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Environmental Land Use Planning

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ENVIRONMENTAL LAND USE PLANNING

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Contributors

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Meet the editor

Dr. Seth Appiah-Opoku is Associate Professor of Geography at the University of Alabama, Tuscaloosa, USA. He teaches Environmental Management, Land Use Regulation, Principles of Planning, Geography of Africa, Regional Planning and Analysis, and Field Studies in Africa course. He is a member of the American Institute of Certified Planners. He serves on the international editorial board of the Journal of Environmental Impact Assessment Review and has published scholarly articles in several renowned journals including Environmental Management, Society and Natural Resources, The Environmentalist, Environments, Plan Canada, Journal of Environmental Impact Assessment Review, and Journal of Cultural Geography. He is also the author of The Need for Indigenous Knowledge in Environmental Impact Assessment: the Case of Ghana (Edwin Mellen Press, NY, June 2005).

Contents

Preface

Environmental consideration is increasingly taking center-stage in planning and policy decisions at all levels of government. This is due to the growing concerns over the damage being caused to the environment by human activities. Today, the vital functions of the Earth are nearly all seriously compromised or moving in that direction. We now live in a riskier world with more consumption, more waste, more people and pollution but with dwindling biodiversity, fresh water and ozone layer. Thus, one thing is clear – our current destructive paths to development are unsustainable. There is an urgent need to reverse the trend and preserve the integrity of the environment, both for the current and future generations.

In response, environmental land use planning has evolved to provide thoughtful intervention tools and strategies aimed at reducing or minimizing the environmental burden on current and future generations; preserving or conserving our natural resources for current and future use; and minimizing environmental threats to human health and safety. With a more holistic view, environmental land use planning places emphasis on the biophysical environment and human communities. It adopts a perspective which recognizes all components of the earth, as well as the linkages between each and every one of them.

Environmental professionals need to have a basic understanding of environmental problems and their effects on land uses; analytical methods or tools to examine the problems; and understand the role of governments, community grants, and tradable permits in environmental land use planning. This book is intended to educate readers in these areas. The contributors to this volume have brought together a rich tapestry of experiences from all parts of the world. The issues covered in the volume range from land cover changes, environmental problems caused by river bank erosion, predicting changes in land use pattern, ecological footprint analysis, behavioral modelling, community grants and the role of government in environmental land use planning. The book is divided into three parts. Part I provides an overview of selected environmental problems and the effects on land uses. Part II presents analytical methods or tools for environmental land use planning. Part III discusses the role of governments, community grants, and tradable permits in environmental land use planning.

Although there are other significant issues pertaining to environmental planning, time and space have made it impossible to cover all in this volume. Therefore, this book should be seen as a wide brush stroke pointing the way to matters to be addressed in latter volumes. Written at a level that is understandable to most scholars, regardless of their technical background and education, this volume simplifies complex environmental problems and analytical tools. It challenges planners to overlook human-focused limits or boundaries, and plan with nature, including its functions and natural boundaries. Finally, the book recognizes the natural interdependence between the natural, human and social systems, and provides thoughtful and innovative approaches towards environmental sustainability.

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Section 1

Environmental Problems and Effects on Land Uses

Chapter 1

Land Use Changes and Environmental Problems Caused by Bank Erosion: A Case Study of the Kolubara River Basin in Serbia

Slavoljub Dragicevic, Nenad Zivkovic, Mirjana Roksandic, Stanimir Kostadinov, Ivan Novkovic, Radislav Tosic, Milomir Stepic, Marija Dragicevic and Borislava Blagojevic

Additional information is available at the end of the chapter

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1. Introduction

Geomorphological analysis of the dominant erosion processes and their intensity quantification were done in the previous researches of the Kolubara River basin [1-3]. The results showed that, the level of the landscape degradation and modification of geomorphologic processes by human activities has been increased in the past decades [4], and it was initiated by very fast demographic, socio-economic and technological changes in Serbia, likewise in the region [5-7], and in the world [8-11].

According to level and type of degradation, the Kolubara River basin belongs to the most endangered areas in Serbia. Due to the lignite exploitation in the Kolubara River basin, human impact led to morphological change of the entire area, as well as to the changes of the intensity of different geomorphologic processes: changes in river course [12,13], the intensity of bank erosion [14,15], sediment deposition [16] and environmental problems [17,18].

Unlike the other rivers with similar hydrological characteristics, the river network in the lower part of the Kolubara River basin were changed rapidly during the XX century because of direct human impact. Anthropogenic influences on the hydrological network in the study area were very intensive since 1959, when the huge river regulation works were done in the lower part of the Kolubara River. Spatial planning of the area, which included diverting of the Kolubara's river bed, had an aim to prepare the site for the lignite exploitation within the Kolubara mining basin. The Kolubara River divides the mining basin in two parts: eastern and western part. The productive area of the basin (geologic contours of lignite deposits) is 520 km^2. Kolubara mining basin is situated about 40 km south-southeast of Belgrade and represents the largest lignite deposits in the central part of Serbia; the annual production is 30 million tons of lignite, and it is the opencast mine. The mine expansion caused the need for technical solutions of diverting and removing river beds in this area. According to "General project of diverting the Kolubara River and its tributaries for the purpose of lignite exploitation", the Kolubara's riverbed was diverted into the Pestan's riverbed (its right tributary). This caused many problems which were not predicted by the General project.

In this way, anthropogenic factor modified existing natural conditions: the process of fluvial erosion was changed; bank erosion became stronger and resulted in soil loss, larger amounts of sediment load deposition, cutting off the meanders and fossilization of certain parts of the riverbed, floods, land use changes, landscape degradation, sediment load pollution, etc.

2. Research area

Regarding to natural conditions, the Kolubara River basin is similar to the other river basins in the area. Tectonic movements had an influence on a morphological evolution of the river network in the past. During the Paleogene and the Early Neogene a small bay of the Pannonian Sea named the Kolubara's bay existed in the area of the Kolubara River basin. After the sea recession, the fluvial erosion started in this bay and it formed today's hydrological network of the Kolubara River. Tectonic characteristics of this area, more precisely Kolubarsko-pestanski fault and Posavski fault had influenced the orientation of the hydrological network in the Kolubara River basin. But today the Kolubara's hydrological network is influenced by fluvial erosion and anthropogenic factors.

The Kolubara River Basin encompasses the western part of Serbia and covers 4.12% of Serbia's surface area. The highest point of the drainage basin is at 1,346 m, and the lowest has altitude of 73 m. The Kolubara River is the last large right tributary of the Sava River, and according to the flow length (86.4 km) and the basin area (3,641 km^2) it is classified as a middle-sized river on the territory of Serbia [3].

The lower part of the Kolubara River basin is called the Donjokolubarski basin (area of 1,810 km^2) and is situated in the municipality of Obrenovac. The Donjokolubarski basin encompasses the catchment area of the Kolubara's confluences (the Pestan River, the Turija River with the Beljanica River, the Tamnava River with the Ub River and the Kladnica River) and the lower part of the Kolubara's valley. The average altitude of the Donjokolubarski basin is 168 m, the highest point is at 695 m, and the lowest has an altitude of 73 m.

According to the nearest meteorological station in Obrenovac, this area is characterized by continental climate, the average temperature was 11°C, and the mean annual precipitation from year 1925 to 2000 was 722 mm [12]. The average annual runoff of the Kolubara River (at Drazevac gauging station) for the period 1961-2005 was 21.8 m^3/s.

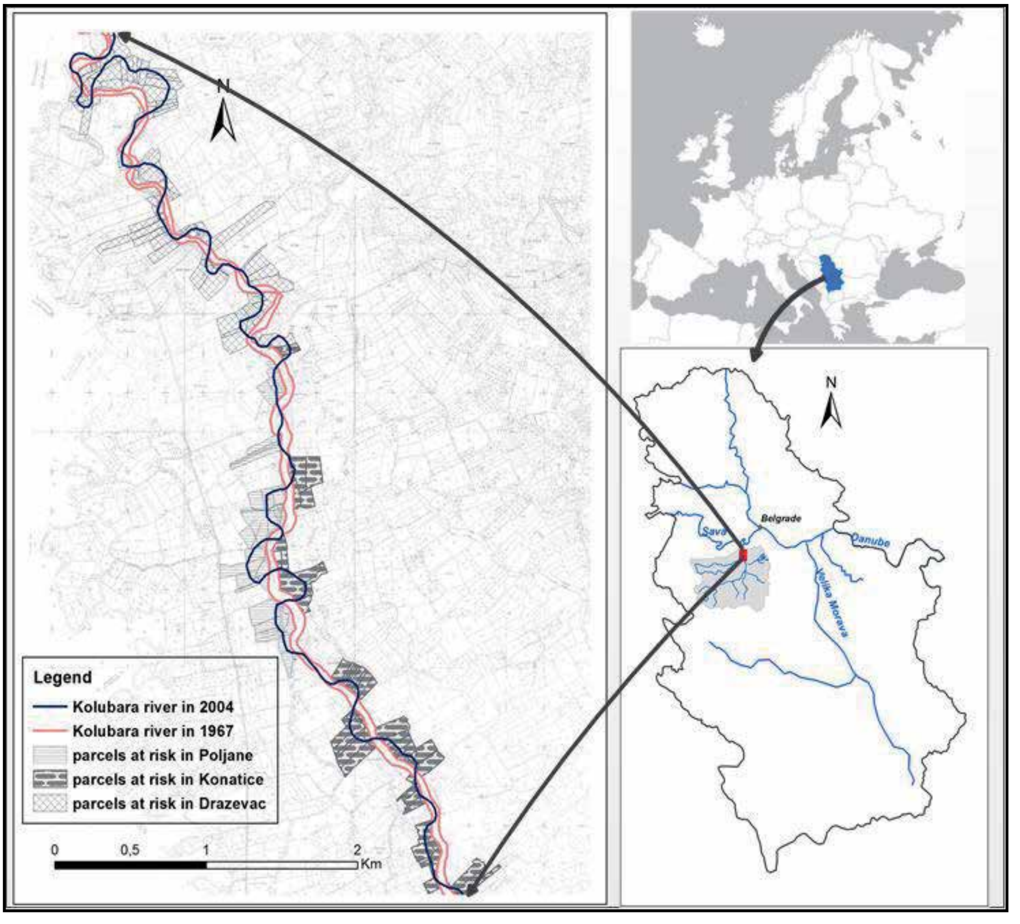


Figure 1. Position of the Kolubara River basin in Serbia (right) and study area (left)

3. Methodology

In this research we used diffrent methods that can be devided into the field and lab work methods. The GIS methods were used for the modeling of terrain evolution and landscape changes, which represents the base for bank erosion intensity quantification.

Analysis of topographical maps, aerial photo and orthophoto images were used in the previous researches aiming to determine the evolution of the riverbed [6,15,19-23]. The results showed that the application of GIS has an advantage in quantification of river migration processes.

For the purposes of this study, comparative analyses have been made on the base of Cadastral maps scale 1:2500 from 1967 and orthophoto images from 2004; reconstruction of the hydrological system has been done for the periods from 1967 to 2004. By comparing the data from two periods, we determined the evolution of the Kolubara River course in 37 years. River bank lines were digitized and the extent of bank erosion was calculated under

Geomedia professional. The same software was used for the estimation of the Kolubara River lateral migration rate. This rate was estimated using the calculated area between river positions in 1967 and in 2004 (area of river migration), which was divided by the total length of the river course in 1967. The loss of land (*S*) is expressed as the ratio between area of endangered land parcels (ha) in 1967 (P1967) and area of endangered land parcels (ha) in 2004 (P2004) [15]:

$$S = \frac{P_{1967} - P_{2004}}{P_{1967}} * 100$$

River erosion and frequent floods make great material damages to people, villages and economy. The owners of the arable land parcels on the Kolubara River banks loose the parts of the parcels that river carries away. The reduction of parcels on the Kolubara River banks, land loss and land use changes were estimated comparing the cadastral maps from 1967 and orthophoto images from 2004.

Land use structure in the area of villages: Drazevac, Konatice and Poljane are characterized by: arable land (which people used for farming mostly wheat and corn-crop rotation practice), forests (alluvial forests of willows and poplars) and few pastures. The river dynamic is intensive in the Kolubara's alluvial zone, which influenced sandbank formation, mostly on the concave side of the river. By statistical analysis of a land use structure [24] in the three villages with degraded land parcels on the river banks, we obtained the results which show significant reduction in arable land. And by analyses of the questionnaire carried out among the owners of degraded land parcels in the villages Drazevac, Konatice and Poljane, it can be concluded that it was significant decrease in the agricultural production. The risks from the floods and further soil loss influenced the land owners' decision making about farming the degraded land parcels.

The change of fluvial erosion intensity was analyzed regarding to changes in water balance and sediment load transport on two hydrological profiles. The results of water balance that D. Dukic [25] has made in his research for the period of 1925-1960 and the results obtained in this study were analyzed and compared. This comparative analysis appoints to the amount of water which Donjokolubarski basin disposed before regulatory changes of Kolubara in 1959/60 and after them. River flow regimes of different periods were compared because that could be a factor which has a significant influence on the observed process. All these efforts should confirm or eliminate the influence of natural factors on the river banks degradation in the Donjokolubarska valley.

Having data of extreme discharges, in order to estimate the impact of future floods on bank erosion, we have made a probability curve of maximum discharges of the Kolubara River and its tributaries.

Because of intense anthropogenic impacts in the Donjokolubarska valley, we have sampled the suspended sediments from the Kolubara's riverbed and later analyzed the pollution of the accumulated load. Since the processes of bank erosion and sediment accumulation occur close to the villages and that endangered land parcels are used for food production, such approach points to ecological aspect of researched problem.

The sediment samples were taken on two locations in the Kolubara's riverbed. For heavy metals and carbon analysis the soil was milled to a fine powder. Heavy metals were determinate by AAS method.

4. The intensity of bank erosion

4.1. Natural conditions changes as a factor of bank erosion in the study area

On the research sector (Fig. 1) the Kolubara River length in 1967 was 8.2 km and 10.6 km in 2004. This fact appoints to the river course evolution through the landscape. In the period between 1967 and 1981 the Kolubara River has migrated 50 m, actually 27 m into left and 23 m into right, and the average migration of the Kolubara River was 3.6 m per year. By further comparison of aerial photo image from 1981 and orthophoto image from 2004 it can be observed that the Kolubara's riverbed was stabilized and during 23 years migrated only 26 m. So, the Kolubara River average migration in this period was 1.1 m per year which is three times less comparing to the previous period of observation (1967-1981) [13].

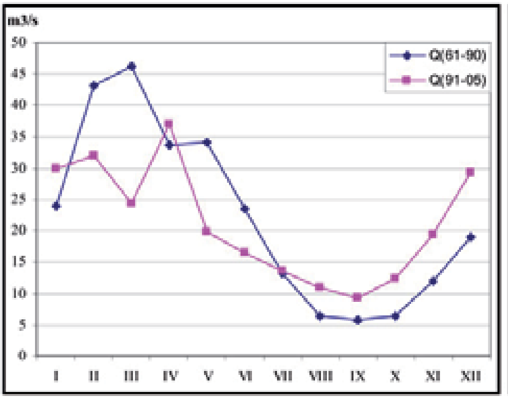
The rate of the Kolubara river lateral migration along the research sector is 47 m in average for the period of 37 years, which means 1.27 m per year. At the most endangered part (in the area of Drazevac village) the most intensive migration rate of the riverbed was 224 m in 37 years, with the average of 6.05 m per a year [15].

The changes of fluvial erosion intensity may result from changes in climatic-hydrological characteristics of the river basin (which are manifested in discharge regime changes) and various human impacts. Therefore, the natural factors of the Donjokolubarski basin were analyzed to determine whether they have influenced the stronger bank erosion.

The results showed that average mean annual discharge of the Kolubara River measured in Drazevac was 22.3 m^3/s in the observation period 1961-1990, and 21.3 m^3/s in the observation period 1991-2005. Amplitude of average high and low flows in the period 1961-1990 was 77.94 m^3/s, and in the period 1991-2005 it was 64.66 m^3/s [13].

To study water balance of the Donjokolubarski basin we used the following periods: 1925-1960, 1961-1990 and 1991-2005. With this approach it was possible to determine the changes that may be occurred after diverting the Kolubara River into the Pestan's riverbed in 1959. Briefly, precipitation analysis showed that the second period was a bit wetter than the first, actually about 60 mm in the Pestan River basin and 80 mm in the Turija River basin and the Tamnava River basin. Meanwhile, higher air temperatures and higher evaporation caused almost the same specific discharges of these rivers. The last period was in mean values similar to the second, apart from intensified variation of extreme values of all climatic elements. The discharges were influenced by more frequent alternation of wet and dry periods, which could be seen on figure 2.

Monthly coefficients of variation of the period 1991-2005 are higher in all river sub basins except in July and August. These differences are significant, the variation of discharges in eight months are higher than the highest coefficients of variation of the period 1961-1990, which is 1.5. The more important is the fact that the period of appearances of unstable discharges is March-April (over 2.5), which is related to snow melting. That is the period of maximum discharges and any sudden disturbance of soil moisture resulting in serious disorder of river bank stability. Some of the natural factors have been changed in the last two decades, for example, March used to be, in Serbia, the month with the most stable discharges (and the highest). The differences in March discharges during the observed periods are over 20 m^3/s (almost twice reduced), and it was followed by extreme discharge variations. These are the significant changes since the area of the Kolubara River basin is bigger than 3500 km^2 and maximum discharges are higher than 500 m^3/s. Although the mean values are not of crucial importance, they indicate some disturbances which should be kept in mind; particularly because the last period of observation is twice shorter than the previous one and all analyses in the world indicate that extreme values of natural phenomena are more pronounced and more frequent.



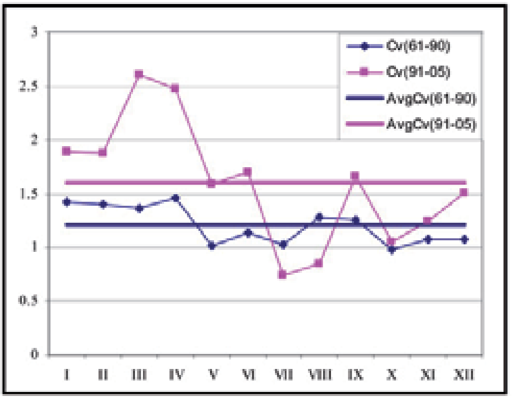


Figure 2. Mean monthly discharges (Q) and coefficients of variation (Cv) of the Kolubara River measured in Drazevac gauging station for the both periods of observation

Preliminary results of the Donjokolubarski basin annual flow variation show discrepancy in spring and summer monthly flow among two studied periods (Figure 2 - right). Further research should examine correlation of monthly flow and bank erosion intensity.

4.2. Anthropogenic influences as a factor of bank erosion in the study area

The erosion control works in the river channel can cause changes in river morphology, since they influence the changes in river regimes, river bank characteristics and amount of sediment transport [26]. The consequences of these interventions are numerous, and often lead to riverbed widening and undermining concave sides of the river banks. The processes of river bank collapsing and erosion are complex since they are results of several factors, including sediment transport, ground lithology, stratigraphy, slope, flow geometry and anthropogenic activities [27].

Opencast lignite exploitation in Kolubara mining basin started in 1952 when the mining field “A” was open (it was exploited till 1966). Mining field “B“ was opened in 1952, mining field “D” in 1961, “Tamnava-East Mining Field” in 1979, “Tamnava-West Mining Field” in 1994 and mining field “Veliki Crljeni” in 2008 [28].

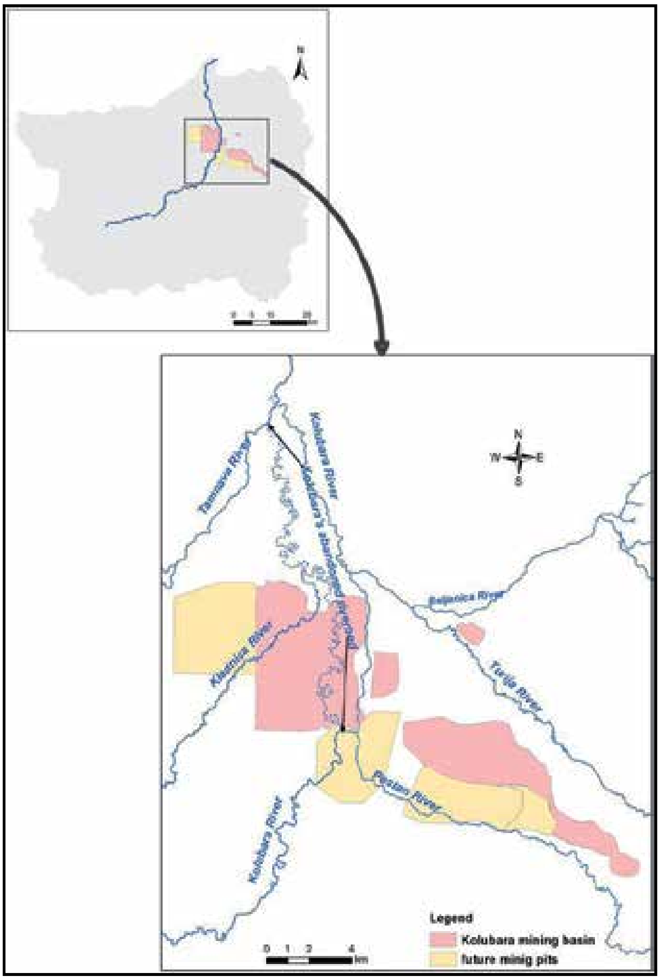


Figure 3. Plan of the mining fields in Kolubara mining basin [28]

Beogradsko-posavska water community “Beograd” has made a project „Regulation of the Kolubara River and its right tributaries from Ćelije to Poljane (km 23+200 – km 55+506)“ in 1957. Regulation works on the Kolubara River and its tributaries had begun in 1959/60. The diverting of the Kolubara River was done to clear the area for lignite exploitation, actually for opening new mining fields.

From that moment the Kolubara River flows through the Pestan's riverbed (its right tributary), and previous Kolubara's riverbed is abandoned with the periodic flow. The length of the Kolubara River was shortened by 20 km because of diverting its riverbed, while the length of the Pestan River was also shortened because its confluence was moved to the South. By diverting the Kolubara's riverbed into the Pestan's riverbed, which morphologically was not predisposed for kinetic energy of stronger flow, bank erosion became a dominating geomorphological process in the area and initiated processes of digging the riverbanks, transportation and deposition of eroded material. It is obvious that river system changes in lower part of the Kolubara River are demonstrated in domination of fluvial (lateral) erosion on one hand, and in cutting the meanders and fossilization of certain parts of the riverbed, on the other hand.

5. The consequences of bank erosion

5.1. Forming of meanders

Map of the Kolubara's basin first trend of relief energy [2] shows that almost whole area of the Donjokolubarska valley is under tectonic movements of slowly sinking. For this reason the sediments are accumulated in the riverbed, river velocity decreases which cause the riverbed meandering and stronger bank erosion. This natural process became more intensive since the Kolubara River was diverted into the riverbed of Pestan. In the Donjokolubarski basin there are numerous sectors with abandoned riverbeds and cut off meanders.

Forming of meanders and cutting the "necks" are recent geomorphologic-hydrological process, which is dominated in the study area. According to results of the recent researches [13], there are 89 abandoned parts of the riverbeds and cut off meanders in the area of the Donjokolubarski basin. The Kolubara and its tributaries tend to move to the east because of the Kolubarsko-pestanski fault, which indicate more abandoned riverbeds and cut off meanders on the left side of the Kolubara valley (64), compared to the right side (25).

In the study area there are 40 cut off meanders with total length of 20.30 km while the number of abandoned parts of the riverbeds is 49 with total length of 76.03 km. Hence, the total length of all abandoned riverbeds and cut off meanders in the Donjokolubarski basin is 96.33 km, and their total surface is 3.35 km^2. The longest cut off meander is 1.7 km long and the shortest is 185.7 m long. The longest abandoned riverbed is 6.49 km long.

The length of the Kolubara's riverbed is influenced by stronger bank erosion and formation of meanders, which is clearly perceived in the field. According to orthophoto image from 2004 and satellite image (Google Earth) the Kolubara River length (in the Donjokolubarska valley) is 66.52 km, while according to topographical map from 1970 it was 67.5 km, and according to topographical map from 1925 it was 87.6 km.

After cut off meander, the riverbed itself morphologically adjusts to the new state [29]. Morphological changes of the rivers are reflected in digging the concave river banks and sediment accumulation on the convex river banks.

5.2. Land use changes

As we earlier indicated, river erosion and frequent floods can make great material damages to people, villages and economy. Since the lateral erosion has more intensity, the river banks on concave side of the Kolubara River often collapse and farmers who have arable land parcels on the river bank (in the area of three villages the Kolubara flows through) loose the parts of the parcels which were carried away by the river. Based on Cadastral maps from 1967 and orthophoto images from 2004 we have estimated the area of diminished land parcels and their land loss.

Farmers who have land parcels in three villages (Drazevac, Konatice and Poljane) on the Kolubara river bank cannot farm them in whole, because the river has changed its course and took some parts of the land parcels away. The cadastral maps of the researched area scale 1:2500 from 1967 and orthophoto images from 2004 were compared. Using the results of this comparative analysis, the evolution of the hydrological system in the period from 1967 to 2004 was presented. The previous research showed that 60.37 ha was lost and degraded by the river bank erosion, which means that the land loss is 50.57 % of the land parcels from 1967 [15].

Land use	**Total**	**Arable land**	**Woods**	**Pastures**	**Meadows**	**Sand banks**	**Other (roads…)**
			Drazevac				
number of endagered parcels	95	39	16	1	5	34	-
area in 1967 (ha)	57.76	34.96	5.56	0.25	2.93	14.07	-
area in 2004 (ha)	28.23	21.76	2.48	0.02	1.30	2.67	-
loss of land (ha)	29.53	13.20	3.08	0.23	1.63	11.40	-
			Konatice				
number of endagered parcels	86	56	2	2	-	25	1
area in 1967 (ha)	50.44	42.73	0.49	1.02	-	6.12	0.09
area in 2004 (ha)	32.13	29.57	0.34	0.55	-	1.60	0.06
loss of land (ha)	18.31	13.16	0.15	0.47	-	4.52	0.03
			Poljane				
number of endagered parcels	66	41	3	-	-	21	1
area in 1967 (ha)	40.09	33.91	0.82	-	-	5.11	0.25
area in 2004 (ha)	26.26	25.15	0.19	-	-	0.89	0.03
loss of land (ha)	13.83	8.76	0.63	-	-	4.22	0.22

Table 1. Land use structure in Drazevac, Konatice and Poljane.

On the basis of the recent and more accurate data from Obrenovac Municipality Cadastre we have determined land use structure of degraded land parcels on the Kolubara River banks. According to these data, total area of all 247 endangered land parcels was 148.3 ha in 1967, and 86.62 ha in 2004. Therefore, 61.68 ha of soil were lost within 37 years [13].

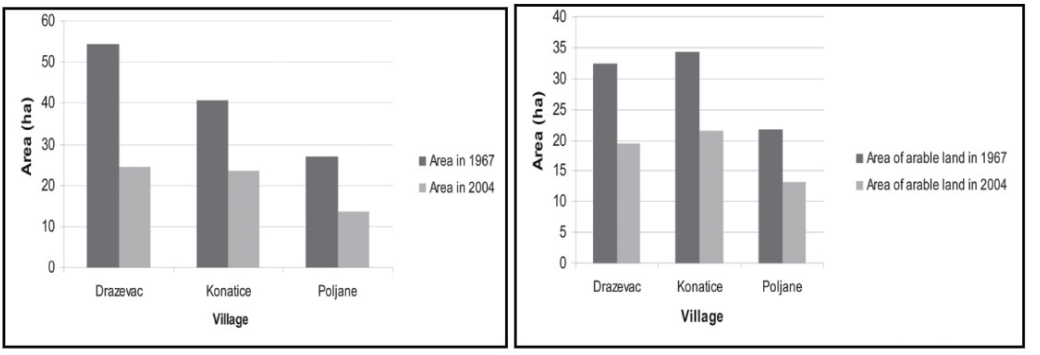


Figure 4. Land use changes in total area (left) and area of arable land (right) in Drazevac, Konatice and Poljane between 1967 and 2004

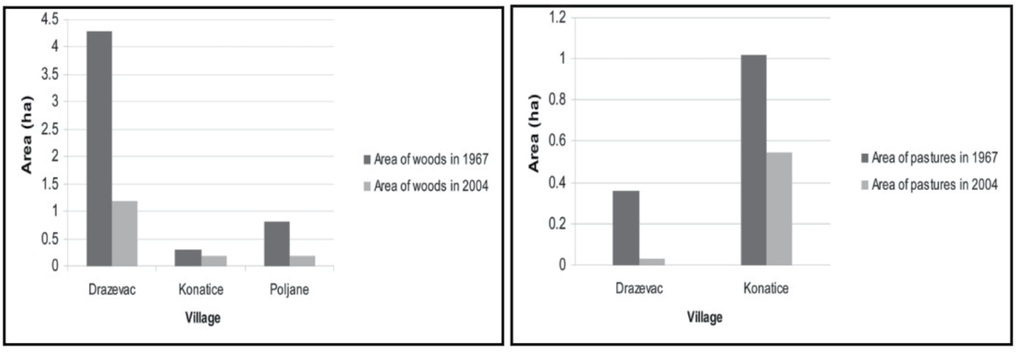


Figure 5. Land use changes in area of woods (left) and area of pastures (right) in Drazevac, Konatice and Poljane between 1967 and 2004

From 247 endangered land parcels, 136 are arable land with the area of 111.6 ha in 1967, and 76.48 ha in 2004, which means that within 37 years 35.12 ha of arable land was lost for farming, and it is 31.5 % of the initial area (in 1967). The woods comprise 21 of all endangered land parcels with area of 6.87 ha in 1967, and 3.01 ha in 2004, which means that it has been lost 3.86 ha of woods. There are only the three endangered land parcels with pastures, and their area was 1.27 ha in 1967, and 0.57 ha in 2004. All five endangered land parcels with meadows are in the area of Drazevac village.

Analyzing the area of endangered parts in the three villages, one can conclude that erosion was the most intensive in the period 1967-1981, when 50.9 ha of soil was lost within 14 years. The riverbed was stabilized later and the erosion decreased. This appoints to the fact that diverting the Kolubara River into the Pestan's riverbed caused more intensive bank erosion since in time erosion was diminished which brought to the riverbed stabilization.

Three villages on the Kolubara River banks (Drazevac, Konatice and Poljane) were characterized by agricultural production and agricultural population. Analyzing the land use structure of endangered parcels one can conclude that arable land parcels are the most endangered and degraded by intensified lateral erosion of Kolubara.

In Serbia there is 4.25 million ha of arable land, and each year 500000 ha (which means 11.74 %) of arable land remain uncultivated [30]. In the above mentioned three villages 33.47 % of arable land (on the Kolubara River banks) remain uncultivated, which is three times more than the average in Republic of Serbia. During the field work, the interviewed owners of endangered arable land parcels pointed that they do not farm their land on the river banks because of flood risks. The Kolubara River floods almost every year and crop is ruined. Therefore, besides the loss of arable land, frequent floods are huge problem in this area.

The economic consequences of bank erosion in the area of the Donjokolubarski basin could be analyzed through losses that the owners of endangered arable land parcels had (because the arable land parcels were reduced). The area of arable land (on the river banks) was diminished by 35.12 ha within 37 years. In the research area the average annual yield is 3-4 t per hectare, so the annual losses of crops (mostly wheat and corn) in recent years are between 100 and 140 t per year.

5.3. Sediment load discharge

Changes of land use structure and changes in sediment regimes are the direct consequences of the bank erosion [22]. The calculation of one-day sediment load discharge at the monitored hydrological profile includes the values of mean daily flow (Q – m^3/s) and the relevant concentration of the suspended load (C–mg/l). The assessment of sediment deposition rate is based on the results of RHMSS [31] measurements and the results of own daily measurements of suspended load concentration during the period (1985-2004). The results show that 193253.8 tons of material was accumulated between two hydrological profiles. And the riverbed itself was raised for 36 cm, which is nine times enlarged comparing to previous research when it was raised for 4.2 cm (with a shorter time series) [2]. The extraction of the river deposited sediments from the Kolubara's riverbed was stopped. Although the river deposits were hand extracted with low intensity, it certainly had great positive effects from the aspect of maintaining the surface of riverbed profile. Simple solutions, like the river deposit extraction, do not need huge investments for the implementation and they can be carried out without limitation of the natural conditions.

REIK Kolubara has a negative ecological impact on the Donjokolubarska valley. There are lots of waste waters after the ore production. Waste waters from the mine "REIK Kolubara" are discharged without any treatment into the Kolubara River. Therefore, the Kolubara River contains waste waters from the mine and after each flood the soil on the river banks is contaminated by substances from the waste waters. The results of soil analysis in the Kolubara river basin show increased concentration of nickel, arsenic and lead in the area of the Donjokolubarski basin [18].

The eroded material from the river banks is accumulated downstream. The accumulated sediments can contain considerable concentrations of heavy metals and that is threat for the aquatic habitats and for the people [8, 32-34].

Ecological aspects of mechanical water pollution by suspended sediment, chemical water pollution by organic and mineral fertilizers used in plant production in the catchment, nutrients found in the soil as well as chemical pollution of water and sediment by pesticides and heavy metals are very important ecological problem in the study area. On two locations we have sampled the accumulated material from the Kolubara's riverbed to examine the transport of contamination and accumulation of contaminated sediments due to bank erosion processes.

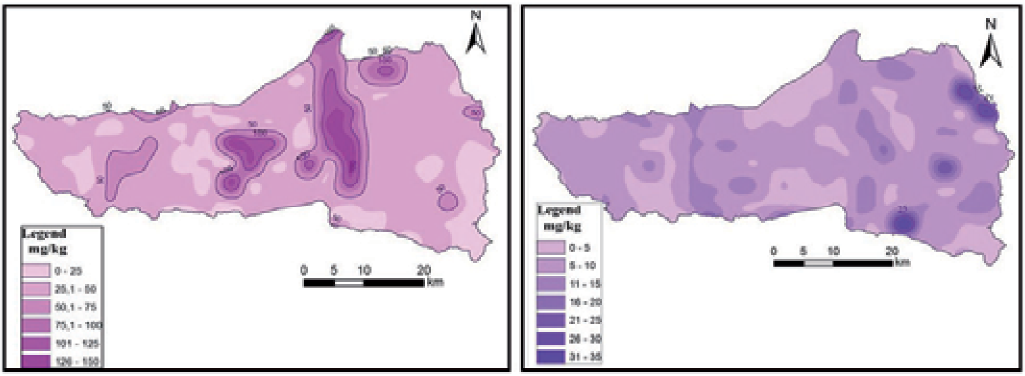


Figure 6. Distribution of Ni (left) and As (right) in the soil of the Donjokolubarski basin [18].

Figure 7. Sampling of deposited sediments on location 1 (left) and 2 (right)

The deposited sediments have sandy-clay texture. Chemical characteristics of deposited sediments from Kolubara's riverbed are: mildly alkaline reaction, high bases saturation degree and low humus content. The average heavy metal concentration in sediments decreased in the order: Ni > Cr > Zn > Pb > Cu > Cd.

In Serbia there is no law defining limitation of heavy metals in suspended sediments. Some European countries have such laws [34], but the differences between countries are significant. In most of the cases the critical values are obtained using the equilibrium method and maximum acceptable concentration (MAC) for the surface waters with regard to direct and indirect effects on living organisms in the water-sediments systems. According to these data, the range for different elements is as follows: 15 - 100 $mg.kg^{-1}$ for Pb; 0.6 – 2.4

mg.kg^{-1} for Cd; 36 - 120 mg.kg^{-1} for Cu; 123 - 1050 mg.kg^{-1} for Zn; 10 - 180 mg.kg^{-1} for Ni and 37 - 120 mg.kg^{-1} for Cr. These ranges are bigger then estimated ecotoxic criteria [35], which are: 5 - 50 mg.kg^{-1} for Pb, Ni i Cu; 0.1 – 1.0 mg.kg^{-1} for Cd; 50 - 500 mg.kg^{-1} for Zn; 10 - 100 mg.kg^{-1} for Cr.

Sample	Zn	Cu	Pb	Cd	Cr	Ni
	mg.kg^{-1}					
Location 1	39.3	15.9	23.0	0.0	94.0	198.3
Location 2	41.0	20.2	27.9	0.1	103.0	210.9

Table 2. Heavy metal contents in the deposited sediment load.

Respecting the above mentioned criteria, mean measured concentration of Pb, Zn and Cr are within the limits (after de Vries and Bakker [35]), while concentration of Cu and Cd are below the limits and concentration of Ni are above the limits. According to OSPAR limitation values [36], average concentrations of Pb, Cu and Cd are below the limits, average concentrations of Cr and Zn are within the limits, while average concentrations of Ni are above the limits.

5.4. Floods

The Kolubara River is a good example which represents the existence of all conditions for frequent and large scale floods. As an indirect consequence of the anthropogenic influence on the hydrological system in the lower part of the Kolubara valley, once a year (sometimes twice a year) the Kolubara River overflows, and the area of lower part of the Kolubara River basin is endangered by floods. Catastrophic floods of the Kolubara River and its tributaries spread over the area of lower part of the Kolubara River basin during the spring of 1937, and they lasted two months approximately (from March to May). In this area large scale floods also happened in 1965, 1975, 1981, 1996, 1998, 1999, 2001, 2004, 2006, 2008 and 2010.

The highest discharge of the Kolubara River in the period of 1959-2000 was 646 m^3/s and it was registered on Drazevac hydrological station. According to probability curve of high discharges the discharge of 646 m^3/s may occur once in a 46 years. The lowest value of annual maximum discharge would be about 25 m^3/s, the highest discharge in a hundred years would be 740 m^3/s, and the highest discharge in a thousand years would be 960 m^3/s. During the first decade of XXI century almost every two years the flood wave was bigger than the biggest one which occurs once in a fifty years. Huge flood waves were occurred in 2001, 2004, 2006, 2008 and 2010. The last flood in December 2010 had already reached the maximum value which occurs once in a hundred years (according to probability calculation (until and including) year of 2000)). Since the floods are directly and indirectly related to bank erosion these data should be included in bank erosion analysis because their analogy is proved, although there is no quantification of their correlation. Therefore, researches should be focused on causes of floods, and on reduction of bank erosion uncertainties. Many factors that influence the Kolubara River floods are already known. Firstly, there is a difference in flows in the upper and lower part of the Kolubara River basin. The drainage conditions in the upper part are more favorable. The area of hydrological profile Slovac is less than 1/3 of the whole basin, but it drains a half of all waters in the Kolubara River basin. Downstream hydrological profile Beli Brod encompasses a half of the basin, and its discharge is 3/4 of Kolubara's discharge. In the Donjokolubarski basin the drainage conditions are different, and the most significant factor is slope (the slope of the river flow and the slope of the river basin). The distance between Beli Brod and the Kolubara’s confluence with the Sava River is 50 km and the altitude difference is 20 m. The present slope of 40 cm/km (0.4 ‰) is declining every year due to intensive sediment accumulation in the riverbed. Relating these processes with the shape of the river basin and rapid concentration of water downstream of the Beli Brod, it does not surprise that Kolubara River “ramp” over its alluvial plain. Moreover, in the last decade there is simultaneity of frequent rains of high intensity with extended duration and sudden snowmelt, and that is the reason for increased concern. Considering that rivers in the sub basins are mostly torrential, this concern is even more enhanced. Additionally, in this area rivers were diverted to bring the economic benefits. Because of all these reasons, the life in the coastal zone of the Kolubara River basin is gloomy but real with lot of uncertainties.

In order to prevent the frequent floods there are a several plans to deal with the actual situation in the area. Construction of several small accumulations on the Kolubara’s tributaries is at its first phase, but there is no indication for solving the existing water problems. There is an idea to channelize the Kolubara’s riverbed for sailing (i.e. for the transportation of lignite from the Kolubara mine), but it is still in the early phase of planning, although the initiative appeared long time ago. The height difference between the Kolubara’s River confluence with Sava River and the location of lignite exploitation in the Kolubara mine basin is 23 m [12]. This height difference and the wideness of the Kolubara’s riverbed would facilitate its riverbed training works, enabling cheaper lignite transportation from the Kolubara mine basin. Training works the Kolubara’s riverbed and its preparation for lignite transportation could easily be carried out, so the invested means would be economically justified. Thus, the meandering flow would be straightened, and the strong bank erosion in the riverbed would be regulated which means that some factors of flooding would be eliminated.

6. Conclusion

Bank erosion, soil loss, sediment load deposition, changes in the river course, floods, landslides, soil and water pollution are the major environmental problems in the Kolubara River basin which could be aggravated by the land-use changes. The solutions for all mentioned environmental problems demand a complex analysis of the area characteristics and development of the strategy for solving the existing water problems in this area, but in the same time they have to provide necessary conditions for the further lignite exploitation. Some villages are located in the lower part of the Kolubara River basin, in the area which is planned for the expansion of the Kolubara mining basin, so it is an important factor for the future sustainable landscape planning.

Hydrological network of the Donjokolubarski basin is constantly changing due to natural factors and anthropogenic impacts. The damage which is done cannot be compensated, but even worse is the fact that no one feels responsible and that the population in this area is still left to the mercy of torrential river. Numerous calls for helping endangered people and goods were sent to the different addresses, but no one tried to help. Apparently, the problem goes beyond the "values" of a few villages and the state interest (lignite exploitation) has absolute priority, like in the case of neighboring Dubrava and unique sources of Obrenovac Municipality [34]. This situation lasted till the catastrophic floods in June 2010, when the shocking images of flood damage terrified the publicity, and problem could not be ignored anymore. As an attempt to repair the flood consequences, during 2010 two dikes were constructed with the length of 200 m in total. The first location was repaired for bridge protection, and the second one for household protection. The total cost of construction works was 100 000 euros. Since, the total length of all degraded river banks of first category is about 5 km; the economic profitability of this repairing method is questioned. It made sense in the initial phase of degradation, but now it goes beyond the reality of existing situation. It seems that, after the construction of two dikes, somebody tries to justify the negligence, because it is obvious that these two dykes are insufficient to solve the problem. In cases like this one, even not doing anything for protection of degraded areas represents a serious violation of principles of sustainable management of natural resources, actually that is an offence. The responsible for effects of the changes in the Kolubara River basin is still unknown, is it nature or man?

Making the constant pressure on state institutions through various appeals, indicating to unsustainability of current situation and stand by position of constant fear, this paper is one of many attempts to help the endangered population. In this context, the monitoring of the Kolubara River in the Donjokolubarski basin is a logical solution and our contribution, with particular results and recommendations, to fight for the basic human right to live without fear from hazards.

What kind of message can be sent to people living in this area and dealing with above mentioned problems? As they say, finding that the state does not protect them from the problems that come upon them, they give up farming the parcels of endangered area (along the river). The even more irrational, is the fact that they still pay taxes on the parcels, which does not exist anymore or they are significantly reduced, because the taxes calculation is made according to Cadaster from 1967! The estimation of all unnecessary loss of land, land values, personal losses of individuals and damage done to whole community is in the course. At the time when the personal status is far beyond collective responsibility due to difficult economic situation, this scientific approach is the only way to inspire the responsible ones in finding the solution.

This research could be the warning for the future anthropogenic activities on the river system since the new changes on the hydrological network were planned in this area. The four new mining fields should be opened, and if it happens, the hydrological network will be changed again and new problems will appear in the river basin.

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7. References

[1] Dragićević S, Stepić M, (2006) Changes of the erosion intensity in the Ljig River basin – the influence of the antropogenic factor. Bull. Serbian Geogr. Soc. 85(2): 37-44 (in Serbian with English abstract)

[2] Dragićević S, (2007) Dominant Processes of Erosion in the Kolubara Basin. Faculty of Geography, Belgrade: Jantar groupe, p. 1-245 (in Serbian with summary in English).

[3] Dragićević S, Carević I, Kostadinov S, Novković I, Abolmasov B, Milojković B, Simić D (2012) Landslide susceptibility zonation in the Kolubara river basin (western Serbia) - analisys of input data. Carpathian Journal of Earth and Environmental Sciences 7(2): 37–47.

[4] Dragićević S, Milevski I, (2010) Human Impact on the Landscape – Examples from Serbia and Macedonia. Advances in GeoEcology, n°41, Global Change – Challenges for soil management (Editor M. Zlatic), CATENA VERLAG GMBH, Germany. pp. 298-309.

