Cytisus scoparia* subsp. *bourgaei*
Perennial grasslands	*Phlomis lychnitis-Brachypodietum phoenicoidis*	*Brachypodium phoenicoides, Phlomis lychnitis, Origanum virens*
Scrublands	*Lavandulo sampaioanae-Cisteum albidi*	*Cistus albus, Lavandula sampaioana, Phlomis purpurea, Teucrium capitatum*
Annual grasslands	*Velezia rigida-Asteriscetum aquaticae*	*Asteriscus aquaticus, Cleonia lusitanica, Velezia rigida, Trachynia distachya*

Table 3. Main replacement steps and bioindicators of *Rhamno laderoi-Querco rotundifoliae Sigmetum*.

In Estremoz, we have selected the Project: "Industrial Zone External Spaces and East Entrance of the Fair and Exhibition Park" [40] for analysis. The space is located in the heart of the industrial grounds, where the accessibility is poor—mainly used by industrial transport, creating an interstitial space in the local urban patterns.

Due to cost containments and for being outside the primary zone of the city, the intervention area needs considerable maintenance—i.e., replanting and plant replacement. In this project, it has been proposed a total of nine vegetal species, among them is the *Rosmarinus officinalis*, native to the flora. Regarding the *arboreum stratum*, we propose *Acer platanoides, Acer platanoides cv. Crimson King* and *Cupressus sempervirens cv. Stricta*. At the shrub level, six plant species have been suggested: *Berberis thunbergii, Cotoneaster horizontalis, Lavandula dentata, Lavandula stoechas, Rosmarinus officinalis*, and *Santolina incana*. A site analysis has enabled to identify several disparities—some relating to the planting plan, as is the case of the replacement of the *Lavandula dentata* with *Lavandula x semidentata* and vegetation gaps, which may have occurred by the bad compatibility of the plants to local conditions.

The proposed vegetation series for this case study shows weak floristic cast in contrast to the previously studied case of Vendas Novas. In this scenario, the destruction of the potential woodland gives a way to a thick bush of *Myrto communis-Quercetum cocciferae*. The second replacement step is composed by *Retama sphaerocarpa-Cytisetum bourgaei*. In deep soils, meadows emerge maintained solely by the presence of the *Phlomis lychnitis-Brachypodietum phoenicoidis*. In derelict soils, a heliophile community of *Lavandulo sampaioanae-Cisteum albidi* emerges. The last replacement step belongs to perennial meadow of *Velezia rigida-Asteriscus aquaticus*.

The project presents a wide, open area, allowing a visual understanding through all the space, verifying only a physical barrier materialized by shrub plants. Still, such barrier is not seen as a critical factor to block the "visual openness" of the space—planting material of higher dimensions would help define space volumetrics and the perception of distance.

Through this case study, it has been possible to verify how the use of local adapted flora—through the natural regeneration of the *Lavandula luisieri*, in the planting area—and also that how the older specimens have given way to new plants that are emerging by seed. This is seen as a contribution toward sustainability of public green spaces—as it may reduce the replacement costs. Being a less complex project that the one analyzed previously, in this case, the chromatography is not as relevant—the interaction is mostly between two opposite colors. Regarding volumetrics, heterogeneity is also present, marked on the south and north space boundaries by *Myrtus communis*, and attenuated by the low volumetrics of *Teucrium capitatum*.

5.2. Discussion

The choice of plant material, regarding landscape architecture projects, should be performed through study and acknowledgement of vegetation series present in each territory. Each replacement step suggested provides a set of typical plants of the evolutionary dynamics of the series—thus properly adapted to local ecological features. Aiming to reach the potential vegetation series of a particular territory, it is pivotal to understand the local edaphoclimatic features, i.e., the thermotypes, the ombrotypes, and biogeography.

However, in the Iberian Peninsula, there are few organizations working with large quantities of native plants, leading to a decrease regarding their demand.

Native plant production is still incipient in Iberian southwest, but still, plant material of local ecotypes should be used, fostering better adaptation to local features. These principles also help avoid importing plants from other countries, such as France or Italy, which despite pertaining to Mediterranean clime would possess different adaptability features. This could be seen a measure to avoid genetic contamination with native material, which would also trigger hybrids less adapted to the studied territory. An example for this would be the introduction of the *Quercus rubra* on Iberian territory, which has caused several issues regarding replacement of native agglomerations of *Quercus robur* subsp. *broteroana*, due to the frequent hybridization between these oaks, modifying the composition of their forest settlements.

6. Final remarks

Through the research, it has been possible to verify the relationship between landscape architecture and phytosociological studies. Such knowledge has as basis sciences as: phytogeography, geology, bioclimatology, and phytosociology that differentiate and define edaphoclimatic features and their distribution on landscape vegetation series. For each series, the integrated dynamic and the main vegetal bioindicators have been studied. Based on the replacement steps (of potential series) plant materials for the analyzed projects have been selected, taking into account the biogeographic distribution patterns of each plant. Framed within Iberian southwest territories, projects have been analyzed—at urban context and periurban context—at the cities of Vendas Novas and Estremoz, aiming to work with different vegetation series.

Contextually, the main vegetation replacement steps for the case studies have been put forward. Through phytosociology pools, it is possible to show the specific floristic cast.

In this regard, such approach should be used more often aiming to value the biodiversity and preserve landscape identity—once it facilitates the plant material chosen regarding biophysical features. Still, some gaps remain on the procedure—mainly related to the reduced offer for these (native) plants on the market. Even if a growth tendency has been verified in the last few years, a number of native plant productions still do not satisfy the actual needs. Thus, decision-makers should carry out policies of territorial sustainability—i.e., control and audit in landscape architecture projects aiming to avoid the introduction of poorly adapted plants to their "new" territories.

Also, at the phytosociological level, a deeper knowledge should be considered, not only regarding vegetation dynamics but also regarding fostering their potential—once currently the distributing of landscape vegetation series do not possess a detailed cartography.

In the same line, it should be highlighted that the biodiversity loss is caused by the increase of "infested" areas by exotic plants—fertile scenario along the Mediterranean Basin—extensive areas dominated by nonnative plants, as is the case of the *Acacia dealbata* and *Ailanthus altissima* [41], difficult to control, demanding high elimination costs.

As final remarks, native plants should be promoted contributing to the preservation of landscape heritage and also toward sustainable spaces and cities.

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Chapter 14

Wind Farms as a New Element of the Polish Landscape

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Additional information is available at the end of the chapter

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Abstract

Fast development in the wind power industry in Poland resulted in construction of numerous wind farms, mainly in the north and center of the country. The construction of a wind power station is connected with a change in the structure of the landscape through location of new dominant and subdominant landscape elements. The goal of the work was to determine the previous practices of locating wind farms in Poland, effects resulting from the presence of wind turbines in the landscape, and guidelines for designing wind farms in the context of impact on the landscape. Until 2016, spatial planning lacked in clear regulations on locating wind turbines. In 2016, Poland passed new laws regulating the minimum distance of wind turbines from residential and mixed-use buildings. Based on selected examples of wind farms in West Pomerania Province and Kuyavian-Pomeranian Province, it was found that the existing wind turbines do not comply with the requirements of the minimum distance. Also, there were cases of damaging the esthetics of protected landscape areas. The appearance of new dominant elements of the landscape, i.e., wind power plants, may cause substantial transformations in the landscape, mainly in Northern and Central Poland.

Keywords: impact, landscape, Poland, regulations, wind turbine

1. Introduction

In the first decade of the twenty-first century, Poland saw fast development of investments in the wind power industry, which was connected with construction of new wind farms in almost the whole country. Until 2004, energy from wind made up only 0.3%. In 2013, after 10 years, it rose to 6% [1, 2]. In 2009–2013, there was a growth in installed wind power plants of as much as 277%, i.e., from 301 to 835 power generation units. The total installed power increased in this period from 724.657 to 3389.541 MW, i.e., nearly five times [3].

Single wind turbines were initially looked at with a typical interest for any novelty. However, in the course of time and with the growing number of turbines, negative effects of development of wind energy started to be noticed more frequently. The most important downsides of wind power plants included noise emission, infrasound emission, high investment costs, a threat to birds and bats, radio and television wave interference, a decrease in property value, and loss of agricultural production areas [4–7]. Plans for constructing installations in the vicinity of built-up areas were met with especially strong resentment. Similar to other EU countries, Poland witnessed the start of numerous protests against wind installations [3, 8–11]. One of the most frequently mentioned disadvantages of wind farms was also negative impact on the landscape [3, 12–14]. Mostly, such arguments were raised in the regions of high values of the landscape and with a developed tourist sector.

Negative reception of wind turbines may have been caused by the lack of precise rules of their location. The goal of the work was to determine the previous practices of locating wind farms in Poland, effects resulting from the presence of wind turbines in the landscape and guidelines for designing wind farms in the context of impact on the landscape.

2. Material and methods

The work used data from the Central Statistical Office of Poland from 1990 to 2015 (www.stat.gov.pl) regarding the installed power of wind installations in Poland in total and for particular regions, as well as data about location of wind turbines from the Institute for Renewable Energy (http://ioze.pl). The rules of locating wind turbines in force until 2016 and since 2016 were described on the basis of analysing legal acts from the Internet System of Legal Acts (ISAP) database (http://prawo.sejm.gov.pl); practices of locating farms were described after the analysis of a report by the Supreme Audit Office [3] and case studies of wind farms in Tymień (West Pomerania Province) and farms in the communes of Strzelno and Mogilno (Kuyavian-Pomeranian Province). Specification of the guidelines and recommendations for construction of wind farms was based on the available scientific and specialist literature.

3. Rules of locating wind farms in Poland

3.1. Rules of locating wind farms in Poland until 2016

Until passing the law on investments [15], in spatial planning, there were no unambiguous regulations concerning the location of wind turbines. The regulations applicable to the location were contained in many documents, e.g., in laws regulating the issues of environmental protection, protection of agricultural and forest areas, health resort protection, heritage preservation, construction law, water resources law and, in many ministry regulations [9, 16, 17]. Locating wind farms was mainly based on the regulations of the Spatial Planning and Land Development Act of 27 March 2003 [18]. The main document by means of which communes shaped their spatial order was the local spatial management plan. In case of the lack of such a plan, specifying the type of land management and development conditions was conducted through decision on land development conditions. Preparing the local spatial management plan for a commune was bound by the study of conditions and directions of spatial development. It was obligatory for a commune's study of conditions and directions of spatial development to include only the provisions regarding the location of renewable power installations of a power exceeding 100 kW.

The legal regulations in Poland did not specify in length units the safe location of wind power plants in the natural environment. The major criterion used for determining a distance of wind turbines from buildings, especially those inhabited by people, was the permissible level of noise emitted by wind power plants. However, the laws regulating the methodology of noise emission measurement did not guarantee reliable evaluation of nuisance generated by such facilities. Taking measurements could take place, in accordance with the binding requirements, only in conditions of low wind speed (<5 ms^{-1}). Wind power plants generate the most intense noise only with the optimal wind velocity, equating to 10–12 ms^{-1}, but in such conditions, measurements were not made. The legal regulations also did not define permissible norms for other potential threats, such as infrasound or the stroboscopic effect.

The solutions in this respect accepted in other EU countries were diverse. Location of wind turbines in relation to human-inhabited buildings was mainly determined by a distance expressed in metres and sometimes by the permissible level of noise. The permissible level of noise was used to define the distance e.g., in Germany, Holland, and Portugal. The criterion of distance is used e.g., in Denmark (the location of a turbine from buildings cannot be smaller than four times the total height of the turbine) and in Italy (e.g., Calabria) where the distance was specified to be 20 times larger than the turbine height, which in practice results in a distance from a wind farm to urbanised areas of approximately 2 km. In France, the distance from wind farms to buildings was determined by the level of sound, i.e., a difference in noise levels in relation to the background level so that the difference in the noise level would not exceed 5 dB during the day and 3 dB at night. The location of wind farms is determined differently in Sweden where it is specified by local building committees who consider impact on the environment and local development plans. Also, in Great Britain, there are no national regulations regarding the minimum distance from urbanised areas. The regulations in this respect depend on regional authorities. This way, in Scotland, the recommended distance from towns and villages is 2 km, in Wales 500 m from houses and in England, the distance should equal at least the turbine height plus 10% in case of its collapse (Najwyższa Izba Kontroli [Supreme Audit Office], Warszawa, [3]).

3.2. Rules of locating wind farms in Poland after 2016

In 2016, Poland passed new laws regulating the minimum distance of wind turbines from residential and mixed-use buildings. The provisions of The Investments of Wind Power Plants

Act of 20 May 2016 [15] introduced the notion of the minimum distance of a wind turbine from residential buildings. In accordance with the act, the required distance should be at least 10 times the wind turbine height (measured as the height of the tower with the length of the blade). The introduced limitation should work both ways; i.e., residential buildings, which could be built in the vicinity of the existing wind power plants, must also comply with the minimum distance requirement. The minimum distance requirement for wind farms is also obligatory in relation to nature protection areas such as national and landscape parks, nature reserves, *Natura 2000* areas, and also promotional forest complexes [15]. Moreover, location of new wind farms is possible only on the basis of the provisions of local spatial development plans. Thus, there is no possibility to obtain an individual decision on land development. The local plan must define the maximum total height of a planned wind power plant and cover the whole area where, in view of the specified permissible height of the power plant, there will be regulations as to the location of residential buildings. Once the law comes into effect, previous studies of spatial management directions and local spatial development plans will remain valid and in force. However, applying for building permission on their basis will be limited for investments (both power plants and residential buildings), which do not comply with the new requirements specifying a distance in relation to previously constructed buildings.

In the case of projects such as wind turbines, which may significantly influence the natural environment, it is obligatory to prepare environmental impact assessment. In Poland, this requirement applies to inland installations of a nominal power not less than 100 MW. The environmental impact assessment report should also contain the analysis of effects on the landscape. Such a solution gives local communities access to information and a possibility to influence decisions of authorities who grant permissions for building wind farms, which are considered projects which may significantly affect the natural environment. Further on, the work analyses possible impact of wind turbines on the landscape.

4. Impact of wind turbines on landscape

Locating wind turbines in the environment brought a necessity to assess their impact on the natural environment, including the landscape. Generally, it is agreed that the scale of such impact is affected by the height of towers and their number, a type of turbine, a type of tower and arrangement of towers, as well as terrain features [19–22] . For Gromadzki and Przewoźniak [4], the essential factors affecting exposition of wind turbines in the landscape are as follows: terrain, types of land management, geometry of the arrangement of wind farms and a distance from human settlements, a type of tower and a type of turbine, the height of a wind turbine structure, and colours of the structure.

Impact of the terrain may be diverse depending on the location of a turbine in the landscape. If a wind farm is not situated among dominant landscape elements, then the diverse terrain is conducive to a reduced visibility range of wind farms. However, a lower visibility range is not equal to lower impact on the landscape as visual and aesthetic values of diverse terrain are usually higher than that of flat land.

Diversity of land management types causes a change in the visual effect produced by a wind farm. A forest growing in the edge zone or the terminal moraine zone significantly reduces visibility of wind farms. On the other hand, the land used agriculturally, mainly to cultivate field crops, is an area that does not limit visibility of wind farms.

Exposition of wind turbines is also affected by the way of their arrangement and their number in wind farms. If turbines are situated symmetrically in one line, they form a greater dissonance in the landscape than the arrangement of turbines distributed non-symmetrically. In hilly terrain, power plants located on the slopes are far less visible than those situated on the top. However, such location of a power station is unfavourable in terms of the volume of generated power. Moreover, it was found that lattice truss towers are much less visible from a big distance than tubular towers.

Impact of wind farms on the landscape decreases in a non-linear way along with an increased distance of observation. The strongest visual nuisance persists within a radius of several kilometres. After exceeding the threshold above which wind turbine elements begin to merge with the background, a considerable reduction occurs in power plant visibility in the landscape.

Among the methods of determining impact of wind farms on the landscape, one can enumerate the following: determining visibility based on a digital elevation model (DEM), creating visualisations for potential investments [22–25], the index of visual impact on the general public [22], the visual impact assessment (VIA) for visual perception of wind farms at different distances supported by analyses of photographs [26, 27], the zone of visual influence (ZVI) to determine areas of possible, and actual visibility of wind farms [28].