[5] Tošić R (2006) Soil erosion in the catchment Ukrina. Geographic Society of the Republic of Srpska, Banja Luka. Special issue, No. 13, p. 150 (in Serbian with summary in English)

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[6] Blanka V, Kiss T (2011) Effect of different water stages on bank erosion, case study of river Hernad, Hungary. Carpathian Journal of Earth and Environmental Sciences. 6(2): 101–108.
[7] Milevski I (2011) Factors, Forms, Assessment and Human Impact on Excess Erosion and Deposition in Upper Bregalnica Watershed (Republic of Macedonia). In: Human Impact on Landscape, Eds. S. Harnischmachter and D. Loczy. Zeitschrift für Geomorphologie, Vol. 55, Suplementary issue 1, Stuttgart, p. 77-94
[8] Chen J, Chen J Z, Tan M Z, Gong Z T (2002) Soil degradation: a global problem endangering sustainable development. Journal of Geographical Sciences, 12(2): 243-252.
[9] Goudie A (2006) The human impact on the natural environment: past, present and future. Blackwell Publishing, USA, sixth edition, p. 357.
[10] Li L, Lu X, Chen Z (2007) River channel change during the last 50 years in the middle Yangtze River, the Jianli reach. Geomorpholgy. 85: 185-196.
[11] Denes L (2010) Anthropogenic Geomorphology in Environmental Management. In: Anthropogenic Geomorphology - A Guide to Man-Made Landforms. Eds. József S., Lóránt D., Dénes L., Springer, p .25-38
[12] Dragićević S, Živković N, Ducić V (2007) Factors of flooding on the territory of the Obrenovac municipality. Collection of the papers, Faculty of Geography, Belgrade, 55: 39-54.
[13] Roksandić M (2012) Causes and consequences of changes of hydrographic network in Donjokolubarski basin. Unpublished PhD thesis, University of Belgrade, Faculty of Geography, p. 197 (in Serbian with summary in English)
[14] Dragićević S, Živković N, Kostadinov S (2008a) Changes of hydrological system in the lower course of the Kolubara river. In proceedings of the XXIV Conference of the Danubian countries on the hydrological forecasting and hydrological bases of water management, Bled, Slovenia.
[15] Roksandić M, Dragićević S, Živković N, Kostadinov S, Zlatić M, Martinović M (2011) Bank erosion as a factor of soil loss and land use changes in the Kolubara river basin, Serbia. African journal of agricultural research, 6(32): 6604-6608, DOI: 10.5897/AJAR11.736
[16] Dragićević S, (2002) Sediment Load balance in the Kolubara basin. Faculty of Geography, Belgrade. p. 184 (in Serbian with summary in English)
[17] Dragićević S, Stepić M, Karić M (2008b) Natural potentials and degraded areas of Obrenovac municipality. Jantar groupe, Belgrade. pp 1-180. (in Serbian with summary in English)
[18] Dragićević S, Živković N, Novković I (2011) Preparation of numerical and spatial data basis for the assessment of land and water diffuse pollution in the Kolubara River basin. Ministry of Environment, Mining and Spatial Planning, Environmental Protection Agency, Beograd (in Serbian)
[19] Hooke J, Redmond C E (1989) River-channel changes in England and Wales. Journal of *Institution* of Water and *Environmental Management,* 3: 328-335.
[20] Large R G A, Petts E G (1996) Historical channel-floodplain dynamics along the River Trent, Implications for river rehabilitation. Applied Geography, 16(3): 191-209.

[21] Weng Q (2002) Land use change analysis in the Zhujiang Delta of China using satellite remote sensing, GIS and stochastic modeling. Journal of Environmental Management, 3: 273-284.
[22] Kiss T, Fiala K, Sipos G (2008) Alterations of channel parameters in response to river regulation works since 1840 on the Lower Tisza River (Hungary). Geomorphology, 98: 96-110.
[23] De Rose R C, Basher L R (2011) Measurement of river bank and cliff erosion from sequential LIDAR and historical aerial photography. Geomorphology, 126: 132-147.
[24] Cadastral register of the Municipality of Obrenovac, 1967.
[25] Dukić D (1974) Kolubara's regime and water management problems in its river basin. Bulletin of Serbian Academy of Science and Arts, Department of Science, vol. 36, Belgrade (in Serbian).
[26] Surian N, Rinaldi M (2003) Morphological response to river engineering and management in alluvial channels in Italy. Geomorphology, 50: 307–326.
[27] Youdeowei P O (1997) Bank collapse and erosion at the upper reaches of the Ekole creek in teh Niger delta area of Nigeria. Bulletin of the International Association of Engineering Geology 55: 167-172.
[28] ***Diverting of Kolubara River: http://www.neshvyl.com/doc/prica_o_kolubari.pdf www. rbkolubara.rs
[29] Hooke J (1995) River channel adjustment to meander cutoffs on the River Bollin and River Dane, northwest England. Geomorphology, 14: 235-253.
[30] Pejanović R, Njegovan Z (2009) Actual problems of Serbian agriculture and villages. Industry. 37(1): 87-99 (in Serbian)
[31] Republic Hydro Meteorological Service of Serbia. Values of precipitation, water discharge, sediment load concentration for Kolubara river basin (1961-2005).
[32] Chen D, Duan J G (2006) Modeling with adjustment in meandring channels. Journal of hydrology, 321: 59-76.
[33] Dragićević S, Nenadović S, Jovanović B, Milanović M, Novković I, Pavić D, Lješević M (2010) Degradation of Topciderska River water quality (Belgrade). Carpathian Journal of Earth and Environmental Sciences, 5(2): 177 – 184
[34] Zivkovic N, Dragicevic S, Brceski I, Ristic R, Novkovic I, Jovanovic S, Djokic M, Simic S (2012) Groundwater Quality Degradation in Obrenovac Municipality, Serbia. In: K. Voudouris and D. Voutsa (Eds.), Water Quality Monitoring and Assessment, Rijeka: InTech. pp. 283-300.
[35] De Vries W, Bakker D J (1998) Manual for calculating critical loads of heavy metals for terestial ecosystems. Guidelines for critical limits, calculation methods and input data. Wageningen, DLO Winand Staring Centre. Report 166. p. 144.
[36] OSPAR/ICES (2004) Workshop on the evaluation and update of background reference concentrations (B/RCs) and ecotoxicological assessment criteria (EACs) and how these assessment tools should be used in assessing contaminants in water, sediment and biota, 9–13 February 2004. The Hague, Final report, OSPAR Commission, ISBN 1-904426-52-2

Chapter 2

Effects of Land Degradation on Soil Fertility: A Case Study of Calabar South, Nigeria

Imoke Eni

Additional information is available at the end of the chapter

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1. Introduction

Land degradation is a concept in which the value of the biophysical environment is affected by one or more combination of human induced processes acting upon the land. It literally refers to the impairment of natural quality of soil component of any ecosystem. Land degradation which is also seen as a decline in land quality caused by human activities, has been a major global issue since the 20th century and it has remained high on the international agenda in the 21st century. The importance of land degradation in Calabar South is enhanced because of its impact on food security and quality of the environments. The map of the study area is presented on the next page.

Land degradation can be viewed as any change or disturbance to the land perceived to be deleterious or undesirable (Eswaran, 2001). In the study area, the researcher observed loss of the biological and economic productivity and complexity of rain-fed cropland, irrigated cropland, range, forest and woodlands resulting from land uses or from a combination of processes arising from human activities and habitation patterns such as soil erosion caused by wind or water, deterioration of the physical, chemical, biological and economic properties of soil and long-term loss of natural vegetation. But there are also off-site effects, such as loss of watershed functions which is a major problem in Calabar South.

Natural hazards are excluded as a cause of land degradation in Calabar South, however human activities can indirectly affect phenomena such as floods and bush fires.

Research has shown that up to 60% of agricultural land in Calabar South is seriously degraded. Furthermore, the main outcome of land degradation is a substantial reduction in the productivity of the land as shown in figure 2

The major causes of land degradation include, land clearance poor farming practices, overgrazing, inappropriate irrigation, urban sprawl, and commercial development, land pollution including industrial waste and quarrying of stone, sand and minerals. High population density is not necessarily related to land degradation within Calabar South, but it is what a population does to the land that determines the extent of degradation. In the study area, where a large proportion of human population depend almost entirely on land resources for their sustenance, this over dependency results in the increasing competing demand for land utilization such as grazing, fish pond construction, quarrying, crop farming amongst others.

Figure 1. Map of Calobar South Government Area showing

Figure 2. Degraded agricultural land

The productivity of some land in Calabar South has declined by 60 percent as a result of soil erosion and nutrient loss (Bruinsma, 2003). Presently, reduction of land in Calabar due to past soil erosion range from 55-79% percent with a mean loss of 67%. If accelerated erosion continues unabated, yield reductions by 2020 may be 87%. Soil compaction is a general problem affecting some part of Calabar South especially in the adoption of mechanized agriculture. It has caused yield reduction of 35-60%. It is in the context of these global, economic and environmental impacts of land degradation on productivity in Calabar South that resilience concepts are relevant, since land resources are exhaustible.

2. Underlying reasons for land degradation in calabar south

The study was done at 45 different farm lands to determine the present state of the soil or land, cause and effect relationship and the soil property that was highly degraded. Different varieties of crops planted at different locations were surveyed and their nutrient status measured. Soil auger was used in the collection of the soil samples between the depth of 0-15cm for shallow and 15-30cm for sub-surface depths respectively. The physico-chemical parameters of the soil analyzed were ph, organic carbon, Nitrogen, Phosphorus, Exchangeable acidity, Cations exchange capacity and base saturation. The equipments listed below in table 1 were used in analyzing soil properties.

SOIL PROPERTIES	EQUIPMENTS FOR MEASUREMENT
PH	Potentiometer using glass electrode(Bates, 1954)
Organic Carbon	Oxidation Method (Allison 1965)
Total Nitrogen	Micro Kse/dahi Method(Bremer and Melvaney, 1982)
Exchangeable acidity	Titration Method
Exchangeable Cations	Atomic absorption spectrometer (AAs)
Cation exchange capacity	Titration using (Chapman, 1965)
Base saturation	Total exchangeable bases (Ca, Mg, K, Na) divided by their percentages. (Nssc 1995)

Table 1. Soil Properties and Equipments

Soil loss and runoff were measured at each study location and their respective cumulative yield calculated from the data obtained at the field. Runoff was calculated using the velocity area technique with the formula;

$$Q=AV,$$

where

Q= Discharge

V= Water velocity

A= Cross sectional area of the soil

The result from the research findings is as presented in Table 2 and 3 respectively.

Sampling point	Crop cultivated	Depth (CM)	PH	Organic carbon (C) %	Nitrogen (N) (kg)	Available phosphorus (p) (kg)	Potassium K (kg)	Cation Exchange Capacity (CEC) (mol/mg)	Base Saturation (%)
1.	Water yam	0-15	4.8	0.49	2.30	3.1	0.18	6.30	76
		15-30	5.7	0.65	3.45	4.5	0.34	8.45	84
2.	Yam	0-15	5.8	0.31	2.50	1.5	0.32	5.9	68
		15-30	6.3	0.45	4.20	3.2	0.45	7.20	82
3.	Cowpea	0-15	3.9	0.32	4.10	3.3	0.29	4.50	72
		15-30	5.4	0.54	5.00	4.1	0.36	6.30	81
4.	Melon	0-15	5.3	0.57	4.90	2.4	0.15	3.20	59
		15-30	6.7	0.49	6.21	3.3	0.21	5.40	65
5.	Cassava	0-15	6.8	0.67	6.30	2.7	0.26	6.50	60
		15-30	5.6	0.65	7.23	3.5	0.30	7.35	78
6.	Water Yam	0-15	7.2	0.72	2.40	2.9	0.42	5.20	70
		15-30	4.3	0.69	3.50	4.2	0.51	6.50	89
7.	Cocoa Yam	0-15	4.3	0.69	3.30	2.1	0.19	7.30	67
		15-30	6.5	0.98	4.40	3.3	0.28	8.20	76
8.	Maize	0-15	51	0.61	3.60	3.4	0.22	5.3	68
		15-30	63	0.82	5.50	5.6	0.31	6.00	72
9.	Rice	0-15	4.2	0.69	5.60	2.5	0.22	3.20	59
		15-30	51	0.85	6.70	4.4	0.44	5.40	64
10.	Tomatoes	0-15	4.0	0.43	3.60	2.8	0.15	4.70	53
		15-30	5.0	0.80	4.80	4.9	0.30	5.80	69
11.	Pepper	0-15	3.2	0.43	7.30	2.4	0.26	4.70	58
		15-30	4.9	0.71	9.60	3.8	0.32	6.90	72
12.	Sweet potatoes	0-15	4.2	0.60	6.30	4.2	0.24	5.20	61
		15-30	63	0.75	8.50	6.5	0.41	6.50	74
13.	Waterleaf	0-15	4.9	0.56	3.32	2.3	0.32	6.20	34
		15-30	7.3	0.70	6.55	4.5	0.41	7.40	66

14.	Okro	0-15 15-30	2.6 4.5	0.49 0.60	5.60 7.50	3.4 5.6	0.32 0.51	6.20 7.80	59 61
15.	Vegetable	0-15 15-30	6.9 7.5	0.39 0.65	2.50 4.40	2.5 4.7	0.27 0.37	4.30 6.90	57 70
16.	Spinach	0-15 15-30	4.3 5.0	0.51 0.63	3.20	3.9 5.3	0.29 0.39	5.20 6.50	63 71
17.	Bitter leave	0-15 15-30	5.2 6.2	0.42 0.54	6.70 8.40	2.4 4.9	0.36 0.46	5.40 6.30	52 69
18.	Otazi	0-15 15-30	4.9 7.6	0.34 0.59	2.30 5.40	3.5	0.24 0.32	6.90 8.50	63 70
19.	Afang	0-15 15-30	6.5 8.7	0.26 0.50	2.70 4.70	2.4 4.0	0.28 0.41	6.30 7.40	57 72
20.	Etinkene	0-15 15-30	3.5 5.3	0.41 0.59	4.50 6.50	2.4 3.5	0.34 0.55	4.10 6.20	53 65
21.	Garden Egg	0-15 15-30	4.3 6.9	0.38 076	3.40 4.90	2.2 4.5	0.19 0.28	3.10 4.50	44 75
22.	Sugar cane	0-15 15-30	4.6 6.9	0.42 0.66	5.20 8.20	3.1 5.2	0.20 0.46	3.40 5.60	33 49
23.	Scent leave	0-15 15-30	3.4 6.4	0.34 0.84	3.50 5.40	3.4 4.3	0.15 0.36	3.20 4.50	41 62
24.	Curry leave	0-15 15-30	3.2 4.9	0.34 0.76	4.60 6.40	3.3 4.7	0.12 0.47	6.50 3.20	36 54
25.	Ginger	0-15 15-30	0.6 6.8	0.42 0.69	3.40 7.40	2.6 3.4	0.24 0.56	5.10 3.10	43 67
26.	Pineapple	0-15 15-30	3.9 6.7	0.34 0.75	4.40 5.80	2.2 3.8	0.18 0.41	3.00 4.60	34 56
27.	Banana	0-15 15-30	4.9 8.3	0.41 0.83	6.30 7.80	3.4 4.9	0.21 0.46	3.20 5.30	42 54
28.	Groundnut	0-15 15-30	6.3 7.2	0.36 0.74	3.20 4.80	2.3 4.1	0.16 0.58	2.40 4.10	48 73
29.	Lettuce	0-15 15-30	5.2 6.9	0.41 0.98	2.80 5.90	2.0 3.0	0.25 0.49	2.30 4.70	64 78
30.	Melon	0-15 15-30	4.4 5.7	0.31 0.52	4.10 5.20	4.3 5.6	0.36 0.74	3.40 5.60	50 65

Table 2. Soil Physico- Chemical Properties for Different Varieties of Crops Cultivated in Calabar South.

Table 2 depicts that the selected physico-chemical properties of soil varies between the surface layer of (0-15cm) and subsurface of (15-30cm). The research further revealed that due to land degradation, most of the nutrients were leached in to the sub-surface. The resultant effect was that plants restricted to shallow depth did not do well. At certain times some were seen to die because they were no more having nutrients from their roots, this affected their productivity negatively.

The research further revealed that, severe land degradation has affected significant portion of Calabar South's arable land, decreasing the wealth and economic development of the study area. As land becomes less productive, food security is compromised and competition for dwindling resources increases, the seeds of famine and potential conflict are sown.

Recently in Calabar South, agricultural activities have increased vastly at the expense of natural forests, rangelands, wetlands and even deserts. Some of the expansion is compensated by farmer's investment in soils, such as fertilization, terracing, and tree planting. New soil formation also occurs through natural processes, but in general these proceed too slowly to compensate for human-induced degradation as shown in Figure 3 below.

Figure 3. Degraded Land Due to Poor Farming Practice in Calabar South

This research is based on consultation with experts, extrapolation from case studies, field experiments and other micro studies or inferences from landuse patterns, current land status, trends, and to what extent the degradation processes are human-induced.

Nutrient depletion as a form of land degradation has a severe economic impact on the study area where it represents a loss of long-run carrying power for farmers and negative externalities for the urban populations. Farmlands used for the cultivation of crops such as Maize, Okro, Water leaf, Pepper, Vegetables, Spinach and Afang had their N.P.K nutrients highly depleted because of their shallow root system which can no longer get nutrient from the leached soil. The economic impact of land degradation is extremely severe in Calabar South. On plot and field scales, erosion can cause yield reductions of 50-70% in some root restrictive shallow lands of Anantigha.

Eni et al, (2010), have estimated nutrient balances for some parts of the study in his findings; he estimated annual depletions of soil fertility at 32kg Nitrogen, 5kg phosphorus and 18kg potassium per hectare of land degraded. In 2002 about 85% of Calabar South farmland had nutrient mining rates at more than 30kg nutrients (NPK)/hectare yearly and 40 percent had rates greater than 60kg/ha yearly. Partly as a consequence, cereal yields are the lowest in the study area, averaging about one tonne per hectare for the same ten years age. Within specific agro-ecological environments, experimental data from the field allow soil degradation processes to be observed with greater precision.

Long term data obtained from the field indicates that intensive farming can cause yield reductions of 60% and more in some parts of Calabar South environments. Even under best variety selections and management practices, yields are stagnated and even fallen under long-term intensive monoculture for irrigated cassava and rain fed corn.

Patterns of degradation vary in Calabar South according to agro-ecological conditions, farming systems, levels of intensification, and resource endowments, but this also interact with social and economic systems. The areas of prime concern for this chapter are the Calabar South marginal lands, which have low physical resilience to land degradation, and are also associated with societies in which property rights are weakly defined, information systems are weak and managerial capacity is low.

3. Effects of land degradation in Calabar

Assessing the effects of land degradation in the study area is not an easy task, a wide range of methods were used. Some authors examined the risk of degradation in climatic factors and land use rather than the present state of the land. The methodology utilized for this study is the cause-effect relationship between severity of degradation and productivity. Criteria for designating different classes of land degradation into Low, moderate, high are generally based on soil properties rather than their impact on productivity as presented in figures 4, 5, and 6.

Figure 4. Shows low degraded land

Land degradation in the study area is treated as an open-access resource; it is then difficult to reclaim the value of soil improvements, so land users lack incentives to invest in maintaining long term soil productivity. In areas of low population density, land is abandoned when it has been degraded, and farmers move on to clear new land, leaving the degraded land as a negative externality.

Figure 5. Shows moderate degraded land

Figure 6. Shows high degraded land

Land degradation is a broad term that can be applied differently across wide range scenarios in the study area. The concept of land degradation was considered in four ways which includes, the effect on the soil productivity and the environment around, decline in the land usefulness, loss of bio-diversity, shifting ecological risk and a reduction on the land productive capacity.

Vulnerable lands are exposed to stresses such as accelerated soil erosion by water, soil acidification and the formation of acid sulphate resulting in barren soil, and reduced crop yields. Agricultural activities such as shifting cultivation, without adequate fallow periods, absence of soil conservation measures, fertilizer use and a host of possible problems arising from faulty planning or management of the land all lead to intense land degradation within the study area. Table showing cumulative soil loss and runoff in relation to crop yield in the study area is therefore presented overleaf.

Sampling points	Crops cultivated	Soil loss (Mgh^{-1})	Runoff (mm)	Cumulative Yield (Mg/ha)
Farmland 1.	Water melon	41	12	10.5
2.	Yam	63	18	8.3
3.	Cowpea	20	6	25.6
4.	Melon	35	8	18.7
5.	Cassava	42	16	11.4
6.	Water yam	45	14	10.3
7.	Cocoa yam	43	15	12.1
8.	Maize	56	22	10.7
9.	Rice	49	20	9.6
10.	Tomatoes	7	25	8.0
11.	Pepper	63	46	4.5
12.	Sweet potatoes	33	15	14.7
13.	Water leaf	89	48	3.2
14.	Okro	60	35	5.4
15.	Vegetable	52	38	7.6
16.	Spinach	56	32	8.9
17.	Bitter leaf	42	26	10.8
18.	Otazi	53	31	6.7
19.	Afang	66	42	4.1
20.	Etinkene	13	20	9.6
21.	Garden Egg	38	17	8.5
22.	Sugar cane	42	21	9.6
23.	Scent leave	45	24	10.2
24.	Curry leave	37	18	6.5
25.	Ginger	44	20	7.9
26.	Pineapple	39	22	8.6
27.	Banana	41	20	6.8
28.	Groundnut	34	12	10.3
29.	Lettuce	31	16	9.2
30.	Melon	23	8	5.3

Table 3. Cumulative Soil Loss and Runoff in Relation to Crop Yield in The Calabar South

Table 3 indicates that the greater the soil loss and runoff rates, the smaller the cumulative yield. Farmland number 13, in which water leaf was cultivated had a higher value for soil loss of 89mg/ha and runoff of 48mm, with a lower cumulative yield of 3.2 mg/ha. This means that the soil was severely eroded due to erosion which washed away all the available nutrients. Cowpea located in farmland 3 had the lowest soil loss and runoff rate of 30mg/ha and 6mm respectively with a higher value of 25.6mg/ha for cumulative yield. This was so because the cowpea had a symbiotic relationship with the soil, although it was getting its nutrient from the soil, the plant also played protective role to the soil by serving as a cover crop thereby reducing the runoff rate at the soil surface.

This research have shown that soil erosion carries away a large volume of soil equivalent to one meter deep over 250,000 hectares every year. Some 194 million hectares of land are affected by water erosion. Recently, 6.1 million hectares of land have been lost to water erosion in the study area. Deforestation is also widespread, about 6 million hectares of forest are lost each year. The destruction of the forests is mainly a result of clearance for agriculture. The search for fuel wood, the growing frequency and severity of forest fires, are also taking their toll. As a result of this problem, Crop residues and animal manure, which were previously returned to the soil to add valuable nutrient have to be burnt for fuel.

Land degradation in Calabar south also exhibits hydrological conditions, where vegetal cover is removed, the soil surface is exposed to the impact of raindrops which causes a sealing of the soil surface, and less rain then infiltrates the soil. As runoff increases, stream flow fluctuates more than before, flooding becomes more frequent and extensive, and streams, springs become ephemeral. These conditions encourage erosion; as a result, sediment loads in rivers are increased, dams are filling with silt, hydro-electric schemes are damaged, navigable waterways are being blocked and water quality deteriorates.

4. Policy implications, individual efforts and institution

Attempts to prevent land degradation in the Calabar South have been unsuccessful. One of the main reasons was that these attempts were centrally organized and it produced few short-term benefits for the farmers who had to execute them. The farmers had little motivation for the hard manual work involved in erecting mechanical barriers to control soil erosion. Government must spear head the formulation of policies, mobilize the people and initiate programs and projects that are needed for sustainability.

The key action required to combat land degradation in Calabar South is to develop a long-term land conservation plan which will provide the necessary continuity of the approach. These long-term plans need to be fashioned to suit the exact requirements of individuals in the study area. They should be based on three key principles; improving land use, obtaining the participation of the land users and developing the necessary institutional support.

However, agricultural policies can have a profound effect on land use. Subsidies, incentives and taxes can all have a big effect on what crops are grown where and whether or not the land is well managed. Governments attempting to achieve self-sufficiency in food crops frequently promotes policies which result in marginal land being misused, this, in turn leads to land degradation. On the other hand, the price of food crops is sometimes controlled and kept to such a low level that it becomes pointless for farmers to manage their crops or land well, this also results in land degradation. All government policies which affect the economics of land use should be carefully reviewed and where necessary, modified so that they encourage productive and sustainable land use rather than destructive practices.

Calabar South government explicitly subsidizes practices that increase land degradation, and tax activities that tend to reduce degradation. Examples are subsidies on cultivation of upland crops that drive expansion into the marginal lands; subsidies on water and energy in irrigation schemes; tariff protection for land-degrading crops, and export taxes on more environmentally benign crops. Reversal of these policies will have very high benefit-cost ratio, since their net cost is low, zero or even negative as long as political costs are disregarded. Increased intensity of cultivation in ecologically fragile upper water shed areas of Calabar have contributed to land expansion. Developing countries in particular have undertaken extensive reform of trade policies in manufacturing sectors, driven both by unilateral goals and by the need to conform with international obligations as signatories to regional and multilateral trade agreements.

Agricultural trade reform has lagged behind this process, with the result that average agricultural tariffs are now equal to or greater than those on non-agricultural goods in developing countries such as Nigeria and specifically in Calabar South(Anderson, 2006). Equilibrium simulation experiments, aimed at implementation of package of trade liberalization measures in Calabar South including a modest reduction in cereals prices, was found to exert a substantial effect on land use. The price of cassava the major annual crop grown in Calabar South falls in these experiments by about 0.75 percents. This fall, along with rises in wages and some input prices, causes a contraction of about 0.4 percent in demand for upland land for seasonal crops. If cassava land is primarily responsible for erosion, from upland fields and the base, annual soil loss from the upland farm will be 65-75 million trillion/year, the trade reforms permanent ground cover is re-established assuming that this is what happens after cassava production cases.

Research valued the nutrients lost to soil erosion in Calabar South at 30million/ton, adopting that as a very conservative indicator of the total value of soil lost, the experiment yields a direct, on-site gain of roughly 150million in addition to the other benefits that the trade liberalization brings to the economy. In these and similar tropical economies, substantive trade liberalization will result in major land use changes. Relaxing protectionist policies on crops which contribute to land degradation in Calabar south will shift their production to countries and environments where they can be grown at lower environmental cost.

In the case of subsidies, their relaxation creates fiscal savings that provide an opportunity to compensate farmers, who are often extremely poor. For environmental taxes, e.g. on activities that lead to downstream siltation, the challenge is to monitor and assess such widespread activities. Addressing policy-induced distortions that operate through markets to promote land-degrading activities is the most efficient single means to address land degradation in Calabar South.

The success of policy reforms, however, relies on the pervasiveness of markets and the feasibility of market-based instruments. Not as trade policy reforms on their own but a panacea for environmental damage, with comparative advantage in land degrading crops, greater trade openness without complementary environmental protection policies may lead to rapid worsening of land degradation.

Finally the calabar south government had tried to set-aside programs, land use zoning policies and establishment of conservation areas, bans on degrading activities and public reforestation projects. Cross River State afforestation projects, is targeted at increasing forested areas in Calabar South by 50% and 15% decrease in cultural areas. The current program, however, lacks "Volunteerism" in participation, and therefore suffers from low cost effectiveness and high cost of performance monitoring and evaluation. In general, it is very difficult and costly to police and enforce bans against common and widely dispersed practices when these practices are profitable to land users or perhaps even necessary for survival. Project-based payment for environmental services schemes introduced in Calabar South is meant to provide a means of paying compensation to farmers who desist from environmentally undesirable activities. But since there is no internal mechanism for decreasing cost replication of payment for environmental services measures, in benefit cost terms these are expensive interventions if they are to be widely applied even before counting the cost of contract enforcement and monitoring.

5. Lessons and conclusion

Over the years, there has been a progressive change in the approach to agricultural practices from crop substitution to integrated farming system. A concern for environmental aspects has been explicit till many other projects came up. However, the way this was undertaken, and the priority given to conservation, differs greatly. The use of erosion control structures such as Bench terraces, contour bank, contour ditches were localized.

Recently, based on research findingds, Calabar South farmers started using erosion control measures devoid of physical structures. This marked a major departure from the previous approach. The objective was not simply soil conservation, but sustainable farming systems. Among the key lessons learned are:

a. The importance of having a master plan for water shed development.
b. The importance of the local people participating in all levels of conservation.
c. The use of vegetable barriers as the most pertinent and cost effective erosion control measures in the area.
d. The introduction of new technology in controlling land degradation was made use of in Calabar. These have led to a higher and more assured crop yield while controlling soil erosion.
e. The introduction of a mixture of leguminous creepers as cover crops on land that is planted with rubber and oil palms. Research has shown that desmodium ovalifolium, stylosanthes gracillis and clitoria ternetea provides useful ground cover, and help to control land degradation.
f. The provision of improve varieties and a large increase in the use of fertilizer encourages high yield and provide good ground cover.
g. That the recommendations should be exceptionally comprehensive and user friendly.
h. Finally, the farming system utilized must correctly identify a wide range of indicators and avoid the usual problem of selection of a limited number that can only be applied to specific situations

6. Conclusion

There are six major causes of land degradation in Calabar South, they include; deforestation, shortage of land due to increased populations, poor land use, insecure land tenure, inappropriate land management practices and poverty, problems of valuation, and even of assigning causality, make it impossible to compute accurate benefit-cost ratios for reducing land degradation. A precautionary approach, must take into account the relative magnitude of the problem, the relative importance of land degradation to the poor and the relative weakness of existing institutional and market-based mechanisms to deal with on-site degradation and externalities this means that efforts to reduce land degradation should focus on sloping lands and forest margin areas in Calabar South and should depend mainly on market-based instruments, accompanied by efforts to ease and increase investment in the development of technologies for sustainable agriculture

Land resources are non renewable and it is necessary to adopt a positive approach to ensure sustainable management of these finite resources. Soil scientists have an obligation not only to show the spatial distribution of stressed systems but also to provide reasonable estimates of their rates of degradation. Many assessments in Calabar South have dealt with land degradation risks rather than dealing with degradation status, its socio-economic cause and its political driving force. Most estimates of soil erosion for instance, have been on erosion hazard not actual observed erosion. There are consequently large differences between estimates of areas at risk and areas actually affected by land degradation

One of the most obvious direct causes and driving forces of land degradation in Calabar South is the mismatch between land potential and actual land use which is different from land cover and it includes information on land management and inputs. Some socio-economic data have to be collected at farm level during rapid rural appraisal or other livelihood surveys to establish the general conditions leading to certain land use practices. It is important to realize that the socio-economic parameters collected should be simplified and classified according to their role in the assessment of land degradation.

This research can be summarized in two points. Firstly, it was observed that land degradation is proportionally and absolutely very severe in Calabar South, where it represents a loss of long-run earning power for farmers and negative externalities for larger rural populations. Monetary values aside, the problem of land degradation becomes more acute when the welfare of the poor is given higher priority. Secondly, we must note that the same policy instruments that we have advanced as the best means to alleviate land degradation are also components of reform packages with much broader economic development aims. In this sense our land degradation proposals are "bundled with" measures that deliver gains that extend well beyond the environment.

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7. References

Alston, J. M., M. C. Marra, P. G. Pardey, and T. J. Wyatt, (2000). Research returns redux: a meta-analysis of the returns of agriculture R. & D. the Australian Journal of Agricultural and Resources Economics. 44(2): P. 185-215.

Alston, J. M. and P. G. Pardey (2001). Attribution and other problems in assessing returns to agricultural R. & D Agricultural Economics 25(2-3): P. 141-152.

Anderson, K. and W. Martin (2005). Scenarios for global trade reform, in T. W. Hertel and L. A. Winters, Editors Poverty and the WTO. Impacts of the Doha Development Agenda. Palgrave Macmillan and the World Bank; Hanisphire, UK, and Washington DC.

Banevjee, A. V. and E. Duflo (2005). Growth theory though the lens of development economics, in P. Aghion and S. N. Durlauf, Editors Handbook of economics growth. Elsevier: Ansterdam. P. 473-554.

Bruinsma, J. Ed (2003) World agriculture: towards 2015/2030: an FAO perspective: FAO: Earthscan: Rome; London.

Cassman, K. G. and P. L. Pingali (1995). Intensification of irrigated rice systems: Learning from the past to meet future challenges. Geo-Journal 35:p.299-305.

Conacher, Arthur; Conacher, Jeanette (1995). Rural land degradation in Australia South malbourne, Victoria: Oxford University Press Australia P. ISBN 0195534360

Coxhead, I. and J. Plangpraphan (1978), Thailand's economic boom and agricultural bust. University of wisconsinmadison: Madison, W.

Deininger, K. and J. S. Chamorro (2004). Investment and equity effects of land degradation: The case of Nicraragua. Agricultural Economics. 30 (2): P.101 – 116.

Eni, D. Imoke, Upla,J. Ibu, Oko, C. Omonya, Obiefuna, J.N and Njar, G.N (2010). Effects of land degradation on soil productivity in Calabar south local government area, Nigeria. European Journal of Social Sciences (18) 166-170

Evenson, R. E. and D. Gollin (2003). Assessing the impact of the Green Revolution, 1930 to 2000. science 300 (5620): 1 P.758-762.

Eswaran, H.; R. Lai and Reich, P. F. (2001). "Land degradation: proc. 2nd. International conference on land degradation and desertification New Delhi, India: Oxford press. Retrieved 2012-02-05.

Forest management Bureau, (1998) the Philippines strategy for improved water shed resources management. Philippines Development of environmental and natural resources: Manila.

Good, D. H. and Reureny, R. (2006). The fate of Easter Island: the limit of resources management Institutions. Ecological economics 58(3): P.473.

Lindert, P. H. (2000). Shifting Ground. The changing Agricultural soils in China and Indonesia Cambridge, MA: the MIT Press.

Johnson, Douglas; Lewis, Lawrence (2007). Land degradation; creation and destruction, Maryland, USA.

Olderman, L. R. hakkeling, R. T. A. and Sombrock, W. G. (1991). World Map of the status of human-induced soil degradation: An explanatory soil reference and information centre and United Nations Environment programme.

Pagiola, S. Bishop, J. and Landell-mills, N. Eds. (2002). Selling forest environmental services market-based mechanism for conservation and development. Earthson: London.

Scherr, S. J. (1999). Social degradation. A threat to developing-country food security by 2020? International Food Policy Research Institute: Wastington DC.

Shively, G. E. (2001). Poverty, consumption risk, and soil conservation. Journal of Development Economics 65(2). P 267-290.

United Nations Convention to combats desertification, 1996.

Waggoner, P. E. (1996). How much land can ten billion people spare for nature? 125(3): p.73-93.

Chapter 3

Land Use and Land Cover (LULC) Change in the Boconó River Basin, North Venezuelan Andes, and Its Implications for the Natural Resources Management

Joel Francisco Mejía and Volker Hochschild

Additional information is available at the end of the chapter

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1. Introduction

Land Use & **Land Cover (LULC)** have been historically permanently subject to biophysical and anthropogenic forces which induce changes in different structure-levels and space-time scales, and modify the energy and water exchange of the soil-vegetation-atmosphere system; such modifications become globally significant through their cumulative effects, so it would be particularly hazardous for food production and food security [1] [2] [3]. Thus, Land Use & Land Cover (LULC) changes are simply the most conspicuous changes in cultural landscapes worldwide [4] [5] [6].

Particularly the tropical regions have undergone dramatic Land Use changes in the last few decades, and these changes are the effect of an equally large number of local causes and factors, highlighting a complexity that tends to defy easy generalizations [7] [8] [9] [10] [11].

Many hydrological systems of the tropical regions are relatively densely populated, with relatively high rates of population growth, which has serious implications in the relationships between people and environmental services [12]. In mountainous regions, mostly poor people are settled in steep hillsides (slopes above 15%), usually practicing a smallholder farming system with agricultural production in small parcels for subsistence purposes, as well as shifting cultivation and slash & burn agriculture, which represent a pressure over natural resources in areas which are ecologically fragile and environmentally sensitive. About 25 to 30% of Central America and northern South America consist of mountainous areas where the conditions above mentioned are quite common [13]. Thus, the dynamics of natural resources use in river basins and watersheds across the mountain regions in the tropics are determined by three factors: environmental, social and economical conditions [4] [9] [12] [14] [15].

According to [8], the LULC changes have a notorious impact on climate, at local and regional levels, due to the modifications in the carbon cycle, the local evapotranspiration patterns, as well as precipitation regimes. This fact justifies many concerns about the implications that the LULC changes could have in the water resources, particularly in the hydrological regimes worldwide. These concerns have been motivating the analysis of the relationships between the LULC changes and the hydrological regimes (river flows, runoff dynamic, floodings, water depletion, etc) in a spatial-temporal perspective. Some examples of these includes: [16 - 31].

Certainly, these are valuable experiences to deal with such a complex task; however, there are still many gaps in this process to be solved, and many questions to be answered. Moreover, many of these experiences are all spatially confined to temperate regions, where biophysical as well as socioeconomic conditions are particular. Tropical ecosystems are very different from their counterparts in higher latitudes. They have different geological and evolutionary histories, and different climatic extremes and dynamics. The number of interacting species is typically much higher in tropical ecosystems, including streams networks also, and the interactions are often more complex [9]. Social, economical and political conditions in tropical rural areas are also very complex; thus, the poverty, depressive local economies, instability and lack of plans and investment programs are always current, and usually such complex realities and the collateral relationship has not been well studied so far. Thus, the knowledge remains still weak and the lack of information about local and regional environmental dynamic is remarkable [11] [14] [15] [32] [33] [34] [35].

The river basins are subject to constant processes of change, so the state and the structure of river landscapes and land resources are primarily determined by the type and intensity of the utilisation of the ecological, economic, social or cultural functions provided by the river systems. The new paradigm recognize the river basins as complex, ecological and interactive systems, which means that the integrated water resource management follows the central themes of the **ecosystem approach** and of adaptative management; in fact, the WFD (Water Framework Directive) of the European Union, has adopted the "**ecosystem-oriented river management** " as central approach to be followed by the institution [36].

2. Problem description

The Andean region in Venezuela is considered the most important "**water resource-area**" in the western part of the country. The source streams of many important river systems in the country are located there, having a complex and intricate channel network, with the "**first order streams**" (the most important sources of fresh water in many regions worldwide) broadly dominating the landscape system. Due to the biophysical configuration and the attractiveness of the Andean landscapes, the region has been under anthropogenic impact from times before the arrival of the Spaniards. However, in recent decades that pressure has been gradually increasing, which eventually could have significant impacts on the natural resources basis, particularly water, forest and soils.

Located in the northern part of that region, the Boconó River Basin can be considered as a representative case of the complex dynamics characterizing the Andean hydrological systems. Having a total surface area of 1580 km^2 and a wide altitudinal range, the River Basin harbor many ecosystems ranging from the Sub-Andean Páramo in the upland areas, to the Savannah ecosystem downstream in the upper plains of the Llanos region. With an annual yield of 2,300 million m^3 and a very acceptable chemical quality, the Boconó River was included into the regional planning policies in the Seventies, in order to develop the water resources in the lowlands region, so that the Boconó – Tucupido Dam systems were built in the Llanos region, in order to generate energy, flooding control and for irrigated cropping also [37].

A very significant portion of the area is still under natural Land Cover types, like the **Tropical Montane Cloudy Forest (TMCF)**. This ecosystem has a paramount importance, not only in terms of their ecological richness, but also in terms of hydrological functioning, specifically for water yield. In such forests there is usually a net gain of water that comes from the "**horizontal precipitation**" or "**occult precipitation**" in form of wind-driven drizzle and fog [9] [38].

On the other hand, there are also numerous sparse rural settlements representing a huge potential for agricultural production of some crops like coffee and vegetables (potatoes, carrots, onions, beans and others). The high accessibility through an intricate network of rural and local roads makes it easier to promote the sparse settlement in sloping hillsides across the area, being a crucial factor which determines the LULC changes contributing to the intensification of some erosion and land degradation processes [39].

All these conditions acting together in a strongly integrated way, resulting in a complex situation in which the increasingly sparse population is making even more pressure on natural land cover types, particularly on the **Tropical Montane Cloudy Forest**, so that the conversion of LC into LU appears to be persistent and intense. The River Basin was declared in 1974 "Protected Area" in order to preserve the water resources [40], and the Guaramacal National Park was created in 1988, which cover the southeastern flank of the area. Both figures aimed to guarantee the conservation of the ecosystems, the biodiversity, and to ensure the water production [41].

Nevertheless, the area continues to show a trend respect to the anthropogenic pressure, so the agricultural frontier is even more extended, meanwhile the forested land cover types tends to be decreased, and some land degradation processes like erosion and sediment yield seems to be even more intense. This has severe implications for the biodiversity, but also affects substantially the hydrological dynamic through changes in local microclimates, changes in moisture regimes, that eventually could lead changes in the hydrological regimes, especially the seasonal flows, peak flows, as well as changes in the water quality.

2.1. Main goal

The main goal of this paper is to analyze the spatial dynamic of the Boconó River Basin during the Period 1988 – 2008, in terms of the main LULC changes and systematic transitions that have been occurring in the area under an ecosystem-oriented approach.

They were discussed in terms of the implications that such changes and transitions have for the natural resources management at the river basin level (watershed management). The results showed here are only a partial output of the still ongoing PhD project: "Spatial changes and hydrological dynamic of the Boconó River Basin, north venezuelan Andes", which is actually developed at the Eberhard Karls University – Tübingen, Germany.

3. The geographical context – study area

The study was focused on the upland part of the Boconó River Basin, located in the south-east part of the State of Trujillo, between the coordinates 09°11′40″ - 09°31′50″ N and 70°04′08″ – 70°22′53″ W, with a surface area of 537.62 km^2. The highest point in the Basin is 3400 m.a.s.l in the Páramo of Cendé, and the lowest point (outlet) is the confluence between the Boconó and Burate river (1100 m.a.s.l) (Fig. 1). The Boconó River drops from the north-east to the south-west, over a distance of approximately 57 km, having a mean runoff about 15, 55 m^3/sec [33].

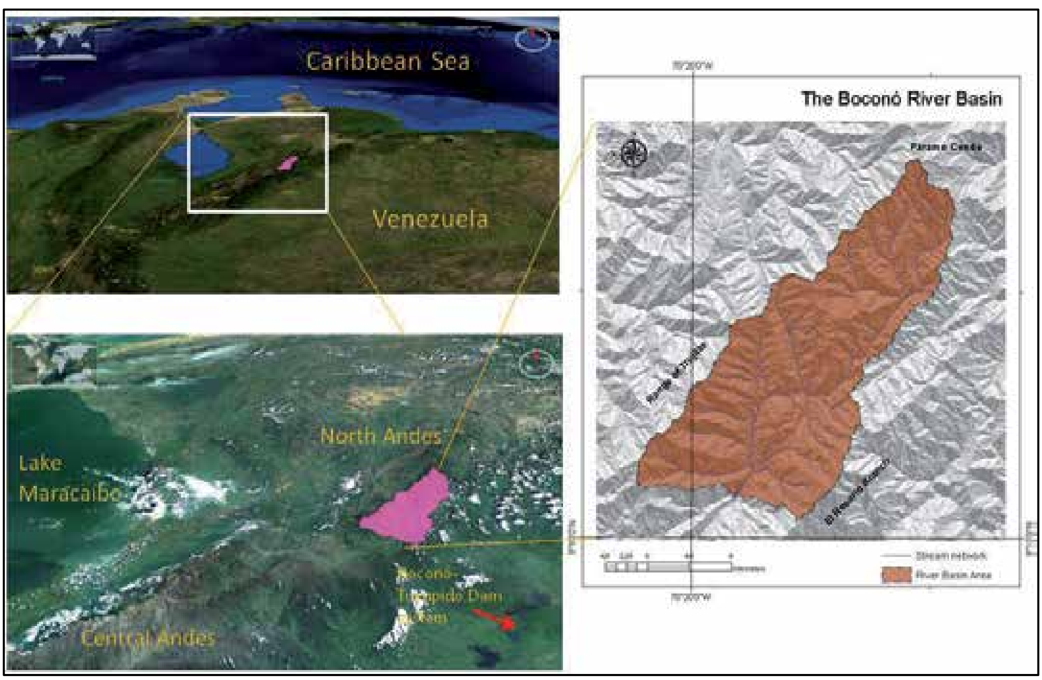

Figure 1. Location of the Study area

The area has a seasonally humid climate, having a wet period from April to October, and a dry period from November to March. Annual mean rainfall is about 1838 mm, and the annual mean temperature range from 19.7 °C to 21.5 °C [42]. The Basin has a relatively elongated form, and the drainage pattern is dendritic with a tendency to be rectangular, due to the intense tectonic activity [37].

The catchment is located within the tectonic axis formed by the Boconó Fault, which is the most important structural feature of the Venezuelan Andes [37]. The Fault cross longitudinally the river, separating the metamorphosed crystalline rocks in the north portion, from those less metamorphosed in the south part [33]. The basin has a massive and strongly dissected topography, so that the topographic conditions are quite complex and varied, determined by different landforms like: structural risks, erosion risks, structural escarpments, hillsides and alluvial accumulations, and a mean slope which range between 35 – 40% [43].

The lithological framework is generally highly jointed, due the tectonic dynamic, and the rocks basically correspond to the formations: Iglesias Group (gneisses and schist), Sierra Nevada (granites), Mucuchachí (Shale and phyllites) and Palmarito (shale and marl) [44]. Soils are in general relatively deep, with textural classes ranging from clayed to sandy loam, being Ultisols, Inceptisols and Alfisols the most important and representative taxonomic categories in the area [45].

The altitudinal gradient (2300 m.a.s.l) and the climatic conditions, particularly the intense rainfall regime, lead to the existence of the Tropical Montane Cloudy Forest, which cover the 44, 6 % of the total surface. Other important ecosystems in the area are: sub-montane forest, grass, sucessional shrubland, schrub and sub-alpine Páramo. These categories of land cover coexist also with specific land use types, which are very importance not only in economical terms, but in social and cultural perspectives also [46]. Shifting cultivation is located mostly in upland areas, where slash and burning are usual tasks. Conventional agriculture is also developed in lower parts and quaternary landforms, in some cases under irrigation. Coffee plantations are very usual between 800 and 2000 m above sea level, occupying an important portion of the Sub-montane forest. In a small proportion, the extensive grazing shows a moderate development, being usually spatially confined to the low parts and the quaternary landforms [42]. Finally, the 1, 6 % of total surface is occupied by urban use, being the Boconó city the most important urban system in the area.

4. Methodological approach

In order to achieve the purpose of this project, a methodological approach combining remote sensing methods with spatial and multi-temporal analysis in GIS in an interactive way was implemented. At first, the study area was delineated from the SRTM data set (90 m spatial resolution) using the open source GIS software SAGA (System for Automated Geoscientific Analysis), in order to build the Digital Elevation Model (DEM), and also to prepare the basic thematic maps (Topography, Slope, Aspect, Drainage Network). Based on the structure pointed out by [47], the LULC mapping process was done in three main straightforward steps, as follows:

4.1. The pre - processing

Three time-points were defined in order to analyse the LULC dynamic in the river basin: T0 (1988); T1 (1997); and T2 (2008). For each time-point a group of LANDSAT TM scenes corresponding to missions 4, 5 and 7 were compiled from USGS LANDSAT Archive and the Institute of Geography (IGCRN) – ULA (Venezuela), which were considered suitable to the research requirements. The compilation process was quite difficult because the study area is frequently covered by dense clouds, especially during the rainy season. It means that the cloudiness and fog represented a challenge to deal with into the classification process, leading to compile additional scenes for special processing. Thus, the compiled scenes were classified in two groups: "**pilot**" scenes and "**control**" scenes. The first group included the main scenes to be classified for each time-point to be considered in the multi-temporal evaluation: 1988, 1997 and 2008, respectively. The second group were used as control images for the optimization of the classification for the first group, in order to improve the clustering processing in those areas covered by cloud, fog and shadows.

All the LANDSAT scenes compiled were pre-processed individually to make the geometric and radiometric correction, as well as the enhancement of some elements like brightness, contrast, haze reduction and equalization, in order to improve the image quality. All these processes were carried out interactively.

4.2. The LULC classification/analysis process

The classification process was developed through a semi – supervised method, following a multi – level clustering for a multi – class segmentation of the scenes. The scenes were separately classified, a procedure considered highly flexible and extensively used in the past, with good results reported [47].

At the first level the scenes were classified through an unsupervised method using the "**hyperclustering approach**", a simple and relatively common approach to classify multiple LANDSAT scene mosaics. This classification approach generate many hyperclusters from the image data available by testing for within – cluster heterogeneity; then the hyperclusters can be merged into a smaller number of more reasonable groups which may resemble homogeneous classes, and finally label the resulting classes as spatial features of interest according to a pre-determined map legend or class hierarchy [48]. The process was done using the algorithm K-means available within the ISODATA decision-rule. In this case, the method was applied using 50 clusters to be classified after 24 iterations through the unsupervised approach (previous tests using 80 and 100 clusters, showed not many differences in the effective separation of the classes). The amount was then though reasonable to manage by the interpreter, and appropriate to differentiate the LULC classes in the study area.

Two groups of clusters were then identified: "**pure clusters**" representing categories with unique spectral signal; and "**mixed clusters**", having two or more categories with similar spectral signal, which is normal because LANDSAT imagery for tropical forest regions display minimal band separability among vegetation types, so that different types of categories can be usually difficult to separate [49]. The "**mixed clusters**" were prone to a second - level classification process. They were separated from the scene through masking process, and after that they were submitted into a second clustering process, using supervised and unsupervised methods. Thus, the classes were correctly separated from the others. During the second – level classification, the clouds, fog and shadows were appropriately separated from other classes. They were used as mask scenes in order to cut the control images through spatial analysis, and finally they were processed like the "**mixed clusters**", in the same way above described.

4.3. The product generation process

All the clusters were merged to form twelve final classes using the grouping process. Additionally, a spatial modelling process was done in order to make the altitudinal differentiation of the LC in the river basin, defining the Land Cover categories in an ecological sense, following the ecosystem approach. For this purpose the DEM was combined with the classified images using the ecological criteria from Sarmiento & Ataroff in [50]. Thus, the Land cover categories delineated are virtually "ecosystems units". The classified scenes were finally filtered and exported to GIS software for the mapping creation and display processes.

The classifications were validated using conventional methods, depending on the availability of the reference ancillary data. For the T0 classification, only a land use map for 1980 was available in a non digital format. This map was then used as a reference source for the validation. A total of 255 validation points corresponding to reference pixels were randomly selected using the "**stratified random**" sampling method. They were interactively compared with the digital reference map, and the results were stored in the Accuracy Assessment Cell Array (software ERDAS 9,3), which is simply a list of class values for the pixels in the classified image file and the class values for the corresponding reference pixels [51]. The tool finally calculated the error matrix and the corresponding basic statistics, including the Kappa Coefficient, which were listed in the Accuracy report. For T2, a field validation process was driven, combined with validation points defined using Quickbird high resolution scenes available on the "open source" software GOOGLE EARTH, through the same process described for the T0 scenes. Finally, the T1 Classification was validated using the maps for T0 and T2, defining validation points basically in areas considered persistent across the time-period.

4.4. Multi-temporal evaluation of LULC changes in the Boconó River Basin (Post classification)

The multi-temporal evaluation process was conducted through spatial analysis in GIS. Hence, paired overlay was done in order to detect the changes occurred during the time-period considered. The Matrix operation used in this case allows two thematic images or vector files of different years to be compared [52]. This tool allowed to cross two different maps corresponding to the same area, in order to differentiate the changes occurred between the time-points. The resulting class values of a matrix operation are thus unique for each coincidence of two input class values described by rows (input layer 1) and columns (input layer 2) [53]; hence, the process produce two type of results: Maps which can illustrate the changes in a spatial context (land cover change map); and a **cross-tabulation matrix** containing the differences in area for the different classes.

The **cross-tabulation matrix**, also denominated "**transition matrix**" follows the format displayed on Table 1. The rows display the categories of time 1, and the columns display the categories of time 2. Entries on the diagonal indicate persistence in the landscape between the time-period, meanwhile the entries off the diagonal indicate a transition from category "*i*" to a different category "*j*" [54].

	Time 2				Total Time 1	Loss
Time 1	Category 1	Category 2	Category 3	Category 4		
Category 1	P_{11}	P_{12}	P_{13}	P_{14}	P_{1+}	$P_{1+} - P_{11}$
Category 2	P_{21}	P_{22}	P_{23}	P_{24}	P_{2+}	$P_{2+} - P_{22}$
Category 3	P_{31}	P_{32}	P_{33}	P_{34}	P_{3+}	$P_{3+} - P_{33}$
Category 4	P_{41}	P_{42}	P_{43}	P_{44}	P_{4+}	$P_{4+} - P_{44}$
Total Time 2	P_{+1}	P_{+2}	P_{+3}	P_{+4}	*1*	
Gain	$P_{+1} – P_{11}$	$P_{+2} – P_{22}$	$P_{+3} – P_{33}$	$P_{+4} – P_{44}$		

Table 1. General cross-tabulation matrix for comparing two maps from different points in time

Starting from the matrix-values, the Gain (G_{ij}) was calculated through the difference between the total value for time 2 (P_{+j}) and the persistence (P_{ij}), using the Eq 1:

$$G_{ij} = P_{+j} - P_{jj} \tag{1}$$

On the other hand, the Loss (L_{ij}) was the difference between the total value for the time 1 file (P_{j+}) and the persistence, using the Eq 2:

$$G_{ij} = P_{+j} - P_{jj} \tag{2}$$

The swapping (S_j) between the categories was calculated as two times the minimum value of the gains and losses, through the Eq 3:

$$S_j = 2 \text{ x MIN} \left(P_{j+} - P_{jj}, P_{+j} - P_{jj} \right) \tag{3}$$

The total change for each category (C_j) was the sum of net change (D_j) and the swapping (S_j), or the sum of gain and loss (Eq 4):

$$C_j = \left(D_j + S_j \right) \tag{4}$$

In order to intend a more detailed analysis of the LULC changes, particularly the systematic inter-category transitions, the methodology proposed by [54] was applied, which analyze the off-diagonal entries to identify systematic transitions of land change for a given landscape´s degree of persistence. For that, the transitions must be interpreted relative to the sizes of the categories, leading to define the gain/loss that would be expected if the gain/loss in each category were to occur randomly [54]. The randomly expected gains for each category were calculated using the Eq 5:

$$Gij = \frac{(P+j-Pjj)x\ Pi+}{1-Pj+} \tag{5}$$

In this case, the gain as well as the proportion for each category at time 2 is considered fixed, distributing the gain across the other categories according the relative proportion of the other categories in time 1. The procedure to calculate the randomly expected losses for each category is quite similar to those explained above, using the Eq 6:

$$Lij = \frac{(Pi+\ -Pii)x\ P+j}{1-P+i} \tag{6}$$

As in the gain, the equation assumes that the loss of each category is fixed, and then distributes the loss across the other categories according to the relative proportion of the other categories in time 2.

Finally, the systematic transitions were identified trough a comparison between the observed and expected values for gain and loss, for each category.

5. Results & discussion

Twelve (12) LULC categories to be analyzed were identified in the Boconó River Basin for T0, T1 and T2 classifications. The Table 2 display the LULC categories, each with the corresponding identity-code, designation, as well as a brief description. The results showing the accuracy and the Kappa Coefficient for the three time-points are displayed on Table 3. Two important clarifications must be here pointed out:

1. - The Category Open-cleared Forest (Oc-F) correspond to the lower sectors of the Tropical Montane Cloudy Forest (Tmc-F), which are prone to a clearcutting process for logging and wood extraction, eliminating partly the canopy of the tallest forest species; the clearing alter greatly the phenological structure of the forest, resulting in a very specific and different spectral signal respect the climax or undisturbed forest. They were conveniently considered separated categories for practical purposes inherent to the research goals.

2.- Coffee plantations constitute an important land use practice in the area; however, during the classification process the plantations (shade coffee) usually showed a very similar spectral signal as the Sub-montane Forest, which is the ecosystem where these plantations are usually located. They couldn't be effectively separated at this resolution level, and more detailed remote sensing material for the study area was no available. For that reason the coffee plantations were necessarily combined with the Category: Sub-montane Forest (Sm-F).

5.1. General quantification of the change

The corresponding surface values for the time-points analyzed (T0, T1 and T2), are gently resumed on Table 4. An overview of the differences among the period, lead us to set up a basic differentiation between the LULC categories in three main groups as follow:

a. LULC categories losing surface: basically the natural LC like forest (Tmc-F, Oc-F, Sm-F) and Grass (Gr-L) were included here. All of them show a decreasing trend between T0 and T2 (except Gr-L, which experienced a light increase between T1 – T2). The Tmc-F and Oc-F had a reduction of 3530, 43 ha between T0 – T2, representing the 12, 8 % of the total for the two categories combined in 1988. The reduction of the Sm-F in the river basin was more dramatic, losing the 43, 1% of the surface area respect to 1988, that is, 3244, 59 ha. On the other hand, Gr-L loosed 412, 11 ha between T0-T1, and slightly recovered 85, 05 ha in the next period, losing a total of 327, 06 ha (9 % of the total in 1988).

Category	Identity-Code	Designation	Description
1	Tmc-F	Tropical Montane Cloudy Forest	Multilayered forest with a very complex structure. The vegetation is dominated by evergreen Trees whose crowns may rise up to 35 m height, bearing a large number of different epiphytes (> 100 species). The forest may have accounted for an average of 100 tree species per hectare.
2	Oc-F	Open – Cleared Forest	In fact this category corresponds to the lower sector of the Tropical Montane Cloudy Forest, which is undergoing a clear-cutting process. There are evidences of selective clear cutting of tree species, so that the forest presents a less dense and more open canopy, as well as the presence of successional vegetation.
3	Sm-F	Sub-Montane Forest	Multilayered forest with a complex structure. During the short dry season (1 – 3 months), the upper – canopy trees throw a lot of its leaves, having a reduced foliage; although the lower trees and shrubs are mostly evergreen. The canopy reaches up from 20 to 30 m height; however some individuals trees can reach up to > 40 meters. The coffee plantations, specially the coffee planted under shadow belong also to this category.
4	Schr	Schrub	Open forest with dense vegetation, which can reach a height of 3 – 6 meters. Corresponds to the transitional zone between the High Montane Cloudy Forest and the Sub-andean Paramo.
5	Gr-L	Grassland	Areas with natural mixed herbaceous vegetation ad grass. The vegetation is generally dense and can reach 2 meters height.
6	Cro-L	Cropping area	Area under crop systems typologies diverse as horticulture and coffee without shadow.
7	Sa-P	Sub-andean Páramo	Special ecosystem existing in the whole Andean region, consisting mainly of grass, ground rosettes, dwarf shrubs cushion plants and conspicuos giant rosettes like Espeletia and Puya. However, the vegetation vary greatly depending on the altitude, humidity and other environmental factors.
8	Gr-An	Grassland (anthropogenic)	Areas of cultivated grasses and / or pastures established for extensive grazing and cattle
9	S-Shr	Successional shrubland	Areas with successional vegetation being in regeneration process after the clear cutting, or after they were cultivated. The vegetation usually has low hight and variable density.
10	Ero-L	Eroded Soil	Bare soil surface, prone to the direct action of erosion agents.
11	Fl-P	Flooding Plain	Area occupied by the river bed, usually having low slope where the river can be horizontally expanded.
12	Ur-U	Urban Use	Area occupied by the Boconó city, as well as the towns San Miguel and San Rafael. Basically corresponds to a residential, commercial use and associated services.

Table 2. Land Use / Land Cover (LULC) Categories identified in the Boconó River Basin.

Indicator	T0 (1988)	T1 (1997)	T2 (2008)
Producers Accuracy	87,46	85,02	91,53
Users Accuracy	87,62	82,90	91,67
Total Accuracy	87,35	82,59	88,80
Kappa Coefficient	0,79	0,79	0,87

Table 3. Main results obtained in the Accuracy assessment for the T0, T1 and T2 classifications.

LULC Categories	1988 (T0)	1997 (T1)	2008 (T2)	Dif T1-T0	Dif T2-T1	Dif total T2-T0
	Area (ha)	Area (ha)	Area (ha)			
Tropical Montane Cloudy Forest	24573,78	23676,12	22493,97	-897,66	-1182,15	-2079,81
Open-cleared Forest	2973,51	1648,8	1522,89	-1324,71	-125,91	-1450,62
Sub-Montane Forest	7523,1	6224,13	4278,51	-1298,97	-1945,62	-3244,59
Scrub	1142,37	1199,88	1277,73	57,51	77,85	135,36
Grasland	3662,82	3250,71	3335,76	-412,11	85,05	-327,06
Sub-andean Paramo	1114,2	1117,71	1114,47	3,51	-3,24	0,27
Grassland (Anthropogenic)	1280,34	1181,16	2832,03	-99,18	1650,87	1551,69
Cropping Area	2202,84	2330,46	2867,4	127,62	536,94	664,56
Eroded Land	28,62	27,27	39,87	-1,35	12,6	11,25
Urban Area	433,98	729,18	865,26	295,2	136,08	431,28
Flooding plain	234,9	391,95	293,76	157,05	-98,19	58,86
Sucessional Shrubland	8591,67	11984,76	12840,75	3393,09	855,99	4249,08
Total	53762,13	53762,13	53762,13	-	-	-

Table 4. LULC evolution during the considered period

b. LULC categories gaining surface: they are basically the human-induced types of land cover categories (Gr-An, Cro-L and Ur-U), as well as the categories: Schr and S-Shr. They increased progressively during the period, except Gr-An, which experienced a decrease in T0 – T1; however, the evident increase experienced during T1-T2 justify the inclusion of the category in this group. Gr-An and Cro-L combined, gained 2216, 25 ha, representing an increase of 63, 6 % of the agriculture in the river basin respect 1988. The Urban use (Ur-U) experienced a dramatic increase during the whole period, gaining 99,36 % (431,28 ha) of the surface area that the category occupied in T0. Meanwhile, the LC category S-Shr experienced a big change, gaining almost 50% (49, 5%) of the surface area for T0; so it gained a total of 4249, 08 ha. respect 1988. During the period Schr category gained 135, 36 ha (12%) respect to T0.
c. Relatively stable LULC categories: here are included the rest of the LC categories: Sa-P, Ero-L and Fl-P. These categories showed a similar pattern during the whole period, in which they loosed and gained surface, but maintaining its proportionality respect the rest of the LULC categories. The Fl-P gained 157, 05 ha (67%) because of the flooding events occurred during the T0-T1. But in the second time-period it loosed 98, 19 ha to other categories.

These basic groups illustrate the general trends for the recent evolution of the LULCC in the river basin. However, they are only the initial framework to understand the spatial dynamic in the study area, so they cannot reflect conveniently the spatial changes in a quantitative/qualitative way. The next section provides a more comprehensive and detailed description of the LULC categorical changes for the two time-periods, in terms of quantification, net change, swapping as well as inter-category transitions.

The Figure 2 show the spatial distribution of the changes in the Boconó River Basin, which occurred within the both periods: T0 - T1 and T1 – T2. In the first period the River Basin experienced a total change of 30,34%, which means that 16309,89 ha were affected by a kind of spatial change processes, meanwhile the 69,66% of the surface area (37452,24 ha) was accounted as persistent landscape or simply persistence. Thus, persistence dominates widely the landscape system of the River Basin, which is considered normal, because the persistence usually dominates most landscapes, including those where authors claim that the change is important and / or large [54].

[55] accounted 92% of persistence for natural land covers in Mexico; in the Atlanta metropolitan area (one of the USA´s fastest growing metropolises), there have been 75% persistence over the last 3 decades (Yang & Lo, 2002) in [54]. [56] determined a persistence of 94, 2% in the community of Madrid – Spain. [57] accounted 93, 3 of landscape persistence in the State of Mexico – Mexico. Finally, [30] also detected a persistence of 80, 5% in the Catamayo-Chira Basin (Ecuador – Peru).

Although the persistence dominates the landscape, as usual, the persistence value of the Boconó River Basin can be considered slightly lower in comparison with those values above mentioned. This fact is important to highlight, considering that the whole river basin is defined as "**Protected Area**", with a portion of the surface area also belonging to the **Guaramacal National Park**.

In the second period the total change was slight higher, with 18464, 7 ha affected by a type of change, representing the 34, 35% of the total area, and the persistence value descended to 65, 65 % of the total surface (35297, 46 ha).

As seen on Figure 2, the change have been occurring in the middle – lower part of the river basin, basically across the sloping dissected areas, the river valley and some extensive quaternary landforms located in the lowest part; in this case, the LULC categories coexist in a very intricate way, showing a very complex and strong patching effect, which is typical of landscapes where the categories are highly fragmented, originating the so – called "**chessboard effect**" or "**chessboard landscape**" [58].

5.2. Landscape dynamic: A more detailed view of changes in the River Basin

A more detailed analysis of the transition Matrix derived for the two combined time-periods (T0-T1 and T1 – T2), using the approach proposed by [54], lead to interpret the changes in a more detailed perspective, as follows:

5.2.1. Net change and swapping

The Table 5 resume the landscape dynamic observed for the period T0 – T1. S-Shr was the most dynamic category in the river basin during this period, having a total change which represent the 22,4 % (12037,6 ha), of the total surface. It showed also the highest values for gain and losses respect the rest of LULC. During the period, S-Shr gained 14, 35% of surface area, losing at the same time 8 % to other categories. This category has also the highest value for swapping (16,1 % of the surface area), which means that this LCC constantly experienced changes during the period, losing surface area to other categories and gaining at the same time area from other categories whose changed to this one. Thus, 72% of the change for this category occurred as swapping-change dynamic.

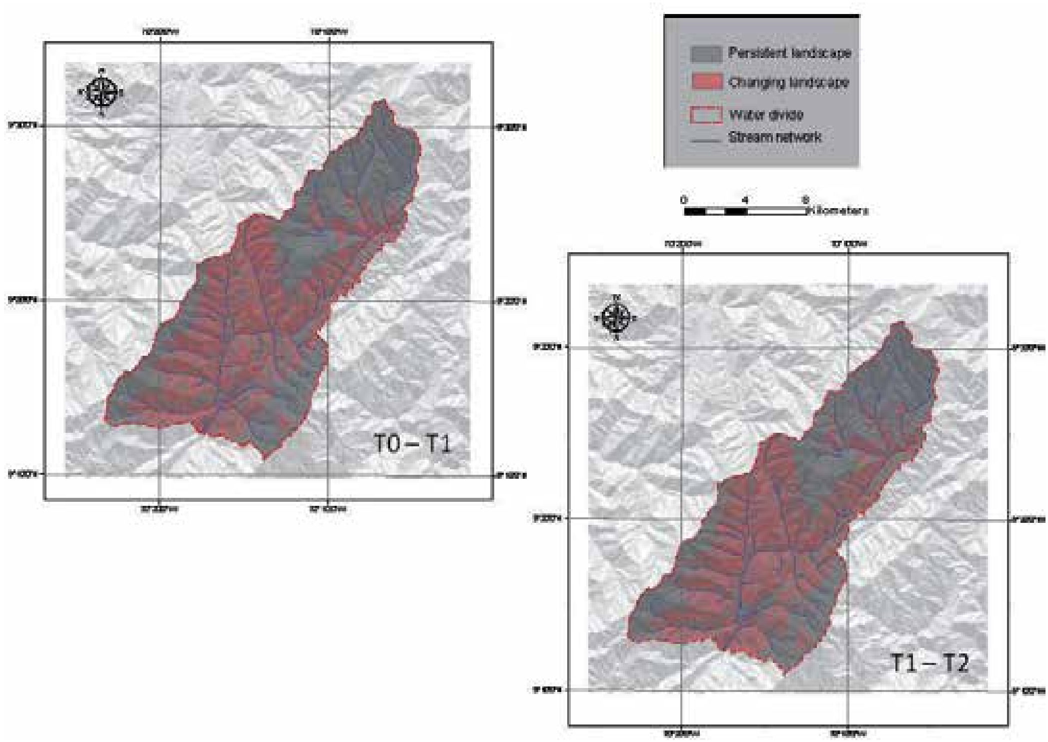

Figure 2. Persistence and changing area in Boconó River Basin

The second more dynamic category in the area was Sm-F, which experienced a total change of 4485, 51 ha, representing the 8, 3% of the total surface area. In this period Sm-F gained 1593, 27 ha (third highest value), which in many cases could represent an expansion of the shade coffee plantations in the area (included in this category). However, it lost 2892, 24 ha (second highest value) to other categories, representing an important reduction of the forested cover in the area. The category has the third highest value of swapping (3186, 54 ha), which suggest that the Sub-montane Forest also experienced a swapping-change dynamic.

The third category experiencing important changes in the period is the Oc-F, with a total change value of 3721, 41 ha, (7 % of the total area). The Open-cleared Forest gained the fifth biggest portion of surface: 1198, 35 ha, suggesting that the clearcutting and logging in the lowest part of Tmc-F were intense during the period. However, it lost 2523, 06 ha (third biggest amount) to other categories, showing that the clearcutting and logging was also intense within the category. A total of 2396, 7 ha (fifth highest value) were swapping-change dynamic for this category.

LULC Categor y	Gain		Loss		Total Change		Swap		Absolute value of net change	
	ha	%	ha	%	ha	%	ha	%	ha	%
Tmc-F	792,45	1,474	1690,11	3,143	2482,56	4,617	1584,9	2,948	947,66	1,669
Oc-F	1198,35	2,229	2523,06	4,693	3721,41	6,922	2396,7	4,458	1324,71	2,464
Sm-F	1593,27	2,963	2892,24	5,380	4485,51	8,343	3186,54	5,926	1298,97	2,417
Schr	58,86	0,109	1,35	0,003	60,21	0,112	2,7	0,006	57,51	0,106
Gr-L	1565,1	2,911	1977,21	3,678	3542,31	6,589	3130,2	5,822	412,11	0,767
Sa-P	7,29	0,014	3,78	0,007	11,07	0,021	7,56	0,024	3,51	0,003
Gr-An	1085,49	2,019	1184,67	2,204	2270,16	4,223	2170,98	4,038	99,18	0,185
Cro-L	1789,2	3,328	1661,58	3,091	3450,78	6,419	3323,16	6,180	127,62	0,237
Ero-L	13,59	0,025	14,94	0,028	28,53	0,053	27,18	0,052	1,35	0,003
Ur-U	295,92	0,550	0,72	0,001	296,64	0,551	1,44	0,004	295,2	0,549
Fl-P	195,03	0,363	37,98	0,071	233,01	0,434	75,96	0,142	157,05	0,292
S-Shr	7715,34	14,350	4322,25	8,040	12037,6	22,390	8644,5	16,080	3393,09	6,310
Total	16309,89	30,335	16309,89	30,339	16309,89	30,337	12275,91	22,84	4058,98	7,501

Table 5. Landscape Dynamic in the Boconó River Basin for the Period T0 – T1 (1988 – 1997).

The fourth position in terms of total change (3542, 31 ha), gains (1565, 1 ha), loses (1977, 21 ha) and swapping (3130, 2 ha), is for Grassland; the balance between gains and losses, as well the swapping value, suggest that this category has a strong interaction with other LULCC. The fifth changing category with a total change of 3450, 78 ha (6, 4 % of the total area) is Cro-L, suggesting that the cropping area also experienced important changes during the period. The category gained 1789, 2 ha, which is the second highest value for the period, losing also 1661, 58 ha (sixth value). With the second highest value (3323, 16 ha), Cro-L experienced also a swapping-change dynamic in the area.

Tcm-F is located in the sixth position of total changes, with a total value of 2482, 56 ha (4, 6 % of the total). The category gained 792, 45 ha (seventh value), but lost 1690, 11 ha; meanwhile, 1584, 9 ha were accounted as swapping-change. Finally, Gr-An showed the seventh highest change, with 2270, 16 ha (4, 2 % of the total area). It gained 1085, 49 ha and lost 1184, 67 ha, with a swapping value of 2170, 98 ha.

Despite of the dynamic above described the values for net change shows some differences among the positions between categories. Having the highest net value of 3393, 09 ha, the S-Shr remains as the most dynamic category for the period. The Oc-F had the second highest net change value (1324, 71 ha), and the third position was for Sm-F (1298, 97 ha). The Tropical Montane Cloudy Forest had the fourth highest net change value (947, 66 ha), followed by Gr-L (412, 11 ha), and the sixth position is for the category Ur-U, with a net change value of 295, 2 ha (most of the change in this category is net change, as usual), and a swapping value which tends to be cero. These values lead to affirm that the LCC and particularly the Forested LCC experienced the most important net changes in the river basin during this period.

The Table 6 resume the landscape dynamic for the second period T1 – T2. Some slight differences can be observed respect to the last period. S-Shr remains as the most dynamic category, with a total change value of 11750, 85 ha (22 % of the total area). It gained 6303, 42 ha and lost 5447, 43 ha. The 93% of the total value for this category (10894, 86 ha), occurred as swapping-change dynamic. Sm-F remains in the second position, with a total change of 3638, 88 ha (7 % of the total area). It gained less surface than in the last period (846, 99 ha), which is the seventh observed value for the period. Meanwhile, the losses remained high, having the second highest value for the period (2791, 89 ha). A total of 1693, 98 ha changed in a swapping-change form.

LULC Category	Gain		Loss		Total Change		Swap		Absolute value of net change	
	ha	%	ha	%	ha	%	ha	%	ha	%
Tmc-F	877,5	1,632	2023,74	3,764	2901,24	5,396	1755,0	3,266	1146,24	2,132
Oc_F	990,63	1,843	1113,21	2,071	2103,84	3,914	1981,26	3,686	122,58	0,228
Sm-F	846,99	1,575	2791,89	5,193	3638,88	6,768	1693,98	3,152	1944,9	3,618
Schr	29,25	0,054	1,35	0,003	30,6	0,057	2,7	0,006	27,9	0,051
Gr-L	1731,78	3,221	1646,73	3,063	3378,51	6,284	3293,46	6,126	85,05	0,158
Sa-P	7,11	0,013	0,63	0,001	7,74	0,014	1,26	0,002	6,48	0,012
Gr-An	2588,85	4,815	937,98	1,745	3526,83	6,560	1875,96	3,490	1650,87	3,070
Cro-L	2000,25	3,721	1463,31	2,722	3463,56	6,443	2926,62	5,444	536,94	0,999
Ero-L	17,46	0,032	4,86	0,009	22,32	0,041	9,72	0,018	12,6	0,023
Ur-U	138,24	0,257	2,16	0,004	140,4	0,261	4,32	0,008	136,08	0,253
Fl-P	36,54	0,068	134,73	0,251	171,27	0,319	73,08	0,136	98,19	0,183
S-Shr	6303,42	11,725	5447,43	10,132	11750,85	21,857	10894,86	20,264	855,99	1,593
Total	15568	28,956	15568	28,958	15568,02	28,957	12256,11	22,799	3311,91	6,16

Table 6. Landscape Dynamic in the Boconó River Basin for the Period T1 – T2 (1997-2008)

The third category experiencing changes in the period is Gr-An, with a value of 3526, 83 ha (6, 6% of total area) for total change. It had the second higher value for gains in the period (2588, 85 ha), meanwhile the losses (937, 98 ha), were lower in comparison to the last period. Of the total value, 1875, 96 ha changed in a swapping-change form. The fourth position in this period is for Cro-L, having a value of 3463, 56 ha (6, 4% of the total area). Cropland gained 2000, 25 ha (the 3rd highest value) during the period, losing 1463, 31 ha (5th value), which can be explained for the type of agriculture applied in the area (small/scale agriculture with shifting cultivation and slash and burn practices). This could explain the high value for swapping (2926, 62 ha) which is the third highest value for the period.

The Gr-L had a total change of 3378, 51 ha (6, 3% of total area), as the fifth changing category. It maintained the same trend as in the last period, gaining 1731, 78 ha, losing 1646, 73 ha, with 3293, 46 ha as swapping-change value. The sixth position in this period was for the Tmc-F, which showed a total change of 2901, 24 ha (5, 4% of the total area). It showed the same trend for gain as in the last period (877, 5 ha), but the losses were quite higher (2023, 74 ha), with 1755, 0 ha as swapping-change dynamic value.

Finally, the Oc-F descended to the seventh position in the period, showing a total change of 2103, 84 ha (3, 9% of the total area). It gained 990, 63 ha, and lost 1113,21 ha, with a swapping value of 1981, 26 ha for the period.

The dynamic showed by the net change values changed slightly respect the last period. The category with the highest net change value was Sm-F (1944, 9 ha), followed by Gr-An (1650, 87 ha); and the Tmc-F reached the third position, with a net change of 1146 ha. S-Shr descended to the fourth position with 855, 99 ha, followed by Cro-L (536, 94 ha) and Ur-U in the sixth position, with a net change value of 136, 08 ha (most of the change occurring as net change).

5.2.2. Systematic Inter-category transitions in the landscape system

Now is possible to derive the categorical trajectory of the changes which have been occurring in the river basin during the considered period. The Table 7 accounts for the most important inter-category transitions for T0-T1 in terms of Losses. The magnitude of the ratio (fifth column) indicates in all cases the strength of the systematic transition between categories [54].

The first thirteen rows on Table 7 indicate spatial patterns or transitions affecting the Forested Land Covers in the River Basin: Tmc-F, Oc-F and Sm-F. These transitions indicate changes associated with deterioration, decrease or disappearance of the Forested areas, depending on the LULC category for which the forested categories have been migrating during the period. For example, the first transition process: Tmc-F – Oc-F indicate that the Tropical Montane Cloudy Forest changed to Open-cleared Forest in 3,764 times more than would be expected If the change were to occur randomly, losing 348,65 ha more than the expected value. This transition, together with the second one, indicate that the TMCF is changing systematically to an intermediate stage (Open-cleared Forest or Successional Shrubland), before it can finally change or migrate to any human–induced types of Land Use categories (Gr-An or Cro-L). No transitions from Tmc-F to Land Use categories were observed. Similar transitional trends were observed in the Highlands of Chiapas – Mexico by [13] and [59], being also described in two different regions in Chile [60][61].

The processes driving the transitions of the Tmc-F are basically associated with: clearcutting, logging, wood extraction and also plants and non-wood extraction. These processes could have been occurring in a successive way, and particularly the logging is probably occurring in a selective form, as observed during the field validation. The selective extraction or harvesting of non-wood products (like Orchids and Bromeliads), has been also reported as a critical problem occurring in this ecosystem [9].

Another example is the transition Sm-F – Ero-L, indicating that in this portion of the surface area, the clearcutting/ logging processes derived in severe land degradation processes like erosion in 6,428 times more than expected, affecting 12, 33 ha. The rest of transitions contribute to explain the other change patterns occurring in the rest of categories, particularly in the human-induced types of Land Cover.

Sistematic Transition T0 »»»» T1	Ov	Ev	Ov-Ev	Ov-Ev/ Ev	Interpretation of the Transition
Tmc-F »»»» Oc-F	441,27	92,62	348,65	3,764	When Tropical Montane Cloudy Forest loses, Open-cleared Forest replaces it
Tmc-F »»»» S-Shr	1041,12	673,26	367,86	0,546	When Tropical Montane Cloudy Forest loses, Sucessional Shrubland replaces it
Oc-F »»»» Gr-An	168,93	57,19	111,74	1,954	When Open-cleared Forest loses, Grass Anthropogenic replaces it
Oc-F »»»» Cro-L	176,76	112,83	63,93	0,567	When Open-cleared Forest loses, Cropland replaces it
Oc-F »»»» S-Shr	1863,45	580,24	1283,21	2,212	When Open-cleared Forest loses, Sucessional Shrubland replaces it
Sm-F »»»» Oc-F	124,29	100,31	23,98	0,239	When Sub-montane Forest loses, Open-cleared Forest replaces it
Sm-F »»»» Gr-An	124,65	71,86	52,79	0,735	When Sub-montane Forest loses, Grass Anthropogenic replaces it.
Sm-F »»»» Cro-L	339,48	141,79	197,69	1,394	When Sub-montane Forest loses, Cropland replaces it. Cropland gains.
Sm-F »»»» Ero-L	12,33	1,66	10,67	6,428	When Sub-montane Forest loses, Eroded Land replaces it.
Sm-F »»»» Ur-U	61,92	44,37	17,55	0,396	When Sub-montane Forest loses, Urban Use replaces it. Urban Use gains.
Sm-F »»»» Fl-P	83,7	23,85	59,85	2,509	When Sub-montane Forest loses, Flooding Plain replaces it.
Sm-F »»»» S-Shr	2013,39	729,16	1284,23	1,761	When Sub-montane Forest loses, Sucessional Shrubland replaces it.
Schr »»»» S-Shr	1,35	0,31	1,04	3,355	When Schrubland loses, Sucessional Shrubland replaces it.
Gr-L »»»» Gr-An	174,33	46,24	128,09	2,770	When Grassland loses, Grass Anthropogenic replaces it.
Gr-L »»»» Cro-L	316,53	91,22	225,31	2,470	When Grassland loses, Cropland replaces it.
Gr-L »»»» Ur-U	31,32	28,54	2,78	0,097	When Grassland loses, Urban Use replaces it. Urban Use gains.
Gr-L »»»» Fl-P	31,32	15,34	15,98	1,042	When Grassland loses, Flooding Plain replaces it.
Gr-L »»»» S-Shr	1224,45	469,13	755,32	1,610	When Grassland loses, Sucessional Shrubland replaces it.
Sa-P »»»» S-Shr	3,78	0,86	2,92	3,395	When Sub Andean Páramo loses, sucessional Shrubland replaces it
Gr-An »»»» Oc-F	51,39	37,15	14,24	0,383	When Grass Anthropogenic loses, Open-cleared Forest replaces it.
Gr-An »»»» Gr-L	230,4	73,24	157,16	2,146	When Grass Anthropogenic loses, Grassland replaces it
Gr-An »»»» Cro-L	100,89	52,51	48,38	0,921	When Grass Anthropogenic loses, Cropland replaces it.
Gr-An »»»» S-Shr	706,68	270,02	436,66	1,617	When Grass Anthropogenic loses, Sucessional Shrubland replaces it.
Cro-L »»»» Sm-F	283,32	201,08	82,24	0,409	When Cropland loses, Sub-montane Forest replaces it.
Cro-L »»»» Gr-L	221,85	105,02	116,83	1,112	When Cropland loses, Grassland replaces it.
Cro-L »»»» Gr-An	70,11	38,16	31,95	0,837	When Cropland loses, Grass Anthropogenic replaces it.
Cro-L »»»» Ur-U	98,1	23,56	74,54	3,164	When Cropland loses, Urban Use replaces it.
Cro-L »»»» Fl-P	49,05	12,66	36,39	2,874	When Cropland loses, Flooding Plain replaces it
Cro-L »»»» S-Shr	846,63	387,19	459,44	1,187	When Cropland loses, Sucessional Shrubland replaces it.
Ero-L »»»» Tmc-f	7,74	6,58	1,16	0,176	When Eroded Land loses, Tropical Montane Cloudy Forest replaces it.
Ero-L »»»» Cro-L	1,35	0,65	0,70	1,077	When Eroded Land loses, Cropland replaces it.
Ero-L »»»» Fl-P	1,35	0,11	1,24	11,273	When Eroded Land loses, Fluvial Plain replaces it.
Ur-U »»»» Fl-P	0,72	0,01	0,71	71,000	When Urban Use loses, Flooding Plain replaces it.
Fl-P »»»» Gr-L	2,7	2,31	0,39	0,169	When Flooding Plain loses, Grassland replaces it.
Fl-P »»»» Cro-L	14,31	1,66	12,65	7,620	When Flooding Plain loses, Cropland replaces it.
Fl-P »»»» Ur-U	6,57	0,52	6,05	11,635	When Flooding Plain loses, Urban Use replaces it.
Fl-P »»»» S-Shr	11,43	8,53	2,90	0,340	When Flooding Plain loses, Sucessional Shrubland replaces it.
S-Shr »»»» Oc-F	513,0	170,58	342,42	2,007	When Sucessional Shrubland loses, Open-cleared Forest replaces it.
S-Shr »»»» Sm-F	984,69	643,94	340,75	0,529	When Sucessional Shrubland loses, Sub-montane Forest replaces it.
S-Shr »»»» Gr-L	811,44	336,32	475,12	1,413	When Sucessional Shrubland loses, Grassland replaces it.
S-Shr »»»» Gr-An	497,34	122,20	375,14	3,070	When Sucessional Shrubland loses, Grass Anthropogenic replaces it.
S-Shr »»»» Cro-L	766,53	241,11	525,42	2,179	When Sucessional Shrubland loses, Cropland replaces it.
S-Shr »»»» Ur-U	84,06	75,44	8,62	0,114	When Sucessional Shrubland loses, Urban Use replaces it.

Ov: Observed Value/ Ev: Expected Value

Table 7. The most systematic transitions occurred in T0-T1, in terms of Losses

As seen on Table 7, Gr-L is basically migrating to Gr-An (174, 33 ha), Cro-L (316, 53 ha) and S-Shr (1224, 45 ha), and with less importance, to Fl-P (31, 32 ha) and Ur-U (31, 32 ha), respectively. Gr-An is basically migrating to Gr-L in 2,146 times more than expected (230, 4 ha). This contributes to explain the high swapping value observed for Gr-L during the period. The category Cro-L migrated to Ur-U in 3,164 times more than expected (98, 1 ha); to Fl-P in 2,874 (49, 05 ha), and to S-Shr in 1,187 times more than expected (846, 63 ha). Particularly the transition Cro-L – Fl-P indicates that the hydrological dynamic of the river, especially the peak flows or flooding events, affected cropping areas. The transition Ero-L – Fl-P suggests an intense hydrological dynamic during the period, which augmented the sediments emission of the river. [62] determined that the yield of sediments in the whole catchment area have increased by 914 % with respect of the estimated value in order to build the Boconó-Tucupido Dam System, located dowmstreams in the lowland region.

The transition Ur-U – Fl-P also suggest that the hydrological events occurred during the period, affected the urban area of Boconó city, which had been expanding across the fluvial plain of the River; it can be corroborated some rows below, with the transition Fl-P – Ur-U, in which the urban area grew up across the Flooding Plain 11,625 times more than expected (6,57 ha). Important flooding events occurred in 1988, 1989, 1991 and 1995 were analyzed by [63]; unfortunately, the historical data for the River Basin is quite deficient and no more reference data exist since 1997.

Finally, the transitions for the category S-Shr suggest a trend for the category to migrate to the human-induced types of Land Cover categories Gr-An (3,070 times more than expected); Cro-L (2,179 times more than expected) and Ur-U (0,114 times more than expected). The rest of the transitions suggest a regeneration process. Shrubland was also observed as a highly dynamic category in the Kalu District-Ethiopia by [64], and also in Central Chile by [60], which can be explained by the forms of cultivation above mentioned, mostly typical in these regions.

The Table 8 shows the most systematic inter-category transitions occurred in the period T0 – T1 in terms of gain. The first twelve transitions are associated to changes in the Forested Land Covers. Particularly the transition Sm-F – Ero-L indicate erosion processes occurring after the clearcutting of the Sub-montane Forest, in 5,489 times more than expected, affecting a total of 12,33 ha. On the other hand, the transitions Gr-An – Gr-l (4,760); Gr-An – S-Shr (2,231), and Gr-An - Sm-F (0,232) suggest a regeneration/revegetation process.

As seen on Table 8, the cropland area in the river basin is growing at the expense of the categories: Oc-F (176, 76 ha), Sm-F (339, 48 ha), Gr-L (316, 53 ha), Gr-An (100, 89 ha), and S-Shr (766, 53 ha). On the other hand, the Gr-An gained surface area migrating basically from: Oc-F (168, 93 ha), Gr-L (174, 33 ha), Cro-L (70, 11 ha), and from S-Shr (497, 34 ha).

The transition Cro-L – Sm-F could to indicate regeneration, or perhaps a change to coffee plantation, or a combination of both scenarios. The transition Cro-L – Gr-L could be explained by the type of cultivation usually practiced in the area, above mentioned.

Sistematic Transition T0 »»»» T1	Ov	Ev	Ov - Ev	Ov–Ev / Ev	Interpretation of the Transition
Tmc-F »»»» Schr	58,32	27,49	30,83	1,121	When Schrub gains, it replaces the Tropical Montane Cloudy Forest
Tmc-F »»»» Sa-P	6,93	3,40	3,53	1,038	When Sub Andean Páramo gains, it replaces the Tropical Montane Cloudy Forest
Oc-F »»»» Sm-F	130,32	102,46	27,86	0,272	When the Sub-montane Forest gains, it replaces the Open-cleared Forest.
Oc-F »»»» Gr-L	149,31	92,90	56,41	0,607	When the Grassland gains, it replaces the Open-cleared Forest
Oc-F »»»» Gr-An	168,93	61,50	107,43	1,747	When Grass Anthropogenic gains, it replaces Open-cleared Forest
Oc-F »»»» Cro-L	176,76	103,19	73,57	0,713	When Cropland gains, it replaces the Open-cleared Forest
Oc-F »»»» S-Shr	1863,45	507,89	1355,5 6	2,669	When Sucessional Shrub gains, it replaces Open-cleared Forest
Sm-F »»»» Cro-L	339,48	261,07	78,41	0,300	When Cropland gains, it replaces the Sub-montane Forest
Sm-F »»»» Ero-L	12,33	1,90	10,43	5,489	When Eroded Land gains, it replaces the Sub-montane Forest
Sm-F »»»» Ur-U	61,92	41,75	20,17	0,483	When Urban Use gains, it replaces the Sub-montane Forest
Sm-F »»»» Fl-P	83,7	27,41	56,29	2,054	When Flooding Plain gains, it replaces the Sub-montane Forest
Sm-F »»»» S-Shr	2013,39	1284,98	728,41	0,567	When Sucessional Shrubland gains, it replaces the Sub-montane Forest
Gr-L »»»» Sm-F	136,08	126,21	9,87	0,078	When Sub-montane Forest gains, it replaces the Grassland
Gr-L »»»» Gr-An	174,33	75,76	98,57	1,301	When Grass Anthropogenic gains, it replaces Grassland
Gr-L »»»» Cro-L	316,53	127,11	189,42	1,490	When Cropland gains, it replaces Grassland
Gr-L »»»» Ur-U	31,32	20,33	10,99	0,541	When Urban use gains, it replaces Grassland
Gr-L »»»» Fl-P	31,32	13,35	17,97	1,346	When Flooding Plain gains, it replaces Grassland
Gr-L »»»» S-Shr	1224,45	625,63	598,82	0,957	When Sucessional Shrubland gains, it replaces Grassland
Gr-An »»»» Oc-F	51,39	30,21	21,18	0,701	When Open- cleared Forest gains, it replaces Grass Anthropogenic
Gr-An »»»» Sm-F	54,36	44,12	10,24	0,232	When Sub-montane Forest gains, it replaces Grass Anthropogenic
Gr-An »»»» Gr-L	230,4	40,00	190,40	4,760	When Grassland gains, it replaces Grass Anthropogenic
Gr-An »»»» Cro-L	100,89	44,43	56,46	1,271	When Cropland gains, it replaces Grass Anthropogenic
Gr-An »»»» Ur-U	9,72	7,10	2,62	0,369	When Urban Use gains, it replaces Grass Anthropogenic
Gr-An »»»» S-Shr	706,68	218,69	487,99	2,231	When Sucessional Srhubland gains, it replaces Grass Anthropogenic
Cro-L »»»» Sm-F	283,32	75,90	207,42	2,733	When Sub-montane Forest gains, it replaces Cropland
Cro-L »»»» Gr-L	221,85	68,82	153,03	2,224	When Grassland gains, it replaces Cropland
Cro-L »»»» Gr-An	70,11	45,56	24,55	0,539	When Grass Anthropogenic gains, it replaces Cropland
Cro-L »»»» Ur-U	98,1	12,22	85,88	7,028	When Urban Use gains, it replaces Cropland
Cro-L »»»» Fl-P	49,05	8,03	41,02	5,108	When Flooding Plain gains, it replaces Cropland
Cro-L »»»» S-Shr	846,63	376,26	470,37	1,250	When Sucessional Shrubland gains, it replaces Cropland
Ero-L »»»» Tmc-F	7,74	0,78	6,96	8,923	When Tropical Montane Cloudy Forest gains, it replaces Eroded Land
Ero-L »»»» Cro-L	1,35	0,99	0,36	0,364	When Cropland gains, it replaces Eroded Land
Ero-L »»»» Fl-P	1,35	0,10	1,25	12,500	When Flooding Plain gains, it replaces Eroded Land
Fl-P »»»» Cro-L	14,31	8,15	6,16	0,756	When Cropland gains, it replaces Flooding Plain
Fl-P »»»» Ur-U	6,57	1,30	5,27	4,054	When Urban Use gains, it replaces Flooding Plain
S-Shr »»»» Tmc-F	638,01	233,26	404,75	1,735	When Tropical Montane Cloudy Forest gains, it replaces Sucessional Shrubland
S-Shr »»»» Oc-F	513	202,72	310,28	1,531	When Open cleared Forest gains, it replaces Sucessional Shrubland
S-Shr »»»» Sm-F	984,69	296,05	688,64	2,326	When Sub-montane Forest gains, it replaces Sucessional Shrubland
S-Shr »»»» Gr-L	811,44	268,40	543,04	2,023	When Grassland gains, it replaces Sucessional Shrubland
S-Shr »»»» Gr-An	497,34	177,70	319,64	1,799	When Grass Anthropogenic gains, it replaces Sucessional Shrubland
S-Shr »»»» Cro-L	766,53	298,15	468,38	1,571	When Cropland gains, it replaces Sucessional Shrubland
S-Shr »»»» Ur-U	84,06	47,68	36,38	0,763	When Urban Use gains, it replaces Sucessional Shrubland

Ov: Observed Value/ Ev: Expected Value

Table 8. The most systematic transitions occurred in T0-T1, in terms of Gains

The fact that the urban areas have been growing at the expense of croplands is corroborated again with the transition Cro-L – Ur-U, which indicates that the urban areas grew up from

Cropland in 7,028 times more than expected (98,1 ha). The urban areas also grew up at the expense of other categories: Sm-F (61, 92 ha), Gr-L (31, 31 ha), S-Shr (84, 06 ha) and Gr-An (9, 72 ha). On the other hand, the Fl-P grew up at the expense of Cro-L in 5,108 times more than expected, affecting 49, 05 ha.