A relationship between the visual effect of a wind farm and a distance became a basis for separating four impact zones of wind power plants in the flat land landscape. According to this division, in the first zone, at a distance up to 2 km from a wind farm, the wind power plant constitutes a visually dominant element, and the rotating movement of blades is clearly visible and seen by a human. In the second zone, at a distance of 1.0–4.5 km, the wind power plant is an important element of the landscape; it is easily noticeable, but it does not dominate; the rotating movement of blades is visible and attracts sight. In the next zone at a distance of 2–8 km, the turbine is a noticeable element; in good visibility conditions, it is possible to see the rotating blades, but against their background, the turbines seem to be relatively small. The fourth zone is further than 7.0 km; the turbine is a small element in the distant landscape and the rotation of blades from such a distance is practically indiscernible [6]. It results from the presented division that wind farms situated in the first and second zones significantly affect aesthetic values of the landscape. The above-presented values are approximate and may very often assume different parameters. In hilly terrain, these distances may be considerably smaller or bigger depending on the observation point and the location of a wind farm. Wind farms located away from the hills at the observation line may be invisible, despite a small distance. However, if they are situated on the tops of the hills, their visibility will considerably increase. For some sites, it may reach even 20 km [6].

According to Shang and Bishop [29], the distance at which wind turbines are visible is equal to 150 heights of the turbine. On the other hand, in the visual assessment of wind farms: Best practice [27], it was assumed that depending on the height of a turbine, the value of a radius determining the zone of theoretical visibility (ZTV) equals from 15 to 35 km. In the same study, it was assumed that the maximum ZTV range is determined by a radius of 30 km from the wind turbine irrespective of its height.

The borders between the zones of impact on the landscape may also be determined taking into account parameters of the human visual field [30]. Then, five zones of impact can be distinguished: I—proximity, II—foreground, III—average distance, IV—distant view, and V—very distant view. The range of particular zones depends on the height of a wind turbine. The border of the first impact zone is determined in such a way that the wind turbine cannot be seen in one view; it can be discerned as a whole only while "scanning the space with one's eyes." In the second zone, the turbine is clearly visible and fills at least half of the visual field. In the third zone, the whole outline of the wind turbine is visible in one view, but it fills from a quarter to half of the visual field. In the fourth zone, the wind turbine is a subdominant object, which fills from one tenth to a quarter of the visual field. In the fifth zone, the turbine is visible only in the case when the tower colour is white, with good lighting and very good visibility; the upper boundary of this zone delineates the zone of theoretical visibility.

In Poland to assess the visual impact of particular wind farms on the landscape, the so-called Spanish method is also used [31]. Due to specific characteristics of the rural development, it was modified and adapted to the Polish conditions [32]. The Spanish method conducts assessment of the visual effect in three stages. Its final stage gives an average score of the visual impact of a wind turbine on the resident inhabiting the zone of a radius of 5 km from the central point of the wind farm. The accepted value of 5 km corresponds to the first and second zones of the visual impact where wind turbines are distinct dominant elements of the landscape. In the zones limited by the 5-km buffer, the areas are determined with no visible wind turbines. The visual effect of a wind farm increases when the number of inhabitants seeing the farm grows. The last stage of the analysis consists in calculating the coefficient of the final score of the farm's visual effect (PA), which is a product of partial coefficients, and assigning one of the six levels of the visual impact on localities within the area delineated by the 5-km buffer from the wind farm centre.

The research conducted in the lowland landscape of Lower Silesia found that wind farms are a strongly dominating element of the landscape attracting attention of the observer and may dominate the elements and symbols important for preservation of identity of the rural areas [33]. Similar observations were made by Fiutowska and Dąbrowski [20] who examined a landscape aspect of wind power development in the north of Poland, in Central Pomerania. The exposition of wind power plants was strongly affected by terrain. Moreover, they also stated that impact of the wind farms went far beyond the area of their location.

5. Guidelines for locating wind farms with regard to impact on landscape

In order to decrease negative impact of wind farms on the landscape, certain recommendations were developed whose applications at the design and construction stage allow reducing the visual effect of building such facilities. The most important ones include using towers of the same height within one wind farm or several neighbouring farms, using light colours for towers and rotor blades (e.g., grey, brown) or adapting the colour of the whole wind power plants to the surroundings, selecting wind turbines whose rotors consist of three blades [34]. It is also possible to apply technologies improving the aesthetics of turbines, i.e., resigning from truss towers, burying power lines underground, using nacelles of streamlined shape, placing obstruction lights only on the highest situated turbines, adapting colours to a specific site. Negative impact of turbines on the landscape may also be limited by painting rotor blades and towers with light colours, thanks to which it is possible to additionally eliminate flickering effects and by applying turbines with rotors of three blades. It is more favourable for the observer when a wind farm consists of a smaller number of turbines, but of a bigger power (National Wind Coordinating Collaborative).

In order to reduce negative impact of wind turbines on the landscape, it is also recommended to use appropriate proportions while designing turbines (specifically, the proportion of the rotor diameter to the tower height from 0.9 to 1.35) and for proper arrangement in space (the distance between turbines should not be bigger than 3 or 4 diameters of the rotor) [16].

Wind power plants should not be located near the sites with specified norms of acoustic environment and where they could constitute a dominant element in the landscape of high visual values. Locating wind turbines in the foreground of scenic viewpoints, view corridors, natural site scenery, historic monuments and valuable buildings, parks complexes, and also within planned landscape parks is considered highly inappropriate [35].

6. Practices of locating wind turbines in Poland

Distribution of wind farms in Poland corresponds mainly to the system of wind zones of the best wind conditions for energy generation, determined by institute of meteorology and water management (IMGW) on the basis of wind energy resources [16]. Special conditions for wind power are offered by the north Poland regions, which are dominated by lake landscape marked by big differences in relative height (**Figure 1**).

As it can be observed, a vast majority of wind power plants is white with red blade tips. It results from the aesthetic character of this colour and from increased visibility of the structure in the case when a wind power plant is an air traffic obstacle. Sometimes, also other colours are used, e.g., from grey to green, due to which wind power plants produce less contrast for the observer from a bigger distance.

On the basis of the examples of wind farms, the work examined practices of locating wind turbines in respect of a distance from residential buildings.

The first examined case is the Tymień wind farm in the commune of Będzino (West Pomerania Province). The size of the farm is approximately 700 ha (with 166 km^2 of the whole commune). It is equipped with 25 wind turbines, operating since 2006 (**Figure 2**). The total installed power

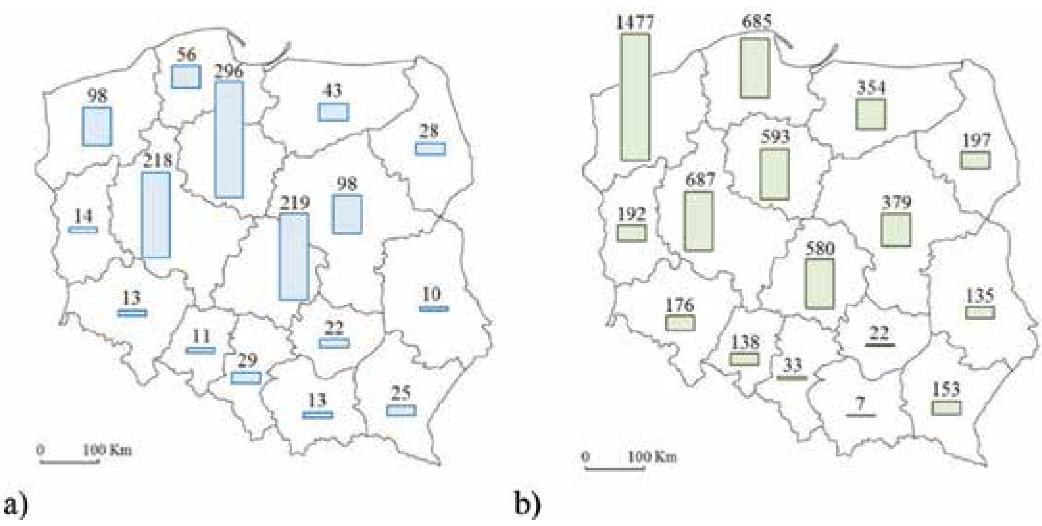

Figure 1. Number of wind installations (a) and installed power (MW) of wind installations (b) by provinces in Poland, in 2016.

amounts to 50 MW; the turbine parameters are the following: the towers of a height of 100 m, and the blades of a span of 80 m.

In accordance with The Investments of Wind Power Plants Act of 20 May 2016 [15], the distance of wind power plants from buildings should amount to at least 1400 m. In the vicinity of the Tymień wind farm and within its impact range, the development is dispersed, often consisting of individual, one-family buildings. The analysis of the distribution of turbines showed that the distance from buildings lies within a range from 500 (five turbines) to 1350 m. Thus, in each case, it is below the minimum specified in the act. Moreover, 21 out of 25 turbines (84%) are situated at a distance up to 1000 m from buildings.

The second analysed case is the communes of Strzelno and Mogilno in Mogilno District, Kuyavian-Pomeranian Province, which house 11 wind turbines in total, 6 in the commune of Mogilno, and 5 in the commune Strzelno (**Figure 3**). The landscape of both communes is the lake landscape, with numerous river valleys, watercourses and troughs, very diverse terrain consisting of hilly morainic upland with height differences reaching several dozen metres, flat morainic upland with small slopes and landforms up to several metres, and undulating morainic upland with slopes up to 5% and landforms of a height between 10 and 20 m.

The comparison of parameters, and the distribution of wind turbines and buildings, showed that the minimum distance from turbines to buildings is only about 160 and 190 m for the closest installations; none of the turbines complied with the legal requirements. All the turbines have a form of steel tower with an entrance from the outside. The colours of the facilities are calm, light pastel, and matte, which prevents the effect of glint. Some turbines for the reason of being air traffic obstacles were equipped with obstruction marking and lighting. The rotor blade tips are painted with five stripes of the same width, perpendicular to the

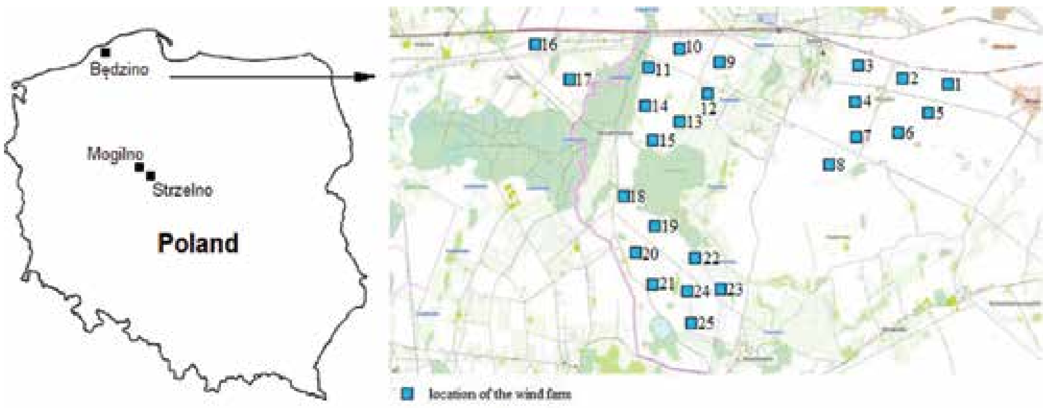

Figure 2. Distribution of the wind farms in the commune of Będzino (West Pomerania Province).

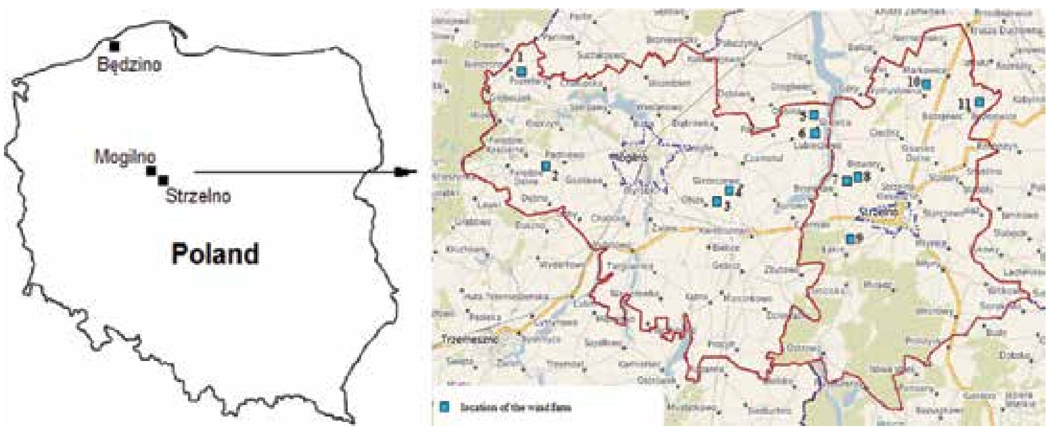

Figure 3. Distribution of the wind farms in the commune of Strzelno and in the commune of Mogilno (Wielkopolska Province).

longer dimension of the rotor blades and cover one-third of the rotor blade length. The obstruction lights are mounted at the top of the nacelle.

Relatively close, or even excessively close, location of wind turbines from buildings was confirmed by inspection results of the Supreme Audit Office [3, 10]. In more than one-third of the examined communes (10 communes), the location of wind turbines was less than 500 m from residential development. The closest wind turbines were located at a distance of 205 (the commune of Kleczew) and 230 m (the commune of Babiak). In eight communes (29%), wind farms were located at a distance from 251 to 500 m, in four communes (14%) within a range from 501 to 800 m. In 14 communes (50%), wind farms were located at a distance of more than 801 m from buildings. An extreme situation was found in the commune of Żurawica (Podkarpacie Province), where a wind turbine was situated at a distance of only 55 m from animal shelter buildings.

Wind farms were conditionally located even within natural protection areas of significant landscape and natural values, only except for national parks and nature reserves [3, 10]. Such practices and also the consent to locating wind farms in a protected landscape area were for example encountered in the Suwałki Lake District. At least 10 out of 14 turbines of the Suwałki Wind Park are situated in the protected landscape area of the Lake District of the northern Suwałki Region. In several view corridors (from the bank of the valley of the Czarna Hańcza, from Osowa to the east towards the Czarna Hańcza valley, from Stary Bród and towards Lake Okminek), wind farms constitute a dominant element in the protected landscape. Irrespective of the terrain, they block out the view at different levels and constitute an alien technological element in the typically agricultural landscape. Other examples are the commune of Przerośl in Podlasie Province, in which one of the six wind turbines of the Taciewo Wind Farm is located in the protected landscape area of the Lake District of the northern Suwałki Region, and the commune of Babiak, Wielkopolska Province. In the latter, wind turbines were located in the Gopło-Kujawy Protected Landscape Area, which is highly suited for any forms of tourism and leisure.

Similarly, in the case of building a wind farm, the commune of Pelplin (Pomerania Province) risks the loss or strong transformation of aesthetic and visual, as well as historical and symbolic values of the landscape [7]. The visibility range of the existing and planned wind farms was determined to amount to several kilometres from their location. The impact may be amplified by the motion of rotating blades. The planned investment will also lower the values of the Gniew Protected Landscape Area and reduce the sense of establishing the Kociewie Protected Landscape Area. The absolutely negative (significant) impact on the landscape mainly results from the fact that its area possesses great landscape value, and exceptional in Poland characteristics pertaining to a vast and clear view where landscape perception is only limited by the horizon [7].

7. Conclusions

Intensive development of the wind power industry, which occurred in Poland from the beginning of the twenty-first century, led to significant interference in the harmonious cultural landscape, mainly in the northern and central parts of the country. Until 2016, spatial planning lacked in clear regulations on locating wind turbines. Wind farms were most frequently located in agricultural areas of a high dispersion of residential development and utility buildings. Along with the expansion of inland wind power installations, there were cases of damaging the aesthetics of protected landscape areas.

The applicable regulations with regard to the location site were contained in many documents, and did not specify in distance units the safe location of wind farms in the natural environment. The major criterion used for determining a distance of wind turbines from buildings was the permissible level of noise emitted by wind farms. In 2016, Poland passed new laws regulating the minimum distance of wind turbines from residential and mixed-use buildings. In accordance with the new law, the required distance should be at least 10 times the wind turbine height (measured as the height of the tower with the length of the blade). Moreover, location of new wind farms is possible only on the basis of the provisions of local spatial development plans. Based on selected examples of wind farms in West Pomerania Province and Kuyavian-Pomeranian Province, it was found that the existing wind turbines do not comply with the requirements of the minimum distance. In one case, a wind turbine was located only 55 m from buildings. The changes introduced in 2016 regarding the rules of locating wind turbines in the time perspective of the coming 20–30 years will cause significant limitations in locating wind farms in Poland.