The transition Ero-L – Tmc-F suggest a regeneration/revegetation process, showing a high level of resilience for the TMCF to be regenerated after such disturbances like landslides, as in this case. The transition Ero-L - Fl-P focuses a source of sediments which were transported by the river during the period. On the other hand, the transition Fl-P – Ur-U confirms the fact that the urban areas (in this case, the urban area of Boconó city) is expanding through the Flooding plain. The last transitions help to confirm the higher swapping-change dynamic associated to the category S-Shr.

The Tables 9 and 10 resume the most systematic transitions occurred in the second period (T1 – T2) in terms of losses and gains, respectively.

As seen on Table 9, the number of rows accounting for changes in the Forested LC was reduced to 9, because of a slight reduction in the transitions of Sm-F, which explains the reduction in the swapping value observed in the category for this period.

The same trend in the transitions for the Tmc-F can be observed in this period, but additionally 5,31 ha of the area covered by the category was affected by erosion processes, particularly landslides. An incipient transition process for the Sa-P occurred during the period, suggesting that some changes derived by anthropogenic pressure have been occurring in the Páramo ecosystems of the river basin. The growing anthropogenic pressure over the Sub-Andean Páramo in the study area was already reported by [65].

The categories Gr-L, Gr-An and Cro-L show the same transitional trends as in the last period. The Urban use continued to growing up at the expense of croplands and the flooding plain, and at the same time, the urban area continued being affected by peak flows or flooding processes. Finally, the S-Shr showed migrating trends to Gr-An (3,168), Cro-L (1,719), to Gr-L (1,507) and to Oc-F (0,910) also.

Respect to the gains in this period, the Table 10 illustrates the trend, where the first ten rows show the changes affecting the Forested LCC. In general, the trends and patterns for the transitions observed on last period remain during the second period.

The category Gr-L showed less intensity in the swapping, meanwhile Cro-L gained surface at the expense of Oc-F (66, 78 ha), Sm-F (269, 37 ha), Gr-L (361, 17 ha), Gr-An (172, 44 ha), Fl-P (36, 9 ha) and S-Shr (1037, 97 ha). Gr-An gained surface migrating from Gr-L in 2,142 times more than expected (502, 83 ha), and also from Cro-L (213, 39 ha), and from S-Shr (1571, 40 ha).

The urban areas continued to growing up in the period, gaining surface area basically from Sm-F (43, 38 ha), Gr-An (3, 78 ha), Cro-L (46, 08 ha), Fl-P (5, 85 ha) and S-Shr (31, 95 ha). Particularly the urban area growing close or into the category Fl-P is vulnerable to the river dynamic. During this period the category S-Shr reported systematic transitions with all the rest of the categories, which explain the high value for swapping-change for the category in this period.

Systematic Transition T1 »»»» T2	Ov	Ev	Ov - Ev	Ov–Ev / Ev	Interpretation of the Transition
Tmc-F »»»» Oc-F	470,07	98,89	371,18	3,753	When Tropical Montane Cloudy Forest loses, Open-cleared Forest replaces it.
Tmc-F »»»» Ero-L	5,31	2,58	2,73	1,058	When Tropical Montane Cloudy Forest loses, Eroded Land replaces it.
Tmc-F »»»» S-Shr	1335,15	832,04	503,11	0,605	When Tropical Montane Cloudy Forest loses, Sucessional Shrubland replaces it.
Oc-F »»»» Gr-An	77,13	60,35	16,78	0,278	When Open-cleared Forest loses, Grass Anthropogenic replaces it.
Oc-F »»»» Cro-L	66,78	61,11	5,67	0,093	When Open-cleared Forest loses, Cropland replaces it.
Oc-F »»»» S-Shr	900,0	273,65	626,35	2,289	When Open-cleared Forest loses, Sucessional Srhubland replaces it.
Sm-F »»»» Cro-L	269,37	161,78	107,59	0,665	When Sub-montane Forest loses, Cropland replaces it.
Sm-F »»»» Ero-L	3,15	2,25	0,90	0,400	When Sub-montane Forest loses, Eroded Land replaces it.
Sm-F »»»» S-Shr	2122,38	724,49	1397,89	1,929	When Sub-montane Forest loses, Sucessional Shrubland replaces it.
Schr »»»» Gr-An	0,18	0,07	0,11	1,571	When Schrubland loses, Grass Anthropogenic replaces it.
Schr »»»» Ero-L	0,72	0,001	0,72	719,000	When Schrubland loses, Eroded Land replaces it.
Schr »»»» S-Shr	0,45	0,33	0,12	0,364	When Schrubland loses, Sucessional Shrubland replaces it.
Gr-L »»»» Gr-An	502,83	92,48	410,35	4,437	When Grassland loses, Grass Anthropogenic replaces it.
Gr-L »»»» Cro-L	361,17	93,64	267,53	2,857	When Grassland loses, Cropland replaces it.
Gr-L »»»» S-Shr	696,15	419,33	276,82	0,660	When Grassland loses, Sucessional Shrubland replaces it.
Sa-P »»»» Schr	0,36	0,01	0,35	35,000	When Sub-andean Páramo loses, Schrubland replaces it.
Sa-P »»»» Gr-An	0,18	0,03	0,15	5,000	When Sub-andean Páramo loses, Grass Anthropogenic replaces it.
Gr-An »»»» Gr-L	124,29	61,43	62,86	1,023	When Grass Anthropogenic loses, Grassland replaces it.
Gr-An »»»» Cro-L	172,44	52,81	119,63	2,265	When Grass Anthropogenic loses, Cropland replaces it.
Gr-An »»»» S-Shr	557,19	236,49	320,70	1,356	When Grass Anthropogenic loses, Sucessional Shrubland replaces it.
Cro-L »»»» Sm-F	161,73	123,04	38,69	0,314	When Cropland loses, Sub-montane Forest replaces it.
Cro-L »»»» Gr-L	266,58	95,91	170,67	1,779	When Cropland loses, Grassland replaces it.
Cro-L »»»» Gr-An	213,39	81,43	131,96	1,621	When Cropland loses, Grass Anthropogenic replaces it.
Cro-L »»»» Ero-L	1,89	1,15	0,74	0,643	When Cropland loses, Eroded Land replaces it.
Cro-L »»»» Ur-U	46,08	24,88	21,20	0,852	When Cropland loses, Urban Use replaces it.
Cro-L »»»» Fl-P	10,08	8,45	1,63	0,193	When Cropland loses, Flooding Plain replaces it.
Cro-L »»»» S-Shr	656,55	369,19	287,36	0,778	When Cropland loses, Sucessional Shrubland replaces it.
Ero-L »»»» Sm-F	1,89	0,39	1,50	3,846	When Eroded Land loses, Sub-montane Forest replaces it.
Ero-L »»»» Cro-L	0,9	0,26	0,64	2,462	When Eroded Land loses, Cropland replaces it.
Ero-L »»»» Fl-P	0,45	0,03	0,42	14,000	When Eroded Land loses, Flooding Plain replaces it.
Ero-L »»»» S-Shr	1,53	1,16	0,37	0,319	When Eroded Land loses, Sucessional Shrubland replaces it.
Ur-U »»»» Fl-P	2,16	0,01	2,15	215,000	When Urban Use loses, Flooding Plain replaces it.
Fl-P »»»» Sm-F	41,31	10,78	30,53	2,832	When Flooding Plain loses, Sub-montane Forest replaces it.
Fl-P »»»» Gr-L	11,16	8,41	2,75	0,327	When Flooding Plain loses, Grassland replaces it.
Fl-P »»»» Cro-L	36,9	7,23	29,67	4,104	When Flooding Plain loses, Cropland replaces it.
Fl-P »»»» Ero-L	0,18	0,10	0,08	0,800	When Flooding Plain loses, Eroded Land replaces it.
Fl-P »»»» Ur-U	5,85	2,18	3,67	1,683	When Flooding Plain loses, Urban Use replaces it.
Fl-P »»»» S-Shr	33,93	32,36	1,57	0,049	When Flooding Plain loses, Sucessional Shrubland replaces it.
S-Shr »»»» Oc-F	387,99	203,17	184,82	0,910	When Sucessional Shrubland loses, Open-cleared Forest replaces it.
S-Shr »»»» Gr-L	1113,21	444,05	669,16	1,507	When Sucessional Shrubland loses, Grassland replaces it.
S-Shr »»»» Gr-An	1571,4	377,00	1194,40	3,168	When Sucessional Shrubland loses, Grass Anthropogenic replaces it.
S-Shr »»»» Cro-L	1037,97	381,71	656,26	1,719	When Sucessional Shrubland loses, Cropland replaces it.
S-Shr »»»» Ero-L	6,12	5,31	0,81	0,153	When Sucessional Shrubland loses, Eroded Land replaces it.

Ov: Observed Value/ Ev: Expected Value

Table 9. The most systematic transitions occurred in T1-T2, in terms of Losses

Sistematic Transition T1 »»»» T2	Ov	Ev	Ov - Ev	Ov–Ev / Ev	Interpretation of the Transition
Tmc-F »»»» Oc-F	470,07	450,06	20,01	0,044	When Open-cleared Forest gains, it replaces Tropical Montane Cloudy Forest.
Tmc-F »»»» Schr	14,67	13,18	1,49	0,113	When Schrubland gains, it replaces Tropical Montane Cloudy Forest.
Tmc-F »»»» Sa-P	3,33	3,20	0,13	0,041	When Sub-andean Páramo gains, it replaces Tropical Montane Cloudy Forest.
Oc-F »»»» Cro-L	66,78	64,12	2,66	0,041	When Coppland gains, it replaces Open-cleared Forest.
Oc-F »»»» S-Shr	900,0	248,77	651,23	2,618	When Sucessional Shrubland gains, it replaces Open-cleared Forest.
Sm-F »»»» Cro-L	269,37	242,07	27,30	0,113	When Cropland gains, it replaces Sub-montane Forest.
Sm-F »»»» Ero-L	3,15	2,02	1,13	0,559	When Eroded Land gains, it replaces Sub-montane Forest.
Sm-F »»»» Ur-U	43,38	16,22	27,16	1,674	When Urban Use gains, it replaces Sub-montane Forest.
Sm-F »»»» Fl-P	6,39	4,26	2,13	0,500	When Flooding Plain gains, it replaces Sub-montane Forest.
Sm-F »»»» S-Shr	2122,38	939,10	1183,28	1,260	When Sucessional Shrubland gains, it replaces Sub-montane Forest.
Schr »»»» Ero-L	0,72	0,39	0,33	0,846	When Eroded Land gains, it replaces Schrubland
Gr-L »»»» Gr-An	502,83	160,05	342,78	2,142	When Grass Anthropogenic gains, it replaces Grassland.
Gr-L »»»» Cro-L	361,17	126,42	234,75	1,857	When Cropland gains, it replaces Grassland.
Gr-L »»»» Fl-P	3,6	2,23	1,37	0,614	When Flooding Plain gains, it replaces Grassland.
Gr-L »»»» S-Shr	696,15	490,47	205,68	0,419	When Sucessional Shrubland gains, it replaces Grassland.
Gr-An »»»» Tmc-F	40,5	34,45	6,05	0,176	When Tropical Montane Cloudy Forest gains, it replaces Grass Anthropogenic
Gr-An »»»» Sm-F	23,85	21,04	2,81	0,134	When Sub-montane Forest gains, it replaces Grass Anthropogenic
Gr-An »»»» Gr-L	124,29	40,50	83,79	2,069	When Grassland gains, it replaces Grass Anthropogenic
Gr-An »»»» Cro-L	172,44	45,94	126,50	2,754	When Cropland gains, it replaces Grass Anthropogenic
Gr-An »»»» Ur-U	3,78	3,08	0,70	0,227	When Urban Use gains, it replaces Grass Anthropogenic
Gr-An »»»» S-Shr	557,19	178,21	378,98	2,127	When Sucessional Shrubland gains, it replaces Grass Anthropogenic
Cro-L »»»» Tmc-F	78,03	67,97	10,06	0,148	When Tropical Montane Cloudy Forest gains, it replaces Cropland
Cro-L »»»» Sm-F	161,73	41,52	120,21	2,895	When Sub-montane Forest gains, it replaces Cropland
Cro-L »»»» Gr-L	266,58	79,90	186,68	2,336	When Grassland gains, it replaces Cropland
Cro-L »»»» Gr-An	213,39	114,74	98,65	0,860	When Grass Anthropogenic gains, it replaces Cropland
Cro-L »»»» Ero-L	1,89	0,76	1,13	1,487	When Eroded Land gains, it replaces Cropland
Cro-L »»»» Ur-U	46,08	6,07	40,01	6,591	When Urban Use gains, it replaces Cropland
Cro-L »»»» Fl-P	10,08	1,60	8,48	5,300	When Flooding Plain gains, it replaces Cropland
Cro-L »»»» S-Shr	656,55	351,62	304,93	0,867	When Sucessional Shrubland gains, it replaces Cropland
Ero-L »»»» Sm-F	1,89	0,49	1,40	2,857	When Sub-montane Forest gains, it replaces Eroded Land.
Ero-L »»»» Fl-P	0,45	0,02	0,43	21,500	When Flooding Plain gains, it replaces Eroded Land.
Ur-U »»»» Fl-P	2,16	0,50	1,66	3,320	When Flooding Plain Gains, it replaces Urban Use.
Fl-P »»»» Sm-F	41,31	6,98	34,33	4,918	When Sub-montane Forest gains, it replaces Flooding Plain.
Fl-P »»»» Cro-L	36,9	15,24	21,66	1,421	When Cropland gains, it replaces Flooding Plain.
Fl-P »»»» Ero-L	0,18	0,13	0,05	0,385	When Eroded Land gains, it replaces Flooding Plain.
Fl-P »»»» Ur-U	5,85	1,02	4,83	4,735	When Urban Use gains, it replaces Flooding Plain.
S-Shr »»»» Tmc-F	705,42	349,55	355,87	1,018	When Tropical Montane Cloudy Forest gains, it replaces Sucessional Shrubland.
S-Shr »»»» Oc-F	387,99	227,82	160,17	0,703	When Open-cleared Forest gains, it replaces Sucessional Shrubland.
S-Shr »»»» Sm-F	562,95	213,53	349,42	1,636	When Sub-montane Forest gains, it replaces Sucessional Shrubland.
S-Shr »»»» Schr	13,59	6,67	6,92	1,037	When Schrubland gains, it replaces Sucessional Shrubland.
S-Shr »»»» Gr-L	1113,21	410,90	702,31	1,709	When Grassland gains, it replaces Sucessional Shrubland.
S-Shr »»»» Sa-P	3,78	1,62	2,16	1,333	When Sub-andean Páramo gains, it replaces Sucessional Shrubland.
S-Shr »»»» Gr-An	1571,4	590,08	981,32	1,663	When Grass Anthropogenic gains, it replaces Sucessional Shrubland.
S-Shr »»»» Cro-L	1037,97	466,10	571,87	1,227	When Cropland gains, it replaces Sucessional Shrubland.
S-Shr »»»» Ero-L	6,12	3,95	2,17	0,549	When Eroded Land gains, it replaces Sucessional Shrubland.
S-Shr »»»» Ur-U	31,95	31,24	0,71	0,023	When Urban Use gains, it replaces Sucessional Shrubland.
S-Shr »»»» Fl-P	13,05	10,66	2,39	0,224	When Flooding Plain gains, it replaces Sucessional Shrubland.

Ov: Observed Value/ Ev: Expected Value

Table 10. The most systematic transitions occurred in T1-T2, in terms of Gains

6. Implications of the observed LULC changes for the watershed management and land use planning

The dynamic of the LULC in the Boconó River Basin for the considered period and through the approach used in this project, lead to establish key elements and a support basis to be considered in the planning processes at the watershed level or even at regional planning level also. Considering that the Boconó River Basin constitute a double "**Protected Area**", which has a paramount importance for the development of the water resources in the lowlands, the evaluation of LULC change under the ecosystem approach represent a innovative variation respect the traditional LULC evaluations, in which the LULC are usually considered categories in an abstract sense. In this case, the Land Cover categories are essentially valuable ecosystems which have an ecological richness as well as complementary environmental attributes, being very important to the conservation and sustainability of the three basic land resources: water, soils and biodiversity.

The systematic transitions show the trajectory or directionality of the changes in a categorical sense, leading to identify not only the categories which are more dynamic in a spatial-temporal perspective, but also the possible biophysical and anthropogenic processes driving the transitions. When both interpretations are correctly established, they simply lead to define the key elements to be considered in the land planning processes:

a. the way how the land resources have been used in the river basin during the last twenty years
b. the form how the land cover categories as ecosystems have been affected
c. the trends existing for the different Land Use/Land Cover categories, in a spatial/temporal perspective.

Particularly the spatial visualization (geographical visualization) results in a undoubtedly helpful tool for the planning process, allowing to perceive how these trends are spatially occurring, where are occurring specific processes accounted for problems to be solved, and where these problems are more diverse or intense (hot spots).

As an example, the Figure 3 show the geographic visualization of the transitions for the three main forested Land Cover Categories (LCC) (Tmc-F, Oc-F and Sm-F), for the period T0-T1. The transitions occurred during the Period T1-T2 are displayed on Figure 4. A simple observation of the maps, based on the systematic transitions above described, can lead to the following statements:

1.- The changes affecting the forested land covers, particularly the Tcm-F and the Sm-F tends to be produced in the boundary area between categories. The same trend was observed by [30] in Ecuador. This lead to define belts of clearcutting / logging, which are also called "**hot fronts**" of deforestation [9], being more evident for the categories: Tcm-F and Oc-F. In the Sub-montane Forest, the belts or "**hot fronts**" are not clearly defined, because this land cover is highly fragmented among the area. The "Río Negro" Sector located at the upper Boconó River (Figure 4) was severely affected by the changes on the three types of LC, indicating that the processes: clearcutting, logging, wood extraction and non wood & plant extractions were more intense in this sector, during the period. The sector could be defined as "**hot spot**" or "**red flag area**", considering that the deforestation and the LC change is occurring in the sector where the most important streams-sources of the river are located. This sector covers almost the 40% of the stream network area, having therefore the greatest water yield [42].

2.- Observing the two maps, is evident that in the first period, the Open-cleared Forest was systematically reduced among the river basin, meanwhile in the second period, the transition of the Tropical Montane Cloudy Forest was clearly spatially intensified. This lead to corroborate the fact that the dynamic of the TMCF is characterized by a systematic and progressive change, in which the category is migrating to an "intermediate" stage or LCC like Open-cleared Forest or Successional Shrubland, and in other successive stage it can to migrate to another LC or LU categories.

3.- Although the "Guaramacal National Park" was created on 1988, covering the flank south-east of the river basin [41], a "**hot front**" of deforestation can be observed in the inferior border of this protected area (Figure 3), which clearly increased during the second period (Figure 4). This fact reveals that the creation of the Park has not been completely effective in the protection of the ecosystems included in the protected area.

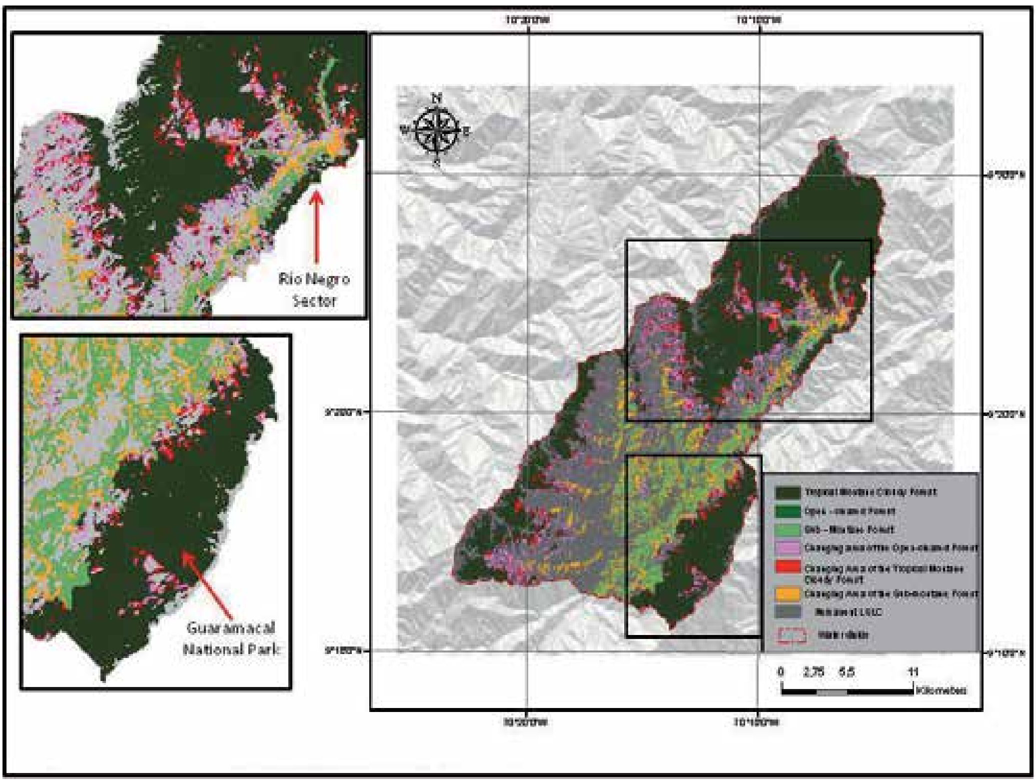

Figure 3. Transition area for the Forested Categories in the period T0-T1

4.- The transitions Sm-F – Fl-P; Cro-L – Fl-P and Ur-U – Fl-P suggests a relevant hydrological dynamic occurring during the period studied. The LC Flooding Plain changed actively on last 20 years, accounting for important events like peak flows or even flash-floodings, which expanded the limits of the category among the area, affecting other categories like Sm-F, Cro-L and Ur-U. The dynamic accounted for the Forested LC and the increase of cultivated soils and grass could have been playing a role in the intensification of the hydrological events. The ecological conditions, and particularly the type and density of the land cover play a very important role in the hydrological behaviour and the hydrological response of the landscape. Many authors like: [9] [36] [38] [66] [67] [68] and [69] have been highlighting the importance of the forest ecosystems in the hydrological patterns. Particularly the TMCF is considered as "**producer-water forest**", playing a paramount role in the rainfall dynamic, as well as the transpiration, interception, water budget and streamflows [9] [38]. Thus, the systematic reduction of this kind of forest may significantly reduce the rainfall interception, probably leading to an even higher streamflow in the area.

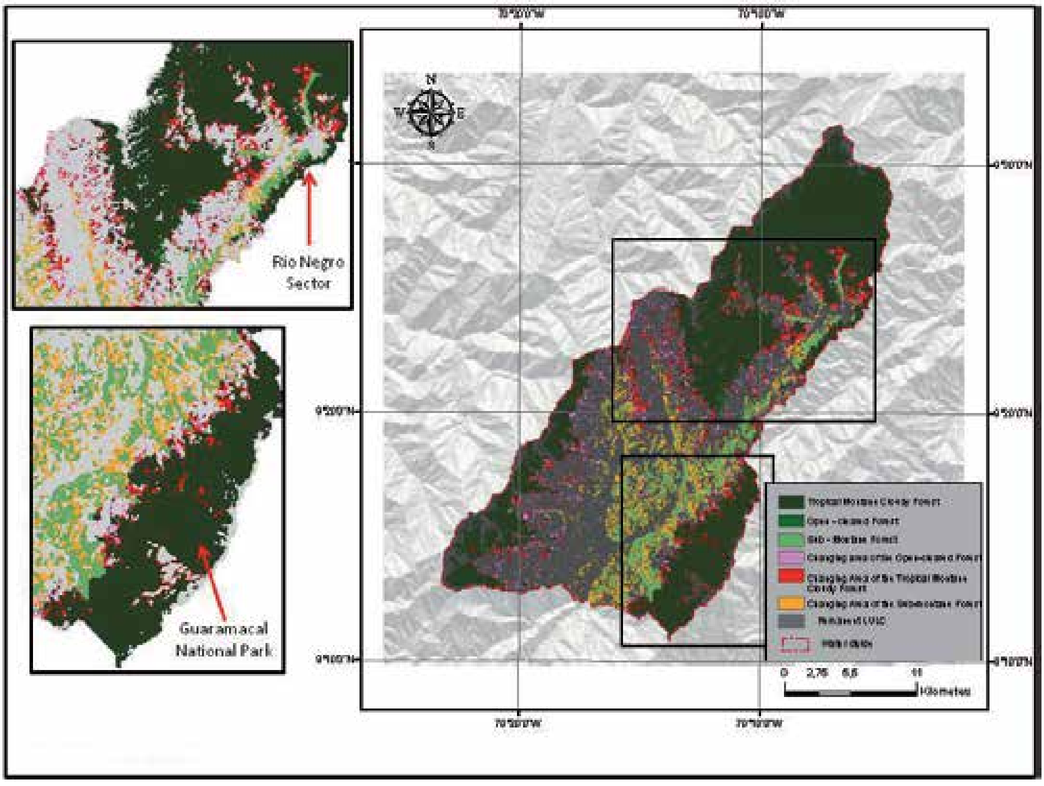

Figure 4. Transition area for the Forested Categories in the period T1-T2

5.- The transitions Sm-F – Ero-L; S-Shr – Ero-L; and Cro-L – Ero-L, indicate that the area is highly susceptible to soil degradation processes like sheet erosion, rill erosion, landslides and so on, processes which have been activating through the migration of Forested LCC to other categories like Cro-L. Only intense erosive processes like landslides were observed in the classification. However, [39] identified severe erosion processes, especially sheet erosion, in the San Miguel and San Rafael Watersheds (within the study area), which are spatially extended due the high accessibility (intricate road network), the fragile soils and the highly jointed bedrocks.

The accessibility (roads network) has been considered as one of the most important and critical drivers facilitating the LULC change in many regions worldwide [1] [39] [57] [67]

[70] [71] [72]. With the exception of the "Río Negro" Sector (See Figure 3), the Boconó River Basin presents a moderately high accessibility [43] [45] [63]. The results obtained by [39] in San Miguel / San Rafael watersheds through a regression tree analysis, revealed that the accessibility had the greatest level of contribution in the occurrence of soil erosion in the area, being the sectors where the cropland have been progressively expanding during the last decades. The occurrence of erosion processes was directly associated to the distance to the road network. This suggest that the accessibility could play a determinant role explaining the intensity and spatiality of the changes that the LULC have been experiencing in the River Basin, as demonstrated by studies conducted in other regions [1] [57] [70-72]. Due the nature and complexity of the variables usually involved, a rigorous analysis of the drivers of LULC change in the area was out of scope of this project, so that further research in this subject is strictly necessary in the near future, in order to comprehensively determine the causal relationship of the factors influencing the changes that affect the River Basin.

The Figures 5 and 6 show the transitions occurred in the Land Use Categories during the first and the second period, respectively. It can be clearly observed where the LUC grow up more intensively in the two periods. The superior window show the San Miguel – San Rafael Watersheds, the sectors where the croplands and the grass anthropogenic grew up more intensively for both periods. These are the sectors which have the most relevant problems related with land degradation in the area, as studied by [39]. The inferior window

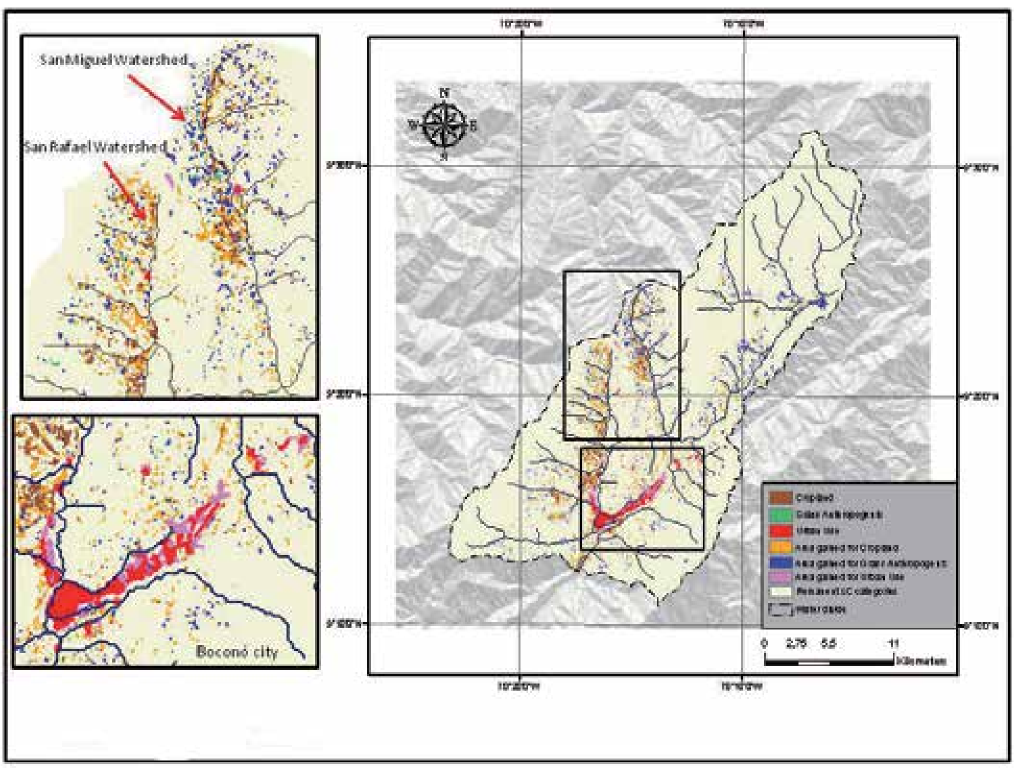

Figure 5. Transition area for the Land Use categories in the period T0-T1

show the expanding process that the Boconó city experienced during the two periods, showing how the city has been expanding among the flooding plain, in areas susceptible to be flooded. The transition Ur-U – Fl-P clearly indicates that some urban sectors have been damaged during the two periods analyzed.

All these interpretations constitutes important tools having practical importance for the institutions or stakeholders involved with the environmental and land planning at local/regional level, being a rational basis to design new plans, or even to improve those which already exists, in order to guaranty the optimization of the natural resource uses in the river basin. This is very important to encourage the effectiveness of the protective figures defined for the whole river basin, accounting for a more sustainable evolution of the LULC in this important "**water resource area**".

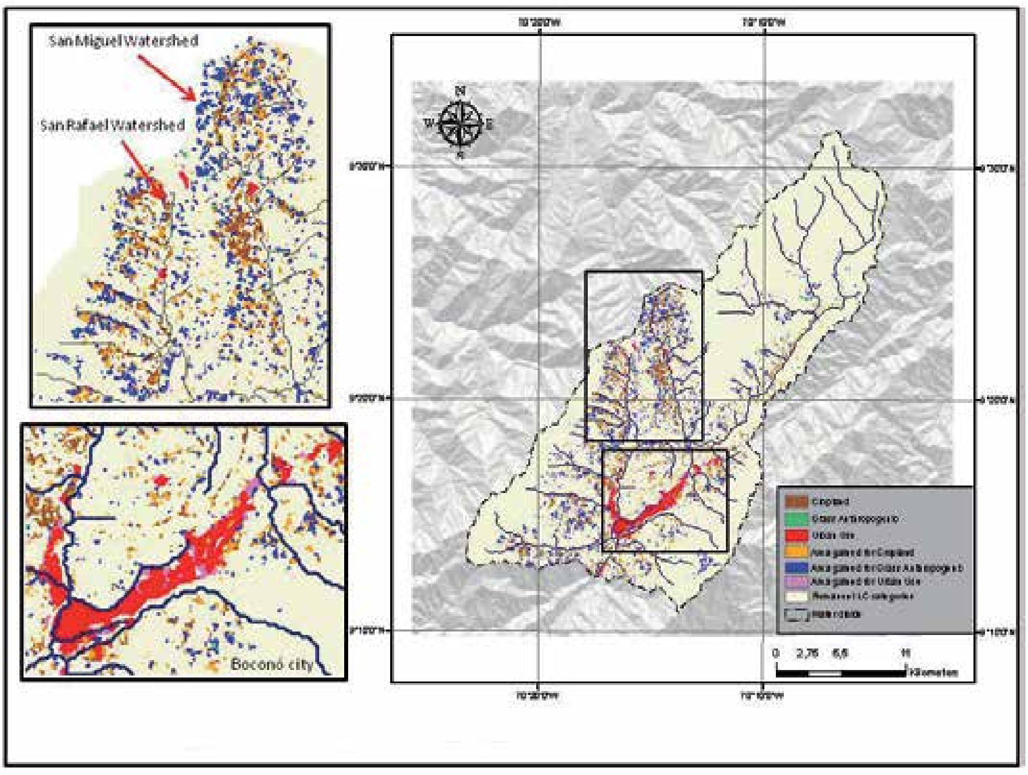

Figure 6. Transition area for the Land Use categories in the period T1-T2

7. Conclusions

The methodological approach combining the multitemporal LULC evaluation, together with the ecosystem approach and the inter-category transitional method, represented a very useful tool to define, to describe an to analyze the LULC system in the Boconó River Basin and the changes occurred in the last 20 years. The study demonstrated that the categories: Successional Srhubland (S-Shr), Sub-montane Forest (Sm-F), Open-cleared Forest (Oc-F) and

Cropland (Cro-L) were the most dynamic among the two considered periods, accounting for the highest total change value, as well as gains, losses, swapping and net change.

The study also demonstrated that the changes and the reduction showed by the Tropical Montane Cloudy Forest in the area, cannot be directly associated to the expansion of land use categories like Cropland or Grass Anthropogenic. At least on the last 20 years, the TMCF have been changing to an intermediate condition for LC, basically to Open-cleared Forest (Oc-F) and Sucessional Srhubland (S-Shr). Even when the TMCF is under anthropogenic pressure, it can be only associated with logging, wood and timber extraction, as well as the extraction of non wood products and plants.

The systematic transitions that have been occurring in the LULC categories reveal that the land uses Cropland (Cro-L) and Grass Anthropogenic (Gr-An) have been growing, gaining surface basically from Sucessional Shrubland (S-Shr), Sub-montane Forest (Sm-F), and Grassland (Gr-L).This justify the higher values for swapping-change, observed in these categories. On the other hand, the urban areas (Ur-U) have been growing basically at the expense of Cro-L, Gr-L and Fl-P.

The systematic transitions Sm-F – Fl-P; Cro-L – Fl-P and Ur-U – Fl-P, as well as the variation of the category Fl-P during the period, suggest an intense dynamic of the river, and the occurrence of high peak flows and important flooding events during the period, which have been affecting the urban expanding area, as well as croplands. Probably, the decrease of the forested areas, and particularly the TMCF, as well as the increase of the croplands and the grass-anthropogenic, could be directly affecting the hydrological dynamic in the river basin, particularly the behavior of the seasonal flows.

Finally, the systematic transitions helped to focus specific processes that suggest the existence of problems which need to be solved into the land use planning or the watershed management processes. The "**hot fronts**" of deforestation could be considered as critical areas or priority areas in order to promote the conservation/preservation of the valuable ecosystems as the TMCF, helping to define "**area-oriented policies**" to ensure the water resources management in the river basin.

Further rigorous research about the associated drivers for LULC change in the area is strictly necessary, in order to reach a comprehensive understanding of the dynamic and transitions of the LULC categories identified and characterized in this project, seeking to encourage the future decisions for land use planning within the watershed management at regional and local level.

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8. References

[1] Verburg P, Overmars K, Witte N (2004) Accessibility and land-use patterns at the forest fringe in the northeastern part of the Philippines. The Geographical Journal, 170 (3): 238 – 255.
[2] Krishna V, Badarinth K, (2004) Land use changes and trends in Human Appropriation of Above Ground Net Primary Production (HANPP) in India (1961-98). The Geographical Journal, 170 (1): 51 – 63.
[3] Turner B, Lambin E, Reenberg A (2007) The emergence of land change science for global environmental change and sustainability. PNAS, 104 (52): 20666 – 20671.
[4] Mannion A, (2002) Dynamic World. Land cover and Land Use Change. London. Hodder Headline Group.
[5] Bormann H, Breuer L, Gräff T., Huisman J, Croke B (2009) Assessing the impact of land use change on hydrology by ensemble modelling: IV. Model sensitivity to data aggregation and spatial (re-) distribution. Advances in Water Resources, 32: 171 – 192.
[6] Houet Th, Verburg P, Loveland Th (2010) Monitoring and modelling landscape dynamics. Landscape Ecology, 25 (2): 163 – 167.
[7] Lambin E, (1997) Modelling and monitoring land-cover change processes in tropical regions. Progress in Physical Geography, 21 (3): 375 – 393.
[8] Lambin E, Geist H, Lepers E, (2003) Dynamics of Land-Use and Land-Cover Change in Tropical Regions. Annual Review of Environmental Resources, 28: 205-241.
[9] Bonell M, Brujinzeel L (Edit.) (2005) Forest, water and people in the humid Tropics. Past, present and future hydrological research for integrated land and water management. Cambridge. Cambridge University Press. and UNESCO.
[10] Armenteras D, Rudas G, Rodriguez N, Sua, S, Romero M (2006) Patterns and causes of deforestation in the Colombian Amazon. Ecological Indicators, 6: 353-368.

[11] Hadgu K, (2008) Temporal and spatial changes in land use patterns and biodiversity in relation to farm productivity at multiple scales in Tigray, Ethiopia. Wageningen University. Wageningen, The Netherlands. PhD thesis.

[12] Poudel, K. (2003) Watershed Management in the Himalayas. A Resource analysis approach. Delhi. ADROIT Publishers. 361 pp.

[13] Cayuela L, Benayas J, Echeverría C (2006) Clearance and fragmentation of tropical montane forests in the Highlands of Chiapas, Mexico (1975-2000). Forest Ecology and Management, 226: 208 – 218.

[14] Richter D, Saplaco S, Nowak P (1985) Problemas de gestión de las cuencas en las tierras altas tropicales húmedas. La Naturaleza y sus Recursos, 21(4): 10-21.

[15] Barrios A (1994) Diagnosis del enfoque de manejo de cuencas y el continuo deterioro de los recursos naturales en las cuencas altas de Venezuela. Memorias del 11 Congreso Latinoamericano de Manejo de Cuencas. Mérida - Venezuela.

[16] Lorup J, Refsgaard J, Mazvimavi D, (1998) Assessing the effect of land use change on catchment runoff by combined use of statistical tests and hydrological modelling: Case studies from Zimbabwe. Journal of Hydrology, 205: 147 – 163.

[17] Brown S, Dee D (2000) Using a GIS-Based solution for watershed analysis and automation: a case study. Conference on water resource Engineering and water resources planning and management. Minneapolis.

[18] Steuer J, Hunt R (2001) Use of a Watershed – Modeling Approach to Assess Hydrologic Effects of Urbanization, North Fork Pheasant Branch Basin near Middelton, Wisconsin. Water-Resources Investigations Report 01-4113. Middleton. U.S. Geological Survey, in cooperation with the City of Middleton and the Wisconsin Department of Natural Resources.

[19] Krause P, (2002) Quantifying the impact of land use changes on the water balance of large catchments using the J-2000 model. Physics and Chemistry of the Earth, 27: 663 – 673.

[20] Legesse D, Vallet-Coulomb Ch, Gasse F, (2003) Hydrological response of a catchment to climate and land use changes in tropical Africa: case study South Central Ethiopia. Journal of Hydrology, 275: 67 – 85.

[21] Bäse F, Helmschrot J, Müller H, Flügel W (2006) The impact of land use change on the hydrological dynamic of the semi arid Tsitsa catchment in South Africa. Göttingen. Procedure 2nd Göttingen GIS and Remote Sensing Days.

[22] Pizarro R, Araya S, Jordán C, Farías C, Flores J y Bro P (2006) The effects of changes in vegetative cover on river flows in the Purapel river basin of central Chile. Journal of Hydrology, 327: 249 – 257.

[23] Siriwardena L, Finlayson B, McMahon T (2006) The impact of land use change on catchment hydrology in large catchments: The Comet River, Central Queensland, Australia. Journal of Hydrology, 326: 199 – 214.

[24] Marshall E, and Randhir T, (2008) Spatial modeling of land cover change and watershed response using Markovian cellular automata and simulation. Water Resources Research, 44: W04423.

[25] Bruns D, Fetcher N (2008) CITY green Watershed Analysis of Toby Creek: An American Heritage River Tributary. Journal of Contemporary Water Research & Education, 139: 29 – 37.

[26] Mialhe F, Gunnell Y, Mering C, (2008) Synoptic assessment of water resource variability in reservoirs by remote sensing: General approach and application to the runoff harvesting systems of south India. Water Resources Research 44: W05411.

[27] Breuer L, Huisman J, Willems P, Bormann H, Bronstert A, Croke B, Frede H, Gräff T, Hubrechts L, Jakeman A, Kite G, Lanini J., Leavesley G, Lettenmaier D, Lindström G, Seibert J, Sivapalan M, Viney N (2009) Assessing the impact of land use change on Hydrology by ensemble modelling (LUCHEM). I: Model intercomparison with current land use. Advances in Water Resources, 32: 129 – 146.

[28] Huisman J, Breuer L, Bormann H, Bronstert A, Croke B, Frede H, Gräff T, Hubrechts L, Jakeman A, Kite G, Lanini J, Leavesley G, Lettenmaier D, Lindström G, Seibert J, Sivapalan M, Viney, N., Willems P, (2009) Assessing the impact of land use change on hydrology by ensemble modelling (LUCHEM). III: Scenario analysis. Advances in Water Resources, 32: 159 – 170.

[29] Shilling K, Chan K, Liu H, Zhang Y (2010) Quantifying the effect of land use land cover change on increasing discharge in the Upper Mississipi River. Journal of Hydrology, 387: 343 – 345.

[30] Oñate F, Bosque J, (2010) Application of GIS and remote sensing techniques in generation of land use scenarios for hydrological modeling. Journal of Hydrology, 395: 256 – 263.

[31] Liu T, Fang H, Willems P, Bao A, Chen X, Veroustraete F, Dong Q (2012) On the relationship between historical land-use change and water availability: the case of the lower Tarim River region in northwestern China. Hydrological Processes. DOI: 10.1002/hyp.9223.

[32] Hauck F, (1985) Soil erosion and it´s control in developing countries. In El Swaify et al. (Ed). Soil Erosion and Conservation. Soil Conservation Society of America. Ankeny, Iowa. USA.

[33] Cornieles M, (1997) Estudio y Modelización del transporte de agua, de elementos disueltos y de particulas en una Cuenca torrencial. Caso del Río Boconó en los Andes venezolanos. Resumen de Tesis presentada ante la Universidad de Avinon y de los Países de Vaucluse para obtener el Título de Doctor en Hidrogeología. Caracas. Ministerio del Ambiente y de los Recursos Naturales Renovables. Servicio Autónomo de Geografía y Cartografía Nacional.

[34] Mejia J, (2000) Un modelo suelo-paisaje para la evaluación automatizada de tierras con fines conservacionistas en cuencas altas. Caso: microcuenca del río Zarzales, Edo. Mérida. Centro de Estudios Forestales y Ambientales de Postgrado. Facultad de Ciencias Forestales y Ambientales. Universidad de Los Andes. Mérida. Tesis MSc.

[35] Thapa G (2001) Changing approaches to mountain watersheds management in mainland south and southeast Asia. Environmental Management, 27(5): 667 - 679.

[36] Dehnhardt A, Petschow U, (Ed) (2008) Sustainability in River Basins. A question of Governance. Münich, OEKOM Verlag.