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Promenade as Landscape Architecture Strategy for Riverbanks of Small Danube Cities: Komárno and Štúrovo

Katarína Kristiánová

Additional information is available at the end of the chapter

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Abstract

The concept of promenade has moved from the city public spaces, from the streets and parks to shopping malls and to virtual public spaces. However, as many case studies of the waterfront regenerations show, the waterfronts possess the potential to enliven the concept of promenading in urban public spaces. Within the framework of the project DANUrB, we have tested the use of the concept of promenade as a landscape architecture strategy for the riverbanks of small Danube cities. We have examined and analyzed the potential of riverbanks in the selected pilot cities Komárno and Štúrovo, and using the method of research through design, we have elaborated proposals for their riverbanks, reflecting the principles of an ecologically sound riverfront design. Results obtained from the research and the design proposals have shown the potential of the riverfronts of small Danube cities Komárno and Štúrovo for the development of the promenades as viable urban places and as greenways, offering recreation possibilities in a balance between nature and social life.

Keywords: promenade, riverfronts, greenways, riverbank design, waterfront regeneration

1. Introduction

Promenade as a verb means to walk or ride leisurely for pleasure or for display and parade. As a noun it means a place, a road or path for such strolling, walking or riding—usually the main avenue of the city, at the park, or at the seashore or riverbank. The promenading phenomenon possesses a special significance for urban society. Promenades as mentioned by Borsay [1] host "kaleidoscopic crowd of dog-owners, courting couples, sun-bathers, juvenile delinquents, voyeurs, joggers, and just plain strollers".

The origins of the promenade in Paris, as both an idea and an activity, from the reign of Louis XIV spread throughout the cities of Europe. The '*promenade de civilité*', the walk as a polite and civil activity, an extension of the elaborate social etiquette that had developed in the salons and the royal court, was peculiarly suited to strolling in a garden and influenced the development of the French garden. As the activity of strolling became democratized, it spilled beyond the bounds of gardens into the streets and boulevards. Bordered by footpaths and rows of trees to provide shade, boulevards integrated elements of the French garden into the urban landscape [2–4].

Today the '*promeneurs*' and *'flâneurs'* of city promenades have moved from the city public spaces, from the streets and parks to shopping malls and to virtual public spaces. The traditional practice of collective promenade as a sign of 'social visibility' moved to the space of internet social media, which supplies the needs of socializing and showing up. As said by Goldgate [5] the '*Cyberflâneur*' strolls through information space, taking in the virtual architecture and remaining anonymous. If the '*Flâneur*' was a decipherer of urban and visual texts, then the '*Cyberflâneur*' is a decipherer of virtual reality and hypertexts [5].

However, the mythology of the great city is still a place where the *'flâneur'* can exist, and as noted by Young [6], today, instead of being limited to the metropolitan promenade, '*flanerie'* has been displaced even to other locations. Though attractions are needed to enliven the concepts of the promenade and usually, *the programs of urban renewals* are those, which possess the potential to create the new sites of contemporary '*flâneur', as for example in the case of High Line in New York, or in the concepts of waterfront regenerations in many cities.*

Waterfronts, seashores or riverbanks have the traditions of promenading—in pre-industrial cities, waterfront areas were intensely used and thriving with people and activities. The close relationship between the waterfronts and the cities was interrupted with the industrial era and by the use of waterfronts as huge ports, for transportation uses, for commercial uses, industry, and warehouses [7, 8]. The economic changes, changes in transportation and trade, led to the abandonment of industrial plants and harbors, and with the increasing environmental awareness waterfronts were rediscovered for the city, and the phenomenon of waterfront regeneration emerged. Urban waterfront regeneration projects have become an effective tool for urban planning and politics in international dimension since 1980s [8].

Successful redevelopments of urban waterfront areas transformed the degraded harbor zones to new urban leisure centers of vital importance. Many examples and case studies show, that by creating public access, walkways and open spaces, by attractive urban design, landscaping and various land uses, the waterfronts become lively urban promenades. Many examples also show that aims to improve, protect and restore the natural features and functions of rivers and watercourses in urban areas, their hydrological, geological and biological characteristics, and the aims to restore riparian and in-stream habitats, create opportunities to use the water corridors as greenways—as green promenades for walking, cycling, with recreational, and sport functions, attractive for inhabitants and for tourists.

Within the framework of the Interreg Danube Transnational Programme project DANUrB, we have examined the possibilities to use and apply the concept of promenade as landscape architecture strategy for the riverbanks of the two selected pilot cities in Slovakia connected to the river Danube—Komárno and Štúrovo.

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The DANUrB Project aims to enhance tourism, and create a sustainable cultural and tourism strategy for small Danube towns, proving social and economic benefits for local inhabitants [9]. Within the project DANUrB we have studied various aspects and strategies—for example, we have examined the green infrastructure of the city Štúrovo for the selection and inclusion into the thematic location-based audio tours offered by the mobile application [10]. One of the aims of the project DANUrB is also to strengthen the Danube regional cultural identity by creating a comprehensive spatio-cultural network—a 'Danube Cultural Promenade', as a common 'Danube Urban Brand,' a brand that can increase the number of visitors and tourists in the small Danube towns [9]. Strategic place branding is often used as a methodology for tourist attraction [11]. For the strategic place branding of Danube cities, the most important spaces are the riverfronts. Very important in this process is that international knowledge and practice is implemented in local conditions, the creation of common strategy is based on individual approach and is site-specific. We have studied the riverfronts of the selected pilot cities, and tested the possibilities to improve the quality of their river landscapes.

2. Material

Komárno and Štúrovo are the only settlements on the Slovak side of Danube, except Bratislava, the capital of the Slovak Republic, having the statute of a city. They have been selected as pilot cities for testing the concept of promenade as landscape architecture strategy for riverbanks of small Danube cities.

2.1. The characteristics of the pilot city Štúrovo

Štúrovo is situated on the left bank of the Danube at the Slovak-Hungarian border. Its twin city on the Hungarian bank of Danube is Esztergom and the two cities are connected by the bridge of Maria Valeria.

The city has a rich history. Its surrounding area was first settled in the Stone Age. During the Roman period it was the site of the 'Anavum', the military garrison of the Limes Romanus, through the middle ages it was the site of the settlement 'Kakath.' Situated on the natural border created by the Danube, it was fortified as a strategic place during the Tatar invasions and later during the Ottoman Empire, when it was called 'Ciğerdelen.' Later it was called 'Párkány.' In 1724 it was granted town status and the rights to hold markets. In 1850, it became a station on the railway track from Bratislava to Budapest. In 1895, the bridge to Esztergom was opened. After World War I, the town became a border town of Czechoslovakia. In 1938, as a result of the First Vienna Arbitration, it was returned to Hungary. After World War II, by the annulment of the Vienna Awards, the town became a part of Czechoslovakia again. It was renamed to Štúrovo in 1948 [12].

Today Štúrovo has a population of 10,666 inhabitants, according to the census in 2013. Its location in the southern—hottest part of Slovakia, in the Danubian lowland, together with natural resources of thermal water in the thermal spa Vadas create opportunities for summer recreation. The city is famous for its tolerance—throughout the centuries, people of different nationalities and religions have lived here together, what gives the city a special atmosphere and flavor. Its main economic sectors are pulp and paper industry, agriculture, and tourism. The main employer is the Kappa Štúrovo paper plant.

2.2. The characteristics of the pilot city Komárno

Komárno is situated in the southern part of Slovakia at the confluence of the Danube and the Váh rivers, on the left bank of Danube. Its former suburb Újszőny, today Komárom, is situated on the right bank of Danube, in Hungary. Komárno and Komárom are connected by the Elisabeth Bridge, which used to be a border crossing between Slovakia and Hungary.

Komárno is an old settlement. First findings stem from the Neolithic, Eneolithic period, and the Bronze Age. Many archeological remains indicate that the area was settled by the Celts toward the end of the first century BC. During the first century AD, the Roman Empire extended its frontiers over the region forming the province of Pannonia. The Romans established the military camp and the settlement Brigetio on the southern shore of the Danube, and a chain of fortifications built along the Danube shores protected the camp and the town. On the northern shore the fortified bridgehead of Celemantia, was built at the beginning of the second century. Gothic, Slavic and Avar findings have been excavated here from the seventh and eight century AD [13].

In the early tenth century the territory came under the rule of the Magyar tribes. According to the medieval chronicle Gesta Hungarorum, one of the Magyar tribal chieftains, Ketel established his domain near the mouth of the Váh river, and his son Alaptolma later built a castle there. Since 1075, it was known as Camarum.

King Béla IV, in 1265, granted the settlement town status and privileges. In the sixteenth century, Komárno became one of the centers of defense for the Habsburg Empire against the expansion of the Ottoman Empire. However, it was occupied by Ottomans between the years 1594–1599. In the eighteenth century, as one of the biggest towns in the country, it began to flourish. Maria Theresa granted the city the status and privilege of a free royal town in 1745. During the eighteenth century, Komárno experienced many natural disasters including floods, fires, earthquakes, and epidemics as cholera and plague. The two earthquakes, in 1763 and in 1783, completely destroyed the town. Komárno played a significant role in the Hungarian Revolution in 1848. It remained the last bastion of the Hungarian resistance against the Austrians until 1849, when the fortress and the town were finally surrendered. During the years of Austrian absolutism, it became a strategic military base. Komárno is famous for its historical fortification system, which is a unique system of forts, bastions, and fortifications in and around the towns of Komárno and Komárom on the banks of both the Danube and Váh rivers. It was started to build in 1546 on the place of the former castle and the whole fortification system was completed in 1871–1877 when the last Igmand fort was built [13].

After World War I With by the Treaty of Trianon, the territory to the north of the Danube was ceded to Czechoslovakia with the territory to the south of the Danube remaining in Hungary. Komárno found itself in Czechoslovakia, separated from its southern part in Hungary. In 1938, under the First Vienna Award, Komárno was returned to Hungary. After the World War II, the territory on the north bank of the Danube and Komárno became part of Czechoslovakia again [13].

Komárno today is Slovakia's principal port on the Danube, the town's largest industrial facility is the Slovak Shipyard Komárno, which was completed in 1950 and greatly promoted the economic development of the town. New factories were constructed on the west side of town near the shipyard and create a new industrial district. It has a population of 34,561 inhabitants, according to the census in 2013.

3. Methods

We have analyzed the riverbanks of the pilot cities and developed landscape architectural proposals for the riverbank promenades using the method of "education by research" and the method of "research by design"—we have involved students from Faculty of Architecture, the Slovak University of Technology in the analytical and also in the design stage of the research [14].

To understand the historical development of the cities and their riverbanks and to understand the development of the relationship between the urban and natural phenomena we have studied historical literary, visual and map sources. To understand the current state and future development trends we have conducted on-site surveys, using various landscape and urban planning analytical methods to analyze the riverbank sites—their current functions, their use, their accessibility, the conditions and features of their riparian and in-stream habitats and the requirements of nature protection, we have studied the available urban planning documents, development intentions and requirements in collaboration with the local municipalities. The estimations of problems and potentials of the riverbanks as results of SWOT analyses were the starting point of the design stage.

As noted by Schönwandt and Voigt [15, 16], the focus of planning processes is on the systematic and methodological identification and solution of spatial problems or the prevention of their emergence. Planning problems are tasks as yet unsolved. The point of departure may be a state of affairs perceived as negative that is to be improved, or a situation which is viewed positively but assumed to require planning and action in order to persist. The clear definition of a problem is a prerequisite for improved problem-solving. Planning usually responds to a need or unsolved issue and is based on a distinct underlying approach.

According to Schönwandt and Voigt [15, 16], planning approaches consist of four components: a set of problems (problem views), a set of aims, a set of methods and defined background knowledge. These four components always interlock and depend on each other. There are many different planning approaches and they act like lenses through which we look at a situation and it is always possible to choose among a variety of approaches.

As mentioned by Zimmerman et al. [17], design thinking is the term often used to describe what designers bring to problem-solving. By design thinking Zimmerman et al. [17] mean the application of a design process that involves grounding—investigation to gain multiple perspectives on a problem; ideation—generation of many possible different solutions; iteration—cyclical process of refining concept with increasing fidelity; and reflection.

The research through design approach allowed to get various different design solutions for the riverbank promenades in Komárno and Štúrovo developed of the on the basis of the site analyses, identification of problems and potentials.

4. Results

From the first analytical part of the research, we have obtained results identifying the main spatial planning characteristics, problems and potentials of the riverbank sites in the examined cities Komárno and Štúrovo.

From the second design part of the research, we have achieved results in the form of design proposals identifying landscape architectural strategies for the riverbank promenades of the examined cities.

4.1. Results of the analytical part of the research

4.1.1. Results of the analysis, problems, and potentials of the riverbanks in Štúrovo

In the analytical part of the research in the city of Štúrovo we have gained results covering the characteristics of the main problems and potentials of the Štúrovo riverbanks in the broad spatial context, in the context of landscape and nature protection requirements, in the context of urban functions and transport requirements, in the context of historical development and cultural heritage, and in the context of socio-economic and socio-cultural development requirements.

The riverfront of Štúrovo consists of parts with a vegetation of alluvial-softwood floodplain forests in the wettest areas which are regularly flooded, with willows, poplars and alders, and of urban part—where the main pedestrian street of the town is connected with the Danube. The public urban spaces of the urban part of the riverfront and also the natural parts of the riverbank lack basic tourist and recreational infrastructure typical for riverside location.

The waterfront offers spectacular views of the basilica, cathedral, and castle across the river in Esztergom, but it is underdeveloped, it does not offer restaurants, cafes or bars, or exterior rest places to enjoy the view, or places and facilities for other activities which are typical for urban waterfronts. For example, the personal port in Štúrovo, consists only from ship pontoons. The ship cruises stop usually on the opposite side, in Esztergom.

EuroVelo 6—'The Rivers Route' which passes through Štúrovo is a long-distance cycling route along the courses of Europe's major rivers, and almost the entire length of Europe's second longest river, the Danube. The flood barrier in Štúrovo offers the linear corridor for this route, but is not equipped with cycling and walkway infrastructure, the natural parts are not used for recreation or sports purposes.

The examples of the graphical presentation of the results of the analytical part of the research are given in **Figures 1** and **2**. The example of the analysis of the pedestrian, cycling and public transport connections of the riverbank in Štúrovo elaborated by students is given in **Figure 1** and the example of the specific "atmosphere" analysis of the Štúrovo riverbanks elaborated by students is given in **Figure 2**.

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4.1.2. Results of the analysis, problems, and potentials of the riverbanks in Komárno

In the analytical part of the research in the city of Komárno, similarly as in Štúrovo, we have obtained important results identifying the characteristics of the main problems and potentials of the Komárno riverbanks, crucial for the second-design part of the research.

In Komárno, the historical city center and the largest fortress of the famous fortification system are not connected with the riverfront because the riverfront is occupied by the industrial area of the port and the shipyard. The port area and the shipyard at present partially lost their former functions. The area is suitable to host new urban functions and waits for redevelopment and revitalization. It offers the opportunity to develop a promenade incorporating the industrial heritage and the specific *genius loci* of the former harbor area with cranes and rails.

The attractive confluence point of the rivers Váh and Danube, which is also the corner point of the fortress, is not accessible, and its potential of the landscape architectural point of view is not used.

The green spaces of the Váh riverbanks offer the possibilities of recreational greenways, however, today, similarly as in the case of Štúrovo, they are not equipped with cycling and walkway infrastructure.

The Elizabeth Island, the green area with gardens and few family houses, with the historical plane tree allée, offers possibilities to develop a promenade and to valorize the potential which is not used today. The corner point of the island is not accessible, as former industrial is not used and is suitable for the development of the personal port.

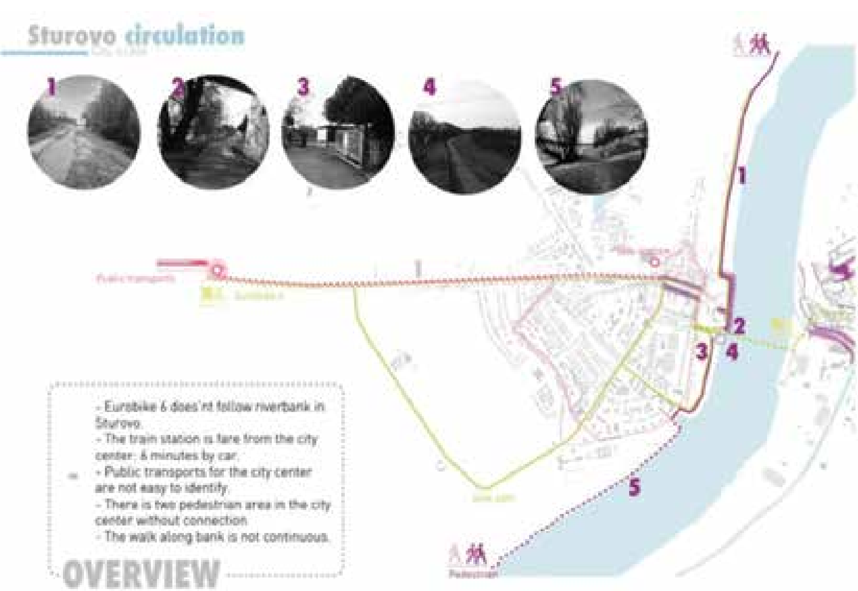

Figure 1. Analysis of the pedestrian, cycling and public transport connections of the riverbank in Štúrovo by students Florence Tiberghien, Noa Schumacher, Camille Clap, 2017, supervisor Katarina Kristianova. Source: Archive of Institute of Urban Design and Planning, Centre for Landscape Architecture.

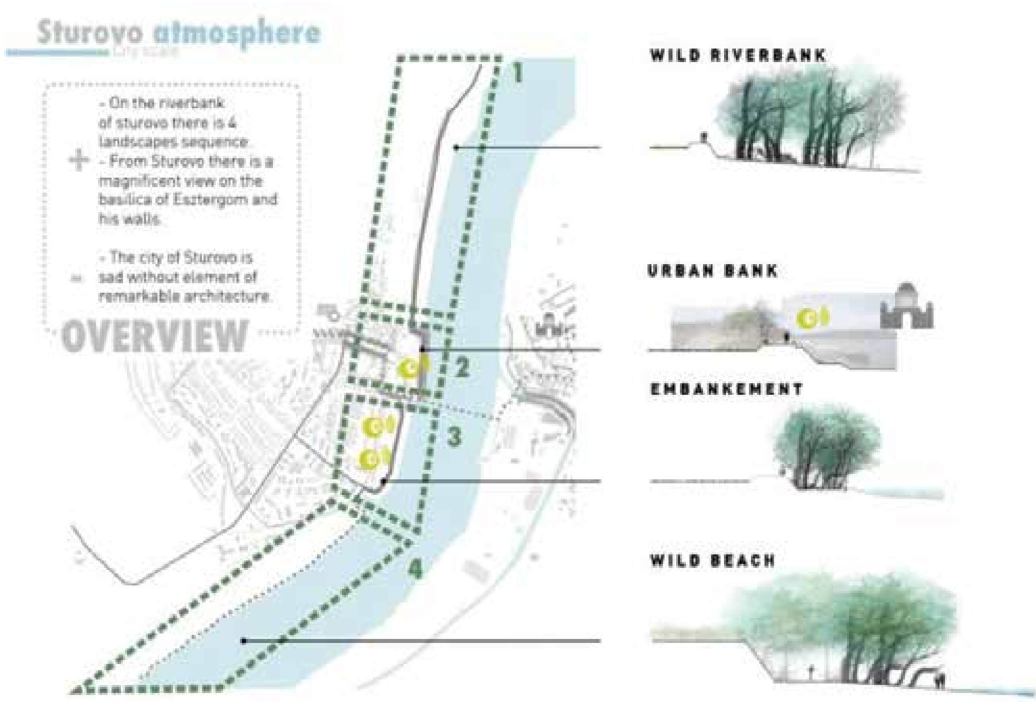

Figure 2. Analysis of the atmosphere of the Štúrovo riverbanks by students Florence Tiberghien, Noa Schumacher, Camille Clap, 2017, supervisor Katarina Kristianova. Source: Archive of Institute of Urban Design and Planning, Centre for Landscape Architecture.

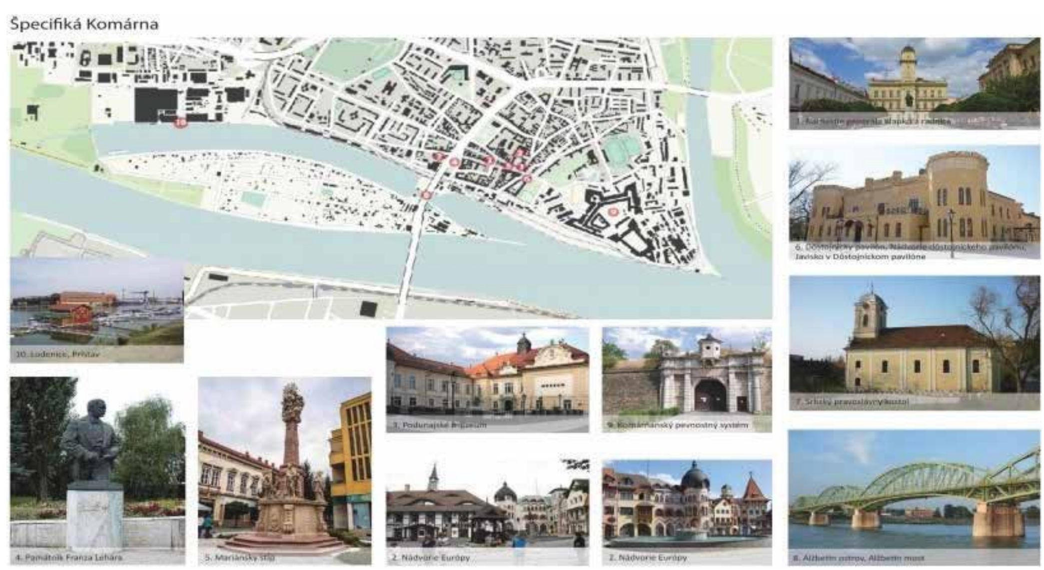

Figure 3. Analysis of the specifics, attractions and cultural heritage linked to the waterfront in Komárno by students Katalin Maga and Krisztina Nagy, 2017, supervisor Katarina Kristianova. Source: Archive of Institute of Urban Design and Planning, Centre for Landscape Architecture.

A substantial part of the research was devoted to the analysis of cultural heritage. From the research of historical literary, visual and map sources we have learned that many values of the historical urban and cultural landscapes of Komárno vanished. The results of the examination of extinct values and vanished phenomena of historical landscapes of Komárno and its intangible cultural heritage have been used in the second-design part of the research.

The main findings of the analytical part of the research, for example the analysis of the specifics, attractions and cultural heritage linked to the Danube waterfront, analysis of the functions and composition of the island riverfront, or the analysis of the landscape specifics of the Váh riverbank have been graphically expressed in the student works, showing results of various aspects of examination.

The examples of analyses of the riverfront in Komárno elaborated by students, are given in the **Figures 3–7**.

4.2. Results of the design part of the research: promenade as landscape architecture strategy for the riverbanks of small Danube cities

In the second-design part of the research we have tested the use of the concept of promenade as a landscape architecture strategy for the riverbanks of Komárno and Štúrovo. The results of the design part of the research are represented by several design solutions for the riverbanks in Komárno and Štúrovo elaborated by students and showing various possible landscape architectural approaches toward development of promenades.

Figure 4. Analysis of the functions of the island riverfront in Komárno by students Katalin Maga and Krisztina Nagy, 2017, supervisor Katarina Kristianova. Source: Archive of Institute of Urban Design and Planning, Centre for Landscape Architecture.

Figure 5. Composition analysis of the island riverfront in Komárno by students Katalin Maga and Krisztina Nagy, 2017, supervisor Katarina Kristianova. Source: Archive of Institute of Urban Design and Planning, Centre for Landscape Architecture.

Landscape architectural proposals for the promenades in Komárno and Štúrovo have been developed on the basis of knowledge obtained in the first analytical research step. They offer various urban attractions of riverfronts, apply the principles of an ecologically sound riverfront design, interpret cultural history and heritage, create recreation possibilities or enhance greenway functions of the riverbanks.

4.2.1. Results: design proposals for the riverbank promenade in Štúrovo

Students have proposed landscape architectural solutions for all parts of the riverfront in Štúrovo: for the main urban node of the promenade, where the main axis of the historical center—its main street opens to the river and offers views to the opposite bank—to Esztergom, with its landmark—the basilica (**Figures 8** and **9**), and also for the natural parts of the riverfront, which offer the closest contact with water.

Students understood that the uniqueness of local natural and cultural heritage in Štúrovo, are the major assets for the development of the promenade, and they appropriately used these assets in their proposals.

For the urban part of the promenade in Štúrovo students have proposed commercial services and facilities which are typical for urban waterfronts—restaurants, cafes, exterior rest places, and also spaces offering place for various uses, and for various specific exterior activities, for example during festivals and markets, which are regularly organized in the city and take place on the waterfront. Some student works proposed also a new terminal for the personal port.

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Figure 6. Analysis of the sequences of the Váh riverbank in Komárno by students Marie Cushing and Federica Petti, 2017, supervisor Katarina Kristianova. Source: Archive of Institute of Urban Design and Planning, Centre for Landscape Architecture.

In the landscape architectural design of the promenade, in both its urban and also natural greenway part, students have incorporated the cycling route EuroVelo 6, and equipped the corridor of the cycling and walkway route with accompanying infrastructure, offering points of rest places and also points of attractions and activities.

For the natural parts of the promenade, they proposed recreational paths with places to rest, play, or to the sport and also educational paths to learn about the natural biotopes and habitats of Danube landscapes.

4.2.2. Results: design proposals for the riverbank promenade in Komárno

Students have proposed landscape architectural solutions for all the parts of the riverfront in Komárno. They created the main urban promenade in the part where the historical city center and the largest fortress connect the Danube bay, with attractive and vibrant facilities (**Figure 10**) and the recreational greenway along the Váh and the fortification system (**Figures 11** and **12**).

They tried to valorize the potential of the attractive confluence point of the rivers Váh and Danube and also the edge point of the island by the location of a landmark—or 'brand mark' of the city.

Figure 7. Analysis of the interesting landscape structures of the Váh riverbank in Komárno advisable for protection and for conservation by students Marie Cushing and Federica Petti, 2017, supervisor Katarina Kristianova. Source: Archive of Institute of Urban Design and Planning, Centre for Landscape Architecture.

Figure 8. Proposal for the main urban square at the riverfront of Štúrovo with the congress center using the motive of containers and with the view of the basilica at the Hungarian side of Danube, by students Nika Partaš, Loïc Favorini and Louis Laheurte, supervisor Katarina Kristianova. Source: Archive of Institute of Urban Design and Planning, Centre for Landscape Architecture.

Figure 9. The proposal for the main urban part of the riverfront in Štúrovo, by students Florence Tiberghien, Camille Clap, 2017, supervisor Katarina Kristianova. Source: Archive of Institute of Urban Design and Planning, Centre for Landscape Architecture.

On the Elizabeth Island, they proposed spaces for recreation, sports facilities and the promenade on the flood protection barrier. They have incorporated the cycling route EuroVelo 6, in urban and greenway parts of the riverfronts. In the landscape architectural design of the riverbanks, students took into account many aspects, for example, water fluctuation and flooding, or ecological interests.

They adopted various design strategies and they created differentiated embankments. They created green riparian zones with riparian vegetation, and they created public spaces, beside the river, with direct contact with the water at various levels. To develop attractive and pleasant

Figure 10. Conceptual proposal for the 'Danube cultural promenade' in Komárno, by students Lívia Pires and Tanja Bozhinova, 2017, supervisor Katarina Kristianova. Source: Archive of Institute of Urban Design and Planning, Centre for Landscape Architecture.

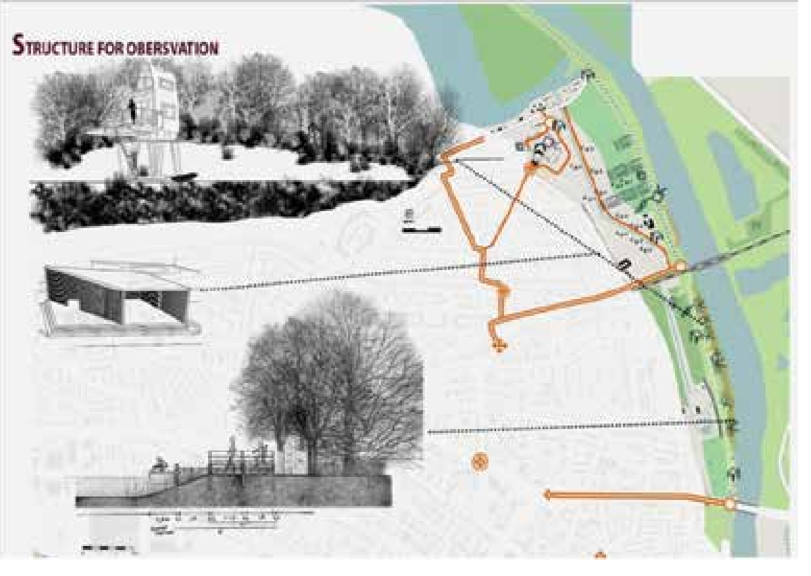

Figure 11. Landscape architectural proposal for the promenade and observation structures at the riverbank of Váh in Komárno by students Marie Cushing and Federica Petti, 2017, supervisor Katarina Kristianova. Source: Archive of Institute of Urban Design and Planning, Centre for Landscape Architecture.

places close to the water they designed broad terraces to access the water, walkways at the water edge, submergible board walks, or floating elements.

To preserve the genius loci of the industrial area and harbor, they incorporated the rails and the cranes as visual highlights of the promenade.

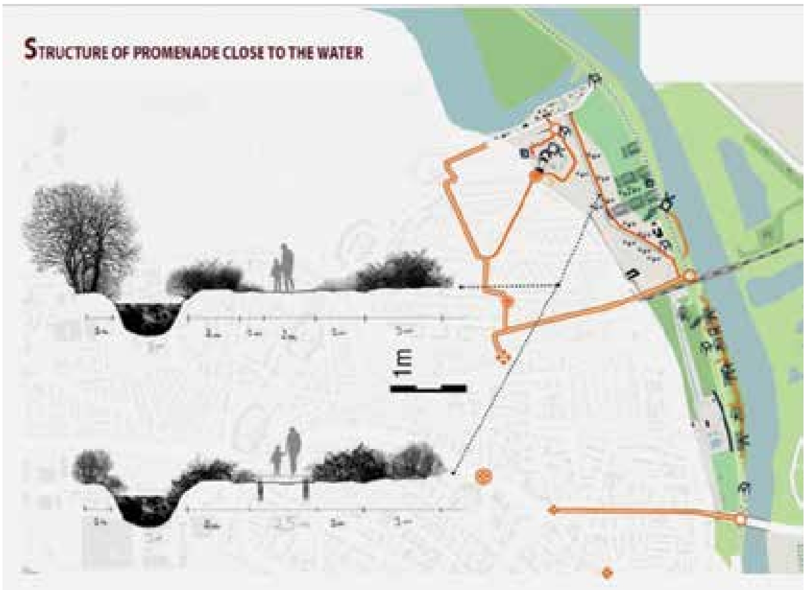

Figure 12. Landscape architectural proposal for the promenade at the riverbank of Váh in Komárno—Natural habitats close to the water, by students Marie Cushing and Federica Petti, 2017, supervisor Katarina Kristianova. Source: Archive of Institute of Urban Design and Planning, Centre for Landscape Architecture.

5. Conclusion

As noticed by Prominski et al. [18], the design of urban river landscapes as attractive locations and highly prized recreational environments must fulfill a broad range of requirements—flood control, open space design, and ecology are as a rule the three dominant themes. The design must be flexible and take into account the changing water levels, shifting seasons, erosion, and sedimentation, the river environment must be understood as a process.