[37] Ostos O, (1975) Estudio integral de la Cuenca alta del Río Boconó (Estados Trujillo, Portuguesa y Barinas Venezuela). Estudio preliminar del uso actual de la tierra en el área San Miguel – Boconó – Páramo de Guaramacal. Guanare. División de Edafología del Ministerio de Obras Públicas.
[38] Hölscher D, (2008) Hydrology of natural and anthropogenically altered tropical montane rainforests with special reference to rainfall interception. Biodiversity and Ecology Series, 2: 129 – 136.
[39] Caraballo N, (2011) Aproximación al estudio de procesos de erosión en cuencas altas tropicales. Caso: Subcuencas de San Miguel y San Rafael, Municipio Boconó. Escuela de Geografía, Facultad de Ciencias Forestales y Ambientales. Universidad de Los Andes, Mérida – Venezuela. Tesis de Grado.
[40] Mendez G, Rivero J, Diaz M, (2004) Actualización del Plan de Ordenamiento y Reglamento de Uso de la Zona Protectora de las Cuencas hidrográficas de los Ríos: Guanare, Boconó, Tucupido, La Yuca y Masparro. Barinas, Edo. Barinas. IV Congreso Forestal Venezolano.
[41] Muñoz D, Castillo R, Salas V, (2006) Estado de Conservación del Parque Nacional Guaramacal. Caracas. BIOPARQUES.
[42] Macias M, (2002) Estimación de la producción de sedimentos en la Cuenca alta del Río Boconó, usando regresiones y curvas de duración de caudal. Municipio Boconó, Estado Trujillo. Trujillo. Universidad de Los Andes - Núcleo Universitario Rafael Rangel. Departamento de Ingenieria. Tesis.
[43] Cuesta J, (1984) Estimación del Indice de Erosividad de la Lluvia (Factor R), en la Cuenca alta del Río Boconó. Universidad de Los Andes. Facultad de Ciencias Forestales y Ambientales. Escuela de Ingeniería Forestal. Trabajo Especial de Grado.
[44] Gil J, (2000) Estudio Geográfico del Municipio Boconó. Boconó. Fundación La Salle de Ciencias Naturales.
[45] Bizzarro C (1985) Determinación de los Factores "C" de Cobertura Vegetal y "P" de Prácticas Conservacionistas en la Cuenca Alta del Río Boconó, Estado Trujillo. Mérida. Universidad de Los Andes. Facultad de Ciencas Forestales y Ambientales. Escuela de Ingeniería Forestal. Trabajo de Grado.
[46] Bone J, Hidalgo P, Velasquez F (1985) Diagnóstico de la Cuenca del Río Boconó. Informe de avance del Plan de Desarrollo. Boconó, Centro de Ecología.
[47] Cihlar J, (2000) Land cover mapping of large areas from satellites: status and research priorities. International Journal of Remote Sensing, 21 (6&7): 1093 – 1114.
[48] Wulder M, Franklin, S, White J (2004) Sensitivity of hyperclustering and labelling land cover classes to Landsat image acquisition date. International Journal of Remote Sensing, 25 (23): 5337 – 5344.
[49] Baldyga T, Miller S, Driese K, Gichaba Ch (2007) Assessing land cover change in Kenya´s Mau Forest region using remotely sensed data. African Journal of Ecology, 46: 46 – 54.
[50] Burga C, Klötzli F, Grabherr G (2004) Gebirge der Erde. Landschaft, Klima Pflanzenwelt. Stuttgart. Wissenschaftliche Buchgesellchaft.
[51] LEICA GEOSYSTEMS. (2007) ERDAS Field Guide. Volume Two. Norcross – USA.

[52] ERDAS. (2008) Change Detection. White Paper. Online Material, available: http://www.erdas.com/Libraries/White_Papers/Change_Detection.sflb.ashx [Accessed 13/09/2011]

[53] Ramoelo A (2007) An innovative method to map land cover changes at a country level utilising hyper-temporal satellite images. A case of study of Portugal. International Institute for Geo-information Science and Earth Observation – ITC. Enschede, The Netherlands. Thesis for the degree of Master of Science in Geo-information Science and Earth Observation for Environmental Modelling and Management.

[54] Pontius R, Shusas E, McEachern M (2004) Detecting important land changes while accounting for persistence. Agriculture, Ecosystems and Environment, 101: 251 – 268.

[55] Velázquez A, Mas J, Díaz G, Mayorga S, Alcántara C, Castro R, Fernández T, Bocco G, Ezcurra E, Palacio J (2002) Patrones y tasas de cambio de uso del suelo en México. Gaceta Ecológica (62): 21 – 37.

[56] Plata R (2007) Descripción del crecimiento urbano en la comunidad de Madrid en el período 1987 – 2000 y una aproximación al análisis de factores explicativos. Tutelado del Doctorado en Cartografía, SIG y Teledetección, Universidad de Alcalá.

[57] Pineda N, Bosque J, Gómez M, Plata W (2009) Análisis de cambio del uso del suelo en el Estado de México mediante sistemas de información geográfica y técnicas de regresión multivariantes. Una aproximación a los procesos de deforestación. Investigaciones Geográficas, Boletín del Instituto de Geografía, UNAM (69): 33 – 52.

[58] Lang S, Blaschke Th, (2007) Landschaftanalyse mit GIS. Stuttgart. Verlag Eugen Ulmer Stuttgart.

[59] Ochoa-Gaona S, (2001) Traditional land-use systems and patterns of forest fragmentation in the Highlands of Chiapas, Mexico. Environmental Management, 27 (4): 571-586.

[60] Schulz J, Cayuela L, Echeverría C, Salas J, Rey-Benayas J, (2010) Monitoring land cover change of the dryland forest landscape of Central Chile (1975-2008). Applied Geography, 30: 436 – 447.

[61] Echeverría C, Newton A, Nahuelhual L, Coomes D, Rey-Benayas J, (2012) How landscapes change: Integration of spatial patterns and human processes in temperate landscapes of southern Chile. Applied Geography, 32: 822 – 831.

[62] Gásperi T, (2006) Condición de sedimentación del Embalse Boconó. Propuesta para su estimación futura. Mérida. Centro Interamericano de Investigación Ambiental y Territorial (CIDIAT). Tesis MSc.

[63] Quevedo M, (1997) Análisis de la relación precipitación-escorrentía en la Cuenca Alta del Río Boconó, Estado Trujillo. Trujillo. Universidad de Los Andes - Núcleo Universitario Rafael Rangel. Departamento de Ingenieria. Tesis.

[64] Tekle K, Hedlund L, (2000) Land Cover Changes Between 1958 and 1986 in Kalu District, Southern Wello, Ethiopia. Mountain Research and Development, 20 (1): 42 – 51.

[65] Hidalgo J, (2007) Análisis Geográfico para una propuesta de Area Protegida en el Páramo La Cristalina, Estado Trujillo. Universidad de Los Andes. Facultad de Ciencias Forestales y Ambientales. Escuela de Geografía. Tesis de Grado.

[66] Naiman R, (Edit) (1992) Watershed Management. Balancing Sustainability and Environmental Change. New York. Springer Verlag Inc.

[67] Chang M (2003) Forest Hydrology. An Introduction to Water and Forest. Florida – USA. CRC PRESS. 373 pp.

[68] Ward A, Trimble St (2004) Environmental Hydrology. II Edition. Boca Ratón – USA. LEWIS PUBLISHERS. 475 pp.

[69] Davie T, (2008) Fundamentals of Hydrology. Second Edition. London. Routledge Taylor and Francis Group.

[70] Serneels S, Lambin E (2001) Proximate causes of land-use change in Narok District, Kenya: a spatial statistical model. Agriculture, Ecosystems and Environment, 85: 65 – 81.

[71] Braimoh A, Vlek P (2005) Land-Cover Change Trajectories in Northern Ghana. Environmental Management, 36 (3): 356 – 373.

[72] Etter A, McAlpine C, Wilson K, Phinn S, Possingham H (2006) Regional patterns of agricultural land use and deforestation in Colombia. Agriculture, Ecosystems and Environment, 114: 369 – 386.

Section 2

Analytical Methods/Tools for Environmental Land Use Planning

Chapter 4

Predicting Changes in Regional Land Use Pattern: The Case of Jiangsu Province, China

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Additional information is available at the end of the chapter

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1. Introduction

1.1. Predict changes in regional landscape pattern

Space-time simulation of regional landscape change is important to regional ecological management. Effective policies and measures according to the study on regional landscape could guarantee the regional sustainable development. The simulation of land use change (LUC) is a frequently required but difficult process. To make informed planning decisions must be able to predict land use change. Many land use change models use remotely-sensed images to make predictions based on historical trends. Accurate land use change information is needed for land use policy making and scientific research. Therefore, scientists realized the need to assess the land use change dynamics and related the special situation of the regional pattern. Recently a large number of studies on future land use change have been conducted at regional scale (Andrew Gilg, 2009; Andy, 1997; C. Ma, 2012)

The Marcov mothod of land use change can provide useful result. This research predicts the landscape pattern with the quantity model. Only do the numerical prediction of research regional, without considering the change of landscape form (2D and 3D).

Land use models are core subject of LUCC. In recent years, the LUCC community has produced a large set ofoperational models that can be used to predict or explore possible land use change trajectories (Verburg et al., 2006). The landscape pattern development model, and simulate different situations of the land using change pattern in the future. Investigate and evaluate the system of land using changes in reality and the potential ecological environment influence and feedback process. It have been considered by many researchers that it's revealed with land use system terrestrial ecosystem interaction mechanism. Optimize land using pattern. It's one of the effective ways to reduce the level of risk potential ecological process in the land using process.

The model's biggest significance can predict the future changes and have very good guidance function for scientific decision. On the one hand, according to the former development trend and direction, decide to the driving factors and the weight and make model operate to the different time in the future. Analyze each scene to the change of land using produce situation. This kind of model can build-up mixed related model. The advantage is that it considers the driving factors in model forecasting, Because of much relationship and the resistance in establishing model, it is not easy to cause the scientific results.

About the prediction model of the landscape pattern, including the concept model and mechanism model. it's classified into dynamic model, CA model, system dynamic model (SD model) that is based on cybernetics, System theory and information theory and it's characterized by studying feedback System structure, function and the dynamic behavior dynamic model. Its outstanding characteristic is to reflect the complex System structure, function and the dynamic behavior of the interaction between the relations. So as to study complex System change behavior and trend in different situations, and provide decision supporting (Chen Shupeng, 1999). The existing research shows that system dynamics model can reflect land using system of complex behavior on macroscopic and it is the good simulation tools in land using (Zhang Hanxiong, 1997; van et al., 1999; Li and Simonovic, 2002). Li, such as using the SD model for North America grasslands waters increased temperatures and ice melt water flooding caused by area of various ways simulation, obtained a good simulation results (Li and Simonovic, 2002). ZhangHanXiong applies system dynamics theory to establish Jin Shan loess hilly-gully region soil erosion dynamic SD model. Markov chain models basically does not consider the landscape pattern changes affecting the driving force, only using the past changes of the landscape pattern and the degree of change. According to the mathematical functions, speculated that the future of the landscape pattern utilization condition. It is based on two period of the landscape pattern and use data to calculate the types of land using change as the transition probability ratio. Markov process on matrix calculate to speculate that different stages of the land utilization condition. For example, Turner and Ruscher rules to mesh the study area and use Markov chain model to calculate the change of landscape plaques type probability, plus eight image elements and the effect of land using category, to determine each box type change the landscape of probability matrix (Turner, 1987, 1989; Ruscher, 1988). In order to reduce the general error that using Markov chain prediction model of the landscape pattern condition. Aoki, etc, introduce Hopfield neural network model. First the research in the area of the landscape pattern changes similar degree is divided into several sub-regional (sub-area).again with Markov chain respectively model to calculate the transition probability matrix. Using this method in the central business district in Tokyo, forecast to 2014 years of urban landscape pattern condition (Aoki et al, 1996).

The feasibility of the model is also an important aspect of the model, at present in the big, mesoscale landscape pattern prediction area using model is Markov chain models. This kind of dynamic simulation model using Markov model can forecast a quantitative description of dynamic landscape plaques. Markov transfer matrix make dynamic of landscape patches quantitative (Han Wenquan, 2005). If many in the period of transformation probability are compared, and further explains the change in ecological meaning, it can make the landscape plaques dynamic quantitative research more valuable.

2. Materials and methods

The data of land use and land cover (LULC) were obtained from Chinese Academy of Science. Landsat Thematic Mapper (TM) images for the 1985,1995,2000 and 2005 years after being geometrically registered. They were classified analysis and aggregated into six major land types, they are build-up-up, forest, water ,farm, grass and other land. There are main three types for studying. There are main reasons accounted for selecting this scheme of LULC classification. First, three LULC types represented the dominant ecosystems and reflected the land use in the study area. Second, the selection keeps in accordance with the local official standards for land use classification and at the same time considers the ability of TM images to interpret LULC patterns. The local official standards for land use classification divided the LULC into two hierarchica levels.

2.1. Study area

Jiangsu Province is located in the lower reaches of the Yangtze River, east of the Yellow Sea, at latitude 30 ° 46'N-35 ° 02'N, longitude 116 ° 22'E-121 ° 55'E. The province's total area of

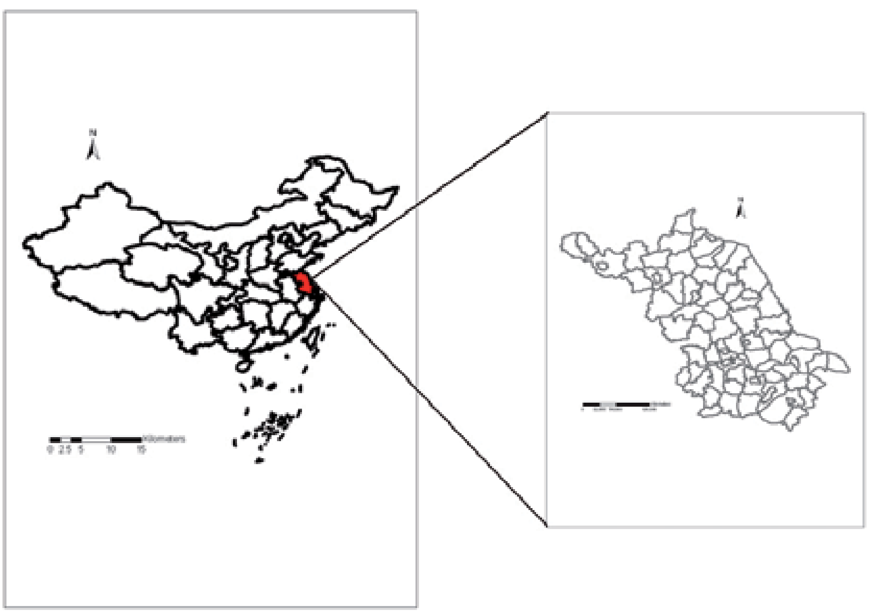

Figure 1. The Study area location map

approximately 102,600 square kilometers, accounting for 1.06% of the total area of 954 km long coastline.

2.2. Method

Markov model has been widely applied in the prediction of urban landscape change, however, it can be amended though the regional socio-economic indicators to improve its forecast accuracy. Based on TM satellite images in different years (1995, 2001, 2005 and 2008), urban land-use change maps were created and analyzed in Taicang County of Jiangsu Province, then a weighed Markov model was established based on the driving force of urban land-use change to predict the urban landscape structure (agricultural land, constructive land, etc.) in 2013. Based on the analysis of driving forces of land-use change, the periods of driving forces were divided into 1995 - 2001 and 2001 - 2005 two stages. The transfer matrixes were used as the weighted factors of Markov model whose weights were calculated to constitute the model in order to build-up a transfer matrix more in line with the urban landscape change in the stage from 2008 to 2013, then the structure of the urban landscape in 2013 was predict. On the basis of status value (2008) of urban landscape, the weighted Markov model was more reasonable than the non-weighted Markov model.

2.2.1. Using Markov model

The Russian mathematician Andrei Andreyevich Markov (1856–1922) developed the theory of Markov chains in his paper "Extension of the Limit Theorems of Probability Theory to a Sum of Variables Connected in a Chain" (Markov, 1907). A Markov chain is defined as a stochastic process fulfilling the Markov property (Eq. (3) with a discrete state space and a discrete or continuous parameter space. In this paper, the parameter space represents time, and is considered to be discrete. In this process, the outcomes of a given experiment can the out come of the next experiment. This type of process is called a Markov chain. Accordingly, a Markov chain represents a system of elements making transitions from one state to another over time. The order of the chain gives the number of time steps in the past influencing the probability distribution of the present state, and can be greater than one.

$$P(\mathrm{X_t} = j \mid \mathrm{x_s} = i) = P_{ij}(s,t) \tag{1}$$

The conditional probabilities are called transition probabilities of order r=t−s from state i to state j .

They are denoted as the transition matrix P. For k states P has the form，The purpose of this section is to introduce the concept of a stochastic complement in an irreducible stochastic matrix and to develop some of the basic properties of stochastic complementation. These ideas will be the cornerstone for all subsequent discussions. It is a non-negative matrix (such a matrix is called stochastic). The transition probabilities matrix can be described as following:

$$P = \begin{bmatrix} p_{11} & p_{12} & \cdots & p_{1k} \\ p_{21} & p_{22} & \cdots & p_{2k} \\ \cdots & \cdots & \cdots & \cdots \\ p_{k1} & p_{k2} & \cdots & p_{kk} \end{bmatrix} \tag{2}$$

At time 0 the initial distribution of states is $P(X_0 = i) = p_i(0) \quad \forall i \in \{1,...,k\}$

The state probabilities pi(t) at time t are estimated from the relative frequencies of the k states, resulting in the vector $P(t) = (p_1(t), p_2(t)....p_k(t))$

Denoting the ν-th observed state with iν, a stochastic chain fulfilling is a first-order Markov chain:

$$P(X_{t+1} = i_{v+1} \mid X_t = i_v, X_{t-1} = i_{v-1}, ..., X_0 = i_0) = P(X_{t+1} = i_{v+1} \mid X_t = i_v) \quad \forall v \geq 2, \forall i_0, i_1, ..., i_{v+1} \in \{1...k\}$$

Predictions of future state probabilities can be calculated by solving the matrix equation

$$p(t) = p(t-1) \cdot P \tag{3}$$

Agriculture land demand data are stochastic time series data, so Markov chain model can be employed to forecast the future data according to historical data. Generally time series data can be divided into a continuous real number zone. In order to use Markov chain model, the continuous real number zone should be divided into finite number unambiguous state sets.

2.2.2. Computation of transition potential

Markov transfer matrix simulate the dynamic landscape pattern not only need to understand a landscape status changes to another landscape the present situation of the process, the more important is clear and the reason for the variation of the landscape pattern. The landscape pattern evolution is the result from a combined effect of natural, economic, social and cultural factors , from the change of landscape pattern driving factors, different driving factors in the landscape pattern change have different functions, establish landscape pattern evolution simulation model of driving mechanism. perhaps is the landscape pattern evolution trend of the development of simulation. The current limit landscape pattern of dynamic simulation of a major reason is the lack of landscape processes and the landscape pattern of the interaction of the understanding and how to integrate this knowledge in the model. The mutual transformation of the landscape, patch and gallery. As the study area of Jiangsu province, the landscape pattern has significantly characteristics. From 1980 to 2005 yr., while the agriculture land area from 1980 in 7.23 km^2 reduced to 2005 years of 6.85 km^2. But in the whole study, regional landscape in the proportion of minimum is 69% (2005 yr.) . So its landscape's substrate position is unshakable. The basal characteristics, the single transfer matrix will not be reflected in the study period. But the whole state as a kind of "information" is retained, how to use this information? Researching needs a model that can have absorbing function for the global information.

Markov process according to system development, time discrete into $k = 1, 2, \cdots, n$, each state with X_k to say, Take n discrete values $X_k = 1, 2, \ldots n$ to introduce the state vector and transition probability vector respectively for

$$\left(A_1(k), A_2(k), \ldots, A_n(k)\right),\ P = \left\{p_{ij}\right\}_{nn}$$

$$A(k+1) = A(k)P$$

Every step of the transition probability can usually through the statistical data to determine, according to all kinds of random factors, the system the whole process of change can usually expressed as

$$X_0 \xrightarrow{P_1} X_1 \xrightarrow{P_2} X_2 \xrightarrow{P_3} \cdots X_{m-1} \xrightarrow{P_m} X_m$$

In the past the study, application Markov process research the process, main is both the math model:

1. $X_{t1} \xrightarrow{p} X_{t2} \xrightarrow{p} X_{t3}$, among $P = P_1 P_2$
2. $X_{t1} \xrightarrow{p_1} X_{t2} \xrightarrow{p_2} X_{t3}$ Use local linearization stages measuring method.

2.2.3. Present problems

The above two models of science has been confirmed. In the actual landscape forecast research, the former method is currently using in the widest range, the last only study in the succession in the forest landscape (XiongLiMin, 1991). The shortage of the Method lies in: （1）In many cases, it is an idealized model by the impact of the initial value (Forman, 1986; Zhao Yi , 2001; ShenJing , 2006). Model sometimes does not reflect the authenticity of the system, the transfer matrix of the simple Markov model with the increase of the transfer step is only related to the most recent time and it's also different with the facts.(2) Segmentation processing methods often require transient from X_{m-1} to X_m or mutant, Rather than a gradual process. If this process is the time span, data integrity, it can be used to describe as P_{t-1} or P_t the status changes.

Otherwise it will cause a large deviation. But the larger regional landscape pattern changes in a gradual process, and began to study the time is not long, such a model can not reflect the actual situation of the regional landscape pattern changes.

Need to construct state transition information on the entire process of absorption of the Bayes method, in order to solve this regional landscape pattern sub- Markov process.

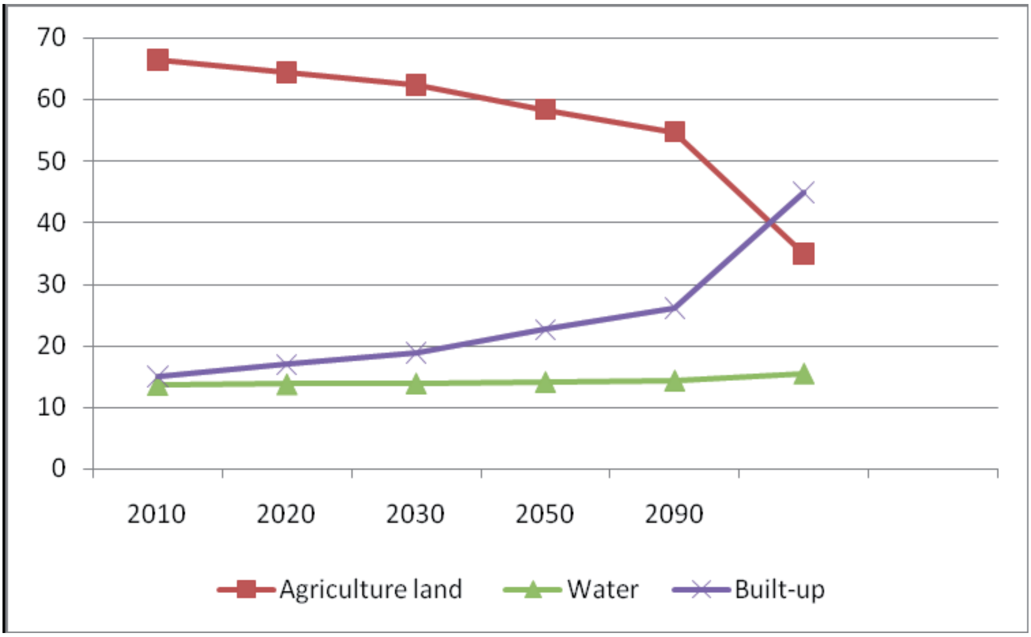

Figure 2. Fig2. Types of land change trends use SM model

2.3. Combination process of Marcov model and Baysian fomula

The change of the landscape pattern is one of the changes of the elements. This change including numbers and forms, Form the landscape pattern change is one of the important research directions in the future. In the stable number of elements, it's better to grasp the landscape pattern. This research predicts the landscape pattern with the quantity model. Only do the numerical prediction, without considering the change of landscape form (2D and 3D). Landscape elements quantity change over time, because of the area of restrictions, the original plaques elements (image element) covered area of change, this state will eventually reach a stable state. The researchers hope to understand the changes among this process . Through the analysis of the development of different opinions predicted results, to explore in this situation, the land using the changes will tend to which direction, what effects. Maybe considering the different degrees of land management policy, predicting the changes and consequences of land using situation in the future.

The changes and the trend of the landscape pattern of Jiangsu province can be used Bayesian-Markov model for research,

There are reasons 1. in research area, different landscape types with mutual transformation can be sex each other 2. Landscape types of mutual transformation between process contains a multiple function relation which can accurate description of events 3. This research data is all kinds of data of land use which is got from TM satellite image data analysis in 1980, 1985, 1995, 2000 and 2005 , largely reflects the changes of landscape in jiangsu province, and to represent the future trend of the development in a certain period 4. GIS technology can provide technical support for establishing a realistic probability transfer matrix 5. This is a practical method which predict short-term changes of landscape structure trend using Markov chain quantitatively. We can consider the effect in the build-uping of model of Markov and proposed the Bayes transition probability model. We will forecast regional changes of landscape structure based on this area.

2.3.1. B-M model

For know initial state X_0 , in the system, we set up its state transition of the prior distribution as $P\left(X_1\right)$. After $P\left(X_k \middle| X_{k-1}\right)$ to X_{k-1} occurred under the conditions of a priori probability distribution. Replacement of the Bayes formula, the a priori probability distribution is amended to get the posterior probability distribution.

First set the state to change the whole process as follows,

$$X_0 \xrightarrow{P_1=P(X_1/X_0)} X_1 \xrightarrow{P_2=P(X_2/X_1)} X_2 \cdots X_{m-1} \xrightarrow{P_{P_1=P(X_m/X_{m-1})}} X_m$$

Among $m \ge 2, P_k = P(X_k / X_{k-1})(k = 1, 2, \cdots m)$ is the state transition probability.

$$P_k = \begin{pmatrix} a_{11}^{(k)} & a_{12}^{(k)} & \cdots & a_{1m}^{(k)} \\ a_{21}^{(k)} & a_{22}^{(k)} & \cdots & a_{2n}^{(k)} \\ \cdots & \cdots & \cdots & \cdots \\ a_{n1}^{(k)} & a_{n1}^{(k)} & \cdots & a_{nm}^{(k)} \end{pmatrix}$$

$$\sum_{j=1}^{n} a_{ij}^{(k)} = 1(i = 1, 2, \cdots, n), k = 1, 2, \cdots, m$$

That the k transition probability matrix, first remove the last three state as follows.

$$X_{\text{m-1}} \xrightarrow{P_{\text{m-1}}} X_m \xrightarrow{P_m} X_{m+1}$$

$$P^{m-1} = P(X_{m-1} / X_m) = \frac{P_{m-1} \cdot P(X_m / X_{m-1})}{P(X_m)} = \frac{P_{m-1} \cdot P(X_m / X_{m-1})}{\sum\limits_j P_{m-1} \cdot P(X_m / X_{m-1})} = \frac{P_{m-1} \cdot P_m}{\sum\limits_j P_{m-1} \cdot P_m}$$

$P^{m-1} = (b_{ij}^{(m-1)})_{1\times n}$ Among $P^{(m-1)}$ is $n \times n$ matrix, defined by

$$b_{ij}^{(m-1)} = \frac{a_{ij}^{(m)} a_{ij}^{(m-1)}}{\sum\limits_{j=1}^{n} a_{ij}^{(m)} a_{ij}^{(m-1)}} \rightarrow \qquad i = 1, 2, \ldots, n \qquad \text{then} \qquad \sum_{j=1}^{n} b_{ij}^{(m-1)}$$

This state transition $X_{m-2} \xrightarrow{P_{m-1}} X_{m-1} \xrightarrow{P_m} X_m$ is revised to $X_{m-2} \xrightarrow{P^{m-1}} X_{m-1} \xrightarrow{P^m} X_m$.
Then revised to $X_{m-3} \xrightarrow{P_{m-2}} X_{m-2} \xrightarrow{P^{m-1}} X_{m-1} \xrightarrow{P^{m-1}} X_m$

$$P^{(m-2)} = P(X_{m-2} / X_{m-1}) = \frac{P_{m-2}P(X_{m-1} / X_{m-2})}{\sum_j P_{m-2}P(X_{m-1} / X_{m-2})} = \frac{P_{m-2}P^{m-1}}{\sum_j P_{m-2}P^{m-1}}$$

set to as follows:

$$P_i^{(m-2)} = (C_{ij}^{(m-2)})_{1\times n}$$

$$C_{ij}^{(m-2)} = \frac{a_{ij}^{(m-2)}b_{ij}^{(m-1)}}{\sum_{j=1}^{n} a_{ij}^{(m-2)}b_{ij}^{(m-1)}} = \frac{a_{ij}^{(m-2)}\left[\frac{a_{ij}^{(m)}a_{ij}^{(m-1)}}{\sum_{j=1}^{n} a_{ij}^{(m)}a_{ij}^{(m-1)}}\right]}{\sum_{j=1}^{n} a_{ij}^{(m-2)}\left[\frac{a_{ij}^{(m)}a_{ij}^{(m-1)}}{\sum_{j=1}^{n} a_{ij}^{(m)}a_{ij}^{(m-1)}}\right]} = \frac{a_{ij}^{(m-2)}a_{ij}^{(m-1)}a_{ij}^{(m)}}{\sum_{j=1}^{n} a_{ij}^{(m-2)}a_{ij}^{(m-1)}a_{ij}^{(m)}} \rightarrow$$

The state transition probability once again amended to next

$$X_{m-3} \xrightarrow{P^{m-2}} X_{m-2} \xrightarrow{P^{m-2}} X_{m-1} \xrightarrow{P^{m-2}} X_m$$

In accordance with the above steps, the final transition probability can be revised to

$$P^{(1)} = P(X_1 / X_2) = \frac{P_1 P(X_2 / X_1)}{\sum_j P_1 \cdot P(X_2 / X_1)} = \frac{P_1 P^{(2)}}{\sum_j P_1 \cdot P^{(2)}}$$

$P^{(1)}$ in i row element $P_i^{(1)}$

$$P_i^{(1)} = \left[\frac{\prod_{k=1}^{m} a_{ij}^{(k)}}{\sum_{j=1}^{n}\left[\prod_{k=1}^{m} a_{ij}^{(k)}\right]}\right]_{1\times n} \quad (i = 1, 2, \cdots, n)$$

This Bayesian - Markov transition probability formula , this model is called as the landscape patch change forecast Bayesian - Markov model (BM model).

2.3.2. Computation of transition by B-M model

From the results of the study in chapter 3,we can see the deceleration of the agriculture land area in our province experiences from increase than sharp decrease than slow decrease and decrease again ,during the process of rapid urbanization, industrialization, on the one hand,scale the construction land use has expanded, valuable agriculture land resources are invaded,on the other hand,in the amount of land in city or development zone, there are scattered layout, land intensive degree lower outstanding problems.At present the notable features is the rapid expansion of the built-up urban scale in the change of land use in Jiangsu province(Zhao YaoYang, 2006),research predict that the population of Jiangsu Province will reach 76.9519 million in 2010 and increase average 0.3086 million every year from 2005 to 2010,but the population will reach 79.192 million by 2020,and increase average 0.2240 million every year from 2010 to 2020,which explain that population growth has a stable state (Yang LiXia, 2006),the development of traffic promotes the Regional towns nearby,for 30 years, jiangsu's traffic will enter the period of big development of network, balanced development situation is clear (han jia, 2008),through the results of this study,we can preliminary judge, the fastest change in regional landscape pattern is in the build-up land in the next period,while the share of agriculture land will be stability have fall.

2.3.3. Summary of the data and the transfer matrix of the generation of landscape

Because this data is made up by two different format in different period, and data of different precision ,at first,they should be unified into the grid of image formats,what's more,we should united them to 1000km * 1000km. Like size of pixel , we can get plaque kind of pixel conversion matrix in Arc Gis spatial analysis.The following were listed four stages patches type number transfer matrix and plaques between the type of transition probability matrix.Due to the limitation of length,we make two transfer number matrix in our four stages, the following table 1 shows for 1980-1985,the following table 2 shows the period of 2000-2005 yr..

Unit 1km^2	Agriculture	Forest land	grass	waters	Build-up land	Other land
Agriculture land	80861	17	0	91	1069	3
Forest land	6	3154	0	0	11	0
grass	17	0	948	4	2	0
waters	19	0	0	10756	7	0
Build-up land	4	0	0	3	4055	0
Other land	0	0	0	0	0	10

Table 1. In 1980-1985, six kinds of number transfer matrix of the landscape types

Unit 1km^2	Agriculture land	Forest land	grass	waters	Build-up land	Other land
Agriculture land	60821	673	85	2159	8359	5
Forest land	638	2490	20	77	177	6
grass	172	22	593	196	121	0
waters	1341	77	79	10447	2890	2
Build-up land	5311	119	40	187	6342	2
Other land	2	6	2	2	0	6

Table 2. In 2000-2005, six kinds of number transfer matrix of the landscape types

From this result,we can generate the transition probability matrix of regional landscape type plaques of the jiangsu province , respectively table3 –table 6,

3. Result

3.1. Model validation

Remote sensing (RS) and geographic information systems (GIS) are essential tools for monitoring land distribution area, and spatial and temporal analysis of wetland dynamic change.

p	Agriculture land(AL)	Forest land(FL)	grass	waters	Build-up land	Other land
AL	9.86E-01	2.07E-04	0.00E+00	1.11E-03	1.30E-02	3.66E-05
FL	1.89E-03	9.95E-01	0.00E+00	0.00E+00	3.47E-03	0.00E+00
grass	1.75E-02	0.00E+00	9.76E-01	4.12E-03	2.06E-03	0.00E+00
waters	1.76E-03	0.00E+00	0.00E+00	9.98E-01	6.49E-04	0.00E+00
Build-up land	9.85E-04	0.00E+00	0.00E+00	7.39E-04	9.98E-01	0.00E+00
Other land	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E+00

Table 3. In 1980-1985 six kinds of transition probability matrix of plaques types

p	Agriculture land	Forest land	grass	waters	Build-up land	Other land
Agriculture land	9.92E-01	3.09E-04	4.94E-05	1.85E-03	6.09E-03	0.00E+00
Forest land	4.73E-03	9.85E-01	0.00E+00	1.58E-03	9.15E-03	0.00E+00
grass	9.60E-02	0.00E+00	7.65E-01	6.43E-02	7.49E-02	0.00E+00
waters	1.66E-03	0.00E+00	4.61E-04	9.97E-01	6.45E-04	0.00E+00
Build-up land	3.30E-03	0.00E+00	0.00E+00	3.89E-04	9.96E-01	0.00E+00
Other land	7.69E-02	0.00E+00	0.00E+00	1.54E-01	0.00E+00	7.69E-01

Table 4. In 1985-1995 six kinds of transition probability matrix of plaques types

p	Agriculture land	Forest land	grass	waters	Build-up land	Other land
Agriculture land	8.69E-01	8.55E-03	2.42E-03	2.14E-02	9.89E-02	3.74E-05
Forest land	1.20E-01	8.29E-01	8.36E-03	1.16E-02	2.93E-02	1.93E-03
grass	4.45E-02	1.67E-02	8.57E-01	5.84E-02	2.09E-02	2.78E-03
waters	3.98E-02	4.83E-03	1.12E-02	9.38E-01	5.92E-03	9.11E-05
Build-up land	2.88E-01	1.36E-02	1.68E-02	2.39E-02	6.57E-01	1.75E-04
Other land	0.00E+00	3.00E-01	0.00E+00	1.00E-01	1.00E-01	5.00E-01

Table 5. In 1995-2000 six kinds of transition probability matrix of plaques types

p	Agriculture land	Forest land	grass	waters	Build-up land	Other land
Agriculture land	8.44E-01	9.33E-03	1.18E-03	2.99E-02	1.16E-01	6.93E-05
Forest land	1.87E-01	7.31E-01	5.87E-03	2.26E-02	5.19E-02	1.76E-03
grass	1.56E-01	1.99E-02	5.37E-01	1.78E-01	1.10E-01	0.00E+00
waters	1.10E-01	6.29E-03	6.46E-03	8.54E-01	2.36E-02	1.63E-04
Build-up land	4.43E-01	9.92E-03	3.33E-03	1.56E-02	5.28E-01	1.67E-04
Other land	1.11E-01	3.33E-01	1.11E-01	1.11E-01	0.00E+00	3.33E-01

Table 6. In 2000-2005 six kinds of transition probability matrix of plaques types

3.2. Analysis of transition matrix

According to 2.1 section,the derivation of process,and the transition probability matrix we get in 2.3 section ,after four times the iterative calculation we can get that in the 1980-2005 study period,considering effect of global information, the leaf Markov transition probability matrix,based on this,we can take 1980, 1985, 1995, 2000 and 2005 years of plaque in the share of landscape type respectively for the initial P0 and the product of the transfer matrix, the landscape pattern change forecast, here to solve the lack of data in 1990, to 1985 years for the initial vector, multiplied by the Bayesian transition probability matrix $P^{(1)}$, (see table 7).

We can get the vector of the occupies plaques of virtual landscape types in 1990, (farmland, forest land, meadow, waters, construction land ,unused land)^T= (78.76588, 3.133267, 0.901077, 10.77607, 5.46728, 0.007758)^T

So we can have a data set of six flags,than we can take the Bayes transition probability matrix $P^{(1)}$ as a step (five years) transfer matrix,because we must consider global effective forecasting methods,the study of data,in this way we can make the data complete,because in the landscape pattern, the basic data of integrity is very common, Markov provides reference method for the missing data of The landscape pattern,at the same time we also must see that when we use this method,we should keep the main character information preserved of the characteristics oflandscape,but this method can't handle mutations,through the raw data we can be see,the area of the build-uping land plaques is nearly doubled during from 1995 to 2000 yr.. The thing which is increasing of the landscape pattern plaques will be weaken because of the global of fusion ways of Bayesian-Markov,we can think that mutations are not resolved, and Bayes framework provides a very good idea. We can add mutations factor in the global transfer matrix. In order to make the prediction based on the stable landscape plaques in this study, the environment of forecast period must be the same with that of 1980-2005.we can take the data of 1980,2000,2005 yr. as the initial state to forecast something,agriculture land, for example,starting share is81.199%in 1980,while he forecast result is 75% if we take the initial state of agriculture land area of 2005. While by the actual measurement data of the gods we can know that in 2000,proportion of agriculture land has less than 70%.But this just shows, feature that the changing proportion in the growth of acceleration in regional landscape pattern plaques. Existing research conclusion points out that when we use Markov models to make prediction, Recent effect of prediction is better than long-term that of prediction (ShenJing, 2006). In order to the reliability prediction, we should choose the data of 2005 to do initial matrix and predict future years. Get table8.

P(1)	Agriculture land	Forest land	grass	waters	Build-up land	Other land
Agriculture land	0.926304	0.000417	2.3257E-05	0.001705937	0.071577	1.3454E-08
Forest land	0.094777	0.851918	0.00278079	0.000916227	0.04962	1.0811E-05
grass	0.060054	0.002472	0.84407206	0.038840138	0.012852	1.9104E-08
waters	0.010645	7.16E-05	0.00016138	0.98	0.009923	1.1433E-08
Build-up land	0.093941	0.00144	0.00029571	0.001649559	0.901701	8.3021E-08
Other land	0.057783	0.722013	0.00013623	0.023523454	0.003758	0.12960613

Table 7. Bayesian transition probability matrix during study period

year	Agriculture land	Forest land	grassland	water	Build-up land	other land
2010	64.60235	2.956314	0.711314685	12.9051	18.78414	0.012721832
2015	62.06647	2.5771644	0.676184411	12.81858873	21.845609	0.009731691
2020	59.96652	2.262479	0.587888366	12.73299	24.40454	0.001291957
2025	58.22519	1.990883	0.513177977	12.64582	26.54399	0.000194895
2030	56.78195	1.760878	0.449939727	12.55778	28.33319	0.00013

Table 8. Bayesian-Markov model to simulate the prediction of proportion of the land type (unit %)

3.3. Analysis result

If we analysis research index of landscape types simply,we can have some knowledge of the landscape pattern.if we want to have further study of the change trend of landscape pattern,we need to do research on the change of type of the landscape or inside structure (Yue TianXiang, 2000). From transfer matrix of the four stages of the landscape plaques, we can see the transfer of the patches of landscape, for example, from the transfer matrix of the plaque-sin 1980-1985,there are 17 zero accounting for nearly half of the total conversion type, in1985-1995 yr. there are 12 zero, in 1995-2000 there are 2 zero,in 2000-2005 yr., in patches transfer matrix, there is only about 1 zero(did not use the land to build-up land type). From this change we can draw a conclusion that is conversion activities in the increase in the regional landscape pattern plaques,change of type of regional landscape plaques enter into the active period around 2000 yr. or so. We can get table 9 through comparing the plaques number of urban construction land. From the table we can see that during agriculture land into land for construction, it experiences that the change of agriculture turning into building-up increased in process of the first and then decreased, rapid increase again. Agriculture land is the main "origin" for the build-uping land plaques.for their own growth of urban construction land use, we can understand their own patch expansion , also can be used as a proof of urbanization. Have to, there are also turn out, the advantage of the transfer matrix is that it can let researchers from two aspects to see a problem.when we take 2000-2005 years of plaques in the land transfer condition built turn out as an example,we will see table 10 for 2005 years to build-up land moved on to turn out and balance in this time. We can see clearly that the water is the second source of the land for construction,in the process of build-uping land expansion. In the study period, the occupation of arable land is very obvious.

	1980-1985	1985-1995	1995-2000	2000-2005
P15	1069	493	7929	8359
P25	11	29	91	177
P35	2	71	15	121
P45	7	7	65	289
P55	4055	5125	5762	6342
P65	0	0	1	0

Table 9. the plaques number of the transfer of the land to build-up in each phase (number of pixel)

	Turn to build-up	Build-up turn to other types	D-value
Agriculture land	8359	5311	3048
Forest land	177	119	58
grass	121	40	81
waters	289	187	102
Build-up land	6342	6342	0
Other land	0	2	-2

Table 10. Interconverting table of build-up land and other types (2005)

From the number prediction of landscape plaques , we can see that after 2005 years land use type change trend for the decrease in the number of agriculture land, forest land reduce more slow, grassland area to reduce slow, build-up the area of land to increase, and after a certain time period of slowing rate increase, unused land is constantly slowly decrease. We can see that at present the landscape pattern is steady change,agriculture land, build-uping land is the biggest patch types of area change. It indicates the landscape pattern in jiangsu province is affected from human activities. Natural landscape in the research area gradually blurred. It is form of urban and rural economic integration of the landscape pattern,if agriculture land diminishing, it is a challenge for the landscape structure based on agriculture land. But at present the implementation of land management policy and considering the effect of global Bayesian-Markov forecast model results show the agriculture land area of landscape plaques , and build-up land types and the rate of change in patches type slow (figure 3). As the economy and population growth,it will be the main form of regional patches type unit bearing capacity of the change of regional landscape pattern, and there are changes in jiangsu province in the future.

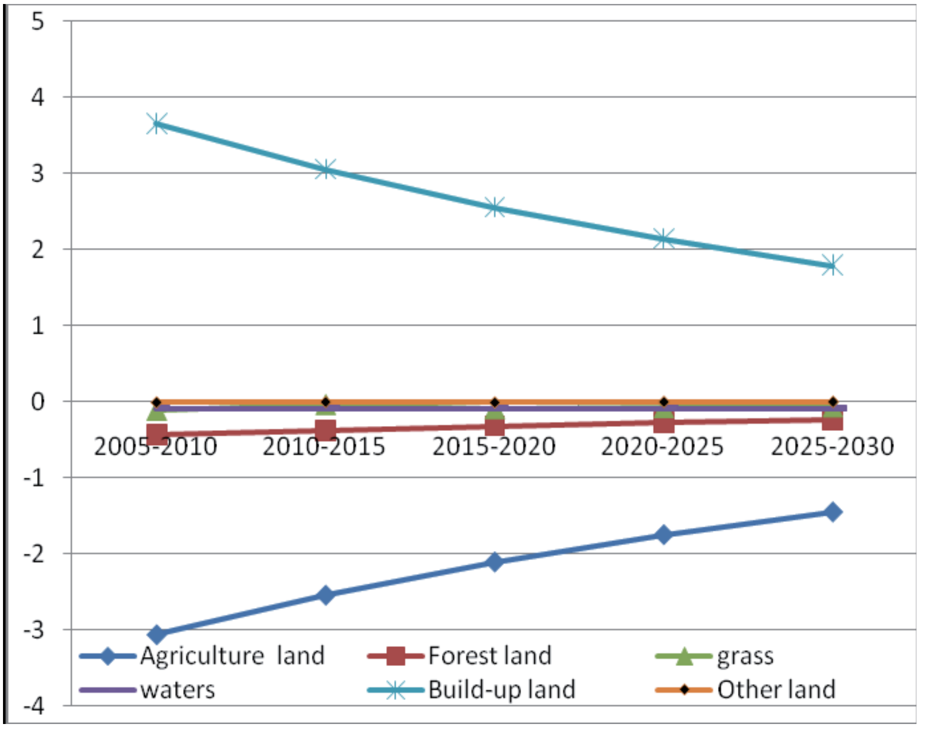

Figure 3. Change difference figure of forecast model of landscape types in different period (%)

4. Conclusion and direction for the future

Bayesian - Markov model landscape pattern of the number of patch types the proportion of change in the whole Jiangsu Province Forecast (2010-2030). Results show that the type of landscape pattern in the region of plaque volume changeson will be leveled off, and arable land remains the matrix characteristics of the region, construction sites still show a growth trend, but not doubling phenomenon around 1995-2000 yr.. Economic, population growth, the region of the plaque type unit bearing capacity increase is the main form of Jiangsu Province regional landscape pattern change, and the layout of the landscape patch types in space is worthy of further study.

It also studied the main driving factors of landscape changes and established a systematic landscape model and made empirical research by using Jaingsu as a subject. The paper's conclusions may offer some essential refernces to the decision making for the regional sustainable development. At last this predict model will use B-M spatial model . This is quantitative model to location model.

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5. References

AndrewGilg. Perceptions about land use Review Article. Land Use Policy, 2009(26): 76-82.

Andy P .Dobson et al. Hope for the future: restoration ecology and conservation biology. Science, 1997(277): 515-525.

Bolker, B.M..Approximate Bayesian Computation (ABC) in practice. Trends in Ecology & Evolution, 2010,25, (7):410-418

C. Ma, G.Y. Zhang, X.C. Zhang, et al. Application of Markov model in wetland change dynamics in Tianjin Coastal Area, China OProcedia Environmental Sciences, 2012(13): 252-262

Peter H. Verburg, C.J.E. Schulp, N. Witte, et al. Downscaling of land use change scenarios to assess the dynamics of European landscapes Agriculture, Ecosystems & Environment. 2006,114(1): 39-56.