As mentioned by Cengiz [19], with the well-planned restoration of urban rivers, multiple ecosystem services that have been lost or deteriorated can be recovered to some extent, and these restorations demonstrate the apparent benefits to human well-being such as health, economic value, life quality and contribution to regional renewal. Planning river management and urban development of waterfronts considering impacts on ecosystems can prevent or minimize the adverse effects, and appropriate mitigation methods can be determined to achieve the important and socially beneficial river functions [18].

Results obtained from the research and the design proposals made by students have shown the potential of the waterfronts in Komárno and Štúrovo for the development of the promenades, as viable, vibrant and popular urban places, and as greenways, offering recreation possibilities in the balance between nature and social life. The design process itself and its results, the various different design solutions for the riverbank promenades, became a way to acquire new knowledge on the possibilities to apply landscape architecture strategies of promenade development in small Danube cities. The results of research and the student proposals can serve the municipalities of

Komárno and Štúrovo to detect the values of riverbanks and to adopt new strategies to valorize their potential. The application of the landscape architectural concept of a promenade, as an interregional and interdisciplinary model for research, evaluation, and implementation, can be transferred also to other regions and small cities, respecting their site, natural and cultural specifics.

The multilateral aspects of the relationship between human settlements and water represent specific values for the urban structure related to water bodies [20, 21]. As the results of the research in Komárno and Štúrovo suggest, the landscape architectural strategies and the promenade concepts are able to rediscover the urban, socio-economic, recreational, ecological, cultural, historical and esthetic potential of urban riverfronts.

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Landscape Architecture of the Atacama Desert

Jose Guerra Ramirez

Additional information is available at the end of the chapter

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Abstract

This work focuses its reflection on the spatial and formal relationship between the conditions of extreme aridity of the Atacama Desert and the expression of an appropriate architecture where the contemporary notions of desert landscape and sustainable architecture intersect. The conditions of the desert environment are presented and differentiated between the different ecological levels that, by altitude, distinguish and determine the architectural response. The notion of the desert landscape linked with the occupation of the Andean cultures is mentioned, contrasting this analysis but not under the traditional concepts that understand the desert landscape as an inhospitable landscape or a place that is not favorable for living beings. On the contrary, we propose to understand the desert as an ecologically fragile landscape of high scenic value, in which a desert culture has been developed, in the archaeological field, in the agriculture of the oases, and a great productive activity of the sustainable mining industry. Finally, the environmental invariants that are considered at the architectural design level are established as attributes or environmental properties integrated in an ecological framework allowing us to distinguish how these significant entities in a certain context organize in an unprecedented way how to inhabit the desert.

Keywords: desert landscape, architecture, arid zones, passive system, Atacama Desert

1. Introduction

The Atacama Desert is recognized as the most arid region of the planet; however, faced against this dry, inhospitable and hostile climate, the desert has revealed itself as a favorable environment to life under conditions of austerity and scarcity, where unpublished proposals for environmental conditioning have been implemented. These developments are what we highlight in this chapter. They are recognized as sustainable architectures, strategies that have allowed to deploy on this extensive territory small human settlements of agricultural origin such as the ayllus, industrial origin as the saltpeter offices, the same as mining and urban camps as cities ports, each one of them with characteristics of remarkable adaptation to this territory, here are vestiges of more than 10,000 years sheltering life from atacameña tradition and perfecting the culture of the desert from small Andean villages, foothills oases, to saltpeter camps and city ports there is a chronology of territorial occupation from the Andes to the coast, which is diverse and complex through the pattern of high mobility and ecological complementarity that, with a history of prosperity and decadence, undergo processes of transformation, evolution and social-environmental conflict up to the present [1, 2].

In its diverse scales each ecological floor of the desert allows to identify units of landscape, micro-environments for example the ravines, they are transformed into natural shelters, their protected hillsides are considered discrete areas of landscape, which allow occasional occupations in relation to the presence of vegetables, more favorable environmental conditions, water availability and quality. This precision allows us to understand the desert landscape not as a void, but as a full territory where each rock, each hill has a name in the diverse toponymy of the Andean culture.

On a territorial scale, the Atacama Desert follows the pattern of high Andes-coast mobility, today full of mining roads, yesterday traces and caravan routes that crossed the wide and open landscapes of high visibility, associated with roads and paskanas (caravanner shelter), that have allowed to delineate roads that articulate the various environments of the desert. The geomorphology of the Atacama Desert offers a spatial continuum that connects the western edge of the Andean range with the eastern edge of the Coastal range. This is a dry world, with minimal groundwater resources, which are manifested in gouaches or utility wells for crossings through a territory of hyper-arid conditions [3].

The choice of certain mountains and hills along the transect, selected with the purpose of transferring the representation of icons inserted in the caravanserai ritual, symbolized the sacralization of the landscape where the geoglyphs marked the character of a sacred hill, in that space is that, making an obligatory transit passage, it was a landscape marked as a ceremonial altar as well [4].

It is necessary to distinguish on a spatial scale, the value of the oases that arise within the monotonous dryness of the desert, environments that offer protection and a favorable climatic condition for life, giving shape to a spatial order pattern relevant to extreme weather conditions, lifestyles, and transhumance of desert societies that are still a key component in the development of existing "islanders" settlements like the agricultural settlements of Chiu-Chui, Peine, Toconao or Socaire in the ecological floor of the Puna Atacameña, enclaves associated with the industrial development of the saltpeter, copper, and lithium mining or port cities of intermediate scale with developments far from the reality and built with styles and types of housing and buildings not consistent with the current challenge of sustainability, energy design, and architectural identity.

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Figure 1. Andes-coast mobility, petroglyphs in route caravans.

The traditional architectural culture of the different ecological levels of the Atacama Desert is productive in examples that allow us to understand the relationship between the architectural form and climate conditioning, the bioclimatic strategies are based on the adoption of an orientation to sunrise, location on slopes protected from the wind, in situations of landscape mastery, use of building systems and local material resources that are manifested as adaptations to face the extreme climatic conditions of the desert. The adaptation practices have been categorized in the following invariants: to inhabit exteriority, to build the shadow and to inhabit the dark (**Figure 1**) [5].

2. Architecture in extreme weather

The Atacama Desert is the region with the greatest radiation and aridity of the planet; it is a territory characterized by the absence of rain and lack of surface water. The causes that determine these conditions of extreme climate are: the climatic stability produced by the subtropical anticyclone of the South pacific. The thermal inversion made by the Humboldt polar current creates a layer of cold air of low humidity called camanchaca establishes a wedge of high pressure between the 1500 m above sea level obstructing the approach of the hot and humid air mass from the South Pacific and the geomorphological condition given by the abrupt elevation of the coastal terrain (Costal Range) that is formed as a closed and continuous wall that prevents the penetration into the interior of humid air masses [6].

These are the conditions in which the architecture that expresses a sensitive approach for the weather is developed, we classify it as extreme, having to respond equally to the high intensity of daytime solar radiation and low night time temperatures, in this thermal contrast, the traditional architecture of the desert creates its formal expression using passive strategies. On one hand, building a thermal solar and light protection with a shadow envelope that shelters the daily activities unfolded in the external environment, as an extension of the interior. On the other hand, building compact inwardness that isolates and protects from the cold with thick stone or adobe walls that perform the function of storing thermal energy that is released at night.

The body perceives the extreme environmental contrasts that happen every day, the body manifests itself by expanding the senses to the enjoyment or the rigor of the thermal (heat or cold), the sharpness and light intensity (full light or deep darkness), and the experience of exteriority and the delimited interiority.

The relationship that the architectural space builds with exteriority, as the most remarkable dimension of the desert space is open, the exterior offers the possibility of growing, expanding, and arranging the open-air environments to carry out daily diurnal acts such as cooking and eating, the spaces of intermediation interior-exterior shelter multiple functions to be in relation with the outside, thus for example hallways, pergolas, terraces, and backyards, besides fulfilling the function of climatic control, allow direct contacts with the elements of the landscape that disrupt and change the sense of inhabiting the desert.

The territorial dimension of the Atacama Desert has always been a visual experience, since the first inhabitants, since the first caravanners, the desert has been related to great distances; a journey through vast territories without limits, a journey through immensity, through emptiness, a path that runs through the last skin.

"Nos sitúa como en ningún otro ambiente en la unicidad, entre el yo y la soledad del ultimo paisaje, en el último extremo, se experimenta la condición de estar sobre la piel más exterior en el último confín, en el límite donde solamente la corporeidad conecta esos dos océanos, acariciando los límites de la exterioridad." – *Author's inspiration, meaning might get lost in translation.*

They are intangible and tangible qualities that provide architecture with new esthetic and creative concepts, whose use requires careful consideration, as it is demonstrated by the vernacular architecture and the informal architecture of the desert [7].

The contemporary architectural culture of the Atacama Desert presents some remarkable examples of this adaptation. Places such as the ESO Paranal hotel, The Museum of the Desert, or the facades of the Court buildings are good examples of this mutation, works that create new expression language building a new esthetic of energy design, a new physiognomy that integrates and reinforces the regional identity, forms that are a contemporary reinterpretation of languages that evoke a patrimonial architecture where the design of an envelope that acts as sunscreen, light sieve, ventilated double skin, shade covers stands out and skylights that fragment the light intensity.

Architecture as part of ecological systems evolves along with the needs and requirements of its inhabitants, recognizing the impact on spatial and formal matters of these factors is part of the interaction and coherence of architecture with the preexisting values of the place, establishing a combination of new identifiable forms which are typical of the desert, with that, the aim is to achieve the integration with the ecological system using the natural energies that flow and impact on the building, in order to achieve the well-being and thermal and luminous quality of the inhabitable interior space where walls and windows, roofs and floors are not only observed as limits to protect against the weather, but as energy-capturing components [8].

The varied strategies of environmental conditioning of the architecture of the Atacama Desert in its various ecological levels are notable examples of the functioning of environmental conditioning strategies in its passive mode. The processes of "acclimatization" are highlighted as actions and the effect that seeks to transform the architectural fact, to dispose it to a better condition of well-being especially in thermal and light matters. These processes which seem natural are not always present, and it is common to find foreign architectural and construction typologies that do not respond to these standards of cultural identity or energy efficiency.

In terms of matter and energy, the features of architectural design that affect the thermal performance of a building are above all its solar load and heat gain in summer, as well as the potential for ventilation and shadow construction. Consequently, the architectural design of warm weather places must consider the following aspects:

to achieve thermal insulation, mass of thick adobe and/or stone walls must be used, to control the direct radiation systems of ventilated facades and roofs should be preferred, and to control the intense natural light and solar protection of windows, blind systems should be chosen, for the sieve and filter among other variants such as incorporation of vegetation according to the ecological floor.

Here the participation of the user or home automation systems is required to operate, for example, the closing or opening of windows and/or shutters during the day, ensuring the darkening and cross ventilation of the interior spaces in the hot or cold periods.

With an adequate selection of passive strategies, habitability conditions are achieved naturally, and by taking advantage of solar energy, it is possible to provide up to 90% of the heating required by normal size building (**Figures 2** and **3**).

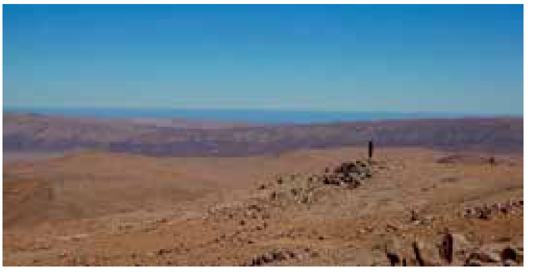

Figure 2. Infinite horizons, stony landscapes.

Figure 3. Spaces of loneliness, full luminosity, extensive landscapes.

3. Ecological landscape and architectural form

The altitudinal factor or geographic verticality defines the heterogeneity of the Atacama Desert, and this is the fundamental feature that defines the microclimatic profile and ecological system, in its transept from the low or coastal floors to the upper floors of the foothills and highlands of the Andes.

The climatic classification of Golubev distinguishes a great variety of ecological landscapes; however, for the purposes of the present analysis, we unify them into three large territories, three great landscapes, and three deserts: (1) ecological flat-littoral desert, (2) ecological flat-intermediate depression or longitudinal valley, and (3) ecological flat-high altitude foothill desert [9].

The altitudinal gradient is the characteristic, which shapes the landscape of the Atacama Desert, distinguishing it as one of the most fragile and inhospitable ecosystems on the Earth due to the combined effects of high solar radiation, low night temperatures, and extreme aridity.

It represents a great challenge of high environmental patrimonial value that in this environment stable habitats of more than 10,000 years of activity and human presence were built [10]. The strategies of adaptation and use of natural resources in each ecological floor are linked with an ancestral knowledge, which constitute an adaptive condition of the desert cultures. The manifestation of this domain occurs because of the productive activities developed in these territories, from the more traditional activities such as agriculture and Andean livestock, the development of small saltpeter mining and the large extractive industry of copper and currently the singular developments of scientific activities such as the important astronomical observatories of ALMA, Paranal, and Armazones to the thriving boom of the renewable energy industry based on the development of solar energy that has occupied large areas of photovoltaic farms, vital to understand the settlement model we find today.

In each ecological-geographical flat, we distinguish a singular occupation pattern of high mobility and Andes-Coast ecological complementarity since pre-agricultural times, this is verified in numerous archeological remains that define a dispersed occupation model following the structure of the streams that offer a natural shelter condition with thermal, hydric and vegetation qualities favorable to mobility between ecological flats.

This is an explicit variable for environmental sustainability, in the ecological, cultural, human and significant matters, understanding this means to overcome the importance of renewed and appropriate actions, where the implementation processes require adaptation to this reality that is inhospitable, with an environment of absolute solitude and where isolation is part of the self-absorbed personality of the desert man (**Figures 4–6**) [11].

The architecture of the desert of greater relevance is understood as a sensitive manifestation for the environment and weather, which connects the work with the landscape, the significance of this relationship establishes a constant interaction referred to the thermal and light aspects of the architectural space.

This circumstance is analyzed below and will be reflected in the ecology, the desert microclimate and the architectural form in the context of the Atacama Desert (**Table 1**).

Figure 4. Geographic verticality – coastal desert.

Figure 5. Geographic verticality – desert intermediate depression.

Figure 6. Geographic verticality – high altitude foothill desert.

Ecological landscape	Coastal Desert Coastal range	Desert Pampa Central depression Intermediate Plain	Andes range Foothill Highlands
Altitudinal factor	0.000–3.000	1.200–2.600	2.600–6.100
Features of the weather and environmental conditions	Tropical desert of marine or coastal plain appears without vegetation in low areas and vegetation like cacti in the high summits because of the presence of camanchaca High humidity Relative Presence of SW wind offers natural ventilation	Tropical desert full of alluvial plains Inter mountains No vegetation Extreme dryness No water Low relative humidity High thermal oscillation (day-night) Environmental dryness	Tropical desert with vegetation of jaral and tolar. Cold highland Andean steppe Oases Elevated temperature difference during day and night time Summer rain during the so-called altiplanic winter
Passive conditioning strategies	Natural ventilation Control of solar radiation on the west facade Control of natural lighting Capture of solar energy on horizontal surface Outside filter Eaves Covered backyards Covered terraces	Humidification Ventilated envelope Vegetation Capture of solar energy Shadow Extreme dryness	Thermal isolation Night cold Thermal mass Small vans Solar energy capture Day shadow Exteriorization of daily outdoor activities

Table 1. Eco-environmental characteristics and passive conditioning strategies.

3.1. Coastal Desert architecture

The geographical profile of the coastal desert corresponds to narrow plains delimited by the abrupt eruption of the Coastal range, reaching heights of more than 3000 m above sea level, such as “Cerro Paranal” of 2600 m above sea level and “Cerro Armazones” of 3046 m above sea level. The weather is characterized by a great atmospheric stability, with abnormally low temperatures for latitude, explained by the presence of the cold Humboldt current and of a characteristic coastal cloudiness (camanchaca) that dissipates at noon, which produces the greenhouse effect produces the “fog oases” between 600 and 1200 m above sea level which allows suitable conditions for the development of an endemic flora.

In the coastal desert architecture, it is possible to maintain an appropriate interior thermal comfort, involving only passive environmental conditioning solutions, and this is possible with the correct application of passive strategies such as an orientation of the building which allows to take advantage of cross ventilation coming from the south west winds, use of passive cooling with double cover systems and ventilated wall, a form of the building that considers the control of the sunlight in the design of west facade envelope and a cover that limits the direct gain on those surfaces [12].

In this latitude, from the tropic of Capricorn, the high solar radiation hits almost vertically, which influences the thermal gain of the horizontal surfaces; hence, the importance of integrating energy-gathering roofs such as solar roofs, and solar control systems on the west facade, in the same way, the great impact of light is a factor to be considered in the architectural design of private and public spaces. The element that provides the greatest comfort in the coastal desert weather is natural ventilation, the constant presence of the sea breeze acts as a thermal regulator, modifying and moderating the temperature and relative humidity [13].

The most effective and efficient passive design strategies are: the design of a ventilated envelope, the solar protection that integrates a double skin on roofs and facades, covering with shadows intermediate spaces such as terraces, corridors and interior patios.

The intense luminous flux that produces visual fatigue and glare requires lighting control strategies of both the direct and diffuse component, here blinds or external filters, screens, skylights, and plant walls are particularly effective in producing light flow fragmentation and generating luminously comfortable interiors.

The building tends to be porous, the form tends to a fragmentation of volumes and openings; eaves, corridors, and terraces as extension of the interior. It has the objective of minimizing the heat gain by direct solar radiation or by conduction (**Figures 7** and **8**).

Figure 7. Shaded patio with cane weave.

Figure 8. Covered terrace.

3.2. Architecture of the Atacama Pampa or intermediate desert

The pampa or desert of the intermediate depression is a plain that rises gently from 1200 m above sea level to 2600 m above sea level. The weather is totally desert, landscapes of extreme aridity, great atmospheric dryness, clear and clean skies, with absolute lack of precipitation, the highest solar radiation indexes of the planet-around 275 W/m^2, it has strong winds and large thermal oscillations from day to night time, during the daytime hours high temperatures are reached and during the night the energy loss by long wave radiation is particularly intense with large temperature drops.

In this uninhabited place, human settlements have a transitory nature (saltpeter offices and mining camps) and linked first to the exploitation of saltpeter, then copper, and today solar energy. The only and largest permanent settlement is Calama, which is located in the oases that is naturally generated by the Loa River and its development is linked to the proximity to the Copper Mine of Chuquicamata at 2900 meters above sea level.

The architecture of this area is prefabricated, and standardized models appropriately adapted to withstand the rigors of the weather which is expressed with generous corridors, eaves, pergolas that build deep shade sheds, that protect the facades of the shadow building from exposure to direct radiation. The high illuminance is controlled with a light envelope of low thermal capacity that allows ventilation that generates shade and diminishes the intense luminosity, and to increase the low humidity, water is used for the vegetation in grapevines and creepers (**Figures 9** and **10**).

3.3. Architecture of the Andean foothill or Puno region

Ecological foothill floor, known as the low and high atacameña puna, goes from the 2600 m above sea level where the gorges, salt flats, and high summits stand out that can exceed 6000 m above sea level as the Llullaillaco Volcano that reaches 6739 m above sea level.

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Figure 9. Double cover shadow.

Figure 10. Shadow under the windows.

Puno region presents the most stringent climatic conditions of the Andes in terms of aridity and the reproduction of flora and fauna. The physical-climatic profile that distinguishes the region is characterized by the tenuous atmospheric layer and a low relative humidity; both factors allow to achieve high solar radiation indexes during the hours of insolation (230–290 W/m^2 annual average) and high loss by long-wave radiation from the Earth's surface 24 h a day.

The greenhouse effect in the Puno region is weak; during daylight hours, high temperatures in the ambient air are not reached, and during the night, the loss of energy by long-wave radiation is particularly intense with large temperature drops. The relationship between global radiation in summer and winter is 2:1; this makes it necessary to use passive systems of accumulation of the day for the night. This implies the use of passive systems using thermal mass, a north-east orientation to collect the first rays of sunlight and a protection of the norponiente wind that is intense at dusk, reaching greater intensity during the winter months in which it develops speeds superior to 60 km/h.

The average temperature has a high thermal oscillation between 21 and 4°C, the lowest temperature in the winter months can reach −2° C. Relative humidity usually low, fluctuates annually between 30 and 50% and, even though there are no many rain events, those are concentrated in the summer months in response to the high plateau winter.

The vegetation in this area is expressed in the oases and the formation of tolar vegetation in the bottoms of fertile ravines and hillsides typical of the ecological floor 3000 m above sea level, significant for its forage potential, favorable for hunting and/or grazing activities.

The vernacular architectural proposal that we observe in the Atacameña Puna is naturally linked to provide a minimum shelter for extreme weather conditions, with the resources that are available in the environment; consequently, the physiognomy of architecture is associated with a direct correlation between ecological and behavioral aspects. The main characteristics assumed by households in the face of climate determinism are: their solar orientation, location in environments protected from the wind and use of local resources as basic building materials, in this case stone or adobe.

Different typologies are found in the use and constructive technique for the construction of walls with thermal mass, black natural stone wall without mortal is used for premises such as corrals and outdoor fireplaces, walls of large white natural stone which is available in the corners, and lintels as structural reinforcement and significance.

From the microclimate point of view, the structure of the house, its arrangement and the order of the backyard work like a solar clock because the solar position establishes the moment of the diurnal-nocturnal cycle.

The structure acts as an energy collector which is open to the East, toward the morning Sun and close to the west where the cold and dry wind whips, where the Sun declines, letting the night emerge, when the “shadow passes through” the cold arrives.

The compact form is an appropriate model for settlements in arid areas, narrow streets, buildings with small intertwined backyards contribute to generate a microclimate or “a cool island,” moderating the temperatures in relation to the external weather. The effect of the urban heat island, in general, in arid cities is mainly a nocturnal phenomenon, and has less relevance than in more tropical regions.

The exposure of the building’s mass to cooler afternoon air could get increased by maintaining a compact configuration during the warmer hours. The walls act as a storage mass, helping to stabilize the large daily temperature fluctuations and increase the thermal delays between the maximum external temperature and the minimum internal temperature, a closed envelope with a high thermal capacity helps to control the loss of energy and the internal/external energy flow and vice versa.

Figure 11. Kitchen and dining room outside.

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Figure 12. Vernacular house in Alto Loa.

The envelope in contact with the outside must be as small as possible to minimize the flow of heat into the building. The possibility of transforming the area of the effective surface of the envelope of the building, in relation to the station or the daily climatic condition (**Figures 11** and **12**).

4. Spatial-environmental invariant features

The environmental invariant features integrated in an ecological framework allow us to distinguish invariant qualities as significant entities in a certain context of related variables that articulate ways of inhabiting:

1. To inhabit the desert as an experience of living the exteriority
2. To inhabit the desert as the construction of the shadow
3. To inhabit the desert like living the darkness or semi-darkness

4.1. To inhabit the desert as an experience of living the exteriority

We define the natural desert space as pure exteriority; the condition of the architecture is forced to manifest this condition in its form. The link between inhabiting the desert with the exteriority has the following formal consequences: on one hand, it brings the elements of the exterior landscape in a controlled and fragmented way into the interior, through elements that filter the light and build shadows; on the other hand, the interiority projects diverse outdoors acts, being confused with it.

To inhabit the desert environments, has as a primordial quality this possibility of inhabiting exteriority as interiority, that is, a great diversity of daily activities can develop fully in the open sky, a circumstance commonly observable in the ways of occupation and exteriorization of inhabiting. However, this quality of the desert space, of an apparent simplicity, involves a subtle complexity, since the temporal condition determines the form of use of outer space. If we notice the form taken by the building, in the occupation of outer space, we will verify that the relationship of the interior with the exterior is based on a dynamic understanding of space, in other words, the shape of the building can grow and/or decrease, it can incorporate or separate spaces, from every point of view, the form is being transformed and interacts with its environment.

From this point of view, the construction of the limit in the desert space, despite having the safety function, is, above all, a response to the need to size exteriority. Likewise, as happens naturally in areas where the relationship with exteriority is mediated by the arboreal mass, constructing the interface of mediation between inside and outside, in desert environments, this notion of mediation or limit does not exist naturally. Therefore, it is necessary to build and configure it, to conquer a distance or size [14].

Indisputably associated with energy parameters, the desert architectural space is determined by the dimensions of an immeasurable landscape deprived of vegetation. To inhabit the desert is to inhabit the immensity; it is to be in the extension to build an order in relation to the tectonics of the Earth, the stone and the sand. In a landscape of infinite horizons, the construction of the vertical to configure the shelter and the shade is an unprecedented fact in this desolate landscape, a wall defines the side of the Sun and the side of the shadow; light and shadow are the binding qualities that found the order of the desert space. The environmental conditions of the outdoor space allow that the interaction between people and their built environment become dynamic so that the interior space is overturned on the outside.

The formal qualities of the desert space are determined by the ways of using the interior-exterior space and by the way of performing the lighting conditioning of the interior. A delicate architecture of filters, of shadows and darkness, of semi-open or semi-covered spaces, an architecture in which daily acts unfold under the shade, in coexistence with the order of exteriority. These qualities have been the architectural material of notable contemporary architects who have succumbed to the magic of the elements, reflecting in their forms the influence of these sunny territories.

Each one of these architectural works is an act of creation that fuses the body and the landscape through the senses and movements, which adapt and respond to that great availability of the Sun and light of the desert territories (**Figures 13** and **14**).

Figure 13. Outdoor yard.

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Figure 14. Exteriorizations of daily activities.

4.2. To inhabit and construct the shadow

For every architectural form, the Sun is an element of essential order, but for the architecture of the desert, according to Thomas Herzog, the Sun offers the highest degree of technical efficiency in direct uses (natural light or passive thermal application) and indirect forms of free emission (wind towers, photovoltaic installations or thermal collectors) [15].

In arid areas, the environmental conditioning needs of the building depend on the type of desert climate, but usually are ventilation, cooling and heating requirements, for which various strategies have been developed and they consist of minimizing the solar gain or heat load through the architectural design, isolate through natural means to reject or capture and store heat for future needs or capture energy. The protection of the intense luminosity with the application of filters in the windows and/or the darkening of the interiors in the daytime hours, to maintain thermal and visual comfort, are some of these strategies.

The preference for energy design represents a unique option for the progress of developing economies, the environmental orientation of the desert architecture implies the integration to local conditions and specific needs, rather than a regulation, the work should be aimed at knowing creative processes and skills, as shown by the solutions proposed by users and architects in the references. In these transformations, new architectural concepts are developed, but without forgetting the traditional proposals. The transformation of housing makes unprecedented possible prototypes, which have the hallmark of informality and "vital architecture" [16].

The process of transformation or conditioning of the households identifies dominant actions in the climatic design for the coastal desert climate, in the fact of building double envelopes such as double covered or double facades. These elements participate in a decisive way in the defensive action, as a passive system of climate control and also, in the spatial definition of the built event, being relevant in the topics of natural ventilation, insulation, and solar protection.

In this constructive action, we distinguish as a founding act in the definition of the desert space, the construction of the shadow, rather than defining the walls, at the beginning the definition of a shadow, an ephemeral shed, almost immaterial, it is significant. This constructive fact establishes a formal, singular, and decisive language for the architecture of the desert, in poetic terms, we can say that the architectural corporeity dresses itself as immateriality, where the limit is diluted in the light of the desert.

To construct the shadow is to construct a form in movement, in constant change, which defines limits and spaces. The shadow is directly linked to the characteristics of the envelope, participating in the definition of the duality of the interior-exterior space. The construction of the shadow involves determining the characteristics of the envelope; in this case, we are not talking about a hard, cold and dark shadow, but rather a dim shadow that filters the light.

The definition of this double envelope in facades and roofs implies a dynamic spatial development, which as a system must respond to the function of solar radiation isolation, allowing also natural lighting and ventilation of interior spaces. In most cases providing spaces of habitable intermediation, spaces of attached extensions such as corridors, portals, shaders, sheds and covered terraces, which also allow environmental regulation in the development of human acts (**Figures 15** and **16**).

4.3. To inhabit the darkness

The regulation of visual comfort in the light field in desert climates is one of the less developed aspects of contemporary architecture, which seeks transparency and luminosity. However, in the vernacular architecture, the care for these aspects was clear, and the different graduation of light and shade in the premises was a function of the degrees of privacy or retreat.

When we observe the transformation made by people in their own homes, we find ourselves with a lighting control strategy appropriate for the local weather, even though the measurements of the lighting level of the indoor areas express values below the recommended, the light perception in these environments is comfortable, because inhabiting the darkness does

Figure 15. Light fragmentation in market in Maria Elena.

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Figure 16. Railroad garage roofs in Antofagasta.

not mean living in the dark but being in a cool environment, in a half-light atmosphere, with pleasant and adequate light in relation to the intense external luminosity.

Today when artificial lighting fills everything, eliminating the last few shadows, it is remarkable to find environments in the homes of the desert where, the light concept of spaces is defined in the coexistence with semi darkness, in the soft twilight.

The discovery of the use of cold and dark colors in the interiors; spaces painted blue-green colors when interacting with dim lighting, they manage to build a smooth exterior-interior graduation through the transition spaces, which contrasts with the external glare offering luminous and thermally comfortable environments in a cool darkness, which is a pleasure from another time [17].

For a long time, the architecture of the desert neglected the environmental and energy efficiency aspects in desert cities, nowadays, there is a growing trend that reverses this attitude, the climatic aspects in the design of housing have been taken into account, the same as solving thermal problems of heating or cooling with renewable energy especially solar and passive strategies and energy, these practices are more frequent and they show a clear signal of the cultural change of comfort and well-being (**Figures 17** and **18**).

Figure 17. Shadow transitions.

Figure 18. Filter and interior darkness.

5. Conclusions

In the words of Peter Reyner Banham, in the book Scenes in America Deserta [18, 19]. Modern cities in the desert seem out of place, clumsy anomalies in a place where nature must prevail properly.

This is a statement that we share, since it can be seen when we see that the development of recent architecture in the cities of the Atacama Desert repeats constructive typologies that are not related to or linked to local climate conditions.

In that sense, it is very clear to establish that the architecture of the desert needs unprecedented and creative responses that answer to environmental invariants, in which the recovery of traditional values is designed, with the incorporation of appropriate technologies, so that the architecture and cities of the desert do not appear uprooted or out of place, without the environmental consideration determined by the landscape.

The interpretation made of the landscape is linked to a proposal of action that is expressed in the constructed form. The recognition of this formal impulse is not exclusive to desert environments, the seduction which the elements of nature manifest themselves with in this landscape makes the expressive language austere and of greater determination.

The qualitative aspects are linked to the appreciation of the desert landscape, especially in relation to the immensity, the extension of its limits, and with the vastness, the tectonic roughness of the skin, or the intense luminosity to which the environments are exposed, among other features.

The relationship that people establish with the built space is linked to the quality of the existential experience of the environment that surrounds us, all of which makes us belong to a social and cultural totality [20].

Our spatial perceptions and experience are associated and stored in our memory, along with the environmental qualities of a certain temperature and luminance quality. In the case of the desert space, these characteristics impact on the quality of the habitat, as well as the experience of satisfaction when contemplating a sunset in the desert, it will be associated to the atmosphere and light quality, to the silence that surrounds us and overwhelms the beauty of colors that lights the desert.

Consequently, the assessment we make of sustainable architecture in desert areas is not limited to highlight energy savings or lower maintenance costs of a building.

The greatest importance of a sustainable building lies in the positive impact and change of the conditions of habitability, which are housed in the levels of well-being in our existential satisfaction matrix of "being," which are ultimately the most important attributes for our existence.

The incorporation of new unpublished and creative proposals with high standards in the architectural quality of the interior environment, and integration of passive environmental conditioning strategies and the technical specification of first quality materials have a positive impact on the construction of a desert architecture with an identity.

This identity leads to the construction of a new esthetic in relation to the physiognomy and expression of the envelope, which integrate the concepts of "energy capture facade," "active facades,"

Figure 19. Cover in new school of Tocopilla city.

“green facades” or “solar roofs” in all of them there is a purpose of integrating renewable energies for solar capture, which ultimately renew the architectural language and urban landscape.

The energetic design is changing the expression and language of the architecture in the Atacama desert, expressions of a new esthetic, a new physiognomy that integrates and strengthens the regional identity, forms that are a contemporary reinterpretation of languages that evoke a heritage architecture, where the design of an envelope that acts as a solar filter, light sieve, double skin, ventilated intermediate space, shade covers, and skylights fragment the light intensity of the desert landscape (**Figure 19**).