Chen Shupeng, Urbanization and Urban Geographic Information System,1999 Environmental Protection Agence (EPA). Landscape monitoring and assessment research plan. Office of Research and Development. Washington, D.C, 1994:221-238

Gert Jan Reinds, Marcel van Oijen, Gerard B.M et al. Bayesian calibration of the VSD soil acidification model using European forest monitoring data Geoderma, 146(3–4): 475-488.

Abraham Tamir . Applications of Markov Chains in Chemical Engineering, 1998 :11-185

He chunyang, Li Jinggang, Shi peijun etal. Modelling scenarios of land use change in northern China in the next 50 years. Journal of Geographical Science, 2005,15(2):177-186

Jamal Jokar Arsanjani, Marco Helbich, Wolfgang Kainz, et al. Integration of logistic regression, Markov chain and cellular automata models to simulate urban expansion, International Journal of Applied Earth Observation and Geoinformation, 2012

Liu Yansui, Ren Zhiyuan. Analysis of the land landscapechanges and its driving mechanism in vulnerable ecological area. Resources Science, 2005, 27 (2): 128-133.

Massimiliano Kaucic . Investment using evolutionary learning methods and technical rules. European Journal of Operational Research, 2010,207(3) : 1717-1727.

MG Turner. Spatial and temporal analysis of landscape pattern.landscape ecology,1990,4(1): 21-30.

Michael Strauch, Christian Bernhofer, Sérgio Koide et al. Using precipitation data ensemble for uncertainty analysis in SWAT stream flow simulation. Journal of Hydrology, 2012, (414-415):413-424

S.Q. Wang, X.Q. Zheng, X.B. Zang. Accuracy assessments of land use change simulation based on Markov-cellular automata model Procedia Environmental Sciences, 2012(13): 1238-1245

Chapter 5

An Integrated Land-Use System Model for the Jordan River Region

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Additional information is available at the end of the chapter

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1. Introduction

The Jordan River region (Israel, Jordan, and the Palestinian National Authority (PA)) is one of the most water scarce regions of the world. The total renewable water resource values in the Jordan River region are 52 to 535 m^3 per capita and year [15], which is far below the threshold value of 1000 m^3 per capita and year indicating chronic water scarcity [14]. On average, water resources withdrawn for agricultural activities, such as irrigated crop production, amount to two thirds of the total actual renewable water resources in the Jordan River region [17]. This makes the agricultural sector the region's major water user and shows the strong regional impact of agricultural land-use activities on water resources. Besides the effect on water resources, land-use activities also have a considerable effect on other natural resources [20]. Examples are desertification caused by maladjusted land management policies [1, 4], biodiversity loss due to habitat destruction and fragmentation [41, 64], and salinization of land induced by irrigation [22]. Current pressures on natural resources in the Jordan River region are likely to aggravate in the future due to high projected population growth rates, economic development, and changing climate conditions. This may cause a further degradation of the region's ecosystems and reduce their capacity to provide ecosystem services in the long run. Hence, there is an urgent need for a better understanding of the complex relationships in these human-environmental systems, in order to develop sustainable management strategies for the use of natural resources in the Jordan River region.

Water resources in the Jordan River region are largely transboundary and their distribution between Israel, Jordan, and PA is a potential source of conflicts. Hence, strategies for sustainable natural resource management in this region have to capture regulations at the state level and have to be based on consistent assessment methods and collaboration between the parties involved. This makes modeling approaches operating at the small scale or approaches focusing solely on natural systems unsuitable. However, existing integrated modeling approaches that cover the entire Jordan River region, such as presented in the Global Environmental Outlook 4 [58], apply spatial resolutions that are too coarse to capture the biophysical heterogeneity in the region, which is governed by a steep precipitation gradient [13].

In order to gain a better scientific understanding of the linkages between natural resources, land management, and ecosystem functioning in the Jordan River region, we developed the integrated modeling system LandSHIFT.JR (Land Simulation to Harmonize and Integrate Freshwater Availability and the Terrestrial Environment - Jordan River). LandSHIFT.JR is based on the spatially explicit land-use model LandSHIFT [49] and covers Israel, Jordan, and PA. It applies a cellular automata approach to calculate land-use changes and corresponding irrigation water requirements under current and future climate conditions. LandSHIFT.JR operates on a regular grid with a spatial resolution of 30 arc seconds. It was tailored specifically to the environmental and socio-economic conditions in the Jordan River region [28, 29]. Since scarce water resources, vegetation degradation due to overgrazing, detrimental effects of climate change on crop yields and irrigation water requirements, and increased soil salinity caused by irrigation are the major environmental issues in the Jordan River region, LandSHIFT.JR explicitly addresses these issues. This distinguishes LandSHIFT.JR from other integrated land-use modeling systems operating at a similar spatial resolution and scale, e.g. the CLUE(-S) model [61, 62]. LandSHIFT.JR simulates the spatial and temporal dynamics of land-use systems in the Jordan River region and allows exploring the impact of alterations in socio-economic and biophysical conditions on the spatial distribution and intensity of land-use activities and the feedback of land-use changes on socio-economic conditions. The modeling system's main field of application is the simulation of spatially explicit, mid- to long-term scenarios of land-use change. These scenarios show trends in land use and support the identification of hot spots of change and competition for land. Thus, spatially explicit land-use change scenarios generated with LandSHIFT.JR provide scientific support for evaluation and formulation of sustainable land-use planning and promote informed decision making.

The objective of this chapter is to provide a comprehensive description of the integrated modeling system LandSHIFT.JR and of its validation. Moreover, we present an example of an application of LandSHIFT.JR - a scenario-based assessment of land-use changes in the Jordan River region. In section 2, a short description of the biophysical conditions and the most important land characteristics of the Jordan River region is provided. In sections 3 to 5, a detailed description of LandSHIFT.JR is given. The description focuses on the underlying concepts of the modeling system as well as on the distinctive features of LandSHIFT.JR. The structure of these sections follows the "Overview, Design concepts, Details" protocol for model descriptions as proposed by [23] and is based on a description of an earlier version of LandSHIFT.JR [30]. Sections 6 and 7 provide overviews of the validation of LandSHIFT.JR and the results of an application example, respectively. The chapter closes with a discussion of and conclusions on the integrated modeling system, its validation, and simulation results in section 8.

2. The Jordan River region

LandSHIFT.JR was developed for Israel, Jordan, and PA (Fig. 1). The Jordan River region is bordered by Lebanon and Syria in the North, by Iraq and Saudi Arabia in the East, by Egypt in the Southwest, and by the Mediterranean Sea in the West. The region ranges from 34.22°E, 29.19°N to 39.30°E, 33.38°N. The terrain in the Jordan River region is very heterogeneous. The Coastal Plain, stretching along the Mediterranean Sea, is flanked by the Negev desert in the

Southeast and a mountainous region in the East and Northeast. In the North, the mountains force the coastal air masses to rise and, as a result, induce relatively high precipitation amounts [13]. A key physiographic feature of the Jordan River region is the Great Rift Valley in which the Jordan River, Lake Tiberias, and the Dead Sea are located. With 407 m below sea level, the Dead Sea marks the lowest point in the region and on the Earth's surface. The highland area in the Western part of Jordan, located along the Great Rift Valley, rises to elevations of 1200 m above sea level and drops gradually in elevation towards the East, where it develops into the Jordan desert plateau [13]. The point with the highest elevation in the Jordan River region is the Jabal Umm ad Dami, located in the South Jordan desert, with about 1854 m above sea level.

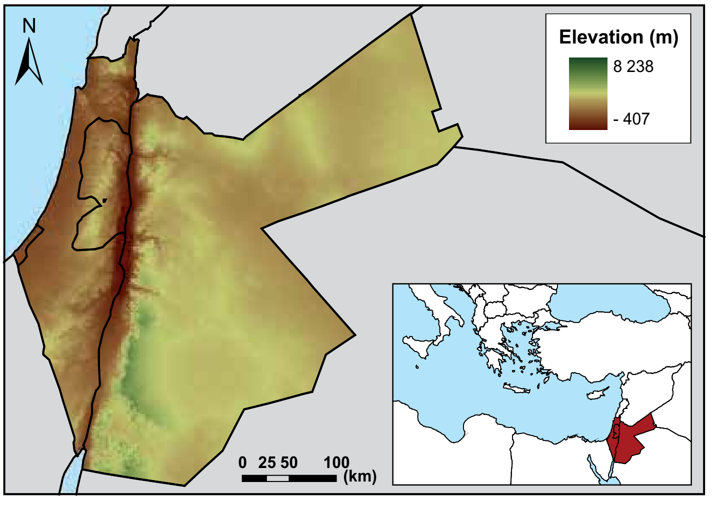

Figure 1. The study region covers Israel, Jordan, and the Palestinian National Authority.

The climate in the Northern, Central, and Western part of the Jordan River region is Mediterranean, characterized by hot, dry summers and cool winters [13]. In the residual part of the Jordan River region a semi-arid to arid climate predominates. A dominant feature of the regional climatic conditions is the steep precipitation gradient, ranging from 900 mm mean annual precipitation in the Northern tip of Israel to less than 50 mm in the desert areas in the South of Israel and the South and Southeast of Jordan. Temperatures also exhibit a high spatial variability across the Jordan River region with cold winters and hot summers in the mountainous regions and more moderate extremes in the Rift Valley and the Coastal Plain [13].

The Jordan River region covers about 116 thousand km^2 of land area and 1 thousand km^2 of inland water area. Approximately 76.1% of the land area in the region is located in Jordan, 18.7% in Israel, and 5.2% in PA [18]. About 2600 km^2 in the region are forest area. Arable land and permanent cropland sum up to about 9200 km^2. Approximately 3000 km^2 in the Jordan River region are equipped for irrigation. Thereof about two thirds are located in Israel. About 14 million people live in the Jordan River region [18]. The largest cities in the study region are Amman, Jerusalem, Tel Aviv, and Gaza.

3. Overview

3.1. Purpose

LandSHIFT.JR is a regional version of the integrated modeling system LandSHIFT [49]. It was adjusted and further developed to specifically simulate the spatial and temporal dynamics of land-use systems in the Jordan River region. LandSHIFT.JR was designed for exploring the effects of changes in socio-economic, climatic, and biophysical conditions on the spatial distribution and intensity of land-use activities. In addition, LandSHIFT.JR serves as a tool to formalize knowledge on and gain new insights into the functioning of land-use systems in the Jordan River region. It can be used to test hypotheses about processes and interlinkages within land-use systems, promote the understanding of these systems by identifying key processes and their interlinkages, and, as a result, reveal demands for future research activities.

LandSHIFT.JR's main field of application is the simulation of spatially explicit, mid- to long-term future scenarios of land-use and land-cover change. These scenarios explore possible trends in land use and visualize alternative land-use configurations. Main model output are maps displaying changes in land-use patterns. These maps help to reveal hot spots of land-use change and allow for the identification of priority areas for further research or focus areas for alternative management strategies. By these means, spatially explicit land-use change scenarios generated with LandSHIFT.JR provide scientific support for the evaluation and formulation of sustainable land-use planning and promote informed decision making.

3.2. State variables and scales

The representation of land-use systems in LandSHIFT.JR is operationalized on interacting spatial scale levels. On these scale levels, the state variables of the modeled land-use systems are defined. In total, there are four different spatial scale levels:

- **Macro level:** The spatial definition of the macro level is based on states. The state of a macro-level entity (i.e. a state) is specified by the state variables *population*, *crop demand*, *livestock number* (goats and sheep), *yield change* driven by technological progress, and *fraction of irrigated crop production* in total crop production. The state variables *crop demand*, *yield change*, and *fraction of irrigation area* are specified separately for each crop category. Changes in macro-level state variables constitute driving forces of land-use change in LandSHIFT.JR.
- **Intermediate level I:** The spatial scale hierarchy of LandSHIFT.JR includes a level based on natural regions. This scale level allows including information on crop demands with a higher spatial resolution such as the output from economic land-use models [26]. The only state variable specified on this level is *crop demand*. This state variable is specified separately for each crop category; a change in *crop demand* constitutes a driving force of land-use change in LandSHIFT.JR. *Crop demand* can only be specified on one spatial scale level. In case it is specified on the macro level, it cannot be specified on the intermediate level I and vice versa.
- **Intermediate level II:** The spatial configuration of the intermediate level II is specified by a regular grid with a spatial resolution of 0.02 decimal degrees (dd), which equals

approximately 2.2 km at the equator. The state variables defined on this level include potential *irrigated wheat yields*, potential *rainfed wheat yields*, and *net irrigation water requirements*. Changes in potential yields are considered to be drivers of land-use change.

- **Micro level:** The geographic area of each state is specified by the micro level - a regular grid with a uniform cell size of 30 arc seconds, which equals about 0.00833 dd or 1 km at the equator. The state of a micro-level grid cell is specified by the state variables dominant *land-use type*, *settlement area*, *population density*, *stocking density* for sheep and goats, *net primary productivity* (NPP) of rangeland and natural vegetation, *relative human appropriation of net primary production* (rel. HANPP [25, 29]), and *crop production*. The latter is defined separately for each crop category. Furthermore, a set of quasi-static landscape characteristics (e.g. slope) and land-use constraints (e.g. conservation areas) are defined on the micro level.

LandSHIFT.JR applies a 5-year time step. The length of the simulation period depends on the research question the respective simulation experiment is supposed to answer and typically ranges between 20 and 50 years. After each simulation step, LandSHIFT.JR writes the simulation results to files. This output comprises micro-level maps displaying the dominant land-use and land-cover type, population density, net irrigation water requirements, stocking density, and rel. HANPP. Moreover, the output includes a set of indicators and area statistics aggregated to the macro level.

3.3. Process overview and scheduling

The processes implemented in LandSHIFT.JR are organized in three modules (Fig. 2), which operate on the different spatial scale levels by modifying the scale-specific state variables. The **Biophysics module**, which describes the environmental subsystem, comprises process representations for the calculation of potential irrigated and rainfed wheat yields, net irrigation water requirements, and NPP of rangeland and natural vegetation. All the variables provided by the Biophysics module are climate dependent and, hence, differ between climate scenarios. This module operates on the intermediate level II and on the micro level. The **Socio-economy module** and the **Land Use Change module** (LUC module) represent the human subsystem. The Socio-economy module provides information on population growth, agricultural production and trade (implemented via the state variables crop demand and livestock numbers), and yield change due to technological progress. The processes of this module operate on the macro level and, in case crop demands are specified with a higher spatial resolution, also on the intermediate level I. For each simulation step, the Biophysics module and the Socio-economy module are executed and the corresponding state variables are updated. Subsequently, the updated information is used by the LUC module to simulate changes in land use and land cover. The processes of the LUC module operate on the micro level. Bidirectional information exchange between the modules is implemented via the exchange of the state variables.

The LUC module calculates the extent and location of land-use and land-cover changes. Therefore, it implements four land-use activities: housing and infrastructure, irrigated crop production, rainfed crop production, and livestock grazing. The processes representing the different land-use activities are organized in submodules: **METRO** for housing and

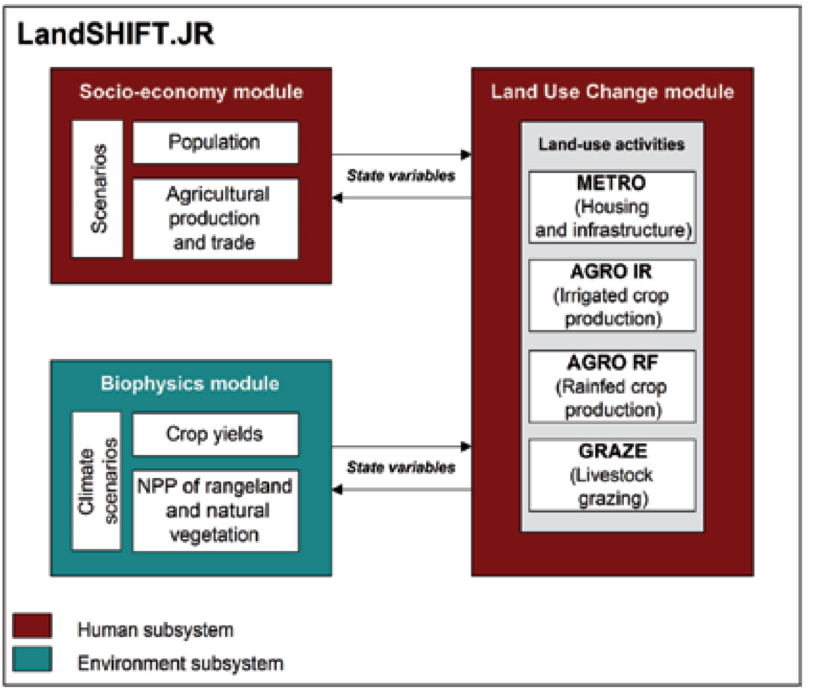

Figure 2. Conceptual structure of the integrated modeling system LandSHIFT.JR, adapted from [48].

infrastructure, **AGRO IR** for irrigated crop production, **AGRO RF** for rainfed crop production, and **GRAZE** for livestock grazing. The competition between these activities for land is addressed by a ranking of the four activities, which defines the sequence of execution. The ranking can be defined flexibly based on the research question; a straightforward way of ranking land-use activities is to follow their economic importance: METRO ▷ AGRO IR ▷ AGRO RF ▷ GRAZE. In one simulation step, cells occupied by a superordinate land-use activity are unavailable for a subordinate land-use activity.

In every simulation step, each land-use activity submodule executes the functional parts **demand processing**, **preference ranking**, and **demand allocation**. This complies with the generalized structure of spatially explicit land-use change models as presented by [63]. First, within the demand processing part, driving forces of land-use change are converted to macro-level/intermediate level I demands for services (e.g. housing) and agricultural commodities. Second, within the preference ranking part, the suitability of the micro-level grid cells for the different land-use activities is assessed, resulting in suitability maps. The grid cells are then ranked based on their suitability. Third, within the demand allocation part, each land-use activity manipulates the dominant land-use type as well as the corresponding state variable (population density for METRO, irrigated crop production for AGRO IR, rainfed crop production for AGRO RF, stocking density for GRAZE) of the best-suited micro-level grid cells, in order to meet the demand for the service or agricultural commodity under consideration. The range and magnitude of change is constrained by the demand for the service or agricultural commodity on the one hand and by the supply, i.e., the productivity on the particular micro-level grid cells on the other hand.

4. Design concepts

The choice of design concepts was guided by the purpose of the modeling system as described in section 3.1. LandSHIFT.JR combines a set of different design concepts that can be specified as a dynamic, integrated, process based, and spatially explicit.

Research questions that land-use modeling typically addresses are related to the timing and rate of land-use changes [35]. A prerequisite for the representation of the temporal behavior of land-use systems is a dynamic modeling approach [63]. LandSHIFT.JR applies such a dynamic modeling approach. It subdivides the simulation period into several time steps and, hence, fulfills the basic requirements for the simulation of land-use change trajectories, feedbacks, and path dependencies in the evolution of land-use systems.

According to [2], integrated modeling systems have to include information from more than one discipline, organize information in a modularized program structure, and link scientific findings with policy analysis. LandSHIFT.JR was developed to bring together information from different disciplines to support decision making and it is typically applied in the context of scenario analyses with strong relevance for land-use planning and policy [29, 31]. Furthermore, it provides a framework for the combination of biophysical and socio-economic information with geographic information in form of a modularized program structure.

LandSHIFT.JR applies a process-based modeling approach in order to describe the land-use systems of the Jordan River region as human-environmental systems and to explore the interlinkages between their subsystems. The modeling system includes representations of the key processes resulting in changes in human-environment systems. As pivotal process, LandSHIFT.JR implements human decision making with regard to the extent, location, and intensity of land-use activities. The process-based approach allows analyzing trajectories and intermediate states of land-use and land-cover change [63].

Spatially explicit land-use models simulate changes in land use for individual spatial entities [63]. In case of LandSHIFT.JR these spatial entities are cells of a regular grid. Spatially explicit models, such as LandSHIFT.JR, are able to simulate the location and spatial variability of land-use and land-cover changes and, as a result, enable the analysis of the interlinkages between socio-economic and biophysical environments as well as variations in location and quantity of land use.

5. Details

5.1. Initialization

Since LandSHIFT.JR integrates data from different fields and sources, considerable effort is required to synchronize the different datasets in an initial simulation step. In order to harmonize the information on population density and the land-use/land-cover map information on urban areas, LandSHIFT.JR initially reads the basic land-use/land-cover map (derived from the MODIS global land cover dataset [21]). This information is then combined with the micro-level information on population density [8]. On micro-level grid cells, at which the land-use type is not “urban”, but where the population density exceeds the upper limit for population density in rural regions, the land-use type is changed to “urban”. Furthermore, spatial information on population density is combined with information on per capita area demands [12] in order to calculate the settlement area on non-urban grid cells; this area is not available for land-use activities such as crop production or livestock grazing.

Available land-use/land-cover map products for the Jordan River region do not distinguish between area under crop for different crops. Furthermore, grazing areas are not assigned separately. Hence, an initial distribution of rangeland as well as area under crop for the considered crop categories has to be generated artificially. In order to derive the initial distribution of area under crop, LandSHIFT.JR distributes areas for the different crop categories to the best suited micro-level grid cells (see section 5.3.3). These areas under crop are derived from national statistics for Israel[1], Jordan[2], and PA[3] for the year 2000. Based on the MIRCA2000 dataset [44], double cropping is assumed for rainfed and irrigated vegetables in all three states. The applied area values are displayed in Table 1. The best suited micro-level grid cells, on which these areas are distributed, are preferably those cells that are categorized as "cropland" in the underlying land-use/land-cover map. The distribution of areas under crop is carried out separately for irrigated and rainfed crop production. In case grid cells categorized as "cropland" in the underlying map are not categorized as one of the considered crop categories during initialization, their land-use type is set to "other crops" and kept static for the rest of the simulation run. This is based on the assumption that "cropland" in the original land-use/land-cover map also includes areas covered with crops that are not contained in one of the considered categories and that for these crops no drivers are specified as model input.

State	IR fruits [km^2]	IR vegetables [km^2]	IR cereals [km^2]	RF fruits [km^2]	RF vegetables [km^2]	RF cereals [km^2]	Rangeland [km^2]
Israel	661.4	253.6	643.0	162.6	22.1	1206.9	1480
Jordan	348.2	155.3	110.3	521.3	9.1	1045.5	7910
PA	81.6	67.1	26.8	1092.9	19.9	440.4	1500

Table 1. Cropland and rangeland areas derived from national statistics and FAOSTAT [18] used to initialize cropland and rangeland area distribution in LandSHIFT.JR.

Based on the resulting land-use type distribution, LandSHIFT.JR relates the macro-level production $pcens_c$ for each of the irrigated and rainfed crop categories c (derived from census data) to the sum of the local production on grid cells with that crop category in the newly generated map $pcalc_c$. This is done in order to calculate a separate management parameter $base_c$ for each of these categories. The management parameter is defined as $base_c = pcens_c / pcalc_c$. It accounts for inconsistencies between different data sources and uncertainties due to agricultural management strategies (e.g. multiple cropping, fertilization) that affect the total production of a crop but are not explicitly considered in LandSHIFT.JR. Crop production values applied in this context are[4]: about 1.78 million tonnes of fruits (Israel: 1.304 million tonnes, Jordan: 0.232 million tonnes, PA: 0.246 million tonnes), about 3.01 million tonnes of vegetables and melons (Israel: 1.643 million tonnes, Jordan: 0.825 million tonnes, PA: 0.541 million tonnes), and about 0.27 million tonnes of cereals (Israel: 0.183 million

[1] http://www1.cbs.gov.il/reader/cw_usr_view_Folder?ID=141
[2] http://www.dos.gov.jo/dos_home_e/main/index.htm
[3] http://www.pcbs.gov.ps/Default.aspx?tabID=1&lang=en
[4] All values derived from FAOSTAT are given as 3-year average for the years 1999-2001.

tonnes, Jordan: 0.044 million tonnes, PA: 0.041 million tonnes). The crop specific management parameter is evaluated for initial conditions and is applied in the following simulation steps in order to adjust the yield values and, as a result, transfer potential crop yields into actual yields. Based on irrigated area under crop, rainfed area under crop, and the adjusted crop yields, the fraction of irrigated crop production in total crop production is calculated. This parameter is also invariant.

There are two different modes available in LandSHIFT.JR for calculating the initial distribution of rangeland and the related stocking densities for small ruminants: a production-driven approach and an area-driven approach. For the production-driven approach, the forage demand is allocated to the best suited micro-level grid cells and the land-use type of these cells is converted to "rangeland". The forage demand is calculated from livestock numbers derived from statistical data and the forage demand per animal [40]. Livestock numbers used in this context were derived from FAOSTAT [18] and amount to 0.4 million sheep and goats in Israel, 2.2 million sheep and goats in Jordan, and 0.9 million sheep and goats in PA. For the area-driven approach, rangeland area for the year 2000 (also derived from FAOSTAT, Table 1) is allocated to the best suited micro-level grid cells. The land-use type of these grid cells is set to "rangeland". The stocking densities on the rangeland cells are then calculated from the local NPP of rangeland and natural vegetation and the forage demand per sheep or goat.

5.2. Input

LandSHIFT.JR input comprises time series on population, crop demands, yield change due to technological progress, livestock numbers as well as socio-economic information, e.g. on environmental policies or regional planning. For the application example presented in this chapter, this information is derived from the participatory scenario exercise of the GLOWA Jordan River project[5]. An overview of the scenarios and the corresponding values for the drivers of land-use change is given in [6]. Besides the above mentioned input specified on the macro level and/or intermediate level I, LandSHIFT.JR requires data on landscape and land-use characteristics specified on intermediate level II and on the micro level. This category of input includes potential crop yields and NPP under current and future climate conditions or landscape attributes such as slope or river network density. A detailed description of the data input on landscape and land-use characteristics is given in section 5.3.4.

5.3. Submodels

The processes in LandSHIFT.JR are organized in the three submodels Biophysics module, Socio-economy module, and LUC module. The details of these submodels are described in this section.

5.3.1. Biophysics module

In each simulation step, the Biophysics module updates the state variables potential irrigated wheat yields, potential rainfed wheat yields, net irrigation water requirements, and NPP of rangeland and natural vegetation. The updated information is then provided to the LUC

[5] http://www.glowa-jordan-river.de

module. The calculation of wheat yields and irrigation water requirements is based on the output of the dynamic, process-based crop growth model EPIC [67, 68]. In order to include future progress in the agricultural sector such as new management methods or fertilizers into the crop yield calculations, yields are corrected with a state-specific factor for yield change due to technological progress. The calculation of the state variable NPP of rangeland and natural vegetation is based on output of WADISCAPE [34]. In contrast to the wheat yield calculations, no effect of technological change on productivity is taken into account. This is based on the assumption that small ruminant grazing in the Jordan River region usually takes place on largely unmanaged marginal lands. The impact of changing climate conditions is considered for wheat yields, irrigation water requirements, and NPP. This is realized by a correction for climate change based on a linear interpolation between the productivities or water requirements calculated for current climate conditions and the respective productivities or water requirements calculated for future climate conditions given by regional climate simulations for the Jordan River region [53].

GEPIC. We applied GIS-based EPIC (GEPIC) [37], a combination of the crop growth model EPIC [67, 68] with a GIS, to simulate wheat yields and crop water requirements under current and future climate. EPIC has been used successfully to simulate crop yields under a wide range of weather conditions, soil properties, and management schemes [37]. EPIC works on a daily time step and considers the major processes in the soil-crop-atmosphere-management system [67]. We used simulated potential yield under rainfed and optimal irrigated conditions for wheat as a proxy crop type. In order to derive irrigated/rainfed yields for the crop categories fruits, vegetables, and cereals from irrigated/rainfed wheat yield, an additional processing step was required. We multiplied the grid cell values of potential wheat yield by the ratio of mean actual yield for an irrigated/rainfed crop category to the mean potential yield on irrigated/rainfed areas covered by the crop category. This step was based on values for the year 2000. The actual yields stem from IMPACT model [45] calculations that were also used to provide input on future crop production. By this means, we ensure the consistency of yield values between the various model drivers and inputs. At the same time, we are able to include spatial and temporal variability of the crop yield simulations with GEPIC in our analysis.

WADISCAPE. The WADISCAPE model [34] provides information on stocking capacities[6] as well as information on the relationship between stocking density with small ruminants (goats and sheep) and productivity of green biomass[7] under current and future climate conditions. WADISCAPE simulates the growth and dispersal of herbaceous plants and dwarf shrubs in artificial, fractal wadi landscapes (wadiscapes) of 1.5 km $\times$ 1.5 km. The main exogenous driver of vegetation dynamics in WADISCAPE is water availability, which is calculated from precipitation under consideration of topography. The simulation of vegetation dynamics is based on validated small-scale models of annual plants [33, 34] and dwarf shrubs [38]. WADISCAPE simulations were conducted for five climatic regions (arid to mesic Mediterranean) and, in factorial combination, five varying slope categories (0° to

[6] Stocking capacity is defined as the number of sheep and goats per hectare for which the green biomass production provides enough food in nine of ten years in year-round grazing [34].

[7] In this context, green biomass is defined as the aboveground biomass of herbaceous plants and leaf mass of dwarf shrubs.

30°). In order to determine the stocking capacity of the vegetation, these simulations were conducted for stocking densities ranging from 0 to 10 animals per hectare.

5.3.2. Socio-economy module

The Socio-economy module operates on the macro level and, if crop demand information with a higher spatial resolution is included, additionally on the intermediate level I. The module accounts for the organization and processing of the state variables population, crop demand, livestock number, and changes in crop yield due to technological progress. For historical periods, information on these state variables is derived from statistical databases (e.g. FAOSTAT [18]). For future periods, this information is typically generated with participatory scenario development, following the SAS approach [3] and the economic model IMPACT [45]. An update of the state variables is carried out by the Socio-economy module within each simulation step.

IMPACT. The International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT), a representation of a competitive global market for agricultural commodities [45], was designed for the analysis of current conditions and possible future developments in food demand, supply, trade, prices, and malnutrition outcomes. The model covers 32 commodities and 36 countries/regions linked through trade and, hence, accounts for almost all of the world's food production and consumption. IMPACT is based on a system of supply and demand elasticities implemented via linear and nonlinear equations. It incorporates demand as a function of price, income and population growth, and changes in crop production. The changes in crop production are determined on the basis of crop prices and productivity growth rates [45].

SAS. The SAS (Story And Simulation) approach to scenario analysis [3] combines both, quantitative and qualitative aspects of scenarios. The combination of those two aspects makes the resulting scenarios on the one hand generally understandable and on the other hand suitable for planning purposes. Distinctive features of SAS are the iterative structure and the intensive participation of experts and stakeholders. A detailed description of SAS is provided by [3]; a description of the SAS application in the context of a scenario analysis for the Jordan River region is given in [6]. Results from this scenario analysis were used to derive information on future development of population and livestock numbers in the Jordan River region for the application example (see section 7).

5.3.3. Land Use Change module

The LUC module is the central component of LandSHIFT.JR. The module accomplishes the simulation of the location and quantity of land-use and land-cover changes. This is realized by a regionalization of the macro-level/intermediate level I demands for area intensive services and agricultural commodities to the micro level. The basic principle is to allocate the demands to the most suitable micro-level grid cells by changing the land-use type, population density, crop production or livestock density of as many cells as required to meet the demand. Each service or commodity is linked to a land-use type. The LUC module implements the submodules METRO (housing and infrastructure), AGRO IR (irrigated crop production), AGRO RF (rainfed crop production), and GRAZE (livestock grazing). In every simulation step, these four submodules are executed subsequently and each of this submodules executes the three functional parts demand processing, preference ranking, and demand allocation. In the following, the general operating mode of the functional parts is described.

Demand processing. The functional part demand processing is responsible for the transformation of the drivers of land-use change to macro-level/intermediate level I demands for the implemented services and commodities.

Preference ranking. The functional part preference ranking operates on the micro level and serves for the identification and ranking of the preferred grid cells for the different land-use activities and the corresponding land-use types. A method from the field of Multi Criteria Analysis [11] is applied in order to calculate the preference values of the grid cells for the different land-use types. The preference value ψ_k of a grid cell k is calculated as

$$\psi_k = \underbrace{\sum_{i=1}^{n} w_i f_i(p_{i,k})}_{\text{suitability}} \times \underbrace{\prod_{j=1}^{m} g_j(c_{j,k})}_{\text{constraints}} \tag{1}$$

with $\sum_i(w_i) = 1$ and $f_i(p_{i,k})$, $g_j(c_{j,k}) \in [0,1]$. The first part of the equation is the sum of the different weighted suitability factors p, contributing to the suitability of a grid cell k for a particular land-use type. The weights w determine the importance of a suitability factor in the analysis. The factor weights were determined according to the CRITIC method [10]. This method allows the calculation of "objective weights" on the basis of the contrast intensity between the evaluation criteria, i.e., the standard deviation of normalized criteria values and the inter-criteria correlation. The second term of the equation is the product of the land-use constraints c. These constraints reflect important aspects of human decision making, e.g. land-use restrictions in conservation areas. One constraint implemented in LandSHIFT.JR is the transition between the different land-use types: not all land-use and land-cover types can be converted into each other. These conversion elasticities are a frequently used method in the field of land-use modeling [62]. A summary of all possible conversions is given in Table 2.

From / To	Urban	IR cropland	RF cropland	Rangeland	Set aside	Natural veg.
Urban	+	-	-	-	-	-
IR cropland	+	+	-	-	+	-
RF cropland	+	+	+	-	+	-
Rangeland	+	+	+	+	-	-
Set aside	+	+	+	+	+	-
Natural veg.	+	+	+	+	-	+

Table 2. Land-use transition matrix. Possible conversions are indicated by "+", impossible conversions are indicated by "-".

The suitability factors, their weights, and the land-use constraints are specified on the macro level and implemented as time-dependent variables. This enables the representation of changing policies and environmental boundary conditions. Suitability factors and constraints are normalized by factor-specific value functions f and constraint specific value functions g. Value functions, based on logistic regression analysis, can be defined as positive or negative relationships and are scaled by the range of the respective factor within a state in order to account for the spatial heterogeneity.

Suitability factors and constraints can be state variables, landscape attributes, zoning regulations, or spatial neighborhood characteristics. The neighborhood of the micro-level grid cells is analyzed in each simulation step in order to generate information about the land-use/land-cover type of the adjacent cells. The neighborhood of a cell can be defined by type and order, e.g. von Neumann or Moore neighborhood. Additionally, a (geographic) search radius can be specified. The set of relevant suitability factors and land-use constraints, the types of value functions, and the factor weights can be derived either by data driven procedures (e.g. geostatistical analysis) or by expert knowledge (e.g. by means of the Analytical Hierarchy Process [46]).

Demand allocation. The functional part demand allocation assigns the macro-level and intermediate-level I demands for the implemented services and commodities to the micro-level grid cells with the highest preference for the associated land-use type. For this functional part, each land-use activity implements its own allocation strategy:

- **METRO.** The submodule METRO simulates the spatial and temporal dynamics of area for housing and infrastructure. Changes in quantity and location of this area are driven by alterations in population numbers, specified on the macro-level. The demand allocation procedure for METRO distinguishes between municipal regions and rural regions. Depending on the category, a different kind of growth process is applied. Therefore, the micro-level grid cells are grouped into these two categories. A municipal cell is defined as a cell that features the land-use type "urban" or has at least one grid cell with the land-use type "urban" in its direct neighborhood. All other cells are defined as rural cells. The growth of urban areas is implemented as urban encroachment process [69], i.e., new area for housing and infrastructure is located at the edges of existing urban area [54].

  In order to allocate additional population, a three-step procedure is applied. First, a parameter defines the fractions of the additional population that is assigned to municipal and rural regions, respectively. Second, depending on the grid cell's actual population density and suitability values, additional population is allocated. On cells with the land-use type "urban", an upper threshold for population density is defined, which limits the population amount that can be allocated to these grid cells. Third, based on the recalculated population densities, land-use conversions are calculated: rural cells feature a threshold value for population density. In case, this population density value is exceeded, the land-use type of the grid cells is changed to "urban".

  In rural regions, each cell has a fraction of settlement area that is occupied by housing and infrastructure. The amount of settlement area on a rural grid cell is calculated based on population density and the per capita area demand [12]. The area not required for housing and infrastructure is available for other land use or land cover that specifies the dominant land-use type on rural grid cells. On grid cells with the dominant land-use type "urban", all area is required for housing and infrastructure.

- **AGRO IR and AGRO RF.** The two AGRO submodules AGRO IR and AGRO RF are separate submodules that are executed one after another (see section 3.3). AGRO IR is responsible for the allocation of the crop categories irrigated fruits (excluding melons), irrigated vegetables and melons, and irrigated cereals. AGRO RF allocates the crop categories rainfed fruits (excluding melons), rainfed vegetables and melons, and rainfed cereals. The crop category definition is based on the crop type aggregation of the FAOSTAT database [18]. Both, AGRO IR and AGRO RF, follow the same general approach regarding demand allocation, and are hence described jointly.

The basic principle of the demand allocation part in AGRO is to formulate a "compromise-solution"-problem for the calculation of a quasi-optimum crop allocation, in order to deal with the competition for land resources between the different crop categories. This is implemented as a modified version of the Multi-Objective Land Allocation (MOLA) heuristic [11]. This heuristic resolves emerging conflicts by a pair-wise comparison; cells claimed by more than one crop category are allocated to the category with the higher preference value. In LandSHIFT, the heuristic was modified in two ways [49]. First, the modified version allocates crop demands instead of a given area. Second, pattern stability is considered in the conflict resolution step, i.e., the land-use patterns remain constant if no changes in crop demands occur.

The amount of crop production on a micro-level grid cell is based on the local production P. The local production P for a crop category c at simulation step t for a particular grid cell, is defined as:

$$P_c(t) = base_c \times y_c(t) \times (1 + tech_c(t)) \times a_c(t) \tag{2}$$

$P_c(t)$ micro-level grid cell production of crop category c for simulation step t [Mg],
$base_c$ management parameter for crop category category c [-],
$y_c(t)$ micro-level grid cell yield for crop category c in simulation step t [Mg km^{-2}],
$tech_c(t)$ technology-induced yield change for crop category c in simulation step t [-],
$a_c(t)$ available cell area for production of crop category c in simulation step t [km^2].

The crop production P is computed by combining state variables from different spatial scale levels (crop yield and yield change) and the cell area a that is not used as settlement area. The local crop yield is updated in each simulation step by the Biophysics module in order to include changes due to alterations in climatic conditions. The management factor *base* is a proxy for agricultural management characteristics (see section 5.1), which are not directly taken into account by LandSHIFT.JR. If not enough suitable land resources are available to allocate the crop demands, unmet demands are documented in a text file. In case more cropland was allocation in a previous simulation step as required in the following simulation step, the land-use type of dispensable cells is converted to "set aside" (fallow).

- **GRAZE.** The GRAZE submodule accounts for the spatial and temporal dynamics of livestock grazing. Changes in quantity and location of grazing area, which has the land-use type "rangeland", are driven by alterations in livestock numbers (sheep and goats) given in livestock units (LU), specified on the macro-level. Based on the livestock number, the amount of required forage, which has to be provided by grazing land, is calculated. This is done under consideration of the daily forage demand per LU and the share of grazing in feed composition. The residual share in feed composition is assumed to be covered by crops and crop residues and is considered indirectly in LandSHIFT.JR.

  The demand allocation part of GRAZE is based on a relationship between grazing intensity (stocking density) and local biomass productivity (NPP of rangeland and natural vegetation). This relationship is specified by non-linear correlation functions between stocking density (number of small ruminants per hectare) and green biomass productivity (tonnes per hectare), calculated with WADISCAPE [34]. The correlation functions were generated for all combinations of five slope categories (0° to <5°, ≥5° to <12.5°, ≥12.5° to <17.5°, ≥17.5° to <25°, ≥25°) with five categories of mean annual precipitation (Table 3). Areas with mean annual precipitation values, that are not covered by the WADISCAPE simulations (values below 80 mm mean annual precipitation) are not suitable for livestock grazing. Except for micro-level grid cells located in these areas, each micro-level grid cell is attributed to one of the correlation functions depending on the grid-cell value for slope and mean annual precipitation.

Category	Mean annual precipitation [mm]
Arid	$\geq$ 80 to $<$ 200
Semiarid	$\geq$ 200 to $<$ 400
Dry Mediterranean	$\geq$ 400 to $<$ 500
Typical Mediterranean	$\geq$ 500 to $<$ 700
Mesic Mediterranean	$\geq$ 700 to $<$ 960

Table 3. Mean annual precipitation categories in WADISCAPE [34].

Two different allocation routines are available for calculating the initial distribution of rangeland and the corresponding stocking densities:

1. Demand-driven approach: The forage demand is allocated to the preferred micro-level grid cells and the land-use type of these cells is converted to "rangeland". The local biomass productivity is calculated from the non-linear correlation function that is valid for the respective grid cells, assuming no former grazing activity on these grid cells. Based on the available biomass productivity, the local stocking density is calculated under consideration of the forage demand per animal.
2. Area-driven approach: Instead of a forage demand, a certain amount of rangeland area (Table 1) is allocated to the micro-level grid cells. The land-use type of these grid cells is converted to "rangeland". The potential total biomass production on these grid cells is calculated from the non-linear correlation functions, assuming no former use of these cells as rangeland. Based on the potential biomass production on the resulting area, the stocking density is adjusted and assigned to the grid cells, in order to meet the forage demand.

In order to calculate the local biomass productivity in the following simulation steps, the cell's correlation function is chosen and combined with the stocking density set in the initial simulation step. The actual stocking density is then calculated from this productivity via the forage demand and assigned to the grid cell. In the subsequent simulation step, this stocking density is then used to derive the new local productivity from the cell specific correlation function. This procedure is repeated for each simulation step [29].

An important effect of this feedback between stocking density and biomass productivity is the resulting self-regulation of the grazing system: the allocation of high stocking densities in one simulation step results in reduced biomass productivity in the following simulation step and, hence, lower stocking densities. In addition to the dynamic calculation of local biomass productivity, change in biomass productivity due to climate change, also derived from WADISCAPE calculations driven by regional climate simulations [53], is considered.

The GRAZE demand allocation part features two different methods for rangeland management: (1) sustainable rangeland management and (2) intensive rangeland management [29]. These allocation modes use micro-level grid cell specific information on stocking capacities calculated by WADISCAPE. The allocation modes apply different procedures in case the local stocking density exceeds the stocking capacity (overgrazing). In case of sustainable management, the local sustainable stocking capacity defines the maximum possible stocking density at a grid cell. The sustainable stocking capacity is a user defined fraction of the maximum stocking capacity. Each time the stocking density, assessed from local biomass productivity, exceeds the sustainable stocking capacity of the grid cell, the stocking density is set back to the sustainable stocking capacity, i.e., no overgrazing is allowed. For intensive management, this limitation is not applied and the stocking density is exclusively limited by the local biomass productivity. For both managements, the upper limit for stocking density is 10 animals per hectare, given by the range of the WADISCAPE simulations [34].

Besides the above mentioned land-use/land-cover types urban, irrigated fruits (excl. melons), irrigated vegetables (incl. melons), irrigated cereals, rainfed fruits (excl. melons), rainfed vegetables (incl. melons), rainfed cereals, other crops, set aside, and rangeland, a set of other types exist. These are: forests, cropland/natural vegetation mosaic, grassland, shrub land, woody savannah, barren land, water, and wetlands. Changes in those are not directly simulated by LandSHIFT.JR but result from land-use conversions of the land-use types that area covered by METRO, AGRO, and GRAZE.

5.3.4. Submodel parameterization

METRO. For METRO, two suitability factors were considered: terrain slope [59] and travel time to major cities [57]. In Table 4, all suitability factors and their weights for the different land-use activities are displayed. As land-use constraint, conservation areas were implemented. As a result, no new urban area can be allocated in conservation areas. Spatially explicit information on national and international nature conservation area was derived from the World Database on Protected Areas [66]. The basic principle of METRO is to convert the population to a cell specific population density value. For this purpose, one part of the population is allocated to urban areas; the residual part is allocated to rural areas. The fraction of population allocation to urban areas is 65 % [58]. In case that the rural population density exceeds 5000 people/km^2, or the area demand for housing and infrastructure on a grid cell exceeds 80 % of the grid cell size, the land-cover type of the grid cell is changed to "urban". The maximum population density per grid cell is 26098 people/km^2, derived from the population density map for the study region for the year 2000 [8].

AGRO IR. For AGRO IR, six different suitability factors were considered. Besides terrain slope and travel time to major cities, additionally area equipped for irrigation [52], irrigated crop yields, population density, and river network density were considered. Irrigated crop yields were calculated with GEPIC and vary with time based on changes in climate conditions. Population density for the year 2000 is derived from the CIESIN dataset [8] and is updated by

Activity	Suitability factor	Factor weight
METRO	Terrain slope	0.366
	Travel time to major cities	0.634
AGRO IR	Area equipped for irrigation	0.233
	Irrigated crop yield	0.145
	Population density	0.049
	River network density	0.262
	Terrain slope	0.147
	Travel time to major cities	0.164
AGRO RF	Population density	0.067
	Rainfed crop yield	0.311
	Terrain slope	0.258
	Travel time to major cities	0.364
GRAZE	Population density	0.044
	NPP of rangeland/nat. veg.	0.529
	River network density	0.256
	Terrain slope	0.170

Table 4. Suitability factors and corresponding weights for the different land-use activities.

LandSHIFT.JR over the course of the simulation. The river network density is calculated as the line density of rivers per grid cell, based on the RWDB2 river-surface water body network dataset [19]. As land-use constraints, conservation areas are considered. Furthermore, a risk map on soil sensitivity to adverse effects of irrigation with treated wastewater [47] was included and can be used for future studies.

AGRO RF. For AGRO RF, four suitability factors were considered. These are rainfed crop yields, slope, travel time to major cities, and population density. Rainfed crop yields were calculated with GEPIC and vary with time based on changes in climate conditions. The only land-use constraint for this activity is conservation area.

GRAZE. For GRAZE, the four considered suitability factors are NPP on rangeland and natural vegetation, slope, river network density, and population density. In conservation areas, the use as rangeland is constrained. The information on NPP is derived from WADISCAPE calculations. To derive the forage demand from the livestock number, we assume one sheep or goat to equal 0.125 LU [51]. In addition, we apply a regional factor for Israel (0.8) and Jordan/PA (0.42) that considers the geographical variability in animal body size [51]. The daily forage demand per goat or sheep is 1.35 kg dry matter [40] of which we assume 30 % to be covered by grazing [4]. The consumable part of the aboveground green biomass is 75 %.

6. Model validation

We applied three different methods to validate our modeling system. First, we validated the underlying assumptions of the suitability assessment with the Relative Operating Characteristics (ROC) method [43]. Second, we used the MODIS land cover dataset for the years 2001 and 2005 to perform a map comparison analysis using version 2.0 of the Map Comparison Kit[8]. Third, we compared macro-level simulation results on area under crop for the different irrigated and rainfed crop categories for the year 2005 with the corresponding values from statistical databases.

6.1. Relative Operating Characteristics

The agreement of simulated and observed land-use change depends on the agreement of both the quantity and location of change. Only if the simulated quantity of change equals the observed quantity of change, the simulated land-use changes can agree perfectly with the real land-use changes. On contrary, if the simulated quantity of change equals the observed quantity of change the location of simulated change can still lead to disagreement of modeled and real land-use change.

The ROC method [43] allows assessing to what degree the model is capable to assess the right location of change independently of the simulated quantity of change. Hence, the ROC analysis can be used to validate the underlying preference ranking processes that guide the location of changes in land use and land cover, represented by a suitability map. For this purpose, an independent real-change map indicating observed land-use or land-cover changes is necessary. Since the ROC method is only meaningful for testing the suitability map for the conversion of any land-use/land-cover type to one single land-use/land-cover type at a time, we applied the method to validate the suitability maps for each land-use activity separately. Whereas the suitability map for a specific land-use activity is a direct model output of LandSHIFT.JR, the categorical real-change map had to be constructed. For this purpose, observed raster maps for two points in time were compared to each other. Grid cells that feature a land-use or land-cover change between these two points in time were categorized as *change* cells whereas all other cells are categorized as *non-change* cells.

The ROC method compares the real-change map to a sequence of virtual simulated land-use change maps that result from a successively increasing quantity of change. The maps are derived by assuming that land-use change occurs on cells where the suitability value exceeds a certain threshold. Typically, the minimum, the deciles, and the maximum of the distribution of the suitability values are used as thresholds to prepare a sequence of maps assuming land-use change on 0 % to 100 % of all cells in 10 %-steps. In order to compare each of these maps to the real-change map, the rates of true positives (TP) and false positives (FP) are calculated. A cell is counted as a TP if real land-use change is modeled correctly. In contrast, if simulated land-use change coincides with non-change in reality, the cell is counted as a FP. The rates of TP and FP are computed as the ratio of the number of TPs and the number of possible TPs and the ratio of the number of FPs and the number of possible FPs, respectively. Based on the results of each comparison in the sequence, the ROC-diagram is constructed by plotting a curve in a coordinate system with the FP-rate on the x-axis and the TP-rate on the y-axis. The ROC curve starts at the point (FP = 0, TP = 0), resulting from the assumption of zero simulated land-use change, and ends at the point (FP = 1, TP = 1), resulting from the assumption that land-use change is simulated on all cells. The performance metric of ROC, the area under the curve (AUC), is calculated by trapezoidal approximation. On average, a random suitability

[8] http://www.riks.nl/products/Map_Comparison_Kit

assessment results in a value of AUC = 0.5. In contrast, a suitability map that assigns the n highest values to the n cells where real change occurs (the perfect suitability map) yields AUC = 1. Hence, an AUC-value between 0.5 and 1 indicates that the suitability assessment explains the location of change better than a random process.

We performed three separate ROC analyses for the land-use activities METRO, AGRO, and GRAZE. Therefore, we compiled three different real-change maps. For METRO and AGRO, we used the MODIS land cover dataset for the years 2001 and 2005. All cells that were "urban" ("cropland") in the 2005 map but not in the 2001 map are categorized as change for METRO (AGRO). For GRAZE, the real change map was derived from the small ruminant density (SRD) maps adjusted to match FAO totals for the years 2000 and 2005 [16]. We defined real change from non-grazing to grazing if the small ruminant density increases by 25% and by a minimum of 25 animals per km^2 over the five year period. The ROC curves resulting from the analyses are shown in Fig. 3.

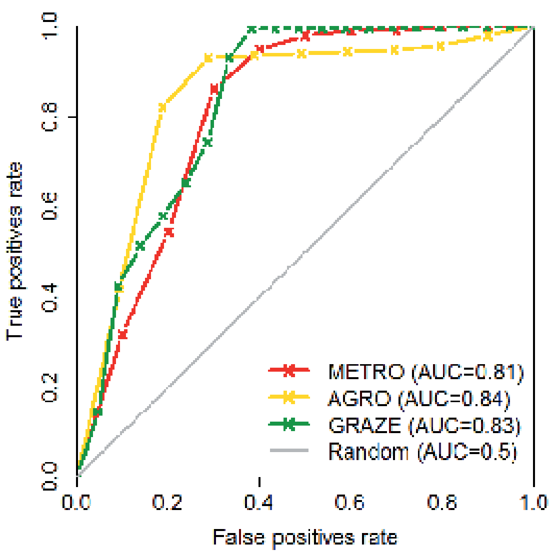

Figure 3. Relative Operating Characteristics (ROC) curves for the three land-use activities METRO, AGRO, and GRAZE. The 45° line indicates the ROC curve for randomly distributed suitability values. The area under the curve (AUC) is the performance measure of ROC.

6.2. Map comparison analysis

We carried out a map comparison analysis to validate the resulting land-use maps. For this purpose, we compared the simulated land-use map S for the year 2005 with the MODIS land cover map for the same year, which we considered the actual or reference land-use map A, by calculating the kappa coefficient of agreement (κ) [9, 42] and kappa simulation (κ_{sim})[60].

We applied κ because it is commonly used for validation of simulated land-use maps. The coefficient takes into account that the proportion of cells that are classified correctly by chance, denoted as the expected proportion correct p_e, can be very large. The p_e depends on the number of categories and the number of cells in each category in S and A. Based on the observed proportion correct p_o and p_e, κ is defined as [60]:

$$\kappa = \frac{p_o - p_e}{1 - p_e} \quad (3)$$

Values for κ range from -1 (indicating no agreement for any of the cells) to 1 (indicating perfect agreement of S and A). If p_o is equal to p_e, i.e., if the land-use types are allocated randomly, κ is equal to 0. The κ coefficient tends to overestimate the performance of land-use change models, which use an initial land-use map as a starting point, if the number of actually changing cells is small compared to the number of cells with persistent land-use. In this case, a model that randomly allocates a small quantity of change, or simulates no change at all, can reach κ values close to 1. Hence, we also calculated the κ_{sim} coefficient, which considers the number of actual and simulated land-use transitions for the calculation of the expected proportion correct $p_{e(transition)}$. In order to calculate $p_{e(transition)}$, additionally the initial land-use map was considered. The value range for κ_{sim} is similar to that of κ and can be interpreted in the same way. Similarly to the standard κ, κ_{sim} is then defined as [60]:

$$\kappa_{sim} = \frac{p_o - p_{e(transition)}}{1 - p_{e(transition)}} \quad (4)$$

In order to calculate κ and κ_{sim}, the land-use categories in the simulated land-use map and the MODIS dataset were harmonized. For this purpose, the land-use categories that LandSHIFT.JR simulates explicitly, i.e., "urban land", "cropland", and "rangeland", were coded similarly in both maps. The remaining land-use types, e.g. "barren land", were lumped together in the categories "natural land-cover" or "water". Rangeland is not classified as a separate land-use type in the MODIS dataset. Therefore, we used the SRD map to derive the extent of rangeland. We defined a cell as rangeland if the density of small ruminants was 87 animals per km^2 or higher and at the same time the land-use/land-cover type assigned in the MODIS map was different from urban, cropland, and water. The threshold value of small ruminant density was adjusted in order to maximize κ. Since SRD is provided on a different spatial resolution (0.05 dd) and the conversion of SRD to "real" grazing land is very straightforward we consider the classification of rangeland to be rather inaccurate. Therefore, we tested the model performance based on two different sets of land-use maps. In set "UCR" urban, cropland, and rangeland were considered; in set "UC" only urban and cropland were considered as separate land-use categories.

For the "UCR" set, the validation results for the map comparison were 0.6 and 0.12 for κ and κ_{sim}, respectively. A value of κ=0.6 indicates that the agreement of the simulated and observed land-use map was significantly better than it can be expected for a random model. Compared to other studies, which report κ values from 0.6 to above 0.9 for land-use change modeling [36, 65], the agreement of LandSHIFT.JR results and the reference map was relatively low. However, it is important to bear in mind that we did not calibrate LandSHIFT.JR in order to maximize the agreement to observed datasets. The results are entirely based on parsimonious assumptions and objective methods to derive model parameters, e.g. the suitability factor weights. Hence, lower κ-values are to be expected.

The κ coefficient can be interpreted as the gain in agreement of the model as compared to a baseline assumption. For standard κ the baseline is a process that randomly allocates the proportion of categories given be the model. For κ_{sim}, the baseline is an improved random process using the additional information that possible changes in land use are limited to a certain, potentially very small, proportion of the cells, which is derived from the simulation results and the reference map. Therefore, the expected proportion correct increases for κ_{sim} and the values are generally lower. Hence, a κ_{sim} of 0.12 still indicates that LandSHIFT.JR explains the land-use changes in the study region significantly better than the improved baseline process.

When we used only the information originally given by the MODIS dataset (i.e. omitting the land-use type rangeland and using the set "UC") κ increased to 0.72 and κ_{sim} increased to 0.22. This can partly be attributed to the inaccuracies induced by the simple approach to derive the reference distribution of rangeland. Furthermore, it is important to consider that the reference map is derived from a remote sensing product (MODIS) and the small ruminant density dataset, which both are subject to classification and measurement errors. Additional sources of error may by introduced by data preparation, e.g. spatial aggregation (MODIS) and disaggregation (SRD).

6.3. Comparison with statistics

We compared the simulated area for rainfed and irrigated cropland for the year 2005 to estimates of the national statistical agencies of Israel, Jordan, and PA (Table 5). Although the model results for area under crops were in very good agreement for PA, the model simulated considerably higher area demands in Israel and Jordan (Table 5). For Israel, the simulated area demand for irrigated and rainfed cropland in 2005 was 48% and 66% higher than reported by the statistics, respectively. According to the Central Bureau of Statistics in Israel, the method to estimate the area under crops has changed starting in 2003. For that reason, a comparison to earlier years is not possible. However, LandSHIFT.JR uses the estimates of area under crops for the base year 2000 as an initial condition. Hence, the simulated area and the area reported by the statistics cannot be compared directly. For Jordan, the simulated area demand was overestimated by 41% and 57% for irrigated and rain-fed crops, respectively. This discrepancy can partly be explained by the fact that, according to the state statistics, the area under crops increased by only 4% while the production of agricultural products, which is the main driver of LandSHIFT.JR, increased by 46% [18]. Assuming that high-quality land resources are already in use for crop production, this is only possible if crop productivity increases considerably due to massive changes in agricultural management, e.g., fertilizer application or irrigation techniques. Currently, LandSHIFT.JR cannot simulate such effects because of missing input data. According to the MODIS land cover dataset for 2005 the area of cropland increased by about 63 %, which is more consistent with the relative increase in crop production simulated with LandSHIFT.JR.

7. Application example

In order to give an application example of LandSHIFT.JR, we set up a modeling exercise. As drivers for the model, we use the assumptions on the dynamics of population number,

	Rainfed cropland		Irrigated cropland		Total cropland	
	Statistics [km^2]	LandSHIFT.JR [km^2]	Statistics [km^2]	LandSHIFT.JR [km^2]	Statistics [km^2]	LandSHIFT.JR [km^2]
Israel	1283	2129 (+66%)	1298	1926 (+48%)	2581	4055 (+57%)
Jordan	1663	2613 (+57%)	610	858 (+41%)	2273	3471 (+53%)
PA	1545	1561 (+1%)	184	184 (0%)	1729	1745 (+1%)

Table 5. Area under rainfed and irrigated crops in 2005 for Israel, Jordan, and the Palestinian National Authority (PA) as simulated with LandSHIFT.JR and estimated by the national statistical agencies.

agricultural production, livestock production, and yield change due to technological progress as given by the GLOWA Jordan River *Modest Hopes* scenario [6]. Figure 4 shows the LandSHIFT.JR results for land-use/land-cover distribution, population density, and livestock density for the base year (2000) and the corresponding projections for the year 2050.

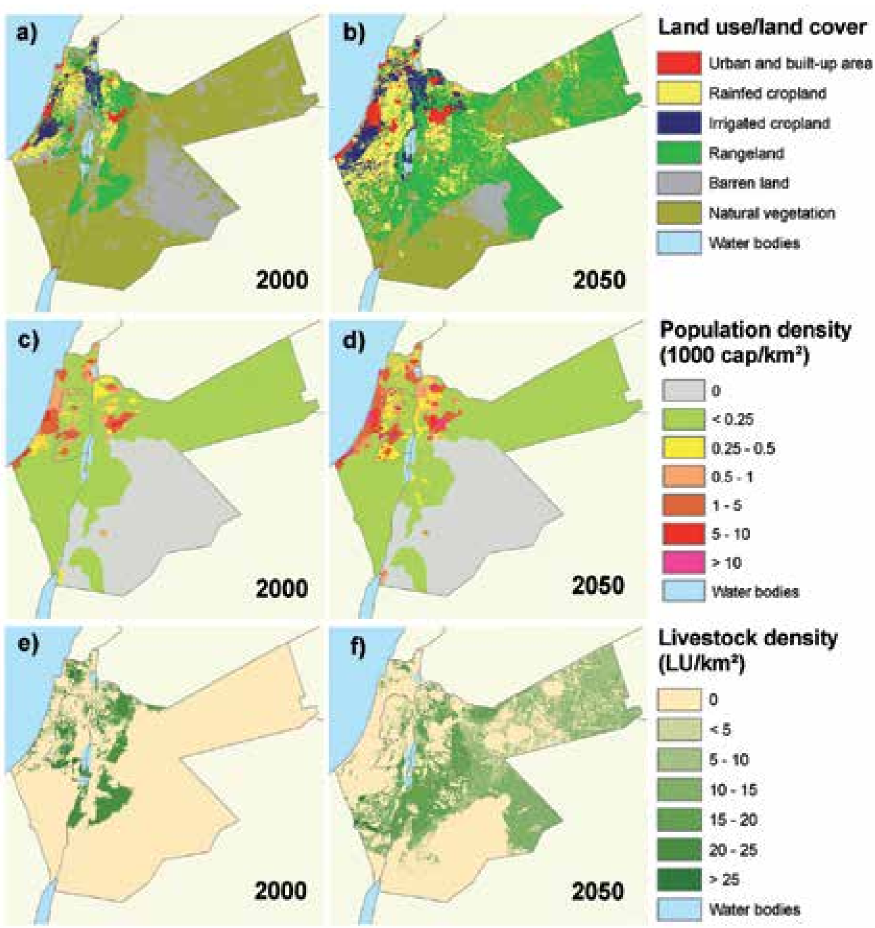

Figure 4. Maps of land-use and land-cover distribution, population density, and livestock density for the years 2000 and 2050 simulated with LandSHIFT.JR for the *Modest Hopes* scenario [6].

A comparison of Fig. 4 (a) and (b) shows considerable increases in the area demands for the main land-use activities. By 2050, the extent of urban land increases by about 56 %, while irrigated cropland expands to more than twice, rainfed cropland to more than three times, and grazing land to more than four times the area as compared to 2000. The figures for agricultural area reflect the ranking of the four activities: the lower the priority of a land-use activity is the lower is the productivity on the areas it is allocated to and, consequently, the larger is the area expansion needed to fulfill the demands. The increasing population density between 2000 and 2050 is shown in Fig. 4 (c) and (d). The maps show the typical differences between the modeling approaches for rural and urban population growth. On the one hand, the urban encroachment approach leads to relative fast growth of urban land (population density above 5000 people/km^2) at the edges of existing cities or urban centers. On the other hand, rural population density increases uniformly and proportional to the initial population density, which is distributed homogeneously over administrative units. Hence, the outlines of these districts can partly be recognized in the maps. The land-use activity with the lowest priority is grazing. Therefore, rangeland is more and more displaced from areas with relatively high productivity, where it is predominantly allocated in 2000 (Fig. 4 (e)), and shifted to less productive areas (Fig. 4 (f)). This leads to a vast extent of rangeland with low stocking densities in 2050. The expansion of irrigated cropland (Fig. 4 (a) and (b)) causes irrigation water requirements to rise. Table 6 presents the simulated total irrigation water demand and area specific irrigation water demand on state level. According to these figures, the projected irrigation water demand almost doubles in PA and Jordan and is about threefold in Israel in 2050 as compared to the year 2000.

State	IR water demand [10^6 m^3]		Avg. IR water demand [mm]	
	(2000)	(2050)	(2000)	(2050)
Israel	638	1477 (+132%)	31	72
Jordan	322	772 (+140%)	4	9
PA	86	162 (+88%)	14	26

Table 6. Total simulated (change between 2000 and 2050 in parenthesis) and average area specific irrigation water demand in 2000 and 2050 for Israel, Jordan, and the Palestinian National Authority (PA).

8. Discussion and conclusions

In this chapter, we introduce the integrated modeling system LandSHIFT.JR for the Jordan River region. We give a detailed description of the modeling system, its parameterization, and validation. We furthermore present a sample application of LandSHIFT.JR for the *Modest Hopes* scenario, developed in the context of the GLOWA Jordan River scenario exercise [6].

Since vegetation degradation due to overgrazing is a major problem in the Jordan River region [1] and since the intensity levels of grazing management strongly affect the environment via different pathways (e.g. woody encroachment [7], biodiversity loss [1] or erosion [27]) we developed a separate module for livestock grazing, that not only implements indicators for grazing intensity, but also includes different rangeland management strategies [28, 29]. This allows to consider the effect of rangeland management strategies in environmental impact assessments.

In contrast to earlier versions of LandSHIFT.JR, the current version includes the effect of changing climate conditions on crop yields and productivity of natural vegetation, which was shown to have a strong effect on land demand in the Jordan River region [32]. The indirect effect of productivity on area demand for the different agricultural activities is included indirectly by spatially explicit simulation models (WADISCAPE and GEPIC), driven by high-resolution climate change simulations for the Jordan River region [53]. This allows the inclusion of a high level of spatial detail into the simulations of land-use and land-cover change, which is carried out on a grid with a spatial resolution of 30 arc seconds. This is of high importance in a region with such high variability in biogeographic conditions as the Jordan River region. Furthermore, it applies a consistent assessment method to the entire Jordan River region and allows the combined assessment of socio-economic and climate impact on the food production systems in the Jordan River region which is considered to be mandatory [55, 56].

Another striking feature of the presented modeling system is the separate module for irrigated crop production. This module allows to simulate spatial and temporal dynamics of irrigated crop production and the resulting land-use patterns and intensities [32]. The model also enables an assessment of climate dependent net irrigation water requirements simulated with the GEPIC model. Hence, the modeling system can now be used the evaluate the effect of changes in cropland extent (induced by changing climate conditions and/or demands for agricultural commodities) on the net irrigation water requirements. However, it has to be mentioned that the current LandSHIFT.JR version only evaluates the demand and no connection to water supply is implemented so far. LandSHIFT.JR considers only crop categories and does not differentiate between crop types. The net irrigation water requirements for the different crop categories were inferred from GEPIC simulations for wheat yields using a crop-specific adjustment parameter. This approach introduces some inaccuracy into the simulation and, as a result, makes the simulation results more suitable for the evaluation of changes in water requirements as compared to the absolute amounts. Furthermore, no information on conveyance efficiencies or irrigation efficiencies (e.g. drip irrigation versus sprinkler irrigation) is included, which would be required to derive the gross irrigation water requirements.

In order to validate LandSHIFT.JR, three different validation methods were applied: (1) ROC analysis [43], (2) map comparison using κ and κ_{sim} as performance measures [42, 60], and (3) a comparison of the quantity of simulated land-use changes with observed land-use changes. The results for the ROC analysis (AUC = 0.81 for METRO, AUC = 0.84 for AGRO, and AUC = 0.83 for GRAZE) indicate that the suitability assessment in LandSHIFT.JR explains the location of change to a high degree. The validation results for the map comparison are at the lower range of values reported for land-use models, with 0.6 and 0.12 for κ and κ_{sim} (0.72 and 0.22 without rangeland), respectively. Bearing in mind that the modeling approach of LandSHIFT.JR does not include a calibration step (e.g. [50, 65]), but is entirely based on parsimonious assumptions and objective methods, we consider these values as acceptable. The comparison of observed and simulated land-use changes shows an almost perfect agreement for PA. Discrepancies resulting for Israel and Jordan might partly be induced by inconsistencies in the reported values. Based on the validation results, we consider LandSHIFT.JR suitable for the simulation of the location and quantity of land-use changes in the Jordan River region.

As shown for the application example, LandSHIFT.JR implements modules for the four land-use activities infrastructure and housing, irrigated crop production, rainfed crop production, and livestock grazing. For each land-use activity, besides the dominant land-use types also an indicator of land-use intensity is allocated (population density, irrigated or rainfed crop production amount, stocking density). Hence, the model concept implemented in LandSHIFT.JR considers not only land-use patterns, but also the corresponding land-use intensities. This makes LandSHIFT.JR land-use simulation results suitable for applications focusing on natural resource management and environmental impact assessment [24, 39].

We see a potential for improvement regarding the validation process. The spatially explicit validation of rangeland, net irrigation water requirements, and the separate validation of irrigated and rainfed cropland was limited by insufficient data availability. This will be caught up for, once suitable datasets are available. We encounter this validation issues by choosing a straightforward modeling approach, based on logical assumptions and renunciation of model calibration and consider this approach as second best to data.

In addition to extensive sensitivity and uncertainty analyses to improve the scientific knowledge and understanding of land-use systems in the Jordan River region, we see a strong potential for future studies on the relationship between irrigation water supply (including treated wastewater), net irrigation water requirements, and soil sensitivity towards the irrigation with treated wastewater [47]. For this purpose, additional GEPIC simulations for other crop types besides wheat would be required in order to be able to assess the irrigation water requirements more accurately. This would allow for interesting analyses regarding the potential of using treated wastewater for irrigation purposes, under consideration of possible environmental problems associated with the use of treated wastewater for irrigation [5].

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9. References

[1] Abahussain, A.A., Abdu, A.S., Al-Zubari, W.K., El-Deen, N.A. & Abdul-Raheem, M. (2002). Desertification in the Arab region: analysis of current status and trends, *Journal of Arid Environments* 51(4):521–545.

[2] Alcamo, J. (2002). Three issues for improving integrated models: uncertainty, social science, and legitimacy, *in* Gethmann, C.F. & Lingner, S. (eds.), *Integrative Modellierung zum Globalen Wandel*, Springer Verlag, Berlin, Heidelberg, Germany, pp. 3–14.

[3] Alcamo, J. (2009). *Environmental futures: the practice of environmental scenario analysis*, Elsevier, Amsterdam, The Netherlands.

[4] Al-Jaloudy, M.A. (2001). *FAO country profiles: Jordan. Country pasture/forage resource profiles*, Food and Agriculture Organization of the United Nations, Rome, Italy. URL: `http://www.fao.org/ag/AGP/AGPC/doc/Counprof/Jordan/Jordan.htm`

[5] Al-Nakshabandi, G.A., Saqqar, M.M., Shatanawi, M.R., Fayyad, M. & Al-Horani, H. (1997). Some environmental problems associated with the use of treated wastewater for irrigation in Jordan, *Agricultural Water Management* 34(1):81–94.

[6] Anonymous (2011). *Future management of the Jordan River basin's water and land resources under climate change - a scenario analysis*, Summary report, Center for Environmental Systems Research, Kassel, Germany and Israel/Palestine Center for Research and Information, Jerusalem, Israel.

[7] Asner, G.P., Elmore, A.J., Olander, L.P., Martin, R.E. & Harris, A.T. (2004). Grazing systems, ecosystem responses, and global change, *Annual Review of Environment and Resources* 29:261–299.

[8] CIESIN (2004). *Global rural-urban mapping project (GRUMP): urban/rural population grids*, Center for International Earth Science Information Network, Columbia University, International Food Policy Research Institute, the World Bank & Centro Internacional de Agricultura Tropical. URL: `http://sedac.ciesin.columbia.edu/gpw/`

[9] Cohen, J. (1960). A coefficient of agreement for nominal scales, *Educational and Psychological Measurement* 20(1):37–46.

[10] Diakoulaki, D., Mavrotas, G. & Papayannakis, L. (1995). Determining objective weights in multiple criteria problems: the CRITIC method, *Computers & Operations Research* 22(7):763–770.

[11] Eastman, J.R., Jin, W., Kyem, P.A.K. & Toledano, J. (1995). Raster procedures for multi-criteria/multi-objective decisions, *Photogrammetric Engineering & Remote Sensing* 61(5):539–547.

[12] Erb, K.-H., Gaube, V., Krausmann, F., Plutzar, C., Bondeau, A. & Haberl, H. (2007). A comprehensive global 5 min resolution land-use data set for the year 2000 consistent with national census data, *Journal of Land Use Science* 2(3):191–224.

[13] EXACT (1998). *Overview of Middle East water resources,* Executive Action Team, Middle East Water Data Banks Project. URL: `http://exact-me.org/overview/index.htm`

[14] Falkenmark, M. & Rockström, J. (2004). *Balancing water for humans and nature: the new approach in ecohydrology*, Earthscan, London, United Kingdom.

[15] FAO (2003). *Review of world water resources by country*, Water Reports 23, Food and Agriculture Organization of the United Nations, Rome, Italy.

[16] FAO (2007). *Gridded livestock of the world 2007*, Food and Agriculture Organization of the United Nations, Rome, Italy.

[17] FAO (2012). *AQUASTAT: FAO's information system on water and agriculture*, Food and Agriculture Organization of the United Nations, Rome, Italy. URL: `http://www.fao.org/nr/water/aquastat/main/index.stm`

[18] FAO (2012). *FAO statistical database*, Food and Agriculture Organization of the United Nations, Rome, Italy. URL: `http://faostat.fao.org/`

[19] FIMA (2011). *RWDB2 River-surface water body network*, Food and Agriculture Organization of the United Nations, Aquaculture Management and Conservation Service (FIMA), Rome, Italy. URL: `http://www.fao.org/geonetwork/srv/en/main.home`

[20] Foley, J.A., DeFries, R., Asner, G.P., Barford, C., Bonan, G., Carpenter, S.R., Chapin, F.S., Coe, M.T., Daily, G.C., Gibbs, H.K., Helkowski, J.H., Holloway, T., Howard, E.A., Kucharik, C.J., Monfreda, C., Patz, J.A., Prentice, I.C., Ramankutty, N. & Snyder, P.K. (2005). Global consequences of land use, *Science* 309(5734):570–574.

[21] Friedl, M.A., McIver, D.K., Hodges, J.C.F., Zhang, X.Y., Muchoney, D., Strahler, A.H., Woodcock, C.E., Gopal, S., Schneider, A., Cooper, A., Baccini, A., Gao, F. & Schaaf, C. (2002). Global land cover mapping from MODIS: algorithms and early results, *Remote Sensing of Environment* 83(1-2):287–302.

[22] Ghasemi, F., Jakeman, A.J. & Nix, H.A. (1995). *Salinisation of land and water resources: human causes, extent, management and case studies*, Centre for Resources and Environmental Studies, Australian National University, CAB International, Wallingford, United Kingdom.

[23] Grimm, V., Berger, U., Bastiansen, F., Eliassen, S., Ginot, V., Giske, J., Goss-Custard, J., Grand, T., Heinz, S.K., Huse, G., Huth, A., Jepsen, J.U., Jørgensen, C., Mooij, W.M., Müller, B., Pe'er, G., Piou, C., Railsback, S.F., Robbins, A.M., Robbins, M.M., Rossmanith, E., Rüger, N., Strand, E., Souissi, S., Stillman, R.A., Vabø, R., Visser, U. & DeAngelis, D.L. (2006). A standard protocol for describing individual-based and agent-based models, *Ecological Modelling* 198(1-2):115–126.

[24] Gunkel, A. & Lange, J. (2012). New insights into the natural variability of water resources in the lower Jordan River basin, *Water Resources Management* 26(4):963–980.

[25] Haberl, H., Erb, K.-H., Krausmann, F., Gaube, V., Bondeau, A., Plutzar, C., Gingrich, S., Lucht, W. & Fischer-Kowalski, M. (2007). Quantifying and mapping the human appropriation of net primary production in earth's terrestrial ecosystems, *Proceedings of the National Academy of Sciences of the United States of America* 104(31):12942–12947.

[26] Kan, I., Rapaport-Rom, M. & Shechter, M. (2007). Economic analysis of climate-change impacts on agricultural profitability and land use: the case of Israel, *Proceedings of 15th Annual Conference of the European Association of Environmental and Resource Economists (EAERE)*, Thessaloniki, Greece, pp. 14-17.

[27] Khresat, S.A., Rawajfih, Z. & Mohammad, M. (1998). Land degradation in north-western Jordan: causes and processes, *Journal of Arid Environments* 39(4):623–629.

[28] Koch, J., Schaldach, R. & Köchy, M. (2008). Modeling the impacts of grazing land management on land-use change for the Jordan River region, *Global and Planetary Change* 64(3-4):177–187.

[29] Koch, J., Schaldach, R. & Kölking, C. (2009). Modelling the impact of rangeland management strategies on (semi-)natural vegetation in Jordan, *Proceedings of the 18th World IMACS Congress and MODSIM09 International Congress on Modelling and Simulation*, Cairns, Australia, pp. 1929–1935.

[30] Koch, J. (2010). *Modeling the impacts of land-use change on ecosystems at the regional and continental scale*, Thesis, kassel university press GmbH, Kassel, Germany.

[31] Koch, J., Onigkeit, J., Schaldach, R., Alcamo, J., Köchy, M., Wolff, H.-P. & Kan, I. (2011). Land-use change scenarios for the Jordan River region, *International Journal of Sustainable Water and Environmental Systems* 3(1):25–31.

[32] Koch, J., Wimmer, F., Schaldach, R., Onigkeit, J. & Folberth, C. (2012). Modelling the impact of climate change on irrigation area demand in the Jordan River region, *in* Seppelt, R., Voinov, A.A., Lange, S. & Bankamp. D. (eds.), *Proceedings of the 2012 International Congress on Environmental Modelling and Software: Managing Resources of a Limited Planet (iEMSs 2012)*, Leipzig, Germany.

[33] Köchy, M. (2008). Effects of simulated daily precipitation patterns on annual plant populations depend on life stage and climatic region, *BMC Ecology* 8(4).

[34] Köchy, M., Mathaj, M., Jeltsch, F. & Malkinson, D. (2008). Resilience of stocking capacity to changing climate in arid to Mediterranean landscapes, *Regional Environmental Change* 8(2):73–87.

[35] Lambin, E.F., Rounsevell, M.D.A. & Geist, H.J. (2000). Are agricultural land-use models able to predict changes in land-use intensity? *Agriculture, Ecosystems & Environment* 82(1-3):321–331.

[36] Lauf, S., Haase, D., Hostert, P., Lakes, T. & Kleinschmit, B. (2012). Uncovering land-use dynamics driven by human decision-making - a combined model approach using cellular automata and system dynamics, *Environmental Modelling & Software* 27-28:71–82.

[37] Liu, J., Williams, J.R., Zehnder, A.J.B. & Yang, H. (2007). GEPIC - modelling wheat yield and crop water productivity with high resolution on a global scale, *Agricultural Systems* 94(2):478–493.

[38] Malkinson, D. & Jeltsch, F. (2007). Intraspecific facilitation: a missing process along increasing stress gradients - insights from simulated shrub populations, *Ecography* 30(3):339–348.

[39] Menzel, L., Koch, J., Onigkeit, J. & Schaldach, R. (2009). Modelling the effects of land-use and land-cover change on water availability in the Jordan River region, *Advances in Geosciences* 21:73–80.

[40] Perevolotsky, A., Landau, S., Kababia, D. & Ungar, E.D. (1998). Diet selection in dairy goats grazing woody Mediterranean rangeland, *Applied Animal Behaviour Science* 57(1-2):117–131.

[41] Pimm, S.L. & Raven, P. (2000). Biodiversity: extinction by numbers, *Nature* 403:843–845.

[42] Pontius Jr., R.G. (2000). Quantification error versus location error in comparison of categorical maps, *Photogrammetric Engineering & Remote Sensing* 66(8):1011–1016.

[43] Pontius Jr., R.G. & Schneider, L.C. (2001). Land-cover change model validation by an ROC method for the Ipswich watershed, Massachusetts, USA, *Agriculture, Ecosystems & Environment* 85(1-3):239–248.

[44] Portmann, F.T., Siebert, S. & Döll, P. (2010). MIRCA2000 - Global monthly irrigated and rainfed crop areas around the year 2000: a new high-resolution data set for agricultural and hydrological modeling, *Global Biogeochemical Cycles* 24:GB1011.

[45] Rosegrant, M.W., Meijer, S. & Cline, S.A. (2002). *International model for policy analysis of agricultural commodities and trade (IMPACT): model description*, International Food and Policy Research Institute, Washington, DC, United States. URL: `http://www.ifpri.org/themes/impact/impactmodel.pdf`

[46] Saaty, R.W. (1987). The analytic hierarchy process - what it is and how it is used, *Mathematical Modelling* 9(3-5):161–176.

[47] Schacht, K., Gönster, S., Jüschke, E., Chen, Y., Tarchitzky, J., Al-Bakri, J., Al-Karablieh, E. & Marschner, B. (2011). Evaluation of soil sensitivity towards the irrigation with treated wastewater in the Jordan River region, *Water* 3(4):1092–1111.

[48] Schaldach, R. & Koch, J. (2009). Conceptual design and implementation of a model for the integrated simulation of large-scale land-use systems, *in* Athanasiadis, I.N., Mitkas, P.A., Rizzoli, A.E. & Gómez, J.M. (eds.), *Information Technologies in Environmental Engineering*, Springer Verlag, Berlin, Heidelberg, Germany, pp. 425–438.

[49] Schaldach, R., Alcamo, J., Koch, J., Kölking, C., Lapola, D.M., Schüngel, J. & Priess, J.A. (2011). An integrated approach to modelling land-use change on continental and global scales, *Environmental Modelling & Software* 26(8):1041–1051.

[50] Schweitzer, C., Priess, J.A. & Das, S. (2011). A generic framework for land-use modelling, *Environmental Modelling & Software* 26(8):1052–1055.

[51] Seré, C. & Steinfeld, H. (1996). *World livestock production systems - current status, issues and trends*, FAO Animal Production and Health Paper 127, Food and Agriculture Organization of the United Nations, Rome, Italy.

[52] Siebert, S., Döll, P., Feick, S., Hoogeveen, J. & Frenken, K. (2007). *Global Map of Irrigation Areas version 4.0.1*, Johann Wolfgang Goethe University, Frankfurt am Main, Germany/Food and Agriculture Organization of the United Nations, Rome, Italy.

[53] Smiatek, G., Kunstmann, H. & Heckl, A. (2011). High-resolution climate change simulations for the Jordan River area, *Journal of Geophysical Research* 116:D16111.

[54] Solecki, W.D. & Oliveri, C. (2004). Downscaling climate change scenarios in an urban land use change model, *Journal of Environmental Management* 72(1-2):105–115.

[55] Tubiello, F.N., Soussana, J.-F. & Howden, S.M. (2007). Crop and pasture response to climate change, *Proceedings of the National Academy of Sciences of the United States of America* 104(50):19686–19690.

[56] Tubiello, F.N., Amthor, J.S., Boote, K.J., Donatelli, M., Easterling, W., Fischer, G., Gifford, R.M., Howden, M., Reilly, J. & Rosenzweig, C. (2007). Crop response to elevated CO_2 and world food supply: a comment on "Food for Thought ..." by Long et al., Science 312:1918–1921, 2006, *European Journal of Agronomy* 26(3):215–223.

[57] Uchida, H. & Nelson, A. (2008). *Agglomeration index: towards a new measure of urban concentration*, Background Paper, World Development Report 2009.

[58] UNEP (2007). *Global Environment Outlook - environment for development (GEO-4)*, United Nations Environment Programme, Nairobi, Kenya.

[59] U.S. Geological Survey (1998) *HYDRO1k: elevation derivative database*, Earth Resources Observation and Science (EROS) Center, Sioux Falls, SD, United States. URL: `http://eros.usgs.gov/#/Find_Data/Products_and_Data_Available/gtopo30/hydro`

[60] van Vliet, J., Bregt, A.K. & Hagen-Zanker, A. (2011). Revisiting Kappa to account for change in the accuracy assessment of land-use change models, *Ecological Modelling* 222(8):1367–1375.

[61] Verburg, P.H., de Koning, G.H.J., Kok, K., Veldkamp, A. & Bouma, J. (1999). A spatial explicit allocation procedure for modelling the pattern of land use change based upon actual land use, *Ecological Modelling* 116(1):45–61.

[62] Verburg, P.H., Soepboer, W., Veldkamp, A., Limpiada, R., Espaldon, V. & Mastura, S.S.A. (2002). Modeling the spatial dynamics of regional land use: the CLUE-S model, *Environmental Management* 30(3):391–405.

[63] Verburg, P.H., Kok, K., Pontius, R.G. & Veldkamp, A. (2006). Modeling land-use and land-cover change, *in* Lambin, E.F. & Geist, H.J. (eds.), *Land-use and land-cover change - local processes and global impacts*, Springer Verlag, Berlin, Heidelberg, Germany, pp. 117–135.

[64] Vitousek, P.M. (1994). Beyond global warming: ecology and global change, *Ecology* 75(7):1861–1876.

[65] Wang, F., Hasbani, J.-G., Wang, X. & Marceau, D.J. (2011). Identifying dominant factors for the calibration of a land-use cellular automata model using Rough Set Theory, *Computers, Environment and Urban Systems* 35(2):116–125.

[66] WDPA Consortium (2004) *Word Database on Protected Areas*. URL: `http://www.wdpa.org/`

[67] Williams, J.R., Jones, C.A., Kiniry, J.R. & Spanel, D.A. (1989). The EPIC crop growth model, *Transactions of the American Society of Agricultural Engineers* 32(2):497–511.

[68] Williams, J.R. (1995). The EPIC model, *in* Singh, V.P. (ed.), *Computer Models of Watershed Hydrology*, Water Resources Publications, Colorado, United States, pp. 909–1000.

[69] Wu, F. (1999). GIS-based simulation as an exploratory analysis for space-time processes, *Journal of Geographical Systems* 1(3):199–218.

Chapter 6

Environmental Land Use and the Ecological Footprint of Higher Learning

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Additional information is available at the end of the chapter

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1. Introduction

The lifestyles of individuals, groups, or nations can be measured by utilizing an accounting tool known as ecological footprint. Ecological footprint refers to the productive land needed to support a given population. As discussed by Wackernagel and Rees (1996), "The ecological footprint concept is simple, yet potentially comprehensive: it accounts for the flows of energy and matter to and from any defined economy and converts these into the corresponding land/water are required from nature to support these flows" (p. 3). A concept known as "overshoot" occurs if demands by humans exceed the supply of a given biologically productive area (Turner et al., 2006). Thus, a larger ecological footprint indicates a less sustainable society.

Research on ecological footprint literature links together the concepts of footprint size and economic development. In other words, footprints represent population size and consumption levels (Wackernagel & Rees, 1996). Furthermore, more-developed countries contain market economies that consume greater levels of natural resources, and environmental degradation is largely driven by the growth and intensification of market economies (Jorgenson, as cited in Jorgenson & Burns, 2006). For example, Americans when compared to the rest of the world exhibit a large ecological footprint due to an intensely consumption-oriented lifestyle. The average ecological footprint for an American is 23.68 acres as compared to the world's average of 5.53 acres (Global Footprint Network, 2003). Further research suggests an economical discrepancy between those who possess large ecological footprints and those who possess small ecological footprints. Wackernagel et al. (2003) found that those contributing most to climate change through their energy intensive lifestyles will most likely be less affected by, and better shielded from, the outfalls of climate change than poor people living on marginal land or in underserved urban conditions.

Though ecological footprint can be used as a useful tool to help measure sustainability, some scientists have criticized ecological footprint calculations for oversimplifying ecosystem processes to numerical values. Assumptions may not be valid as the ecological footprint arbitrarily assumes both zero greenhouse gas emissions, which may not be optimal, and national boundaries, which makes extrapolating from the average ecological footprint problematic (Fiala, 2008). Despite these criticisms, the ecological footprint calculation can serve as a heuristic tool for designing and implementing plans for today as well as for tomorrow. Moreover, plans that take environmental calculations into consideration will have a far greater potential of keeping the Earth as a stakeholder in the planning process than those plans without such calculations.

Colleges and Universities across the world serve as incubators for tomorrow's leaders. In essence, they leave an educational imprint on individuals in an effort to educate and facilitate the development of tomorrow's leaders. These institutions serve as the setting where ideas can take form and this is where ideas can be implemented in a semi contained setting as part of the larger community. Though it is well established that educational institutions leave their imprints on innovative minds, this chapter introduces the idea that institutions of higher learning also leave ecological footprints on the landscape. Universities provide support to environmental issues through policies, programs, and research. The idea of greening campuses has become so popular that the Princeton Review has posted a Green Rating Honor Roll to document the top schools that provide a healthy and sustainable quality of life for the students, environmentally-minded and educational preparations for the future workforce, and environmentally responsible school policies for all to follow (Princeton Review, 2008).

Thinking green has been a hot topic among US Colleges in recent years. To think green is to incorporate environmental impacts into decision-making activities that affect daily lifestyles. The impact that a society imposes on the environment holds importance, as it is a key issue of sustainability. Sustainability refers to the dilemma of how to "meet the needs of the present without compromising the ability of future generations to meet their own needs" (Wackernagel & Rees, 1996, p. 33). Fortunately, one place where sustainable initiatives have spread is on campuses throughout America. Universities have provided support to environmental issues through policies, programs, and research.

The Princeton Review has posted a Green Rating Honor Roll to document the top schools that provide a healthy and sustainable quality of life for the students, environmentally-minded and educational preparations for the future workforce, and environmentally responsible school policies for all to follow (Princeton Review, 2008). The Princeton Review ranked the following eleven colleges throughout the United States as receiving a green rating of ninety-nine points.

- Arizona State University, Tempe
- Bates College
- College of the Atlantic
- Emory University

- Georgia Institute of Technology
- Harvard University
- State University of New York at Binghamton
- University of New Hampshire
- University of Oregon
- University of Washington
- Yale University

Although all the above-listed universities have displayed an extraordinary commitment to green initiatives, Harvard University located in Cambridge, MA; Emory University located near Atlanta, GA; and Bates College in Lewiston, ME, were chosen for closer examination in part due to the accessibility of online information concerning green programs as well as in respect to their diverse financial strategies for integrating sustainable principles. An inventory was performed encompassing a list of similarities and differences concerning green initiatives and strategies. Moreover, this inventory can serve as a framework for other colleges to follow in the future. It is in this context that we discuss the current consumption and environmental awareness levels associated with the use of water and energy resources for dormitory students on The University of Alabama's campus.

The University of Alabama is in the preliminary stages of moving toward a more sustainable campus. Currently, it is difficult to track environmentally friendly progress on campus, as no study has been previously performed to establish where The University of Alabama is concerning environmental initiatives. Thus, if a snapshot of the University were established to include both consumption and environmental awareness levels, then those findings would serve as a benchmark from which the implementation of green strategies may be evaluated in terms of effectiveness. Accordingly, this research documented the environmental awareness and consumption levels of dormitory students concerning energy and water resources on The University of Alabama's campus. Moreover, findings were gathered from the dormitories Ridgecrest East and Lakeside East. The goal was to measure the current ecological footprint of dormitory students on The University of Alabama campus. Specific research objectives were to (a) determine the current state of students' environmental awareness, and (b) determine the current consumption levels in terms of electricity and water usage for specific dormitories on campus.

2. Research methods

A case study approach was utilized during this research. According to Theodorson and Theodorson (as cited in Punch, 1998) a case study is defined as "a method of studying social phenomena through the thorough analysis of an individual case. Described simply, a case study provides a snapshot of particular social phenomena (Hakim, 1987, p. 61). Thus, the case study approach allows for in-depth research on specific populations, such as the dormitory students that will serve as the focus for this research. This approach also permits the researcher to evaluate subjects in a naturalistic setting as well as conduct research from a wide array of methods such as interviews, observations, numerical data, and questionnaires

(Punch, 1998, p. 153). Suitably, interviews, observations, surveys, and data analysis are the primary methods utilized in this research. Even as the case study approach proves to be a viable research tool, a limitation is the inability of the researcher to derive generalizations from specific instances (Punch, 1998, p. 155). In light of this accusation, it is of importance to note that the case study approach warrants merit as this research requires an in-depth inquiry into a particular situation that has yet to be documented.

As mentioned previously, the focus of this research is centered around dormitory students residing on The University of Alabama campus located in Tuscaloosa, Alabama. In the fall of 2008, The University of Alabama reached a record enrollment of 27,052 students (Andreen, 2008). Of the 27,052 students approximately 7,000 students are housed on campus (E. Russell, e-mail, February 24, 2009).[1] Therefore, on-campus residency accounts for approximately 26% of the student population as illustrated by Figure 1.