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Chapter 17

Recreational Landscape Value in Tourism Development of Central Yakutia

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Additional information is available at the end of the chapter

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Abstract

Tourism is a significant element of Russia's social and economic development. Northern territories play an important role in the development of the Russian national economy in general and of the tourism industry in particular. Northern tourism involves careful observance of environmental and social sustainability, promotion of traditional native knowledge and value systems, and preservation of native cultural heritage and cultural landscapes. This article provides an analysis of the promotion of the tourism potential in Yakutia. Russia's northern territories are rich in natural resources and economic potential but lack effective tourist infrastructure due to harsh climates and vast permafrost areas. This research is funded by the Russian Science Foundation (project # 15-18-20047 "Landscape ontology: semantics, semiotics, and geographic modeling"). This article presents the results of an analysis of the recreational landscape of "Orto Doidu" tourist complex, which is open year-round and located in the Khangalassky region of Central Yakutia. The main factors for tourism development were determined to be a set of landscape characteristics (the unique nature of the Lena River, the biological diversity of flora and fauna), ethnocultural and historical context, and infrastructural considerations (proximity to the capital city, inexpensive transportation, and engineering systems).

Keywords: landscape, recreational value, tourism development, cultural and natural heritage

1. Introduction

Territorial differences create various predispositions for regional development in the context of natural conditions, resources, and historical heritage. The North is the largest of the remaining territorial reserves; its resource potential is tremendous. Tourism development in the North could be viewed as one of the ways to explore the new northern lands, where each of the northern nations has its unique regional characteristics. Regional potential depends on the territory's attractiveness, level of national economic development, infrastructure, national mentality, and legislation.

Recently there has been a considerable increase in the number of tourists wishing to visit the North. The growing popularity of environmentally sustainable recreation has resulted in new forms of tourism, as well as in new forms of recreational offerings in the sphere. Among some of the key reasons for the increasing popularity of northern tourism are significant overloading of the traditional mass tourist routes, global warming, and transport development. Environmental and ethnographic factors play a key role in the development of northern tourism. The native population has preserved their traditional lifestyle, while traditional natural resource management is becoming the primary factor in Northern entrepreneurship promotion [10].

The unique natural resources found in the Republic of Sakha (Yakutia), Russia, greatly enable the development of tourism, which is thus capable of becoming an alternative type of economic activity and income source. In Yakutia, one can enjoy the wild density of taiga forest, vast reaches of tundra, the severe beauty of mountain ridges, the icy landscapes of the Arctic, and the unique cultures of the native peoples. Although local climactic conditions do not favor many types of recreation, among some of the most promising forms of tourism are environmental, sport, cruise, ethnographic, social, rural, business, research, and discovery traveling [9].

1.1. Tourist potential of the Republic of Sakha (Yakutia)

The tourist market in the Republic of Sakha (Yakutia) is relatively new due to the territory's geographic remoteness from the major tourist centers and weak transport infrastructure. According to 2013 data, there were 83 travel companies in the republic. 4.8% of those acted as tour operators, 54% as travel agents, and 6% combined the above types of activities, while 34.9% were involved in tour and excursion planning. The revenues from paid tourist services increased significantly (433.2 mln roubles in 2013, which is 60% more than the revenue gained in 2005). The average number of personnel employed by travel companies was 356 people (apart from those employed on part-time basis and subcontractors) [12, 14].

Inbound tourism emerged in Yakutia with the beginning of perestroika, the socioeconomic and political transformations starting in 1985, when the Republic was visited by up to 1.8 mln tourists per year. During the recession years, this number fell drastically to only 60 visits. Nowadays there is a stable growth and development of both inbound and internal tourism in the Republic. According to 2013 data, 3 000 international tourists visited the republic, which is 66% less than in 2005 (4 700 tourists). The majority of visitors come from Germany (26.4%) and China (23.8%). International tourists prefer extreme voyages, such as visits to Oymyakon village ("Pole of Cold" tour), to Verkhoyansk (ascending the sacred Kisilyakh mountains), as well as to the Lena Pillars and Buluus national parks [11].

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As airfares increase one may observe a stable growth of domestic tourism in the republic. Just 5–6 years ago, the local travel companies predominantly dealt with outbound tourism. Nowadays domestic tourism keeps evolving as new travel routes open in various regions of the republic. Among the most popular tours are Lena Pillars river cruises, hunting and fishing trips, the “Pole of Cold” festival, visits to preserved territories (national parks, Ust-Lena preserve), as well as “Yakutsk and its surroundings” cultural and discovery tours. The main types of domestic tours are weekend tours, event tours, and various activities centered on social tourism, such as youth or senior tours [Op.cit.].

The domestic tourism market in the republic is seasonal, peaking in July and early August, when weekend tours to the regions surrounding Yakutsk, Lena River cruises, and rafting tours are in particular demand. The domestic tourism market predominantly comprises vacationing natives of the republic, mostly urban citizens. Over the recent years, there has been an increasing demand for the Republic’s tourist products on the part of Russian tourists from large cities like Moscow, St. Petersburg, Ekaterinburg, and Novosibirsk, among others. According to the Republic’s Federal Statistics Service data from 2013, 8 700 people used the services of tourist companies to travel within Russia. This is 24.5% of the total number of tourists. The most popular domestic tourism destinations were Krasnodar Territory (21.3%), Moscow (10.6%), and Altai Territory (4.7%). Internal republic tourism makes up 61% of the total number [14].

The specificity of tourism in Yakutia defines the principle of five “Es”: ecology, ethnos, extreme, exotic, and exclusive, noted the ex-minister of Entrepreneurship and Tourism of Republic of Sakha (Yakutia) Ekaterina Kormilicina [2]. Today, the Republic of Sakha (Yakutia) attracts international tourists, thanks to its ethnic culture and elements of exoticism.

The leader of tourism development in the Republic is the Khangalassky region. Its tourist attractions are subdivided into three clusters: Orto Doidu tourist and recreational complex, Samartay, and Lena Pillars Nature Park. In 2013 200 000 tourists visited the region. Khangalassky region hosts a strong tourist and recreational potential, with unique nature complexes located in proximity to the capital, marked by a convenient transport scheme, and located on the banks of the Lena. The latter helps to promote environmental, fishing/hunting, adventure, historical and cultural, as well as several other forms of tourism. This is the reason tourism in the region is viewed as one of the high-priority spheres of the municipal economy, along with building materials manufacturing and agriculture.

2. Recreational landscape of Khangalassky region

2.1. Natural heritage

Recreational resources are resources of all types that can be used in satisfying the population’s need for recreation and tourism. Khangalassky region is an example of convenience from the viewpoint of both tourist infrastructure provision and availability of resources necessary for tourism development. Its territory has a rich natural potential for active tourism development, in mass, as well as exclusive forms. Due to the abundance of hills in the area, athletic tourism (activity-based, recreational, and extreme) is particularly popular in Khangalassky region. Some examples are river rafting, snowboarding, and mountain skiing.

Its geographical position and characteristics of its hunting grounds and resources make Khangalassky region the most visited and desirable area for hunting enthusiasts. Management and planning of amateur/professional hunting and photographic tours have great potential for the development of tourism and services on the part of the local hunting centers.

The dominant natural resource is "Lena Pillars" park (included in UNESCO List of World Heritage Sites in 2012) (**Figure 1**). The Pillars present a system of vertically elongated rocks, stretching for many kilometers along the banks of the Lena River across the Prilenskoye plateau. Within the borders of the nature park, one can find stratotype sections of formations from the Lower Cambrian tier of the General Stratigraphic Scale. These formations are unique due to the abundance of their faunistic characteristics. Cambrian sediments are exposed in uniquely picturesque cliffs that reach up to 350 m in height. The park administration takes an active part in developing and promoting tourist products on the park's territory. In 2014 the park offered 12 routes differing in lengths, pricing, and levels of sophistication.

Another paleontological monument is the Oy-Muran reef mass. It is the world's oldest reef mass and clear evidence of the Earth's oldest reef ecosystem, as well as of its fossil flora and fauna. The Oy-Muran reef is a Lower Cambrian rock bioherm where fossilized archaeocyatha and epiphyton-type limestone algae are abundant. The length of the reef is 3 km, with a width of 0.2 km. This natural monument is located 13 km above Iedyai village, on the left bank of Lena, and 2 km below the issue of Mukhatta River (a left tributary of the Lena).

"Sinsk Pillars" present an example of a geological monument. The rocky banks known as "Pillars" stretch for many kilometers. At 70–100 m high, they form quite fantastic shapes. Here one can observe a miraculous combination of breathtakingly beautiful places. At the source of Muustakh Khandaa (Kyryytas) spring lies a large icy buildup, 3–4 m thick in winter months and presenting an unforgettable sight. In some places the left bank of the river is decorated with tall sandy slopes (Kyrtastar) with sandy and pebbly beaches on the banks; its bed is abundant in rapid rifts.

Figure 1. Lena Pillars. The photo is taken by Antonina Savvinova.

Another unique geological object, the hydrogeological natural monument Buluus, is located 3 km to the southeast of Kysyl-Uruie village (**Figure 2**). The source of the mineral spring is represented by three groups of emersions. The compound of the water is hydrocarbonated and calcareous. It forms ice buildups of clear fresh water, which do not melt even on hot summer days at temperatures above +30°C. Some years the depth of buildup in July reaches 3 m. Drawn from a 67-m-deep well, the water of Buluus is the cleanest fresh water. Its quality has been monitored since 1939.

Among the interesting geocryological objects of the area are tukulans—typical sandy formations of the cryolithic zone marked with peculiar vegetation and presenting large dynamic wind-born sandy masses determined by their geographic environment (**Figure 3**). There are two tukulans on the territory of Khangalassky region: "Kysyl Elesin," located on the bank of Lena 8 km from the mouth of the Buotama river, 14–25 m above water level, and "Saamys Kumaga" 40 km away from the first tukulan. The latter is about 5 km long and 850–900 m wide in its widest section. It is presented as an interdigitation of hollows, banks, and ridges; some of the hollows are rich in vegetation.

Unique landscapes are presented by the largest valleys: that of Erkeny and Samartay, the only right-bank Lena valley. Erkeny stretches more than 50 km from the northwest to southeast and is surrounded by Prilenskoye plateau hills on its western side. The Lena lies on its eastern side; it is 10 km wide. Erkeny is the home of the ancestors of the Sakha people and home to many sacred sites. One such site is the Ysyakh complex where the people of Khangalass conduct sacred rites. Every summer, people gather to celebrate the summer solstice and to worship the Sun, nature, and the upper divinities or Aiyy. Located in the center of the valley is Orto Doidu zoo, which is very popular among both people of the republic and its guests. Tekhtur sports and entertainment complex is the center of active, extreme, and family recreational activities. The mountains in this location are round and elongated,

Figure 2. Buluus. The photo is taken by Antonina Savvinova.

Figure 3. Tukulan. The photo is taken by Antonina Savvinova.

which makes them very popular among avid skiers and helps to promote skiing as recreational activity. The prepared track is 450 m long. Snow canons allow the prolongation of the skiing season well into May, as well as its opening in September. Stunning views and close proximity to the city help to promote active recreation among city dwellers. Samartay valley lies on the right bank of Lena. It is home to unique natural attractions like Buluus, the rocky bank of the Lutenge river (Turuk Khaia), Kuruluur water fall on the Menda river, and other places.

Stratigraphical natural monument "Isit" is an open-pit mine which is a hydrostratotype of the Tommot formation of the lower Cambrian system, as well as a stratotype of regularis and lenaicus-primigenius archaeocyte zones. The lower border of the formation is concealed; lower reaches of the pit are exposed by a wellbore in the source of Bydyngaia spring and not far from the source of Kysy-Taas spring. The pit exposes the upward-directed top residuals of Tolbin and variegated (Tommot formation) sets, as well as of Nokhoro band (Atdabanian formation).

2.2. Cultural heritage

Historical and cultural potential is an important advantage of the Khangalassky region. It is the home of numerous sites of cultural heritage, the specifics of which are defined by their predominant archeological and ethnocultural character which have a significant social function: archeological materials are exhibited in local museum complexes; annual festivals are held; the historical heritage of post stations once located along the Irkutsk-Yakutsk post passageway is preserved and used in creating tourist goods.

The cultural landscape includes architectural monuments, archeological excavation sites, museums, monuments, and so on. Some of them are included in the Single National Registry of Objects of Cultural Heritage of the Peoples of Russia, while others are still in the process of undergoing certification. Historical heritage objects found on the territory can be subdivided into following groups:

2.2.1. Archeological monuments

There are four of them on the territory of Khangalassky region: "Kullaty" site, "Diring Uryakh" archeological monument, and two petroglyphs—the Sinsk petroglyphs and Toion-Aryy petroglyphs.

1. "Diring Uryakh" is one of the unique archeological monuments located on the territory of "Lena Pillars" park. It represents the Ymyiakhtakh culture of II c. B.C. It is located at the estuary of the Dirirng-Uryakh river on the right bank of the Lena at the altitude of 105–120 m. It was discovered in 1982 and was studied by the Prilenskaya archeological expedition headed by Svetlana A. Fedoseieva. In 1982–1983 five late Neolithic burials were found there. They were in the form of stone boxes in which men and children were buried. The barrow is unusual not only in displaying the signs of burial ceremony uncharacteristic of Yakutia's ancient cultures but also in the wealth of burial inventory [4].

2. "Kullaty" is considered as the historical home of the ancestors of Yakut people—Tygynites dating from the Neolithic age, paleometals, and early Yakut time.

3. Sinsk petroglyph (Sinskoie, according to A. P. Okladnikov) is located at the mouth of the Sinyaya river, on the rocks of its right back and right under the village of Sinsk. It includes three groups of drawings. The first group, known as "Sinsk frieze," is represented by a group of drawings "predominantly crimson-red in color" and anthropomorphic in shape, where the figure of an elk stands out clearly. The second group of drawings is represented by a mysterious shape or fragment reminiscent of either a face shape or a ladder. The third group is significant for the depiction of 13 vertical long and short "sticks" located on "a separate protuberance" [7].

4. Toion-Aryy petroglyph is located on the left bank of the Lena, 1778 km from its mouth. The rocky ridge around the drawing is composed of rectangular embedded plates of dark-gray limestone and stretches from the small valley of an unnamed creek from Ulakhan-An village for 2 km to the village of Toion-Aryy. Located opposite the rocky outcrops with the drawings and across the creek is Toion-Aryy island. In the petroglyph one surface with ten drawings stands out: zoomorphic creatures drawn and filled in with solid color, elks in skeletal style, and anthropomorphic figures with shaman attributes drawn in dark-red, light-red, and light-crimson ochre. There are singled out six drawings: zoomorphic skeletal figures of elks and three stylized anthropomorphic figures with shaman attributes. In 2001 four previously unknown drawings were discovered: three zoomorphic figures and one diagonal line, hardly visible under the layer of organic buildup. Stylistic characteristics of the drawings allow the object to be dated from II–I c B.C. to between I c.A.D. and the Middle Ages [1].

2.2.2. City building and architectural monuments

This group includes wooden constructions dated to XIX c.: St. Nicholas wooden church and the Fortress—a two-story barn with loopholes.

1. St. Nicholas church (the wooden church) in Kachikatsy was built in 1892. Its construction was funded by parishioners and charity donations. It is a wooden church with an adjoining bell tower. The Kachikatsy St. Nicholas church represents a type of wooden church widespread in Yakutia in the XIX c. It has two domes with six smaller heads and an adjoining two-story bell tower. The building is oriented from west to east along its length. Its total length is 25.65 m and mid-width 9.76 m. The log construction in its middle part is 5.58 m tall, while the height of the bell-tower construction is 7.04 m. The construction is made of big larch trunks 30–40 cm in diameter. The church entrance is located on the western side and runs across the lower construction of the bell tower. The total area of the church is 188.80 m^2. In 1920 the Kachikatsy church was closed, and its crosses and domes were removed; the building itself was used as a literacy center. Nowadays the church building is part of the municipal history and ethnography complex “Satal.” Thanks to the joint efforts by the administrations of Kerdem village and Khangalassky region, the roofing, bell tower, domes, and heads of the church with crosses on them have been restored [5].
2. A wooden two-story barn fortress with loopholes is an architectural monument of the nineteenth century located in Myndyly not far from Kerdem village. It presents a typical construction equipped with special loopholes for arrow shooting on the second story.

2.2.3. Historical monuments

The largest group of historical monuments represents 81.4% of the total number of historical and cultural objects of the region. The majority of these objects are monuments dedicated to the Great Patriotic War heroes (51.8%) and Civil War heroes (29.6%). The remaining monuments honor prominent personalities. Great Patriotic War monuments commemorate events or military and civilian heroes and are found in nearly every community of Khangalassky region. Conversely, Civil War monuments can only be found in locations of mass graves of Soviet heroes.

3. Ethnic culture as factor of tourism attractiveness

Yakutia is primarily known in the world as one of the most recognizable cold inhabited places on the planet. However, lately there is an active ongoing development of summer tourism in Yakutia. The majority of tourists arrive in late June in order to attend the Ysyakh festival. The festival, which nowadays is attended by 150 000 people over the course of 2 days, is one of the best examples of successful regeneration and reconstruction of traditional cultural practices and spiritual heritage which had been partially lost during the Soviet period.

The Yakut national festival of the summer solstice Ysyakh was declared a national holiday in the early 1990s in the republic. Ysyakh is the only ethnic festival displaying native Siberian celebrations that preserved its original character even through the Soviet period. It clearly reflects the ecological culture of the Yakuts, with its complex ideological reverence of nature and respect for all living things. A dialog between humans and the world of nature and the environment created a coded link where a person was incorporated in nature, correlating it with their economic, social, ritual, and biological life. Ysyakh is an ancient ritual festival. It is mentioned and described in old texts of the Olonkho—the ancient Sakha epic. It reflects the cult of the Sun and its annual cycle. It is also known as the "festival of white abundance," for the sacred drink of Ysyakh is mare's milk-based kumys. Sakha are horse breeders and cattle breeders, whose ancestors divided each year into summer and winter time. The long and exhausting winter with its harsh frosts is tiresome both physically and mentally. Thus, the arrival of warmer months brings a certain feeling of awakening and regeneration after a long winter [6].

April ends the Yakut calendar year and marks the beginning of the spring rites. These rites are based on traditions dictated by work cycles, as well as by observations of nature and seasonal changes. Ysyakh (form Yakut verb "ys"—"to sprinkle") is the main Sakha festival. It was celebrated during the summer solstice, on June 21. This day marked the peak of summer for the ancestors of Sakha people. From this day on, the solar day starts to shorten; this also means the arrival of the longest, hottest days and white nights. It was believed that on this day the Aiyy spirits, creators of the world and embodiments of good and creation, approach the Middle world (the world of people) in order to bless them. Thus people gather, dressed in traditional Yakut costumes, to perform the circular dance of "osuokhai"; this is when one can hear the sounds of khomus (mouth harp) and taste fermented mare's milk (kumys) and national dishes [5].

3.1. "Orto Doidu" cultural and historical complex

One of the popular places of Ysyakh is located near the capital city of Yakutsk in Khangalassky region in the area of Orto Doydu. The name of the area is closely linked with the division of the world into the Yakut mythology, the Upper, Middle, and Under Worlds. Orto Doydu means "a Middle World," in which people live, as opposed to the Upper World, the abode of gods, and the Under World populated by abaahy—monsters and devils.

The choice of the site for the annual national holiday Ysyakh is not accidental. The determining factor for this was the historical significance of the place which special beauty and structure of the landscape fits well the rites and ceremonies of the festival, as well as the transport infrastructure for the organization of major cultural events of the regional and now the national level.

Historically, this area is also marked. It is the Erkeeni valley where first stayed and lived ancestors of the Yakut. The old name of the terrain is Ebeh Aana. The word "ebeh" in the Yakut language means "grandmother" and is used for flattery addressing and naming of large water basins, rivers, and lakes, which play an important role in the economic life of the family. The word "aan"—"a door entry"—in geographical aspect means "the entrance to some area or out, or located at the entrance, in front of something."

The terrain on the west side is surrounded by mountains (Yakut. "myraan"), which are considered to be a primordial bank of the Lena River; probably in ancient times, the old mouth of the Lena River flowed near this area. This hill has been successfully woven by organizers with esthetics and philosophy of the event: on the mountainside there was constructed a sacred tree Aal Kuduk Mac in the form of nine circles, representing the ancient Yakut calendar and at the same time an eternal circle of life.

According to the legends and historical documents, in early seventeenth century, Tygyn Darkhan, the legendary leader of the Yakut tribes, relying on the strength of Kangalassky tribes and Bootur warriors invited from other places, subdued many Sakha tribes and clans to combine them into "IL"—Yakut "state." That was his attempt to create a unified state of Sakha people but, as historians and the facts prove, did not achieve its great goal.

3.2. Principles of landscape and architectural organization

The "Ysyakh" complex as a part of "Orto Doidu" tourist and recreational complex is situated 50 km away from Yakutsk, on the left bank of the Lena (**Figure 4**). The place for Ysyakh is selected in accordance with ancient traditions. As a rule, it is a big flat field, open on the east side in order to perform the sun greeting ceremony. The local topography is used to the benefit in "Orto Doidu": on its east side, a wide valley borders with the river; its western side is closed off by a ridge of high hills.

This complex takes up a vast territory where the ancient traditional housings (urasas), and a composition depicting cranes and the regional totem, an eagle—are located. The hill has been successfully woven by organizers into the esthetics and philosophy of the event: on the mountain side, the sacred tree Aal Kuduk Mas appears in the form of nine circles, representing the ancient Yakut calendar.

The design of the complex is based on traditional architecture. This is particularly true for ritual constructions.

The space around Ysyakh festival is based on old legends and, in particular, the olonkho. According to folkloric tradition, the festival projects the Yakut myth of Ellei, a cultural hero and forefather of the Sakha nation. The corpus of mythological texts cited by G. V. Ksenofontov's "Elleiead" (1977) allows for a reconstruction of the primary plot of the festival [3].

Figure 4. Ysyakh complex. Photo is taken by Antonina Savvinova.

The kumys festival “Ysyakh” of the Sakha people, the world’s northernmost horse breeders, presents a system of nature divination based on the worship of the sky, the water, and the Earth. It includes:

- Production cults (linked to cattle breeding).
- Fertility cults (beginning, birth, and regeneration of life).
- Protection cults (protection of humankind).
- Cults of hearth keeper (harmony at home and piece in the family).
- Cult of good luck and well-being (blessing of life).
- Cult of protection against evil spirits (purification and healing).

When designing the complex, its authors were guided by five principles of recreational activities’ spatial organization: concept of value, informational provision, ethnocultural directive, dynamic architecture, and coexistence of spaces. The latter is viewed by the authors as coexistence of natural space and artificial (functional) space. Using the definitions of the postindustrial world, it links several spaces of various structural origins:

- Natural space, historically determined as sacred landscape.
- Ethnocultural directive in design—recreation of space in historical aspect.
- Dynamic architectural space—as an event-oriented phenomenon in contemporary public life.
- Introduction into modern virtual space.
- Emergence of new conceptually valuable cultural space of the region and its introduction into the global cultural space.

According to the vision of Viliam F. Yakovlev, the creator behind the design of “Orto Doidu,” the complex is thus divided into three main areas:

1. Northern, adjoining the lower terrace of the mountain ridge—“Ceremonial.”
2. Southern side of the valley space—“Guest.”
3. Southern, adjoining the highway and beyond—“Parking.”

The main ritual centers of the Ceremonial area are located along the landscape on the higher points. The rites of “Greeting the Sun” and “Drinking Kumys” take place there. The sun greeting rite is the culmination of the festival. Traditionally Ysyakh is celebrated on the longest day of the year (June 21–22). The sun greeting takes place as a collective communion ritual on the night of June 21–22. This is the moment awaited by all who want to “charge” themselves with solar energy for the whole year and to ensure the favor of gods who listen to people’s prayers on these days. Yakuts believe that words of prayer uttered in the hour before dawn are heard by powerful and benevolent deities. As a rule, it is the ritual part of the festival that gathers the majority of participants; it is the ritual that fulfills the festival's primary meaning, allowing people to come closer to nature and to take a philosophical perspective on their lives, to wish good upon themselves and loved ones, to regenerate spiritually and physically (**Figure 5**).

Located in the quieter and cozier places of the same area are "Olonkho" and "Osuokhai" tusulge. Here one can listen to the narrators of olonkho—the ancient epics of the Sakha—and take part in a ritual circle Osuokhai dance. The notion of *tusulge* is central to understanding the space of Ysyakh, which is divided into many thematic tusulge. It is a form of an open-air altar (its entrance faces east where the white deities live), surrounded by the young birch trees, or *chechir*, forming the sacral border forbidden to a sinner. Sacred salama are hung on the birches—these are ritual ropes made of horsehair and colored pieces of cloth with symbols of bounty and well-being made of birch bark. In the center of the kumys-drinking area, in the middle of tusulge, there are three or four horse-tying poles, or *serge*, connected by crossbeams hung with large leather vessels filled with kumys. All the vessels and plates must be wooden, made of a single piece of birch trunk. In general, it is the Ceremonial area which is the spiritual center of the festival. It is a place where an individual participates in the magical rite of Ysyakh, forgetting oneself, becoming one with nature, feeling one with the eternal and endless world [13].

It should be noted that the original plan had undergone a number of changes; eventually, a construction symbolizing the Yakut calendar in a circular spiral shape with poles depicting the 11 Yakut months was built on the slope of the hill. The spiral, counting time rotates toward the outside along with the sun, thus embodying and stating the infinity of life and being. 365 people (in accordance with the number of days in a year) dressed in stylized costumes ascend the Aal Kuduk Mas which is represented by nine circles of Yakut hedge built on the slope of the hill. They represent days and months of a year. Having ascended the complex which represents the eternal circle of life and ancient Yakut calendar, they change costumes as seasons change (**Figure 6**).

Ysyakh intertwines mythology and religion, esthetics, and moral values of the Sakha people. Today Ysyakh is the unifying symbol of rebirth not only of the traditional culture of the Sakha people but also of humanistic trends in national projects of the new Russia.

Figure 5. Yakut people in traditional costumes. The photo is taken by Antonina Savvinova.

Figure 6. Ancient calendar. The photo is taken by Mikhail Mestnikov.

4. Creation of tourist cluster in Khangalassky region

In order to promote further tourism development, the administration of the Khangalassky region has elaborated a tourism development project, which in its turn may become the pilot project for building a series of effective tourist enterprises in the republic.

The cluster approach is the basis for tourism development in Khangalassky region. Its territory is subdivided into three clusters:

- Tourist-recreational cluster "Orto Doidu," located at the 49th km of Pokrovsk tract in close proximity to Yakutsk
- Tourist-recreational cluster "Samartai" which includes the museum complex "Samartai," tourist complex "Buluus," "Kuruluur," and water-park "Kysyl Syyr"
- Tourist-recreational cluster "Lena Pillars" which includes Diring-Yuryakh, rivers Sinyaya and Buotama, and hotel complex "Serkeen Sehen," as well as some others

Currently the following can be found within the "Orto Doidu" tourist-recreational cluster: "Tekhtur" sports and entertainment complex (skiing center), ice complex "Oktem-park," sport and entertainment complex "Orto Doidu" consisting of a restaurant and shooting ground, ritual complex "Ysyakh Erkeeni," and "Orto Doidu" zoo. In addition, 16 entrepreneurs work on the territory involved in sales and catering. Tourists are attracted by the historical sites of Kullaty, Yakut national traditions, culture, epics, lifestyle, beliefs, and legends, as well as by the unique landscapes of the region. In addition, the territory of Orto Doidu cluster is the site of traditional annual celebrations, which attract more than 30 000 people from all over the republic and other areas.

"Tekhtur" sports and entertainment complex is a resort with developed infrastructure located at the 46th km of Pokrovsk tract, not far from Tekhtur village. A relaxed atmosphere, beautiful landscape, and proximity to the city all contribute to building the right conditions for active recreation. The hills in the area have soft and long slopes, which makes them particularly popular among mountain skiing and snowboarding enthusiasts.

"Orto Doidu" cultural and ethnographic complex is located at the 49th km of Pokrovsk tract on the territory of "Orto Doidu" tourist and recreational cluster. Here, in Erkeeni valley people are drawn to the uniquely beautiful and clean natural environment, as well as by opportunity of being involved in healthy recreational activities.

"Orto Doidu" zoo presents a vast sphere of various activities for researchers, university, and school students. Students of the NEFU Faculty of Biology and Geography and Yakut Agricultural College annually hold research observations here, while those studying at the College of Arts and Arctic Institute of Arts come here to make sketches.

"Oktem-Park" ice complex is aimed at promoting tourism as well as at increasing the quality of the tourist service industry and its availability to all members of community. The complex is located at the 49th km of Yakutsk-Pokrovsk highway across the road from "Orto Doidu" zoo.

"Kosmopark" tourist center, "Khangalas-Sakha Omuk Ytyk Sire" museum complex is located at the 49th km of Yakutsk-Pokrovsk highway across the road from "Orto Doidu" zoo. Its main attraction is a planetarium. It occupies 1.13 ha of land. The site is not completed yet.

"Tuekey Myraana" is a scientifically proven location of the Tygynit familial burial ground, among whom are Masary Bazekov and Sofron Syranov. It is located at the 55th km of Yakutsk-Pokrovsk highway, opposite the Kuudu farm, across the road on the hill. There is a need to commemorate the location, perhaps with a monument.

"Kullaty"—the historical home of the ancestors of Tygynites, including Tygyn Munnian Darkhan's father. Since the location is in close proximity to a main tourist route, it should be made part of the tourist-recreational cluster "Northern World."

5. Conclusion

The analysis of tourism development in Khangalassky region shows that this sphere is capable of becoming the locomotive of local development. The promotion of tourism is also quite significant from the perspective of building a positive image of the region and the republic. This, in its turn, may attract not only tourists, but also investments into other spheres; tax inflow into local budgets, as well as creating jobs locally; and an improvement in the educational and cultural environment. Tourism development in the region faces the following challenges: costly transportation expenses, underdeveloped infrastructure, lack of qualified specialists, the need for more research and effective market monitoring, and disunity among stakeholders and participants.

The OECD Tourism Committee emphasizes that the culture is important for tourism and for the attractiveness of destinations. "The most successful destinations are those that can create a positive synergy between culture and tourism. But this synergy does not happen automatically: it has to be created, developed and managed" [8]. For instance, today Khangalassky region faces a lack of tourist-excursion services due to low levels of activity which limits the term of stay to a single day only. That is why one of the priority aspects of "Orto Doidu" cluster development is expanding the range of tourist services, development of tourist and hotel offerings aimed at motivating tourists to prolong their stay. "Orto Doidu" tourist-recreational cluster is analyzed as a project which should reveal the full ethnocultural potential (traditions, practices, traditional production, and culture) of the Republic of Sakha (Yakutia). Therefore,

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the basic element of positioning the tourist product of Khangalassky region is the ethnocultural component with added environmental and entertainment components.

Natural and cultural resources, as well as their concentration form a recreational landscape—a natural landscape—aimed at and transformed for recreational activity.

One of such examples of recreational landscape is "Orto Doidu" tourist-recreational cluster. It is based on the Olonkho epic which in 2005 was granted the status "Masterpiece of oral and non-material heritage of the humankind" by UNESCO. The project is an ethnocultural complex, revealing the culture, traditions, and beliefs of the Sakha people.

The location of Khangalassky region as the republic's main tourist region makes it particularly important to make additional efforts aimed at increasing the quality of tourist services and guaranteeing the safety of tourists. It is also important to conduct marketing research on the tourism potential with particular focus on the demand, high-priority spheres in tourism, potential for the development of municipal units, certification of tourist routes, and establishment of tourist information centers in the region. A powerful positive territorial brand will enable the clusters of "Orto Doidu," "Lena Pillars," and "Samartai" to be more recognized on the local market and to establish a possibility for entering the outer market, including international.

Therefore, tourism development perspectives in Khangalassky region will generate income, part of which is distributed to nature and culture preservation where not only direct costs of various activities are covered (fully or partially) but other areas as well. In its turn nature and culture preservation provides renewable resources for further tourist development. Nature preservation is an essential part of culture preservation, since it promotes the sustainability of traditional uses of natural resources. Thus century-old traditions of rational nature use by the territory's native population are preserved.

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