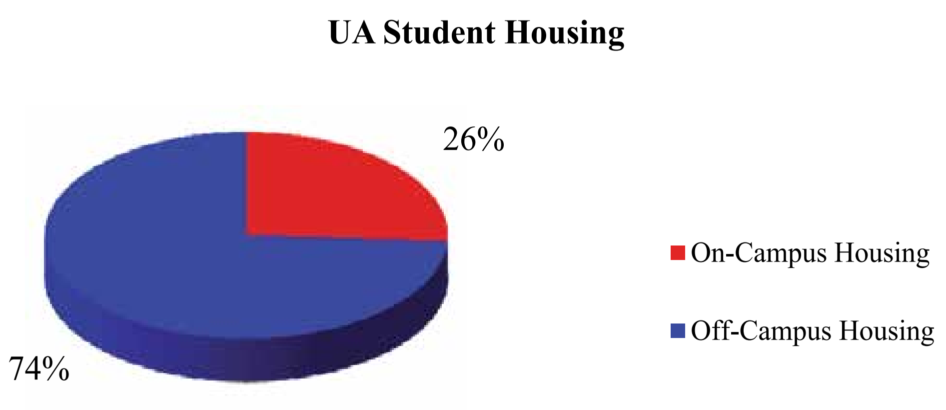


Figure 1. UA student housing.

For this study two dormitories were chosen for sampling. The selection was done by methods of random sampling. Random sampling allowed every dormitory to have an equal opportunity of being selected. The process entailed writing down the names of all the possible dormitories on campus on individual slips of paper. The dormitory names were mixed up and then drawn out of a hat. The dormitories Lakeside East and Ridgecrest East were selected for an analysis of energy and water usage records. The coed student populations housed within Lakeside East and Ridgecrest East are 238 and 316 students, respectively.

3. Survey and data analysis

The University of Alabama's Department of Energy Management aided in providing energy and water consumption records concerning the Ridgecrest East and Lakeside East dormitories. A content analysis of the records was performed to determine applicable

[1] An e-mail was received from Russell, E. on February 24, 2009. This e-mail is not traceable by the reader and is therefore not found in the references per APA style.

Figure 2. Lakeside East Residential Hall.

Figure 3. Ridgecrest East Residential Hall.

themes and patterns. Additionally, the records assisted with the calculation of the ecological footprint analysis of energy and water usage in dormitories on campus. The energy records acquired reported monthly electrical and natural gas usage figures for the two dormitories from 2007 and 2008. Due to some technical problems with the water meters, only the last five months of 2008 were available for analysis. However, water usage assumptions were derived for the entire year of 2008. Ecological footprint calculations were projected from estimates of the average water usage in 2008 and from the actual natural gas and electricity usage figures from 2007 and 2008. Even from water approximations, the derived ecological footprint has the ability to serve as a benchmark that can be utilized in future research. During the analysis of water and energy records, the data concerning the population rates for Ridgecrest East and Lakeside East during 2007 were unfortunately unattainable; consequently, the 2008 population numbers were substituted. In addition to the analysis of energy records, an interview with the Director of Energy Management was conducted in an effort to get a proper vision of the campus in terms of resource management.

4. Calculating the ecological footprint

Data from the Department of Energy Management were utilized in the ecological footprint calculation. The following identifies the process for calculating ecological footprints:

1. Estimate the average population size.
2. Estimate the average annual consumption for a particular item.
3. Estimate the land area appropriated per capita for the production of items consumed.
4. Estimate the ecological footprint of the average person for all items consumed.
5. Multiply the population by the per capita footprint.

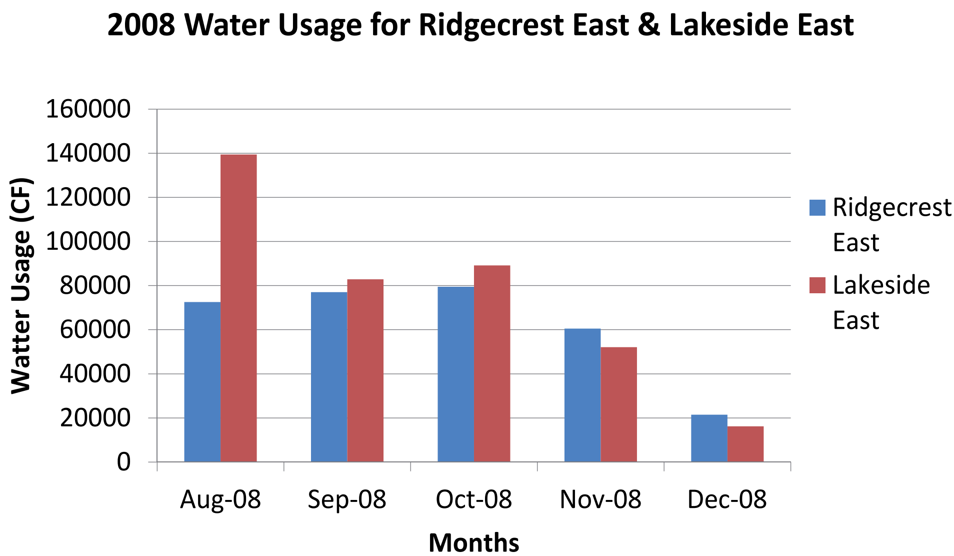
The ecological footprint calculation was utilized to determine land use requirements associated with the consumption of resources. The calculation was performed utilizing water, electric, and natural gas records. All the records used in this study were obtained from the Department of Energy Management.

Water

Water usage records were acquired pertaining to Ridgecrest East and Lakeside East Residential Halls from August to December 2008. Due to some technical problems with the water meters, accurate water usage readings prior to August 2008 were unattainable. The trend for water usage at Ridgecrest East showed little variation during the months of August, September, and October as consumption ranged from approximately 72,000 to 80,000 cubic feet or approximately 538,000 gallons to 599,000 gallons. Usage dropped slightly during November followed by a dramatic decrease in December. Lakeside East Residential Hall demonstrated more drastic trends than Ridgecrest East as usage in August peaked at nearly 140,000 cubic feet followed by a marked decline in September as Lakeside levels dropped around 40%. A slight increase occurred during the month of October. In November and December consumption decreased drastically as water usage dipped below Ridgecrest levels.

Figure 11 details water usage in cubic feet consumed. Figure 12 depicts the steps we were utilized to calculate the ecological footprint of water resources consumed in the dormitories Lakeside East and Ridgecrest East. First, the populations of Lakeside East and Ridgecrest East were established. As mentioned previously, 238 students reside within Lakeside East, whereas 316 students live in Ridgecrest East. A full twelve months of records were unavailable, so estimations were used to approximate the yearly water consumption levels within the dormitories. The 2008 yearly estimations for each building were derived from taking the average amount of water used during the five months and then multiplying that average by twelve months. For Ridgecrest East the figure 746,616 cubic feet was used as the 2008 water usage estimate, while the figure 911,496 cubic feet was used for Lakeside East.

Thus, an ecological footprint calculation concerning water resources can be derived by utilizing the water consumption estimates for the two residential halls as indicated above. Initially, the amount of water consumed in cubic feet per dormitory student must be established. The number was calculated by dividing the total water estimates for each



Source: University of Alabama Department of Energy Management

Figure 4. 2008 Water Usage for Ridgecrest East and Lakeside East.

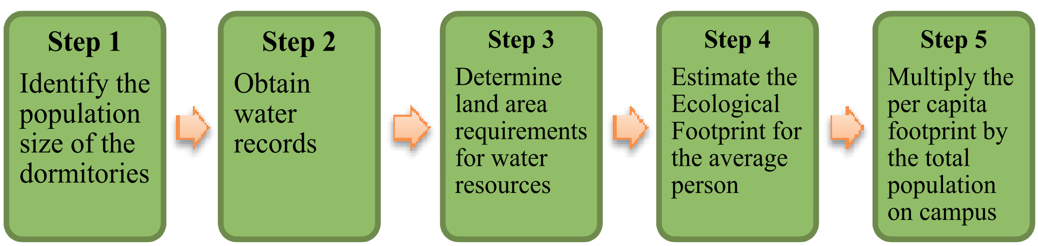


Figure 5. Ecological footprint procedure for water.

dormitory by the subsequent student populations residing in each residential hall. Consequently, the average amount of water consumed per student for Lakeside East was 3,830 cubic feet (28,649 gallons) and 2,363 cubic feet (17,674 gallons) for Ridgecrest East.

To obtain a real-world comparison, consumption figures of the individual dormitory student are listed in gallons as well as cubic feet. The individual usage levels can further be broken down into daily usage figures by dividing by 365 to represent the approximate number of days in a year. As a result the daily consumption level for an individual residing in Lakeside East was 10.49 cubic feet or 78.49 gallons and 6.47 cubic feet or 48.42 gallons for those in Ridgecrest East. Daily usage figures are useful as they can be easily compared to the national average of the average American. According to the Environmental Protection Agency (2003), the average American consumes 90 gallons of water daily in the home, as compared to the average European consuming 53 gallons daily, and the typical Sub-Saharan African citizen consuming only 3-5 gallons per day.

After establishing the consumption levels for water resources, it was necessary to determine the amount of land required for the utilization of water resources. Thus, water resources were converted to cubic meters by multiplying by 0.0283 and then divided by 1,500 m^3/ha/yr to accommodate the amount of forested land needed to accommodate the water consumed (Anundson et al., 2001, p. 26). The result was equivalent to

0.0723 hectares (0.1785 acres) per dormitory student in Lakeside East and 0.0446 hectares (0.1101 acres) per dormitory student in Ridgecrest East.

Ecological Footprint for Water 2008	Lakeside East	Ridgecrest East
Total Water Usage 2008 (cubic ft)	911,496	746,616
Water Usage per Month (cubic ft)	75,958	62,218
Water per Student in 2008 (cubic ft)	3,830	2,363
Total Land Area in Hectares per Dormitory Student	0.0723	0.0446
Total Land Area in Acres per Dormitory Student	0.1785	0.1101

Table 1. Ecological Footprint for Water 2008

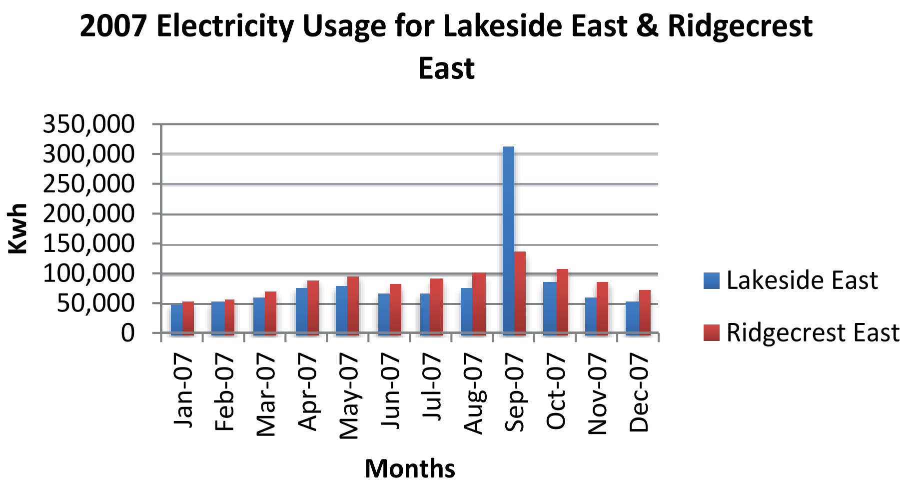
It is germane to keep in mind that all of these figures, concerning hectares/acreage required, only apply to the land required concerning water resources utilized during the consumption of housing. Accordingly, "the ecological footprint concept is based on the idea that for every item of material or energy consumption, a certain amount of land in one or more ecosystem categories is required to provide the consumption-related resource flows and waste sinks" (Wackernagel & Rees, 1996, p. 63). Thus, a complete ecological footprint calculation encompasses many different goods and services as this study looks specifically at water and energy resources associated with housing needs of dormitory students on The University of Alabama's campus.

a. Electricity

In addition to supplying the water records, as indicated in the findings in the previous section, the Department of Energy Management also provided electric and natural gas records for use in this research. To assist with the analysis of Lakeside East and Ridgecrest East Residential Communities, complete electrical and natural gas records were gathered from January 2007 to December 2008. Energy consumptions records from both 2007 and 2008 show a general trend of Lakeside East utilizing slightly less electricity per month with the exception of a peak on September 2007. During September 2007, Lakeside East Residential Hall experienced a spike in usage as

315,007 kilowatt hours (kWh) were consumed. This consumption stands-out on the electrical records as neither Lakeside East nor Ridgecrest East demonstrated another usage level over 140,000 kilowatt hours during the two-year span.

Despite the September peak for Lakeside East, electricity usage throughout the 2007 year remained somewhat consistent as January through March accounted for a range of approximately 50,000 to 65,000 kWh. April to May experienced a slight increase with consumption hovering near 80,000 kWh. June to July numbers were barely below 70,000 kWh, while August numbers increased back up to nearly 80,000 kWh. October boasted the second highest usage for 2007 at 87,151 kWh. Finally, during the months of November and December consumption ranged from 65,000 to 55,000 kWh. Interestingly, even as Lakeside East consistently consumed less power per month during 2007 with the exception of the September spike, the total 2007 energy consumption figures for Lakeside East (1,067,609 kWh) were slightly higher than Ridgecrest East (1,066,400 kWh).

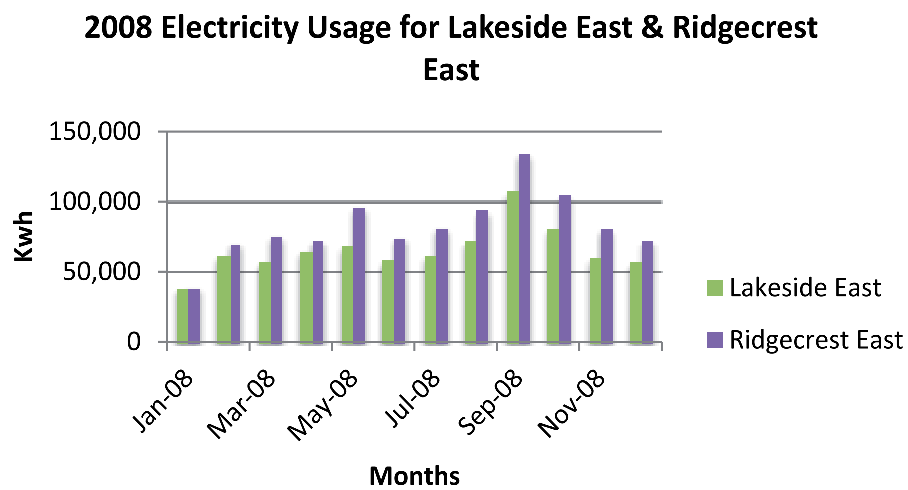


Source: University of Alabama Department of Energy Management

Figure 6. 2007 Electricity Usage for Lakeside East and Ridgecrest East.

As mentioned previously, Ridgecrest East has in general consumed a higher amount of electricity in terms of kilowatt hours per month during 2007 when compared to Lakeside East. Those higher consumption rates for Ridgecrest East are indicated as the following approximated percentages above Lakeside East's usage levels: January was 11% higher, February displayed an 8% increase, March had an 11% increase, April saw a 16% increase, May's increase jumped up 22%, June displayed a 24% increase, July had a 35% increase, October displayed a 27% rise, November increased to 35%, and finally December had a 36% increase over Lakeside East's consumption levels. Electricity consumption for Ridgecrest East during September 2007 was only about 44% of what Lakeside East consumed.

During 2008, Lakeside East consumed less total electricity each month than Ridgecrest East. Moreover, when the total consumption figures of 2008 for both dormitories are compared to the 2007 fiscal year, together the buildings show an overall decrease in electrical usage. Lakeside East displayed the following monthly consumption during 2008 recorded in



Source: University of Alabama Department of Energy Management

Figure 7. 2008 Electricity Usage for Lakeside East and Ridgecrest East.

kilowatt hours: January was 39,628 kWh; followed by February with 62,320 kWh; March consumed 58,206 kWh; April used 65,469 kWh; May was 68,613 kWh; June was recorded at 59,222 kWh; July had 62,597 kWh; August consumed 72,264 kWh; September was recorded at 108,040 kWh; October used 81,022 kWh; November had 60,623 kWh of usage; and finally during December 57,632 kWh were utilized. Similar to the methodology utilized to calculate the ecological footprint concerning water resources, Figure 15 depicts the ecological footprint procedure from which the electrical impact of students was derived.

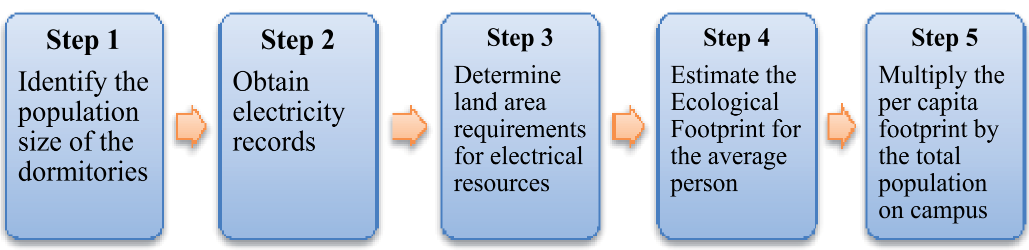


Figure 8. Ecological footprint procedure for electricity

For a more in-depth analysis of electrical usage for the two dormitories, the amount of energy utilized by each dormitory student for the year was calculated as the total electricity consumption numbers were divided by the amount of students residing within each dormitory. This accounted for the amount of electricity utilized per student to be 4,486 kWh at Lakeside East and 3,375 kWh at Ridgecrest East. It is important to note that even though the energy consumption numbers showed little variation during the 2007 fiscal year, the higher population numbers within Ridgecrest East resulted in energy usage per student that was considerably less than those found at Lakeside East. Just as the 2007 electricity records were broken down for analysis, the 2008 electricity records were evaluated for individual usage levels.

To acquire the electricity consumed per dormitory student during 2008, the electrical totals were divided by the amount of the respective residential populations. Thus, the average student consumed 3,343 kWh within Lakeside East and 3,177 kWh for Ridgecrest East. To relate student electricity consumption rates to a real-world example the 2007 and 2008 figures were broken into monthly averages. The 2007 monthly rates per dormitory student were calculated to be approximately 374 kWh for Lakeside East and approximately 281 kWh for Ridgecrest East. For 2008 the monthly averages were approximately 279 kWh for Lakeside East and approximately 265 kWh for Ridgecrest East. According to the Energy Information Administration (2007), the average Alabama household consumes 1,305 kWh per month.

After the consumption levels were successfully calculated for electrical resources, the amount of land could be determined for the usage of electrical resources. To accommodate the carbon emissions from the utilization of electricity the rate of 169 m^2 of forest for every 100 kWh of electricity was used for the following ecological footprint calculations (Anundson et al., 2001, p.11). Thus, the individual amount of electricity per dormitory student was first divided by 100 kWh and then multiplied by 169 m^2. Accordingly during 2007 for Lakeside East, the amount of land needed per dormitory student was 7,581 m^2 (0.758 hectares or 1.873 acres) and for Ridgecrest East 5,703 m^2 (0.570 hectares or 1.409 acres). During 2008, the amount of forested land area necessary per student amounted to 5,650 m2 (0.565 hectares or 1.396 acres) for Lakeside East and 5,369 m^2 (0.537 or 1.327 acres) for Ridgecrest East. In Table 7, meters squared were converted to hectares by dividing by 10,000. Additionally, hectares were converted by multiplying by 2.471.

Ecological Footprint for Electricity 2007	**Lakeside East**	**Ridgecrest East**
Total Electricity 2007 (kWh)	1,067,609	1,066,400
Electricity per Student in 2007 (kWh)	4,486	3,375
2007 Total Land $(m)^2$ per dormitory student	7,581	5,703
2007 Total Land in Hectares per dormitory student	0.758	0.570
2007 Total Land in Acres per dormitory student	1.873	1.409
Ecological Footprint for Electricity 2008	**Lakeside East**	**Ridgecrest East**
Total Electricity 2008 (kWh)	795,636	1,004,000
Electricity per Student in 2008 (kWh)	3,343	3,177
2008 Total Land $(m)^2$ per dormitory student	5,650	5,369
2008 Total Land in Hectares per dormitory student	0.565	0.537
2008 Total Land in Acres per dormitory student	1.396	1.327

Table 2. Ecological Footprint for Electricity 2007 and 2008

As a reminder, it is important to note that all the ecological footprint analysis that has been mentioned in this section pertains only to the electrical energy consumption as related to housing concerns. In reality electricity consumed for housing is only one area of a person's life where electricity is utilized. Therefore, the electrical usage and subsequent land area may in fact be larger than the estimates listed above. In general, ecological footprint calculations encompass a variety of goods and services associated with a person's lifestyle. This research looked specifically at water and energy usage of the footprint equation as related to housing needs.

In addition, each student's consumption of natural gas was calculated in the same way. Thereafter, each students total land area requirement at Lakeside East was calculated as follows: 0.179 acres for water resources in 2008, 1.873 acres for electricity in 2007, 1.396 acres for electricity in 2008, 0.170 acres for natural gas in 2007, and 0.177 acres for natural gas in 2008. Furthermore, Ridgecrest East's numbers were 0.110 acres for water in 2008, 1.409 acres for electricity in 2007, 1.327 acres for electricity in 2008, 0.142 acres for natural gas in 2007, and 0.140 acres for natural gas in 2008. Thus, if the entire student population that resides on-campus of approximately 7,000 individuals adopted the consumption habits of either Lakesides East or Ridgecrest East residents, then the land acreage as illustrated in Table 7 would have been needed.

When evaluating these figures it is important to understand that Lakeside East and Ridgecrest East are both relatively new buildings found on The University of Alabama's campus. As this study represents a sample of consumption levels taken from the new and therefore more efficiently constructed dormitories, the land requirement estimations for the students living on-campus are likely to be a best-case scenario. Overall, from the ecological footprint calculations utilized, Ridgecrest East displayed a lower environmental impact or land requirement than Lakeside East for water, electricity, and natural gas.

Additionally, land requirements decreased for electricity needs for both dormitories from 2007 to 2008. On the other hand, during the two year-span the land requirements for natural gas showed only a slight decrease for Ridgecrest East while Lakeside East showed an increase in demand. Acreage for water resources were not compared from 2007 to 2008 as the required data were unattainable.

Ecological Footprint: Land Requirements in Acres for the Dormitory Student Population	**Lakeside East**	**Ridgecrest East**
From 2008 Water Consumed	1,253	770
From 2007 Electricity Consumed	13,111	9,863
From 2008 Electricity Consumed	9,772	9,289
From 2007 Natural Gas Consumed	1,190	994
From 2008 Natural Gas Consumed	1,239	980

Table 3. Ecological Footprint for the On-Campus Population

5. Conclusion and policy implications

Although much progress has been made in recent years there is more that The University of Alabama can do in support of sustainable practices, as exemplified by green universities across the country. The first step toward becoming a green campus merely entails setting the goal of wanting to be more sustainable. The President of University of Alabama's message to the student body during fall of 2008 was the initial step required to set the tone for the campus. Now that a goal has been set, a subsequent plan will need to be developed. Objectives will need to be established in order to facilitate progress toward the end goal.

Before any other steps of the plan can be formulated lest carried out, it is essential to stop and take an inventory. The inventory determines where the campus is now so that progress may be more accurately measured. Thus, this research has served as a snapshot of where the campus currently is, during the academic semesters of fall of 2008 to early spring of 2009 in terms of sustainability. The snapshot is a useful tool as it was used to compare The University of Alabama to the top green schools. These prestigious universities were utilized in this analysis to serve as the pinnacle of where The University of Alabama may strive to be concerning environmental initiatives.

Taking the other schools analyzed in this research into consideration, our first recommendation is to formulate an official environmental plan that involves a variety of stakeholders in the planning process. This initiative needs the involvement of students, faculty, staff, alumni, investors, and the community as a whole. During the planning process, objectives must be set that are measurable as well as quantifiable to the overall goal of the plan. If these objectives are to serve as serve as milestones towards the goal of sustainability. Ecological footprint calculations as used in this study will be beneficial for monitoring progress towards this goal.

Our second recommendation is to strive to establish a recognizable environmental office on campus supported by a full-time staff. This ensures availability of knowledgeable staff to assist with inquiries from environmentally-aware students and community members as well as to address sustainability issues in accordance with the campus's environmental plan. According to data gathered on sustainable universities by the Sustainable Endowments Institute (2009), a considerable number of schools have recognized the need for full-time campus sustainability administrators. Currently, 56 percent report having dedicated sustainability staff.

We also recommend the incorporation of green building elements within residential student housing just. Generally speaking, universities are long-term owners of institutions. Hence, looking at the cost of operation over the period of a product's life cycle will help them accept some of the additional costs associated with green building methods. According to Moskow (2008), "Sustainable developments are more cost-effective in the long term and, therefore, ultimately, more valuable" (p.xv). This is especially true as the price of resources such as electricity and natural gas continue to rise. Additionally, green buildings have been noted to promote a healthy, productive work environment that would benefit the welfare and academic status of The University of Alabama.

Fortunately, The University of Alabama has already begun incorporating some green features in buildings such as low flow toilets, low flow faucets, low flow showerheads as well as plans for lighting controls and high efficiency hoods for new projects. Though those efforts are commendable, our recommendation is to use Bates College as an example to strive toward concerning green buildings. Due to cost restrictions, Bates College has not filed for the proper LEED certification for their structures. Despite not having filed, Bates College has used the LEED criteria as a standard in which to construct LEED equivalent buildings. Furthermore, green is marketable and green building designs are a good way to promote The University of Alabama's image.

Our final recommendation is education. Additional educational opportunities may in fact reduce the environmental impact of the University. Due to the fact that the role of academic institutions is to educate and facilitate in the development of tomorrow's leaders, this is a prime environment within which to integrate green technologies. Leaders that are unable to recognize the mismanagement of resources will be incapable of solving environmental problems. If environmentally friendly strategies are to be incorporated into future policies, then exposure to sustainable education is essential.

An expansion of research concerning ecological footprint analysis would be beneficial in an effort to determine the environmental impact of the campus. Though food and recycling strategies were only briefly discussed in this study, a more in-depth analysis may be needed to evaluate whether or not the University should try to promote locally or organically supplied food in the cafeterias and whether or not to participate in the *RecycleMania* competition. Additionally as only dormitory students were analyzed in this study, more sample groups could be evaluated and include both on-campus and off-campus students. Studies on climate change, transportation issues, student led initiatives, and a plethora of other opportunities exist for exploration.

In conclusion, we wish to emphasize that if places of higher learning are able to lessen their ecological footprints, they would ultimately have a greater positive impact on humanity and the dwindling resources of the World.

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6. References

American College & University Presidents Climate Commitment. (2008). *About the American College & University Presidents Climate Commitment.*Retrieved March 10, 2009, from http://www.presidentsclimatecommitment.org/ html/about.php

Andreen, C. (2008). *UA Enrollment Reaches Record 27,052 Students; Freshman Class Tops 5,000.*Retrieved February 26, 2009, from http://uanews.ua.edu/anews 2008/sep08/enrollment091608.htm

Anundson, B., Crooks, J., Fletcher, A., Frank, M., et al. (2001). *A Study of the Ecological Footprint of Allegheny College.* Unpublished manuscript.

Barrella, N. (2008, November 20). *In competition, Harvard seeks to "green up" dorms*. Harvard Law Record. Retrieved December 3, 2008, from http://media.www.hlrecord.org/media/storage/paper609/news/2008/11/20/News/In.Competition.Harvard.Seeks.To.green.Up.Dorms-3554348.shtml

Bates College. (2008). *Student Housing at 280 College Street.* Retrieved December 2, 2008, from http://www.bates.edu/x175547.xml

Bralley, B. (2008, September 10). *UA Construction Goes Green*. Crimson White. Retrieved September 12, 2008, from http://www.cw.ua.edu/ua

Bursch, K. (2009, January 7). *UA Starts New Green Campaign.*Crimson White. Retrieved January 15, 2009, from http://www.cw.ua.edu/ua_starts_new _green_campaign

Emory University. (2008a). *Emory Sustainable Initiative: History.* Retrieved December 11, 2008, from http://sustainability.emory.edu/page/1015/History

Emory University. (2008b). *Emory Sustainable Initiative: Sustainable Food.* Retrieved December 11, 2008, from http://sustainability.emory.edu/page/1008/Sustainable-Food

Enck, J., & Turner, S. (2003). *ASHRAE Green Guide: An ASHRAE Publication Addressing Matters of Interest to Those Involved in Green or Sustainable Design of Buildings.* Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

Energy Information Administration. (2001). *Natural Gas Consumption and Expeditures in U.S. Households by End Uses and Census Region, 2001.* Retrieved March 3, 2009, from http://www.eia.doe.gov/emeu/recs/byfuels/2001/byfuel_ng.pdf

Energy Information Administration. (2007). *U.S. Average Monthly Bill by Sector, Census Division, and State 2007.* Retrieved March 3, 2009, from http://www.eia.doe.gov/cneaf/electricity/esr/table5.html

Environmental Protection Agency. (2003). *Water on tap: What you need to know.*Retreived March 25, 2009, from http://www.epa.gov/safewater/wot/pdfs/ book_waterontap_full.pdf

Environmental Protection Agency. (2008). *Wastes – Non-Hazardous Wastes.* Retrieved October 12, 2008, from http://www.epa.gov/epawaste/nonhaz/index.htm

Environmental Protection Agency. (2009a). *Brownfields and Land Revitalization.* Retrieved March 19, 2009, from http://www.epa.gov/brownfields/

Environmental Protection Agency. (2009b). *Wastes – Resource Conservation – Reduce, Reuse, Recycle.* Retrieved April 16, 2009, from http://www.epa.gov/osw/conserve/rrr/reduce.htm

Fiala, N. (2008). Measuring sustainability: Why the ecological footprint is bad economic and bad environmental science. *Ecological Economics*. Retrieved October 11, 2008, from ScienceDirect database.

Glavinich, T. (2008). *Contractor's Guide to Green Building Construction: Management, Project Delivery, Documentation, and Risk Reduction*. New Jersey: John Wiley & Sons, Inc.

Global Footprint Network. (2003). National Footprints.*Global Footprint Network.* Retrieved October 1, 2008, from http://www.footprintnetwork.org/gfn_sub.php?content=national_footprints

"Global Warming". (n.d.).*New York Times*. Retrieved October 11, 2008, from http://topics.nytimes.com/top/news/science/topics/globalwarming/index.html

"Graduate Green Living Program Enters Its Second Year". (2007, Spring). *Harvard Green Campus Newsletter.* Retrieved December 4, 2008, from http://www.greencampus.harvard.edu/newsletter/archives/2007/05/graduate_green.php

Gray, K. (2008, September 19). *Emory Freshman Live 'Green' in New Housing.* [News Release]. Retrieved December 3, 2008, from http://www.emory.edu/home/news/releases/2008/09/green-dorms-open.html

Hakim, C. (1987). *Research Design: Strategies and Choices in the Design of Social Research.* London: Allen & Unwin.

Handwerk, B. (2005, March 31). Earth's Health in Sharp Decline, Massive Study Finds. *National Geographic*. Retrieved October 10, 2008, from http://news.nationalgeographic.com/news/2005/03/0331_050330_unenvironment.html

Harper, C. (2008). *Environment and Society: Human Perspectives on Environmental Issues* (4th ed.). New Jersey: Pearson Education, Inc.

Harvard University. (2008). *Green Campus Loan Fund: Harvard Office for Sustainability.* Retrieved December 11, 2008, from http://www.greencampus.harvard.edu/gclf/

Ireland, C. (2008, November 13). *Living in the green zone at "Rock Hall".* Harvard University Gazette Online. Retrieved December 3, 2008, from http://www.news.harvard.edu/gazette/2008/11.13/11-rockefeller.html

Jorgenson, A., & Burns, T. (2006). The political-economic causes of change in the ecological footprints of nations, 1991-2001: A quantitative investigation. *Social Science Research*. Retrieved October 11, 2008, from Science Direct database.

Kitzes, J., Galli, A., Bagliani, M., Barrett, J., Dige, G., Ede., S., et al. (2008). A research agenda for improving national ecological Footprint accounts. *Ecological Economics*. Retrieved October 11, 2008, from ScienceDirect database.

Kobet, B., Lee, S., & Mondor, C. (1999). *Green Buildings: Guidelines for Creating High-Performance Green Buildings*. Pennsylvania Department of Environmental Protection.

Leopard, T. (2008). *SGA Memo: University Efforts in Regard to Sustainability.* [Memo]. University of Alabama.

Loftus, M. (2007, Autumn). *Emory sprouts new green residence halls*. Emory Magazine. Retrieved December 3, 2008, from http://www.emory.edu/EMORY_MAGAZINE/2007/autumn/halls.html

Mayell, H. (2002, January 10). Green Group Gives Earth Failing Report Card. *National Geographic*. Retrieved on October 11, 2008, from http://news.nationalgeographic.com/news/2002/01/0110_020110worldwatch.html

Moskow, K. (2008). *Sustainable Facilities: Green Design, Construction, and Operations.* New York: McGraw-Hill

National Geographic Website. (2008). *Effects of Global Warming*. Retrieved October 11, 2008, from http://environment.nationalgeographic.com/environment/global-warming/gw-effects.html

Pinkse, J., & Dommisse, M. (2008) Overcoming Barriers to Sustainability: An Explanation of Residential Builders' Reluctance to Adopt Clean Technologies. *Business Strategy and the Environment.* Retrieved September 12, 2008, from Wiley InterScience database.

Princeton Review. (2008). *Green Rating Honor Roll*. Retrieved September 10, 2008, from, http://www.princetonreview.com/green-honor-roll.aspx?uidbadge=%07

Punch, K. (1998). *Introduction to Social Research: Quantitative and Qualitative Methods*. London: Sage Publications.

RecycleMania (2009). *General Overview.* Retrieved January 05, 2009, from http://www.recyclemania.org/

Spiegel, R., & Meadows, D. (2006). *Green Building Materials: A Guide to Product Selection and Specification*.(2nd ed.). New Jersey: John Wiley & Sons, Inc.

Sustainable Endowments Institute. (2009). *Administration – Leaders – Green Report Card 2009*. Retrieved March 9, 2009, from http://www.greenreportcard.org/report-card-2009/categories/administration.

Turner, K., Lenzen, M., Wiedmann, T., & Barret, J. (2006).Examing the global environmental impact of regional consumption activities-Part 1: A technical note on combining input-output and ecological footprint analysis. *Ecological Economics*. Retrieved October 10, 2008, from ScienceDirect database.

Wackernagel, M., Monfreda, C., Schulz, N., Erb, K., Haberl, H., & Krausmann, F.(2003). Calculating national and global ecological footprint times series: resolving conceptual challenges. *Land Use Policy*. Retrieved October 10, 2008, from ScienceDirect database.

Wackernagel, M., & Rees, W. (1996). *Our Ecological Footprint: Reducing Human Impact on the Earth.*Gabriola Island: New Society Publishers.

Wallace, S. (2007, January). Farming the Amazon: Last of the Amazon. *National Geographic.* Retrieved October 11, 2008, from http://environment.nationalgeographic.com/environment/habitats/last-of-amazon.html

Wymer, M. (2008) *UA Experts Offer 'Going Green' Advice*. Retrieved February 16, 2009, from http://uanews.edu/anews2008/apr08/earthday040808.htm

A Flood Control Approach Integrated with a Sustainable Land Use Planning in Metropolitan Regions

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Additional information is available at the end of the chapter

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1. Introduction

The Brazilian National Water Resources Policy, instituted by Law no. 9.433 in 1997, is based on six fundamental principles that structure the whole National Water Resource Management System: 1) water is a commodity in the public domain; 2) water is a limited natural resource, endowed with economic value; 3) in situations of scarcity, the priority water resources use is for human consumption and watering animals; 4) the management of water resources must always provide multiple water uses; 5) the hydrographical basin is the territorial unit for the implementation of the National Water Resources Policy and the activities of the entities belonging to the of National Water Resources Management System; 6) the water resource management must be decentralized and have the participation of public authorities, water users, civil society and communities.

This Law and its regulatory texts incorporate municipalities, along with users and civil organisations, into the management system, ensuring a greater balance of power on water resource committees and boards. However, no legal text has clearly defined the relation between water management, which is a state or federal attribution, and land use planning, which is responsibility of the municipalities. In this sense, there remains a lack of definition regarding the fundamental role of municipal administrations as formulators and implementers of urban policies with impacts on water resources, whether through direct investment, or by means of actions of regulatory nature.

Besides the gap pointed out above, the occurrence of conflicts of competency is also observed in the hydrographical basins related to metropolitan areas, given that the 1988 Brazilian Constitution did not establish clear management rules for these territories. The definition of the needed and related administrative organisation for the metropolitan areas is left to the federative states. On the other hand, overlaps is observed in the attributions of the local, state, or even federal administrations, and various undefined roles are identified, which make the task of coordination and sharing of the responsibilities even more complex.

Based on these elements, and departing from Brazilian reality, the proposed chapter deals with the need of integration of land use planning with water resource management, seeking to establish relations between the types of land use, urban settlements and the problems involving urban flooding.

A case study was developed for the Iguaçu-Sarapuí River Basin, located in the western portion of the Guanabara Bay Basin, which lies at the Rio de Janeiro State Metropolitan Region, in Brazil, and is one of the most critical areas in the state in relation to urban flooding. In this region, urban expansion dynamics is, in general, marked by irregular occupation of risk areas, without the appropriated infrastructure in terms of land tenure.

The significant investments in infrastructure in progress in the region, mainly the construction of the Metropolitan Ring Road[1] will bring substantial transformation to the region current urban configuration. The scenarios built with the aid of mathematical modelling demonstrate that the disorderly urban expansion, induced by the accessibility to the rural areas in the interior of the region, may be degrading for the medium and long term urban flooding control in this basin.

2. The role of the municipality in water resource management in Brazil

The competence of municipalities in federated countries is concentrated on functions that, in general, are related with the allocation or rendering of local public services and with the functions of planning, incentive and inspection of the territorial order, environmental protection and also with some level of regulation of economic activities [1]. In the case of Brazil, recently, municipalities with greater capacity of investment have begun to incorporate functions related with the provision of more comprehensive social services, which, traditionally, were restricted to the state and federal spheres.

In the specific case of water resource management, however, municipal participation in basin committees has been the main form, if not the sole, of interaction with other public and private actors related with water. Many factors hinder the municipality action in the water management sphere, the main one being the legal impossibility, by Constitutional definition, of the municipalities directly managing water resources, even in the case of basins entirely contained by their territories. The exceptions may be associated to the transfer of some specific attributions through cooperation agreements with the states or the Federal Government.

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[1] The Metropolitan Ring Road is a Federal Government work, whose estimated cost is approximately US$ 1.6 billion. It will have an intersection with five federal highways, a railroad and a link with various large scale industrial poles being set up in the Rio de Janeiro Metropolitan Region.

Although local administrations are closer to local populations, their politico-administrative role does not allow a systemic vision of the territory in which they lie. More effective participation of local governments in water management is hindered, or even made unviable, also by the absence of clear definitions about its nature and functions, and by the fact that the majority of municipalities have limited budgetary autonomy, bearing in mind that they depend heavily on fund transfers from the other levels of government administration.

Regarding the financial restrictions [2], it is alarming that most of the multilateral financial agencies, except the Global Environment Facility – GEF, still have not included, in their agenda, projects of integrated natural resources management articulated to land use planning, particularly in urban areas. There are few planning experiments implemented articulating water conservation and/or preservation measures and land use regulation, despite the dysfunctions of urban growth.

Another aspect is that the sectoral nature of local government interests makes them act more as users than as "impartial" managers of water resources [3]. The debility and lack of institutional hierarchy of local governments confronted by actors wielding greater power would lead to greater vulnerability and to the possibility of capture and politicisation in water management [3]. These aspects are aggravated in metropolitan areas, where municipal administrations often express antagonistic interests and priorities among themselves, creating atmospheres of dissension with little space for cooperation.

Although there are restrictions on the participation of municipalities as direct managers of water resources, there is no doubt related to the importance of local governments in territorial planning, as well as in its consequences to water resources conservation. It is the attribution of municipalities to devise, approve and inspect instruments related with territorial order, such as master plans, zonings, development of housing programs, delimitation of industrial, urban and environmental preservation areas, among other activities with impacts on water resources, mainly in the case of predominantly urban hydrographical basins.

These attributions have recently been strengthened upon approval of the Brazilian Statute of the City. This is a Federal Act, established in 2001, which proposes standards of public and social interest to govern the use of the urban property in favour of the collectivity safety and welfare, as well as the environmental balance. The urban policy established aims to organise the fulfilment of the social functions of the city and of the urban property by the application of a set of general guidelines, from which the following topics are detached:

- the guarantee of the right to sustainable cities, meaning the right to urban land, housing, environmental sanitation, urban infrastructure, transport and public services, work and leisure for present and future generations;

- the democratic management through people's participation representing segments of the community in the formulation, implementation and monitoring of plans, programs and projects for urban development;
- the planning of city development to prevent and correct the distortions of urban growth and its negative effects on the environment;
- the supply of urban infrastructure and community equipments, transport and public services to serve the interests and needs of the population;
- the protection, preservation and restoration of the natural and built environment, besides cultural, historical, artistic and landscape heritages.

Several important urban management tools were made available in the context of the Statute of the City and the Urban Master Plan is considered to be the basic instrument for the urban developing policy.

The possibility of achieving a sustainable water resource management must necessarily pass through a clear articulation with land use plans. What is observed in Brazil, however, is the disarticulation between instruments of water resource management and land use planning, reflecting, perhaps, the lack of legitimacy of planning and urban legislation in Brazilian cities, marked by a high degree of informality, and even illegality, in land use occupation. According to Tucci [4], the greatest difficulty for the implementation of integrated planning arises from the limited institutional capacity of municipalities in facing complex interdisciplinary problems, and in the sectoral ways in which local administrations are organized.

Here, however, it is worth stressing the differences among municipalities: while in large cities, mainly metropolitan cores, it is possible to find efficient administrations, with good capacity to access information and with relatively modern legislation, in other minor cities, like peripheral municipalities in metropolitan areas, a total obsolescence in the legislation is verified. This is aggravated by the absence of reliable general data and information about the processes of urban structuring and also by the small number and low qualification of the technical staff [5].

This inequality in the municipal scale presents a great obstacle for a greater effectiveness of water resource management structures and for the cooperation among the different hierarchical levels of government.

3. Flood control in the Baixada Fluminense lowland

Baixada Fluminense lowland is located in the western portion of the Guanabara Bay basin, in one of the most critical regions of Rio de Janeiro State, in terms of urban flooding. It is particularly interesting as an empirical study, considering the following aspects:

- its location is in the metropolitan periphery;
- there are areas with consolidated urban and industrial growth;

- there rural areas in a process of urban development
- the basin also contains rural areas still protected from urbanisation;
- several areas present land use patterns that do not ensure minimal standards of living, especially those of poor drainage;
- consequently, several serious flooding problems occur in the watershed plain areas;
- water sources found in the basin area are used for complementing the Metropolitan Region drinking water supply;
- Tinguá Biological Reserve, the main remnant of the Atlantic Forest in Rio de Janeiro State, is situated in this territory;
- organised social movements, congregating federations of residents associations and entities involved in matters of environment, sanitation, housing, among others, are present in the basin, what demonstrates the great organisation capacity of its population vis-à-vis the questions related to citizenship and quality of life;
- local administrations are becoming more committed to efficiency in public affairs, although in a still timid process;
- the presence of major private and public investments in infrastructure will lead to significant transformations in the present urban configuration of the region.

3.1. Physical and socio-economic characteristics of the basin

The Iguaçu-Sarapuí River basin is situated in Baixada Fluminense lowlands. Its drainage area covers around 727 km^2, all of which is situated in the Rio de Janeiro Metropolitan Region. Iguaçu River springs in Serra do Tinguá massif, at an altitude of 1,600m. Its course runs southeast for approximately 43 km, until it reaches the outfall at Guanabara Bay. Its main tributaries from the left margins are Tinguá, Pati and Capivari Rivers, and, from the right margins, Botas and Sarapuí Rivers.

The physiography of Iguaçu-Sarapuí river basin is characterized by two main elements: the Serra do Mar Mountains and Baixada Fluminense lowlands, with a marked difference in altitude. The climate in the basin is hot and humid with a rainy season in the summer, the average annual precipitation being around 1,700mm, and the mean annual temperature approximately 22^o C. The rivers run down the mountains in torrents with great erosive force, losing speed after reaching the plains, often overflowing their banks into large wetlands.

The basin fully encompasses the municipalities of Belford Roxo and Mesquita, also hosting part of the municipalities of Rio de Janeiro (covering the neighbourhoods of Bangu, Padre Miguel and Senador Câmara), Nilópolis, São João de Meriti, Nova Iguaçu and Duque de Caxias (Figure 1). According to the 2010 Brazilian census, the population of these municipalities reached 9,225,557 habitants (Table 1). However, just two of these municipalities are totally inserted in the basin.

City	Municipal Population			Total Area[1)] (ha)	Area inside the basin[(2)] (ha)	% (*)
	Urban	Rural	Total			
Belford Roxo	469.332	-	469.332	7.350	7.350	10
Duque de Caxias	852.138	2.910	855.048	46.570	27.359	38
Nilópolis	157.425	-	157.425	1.920	1.042	1
Mesquita	168.376	-	168.376	3.477	3.477	5
Nova Iguaçu	787.563	8.694	796.257	53.183	27.894	38
Rio de Janeiro	6.320.446	-	6.320.446	126.420	3.290	5
São João de Meriti	458.673	-	458.673	3.490	2.293	3
Total	**9.213.953**	**8.694**	**9.225.557**	**242.410**	**72.705**	**100**

Source: (1) demographic census of 2010, with the territorial division of 2001, (2) Adapted from the Iguaçu Project; (*) percentage of the municipal area in relation to basin area.

Table 1. Municipal population, total municipal area, and insertion in Iguaçu-Sarapuí River Basin

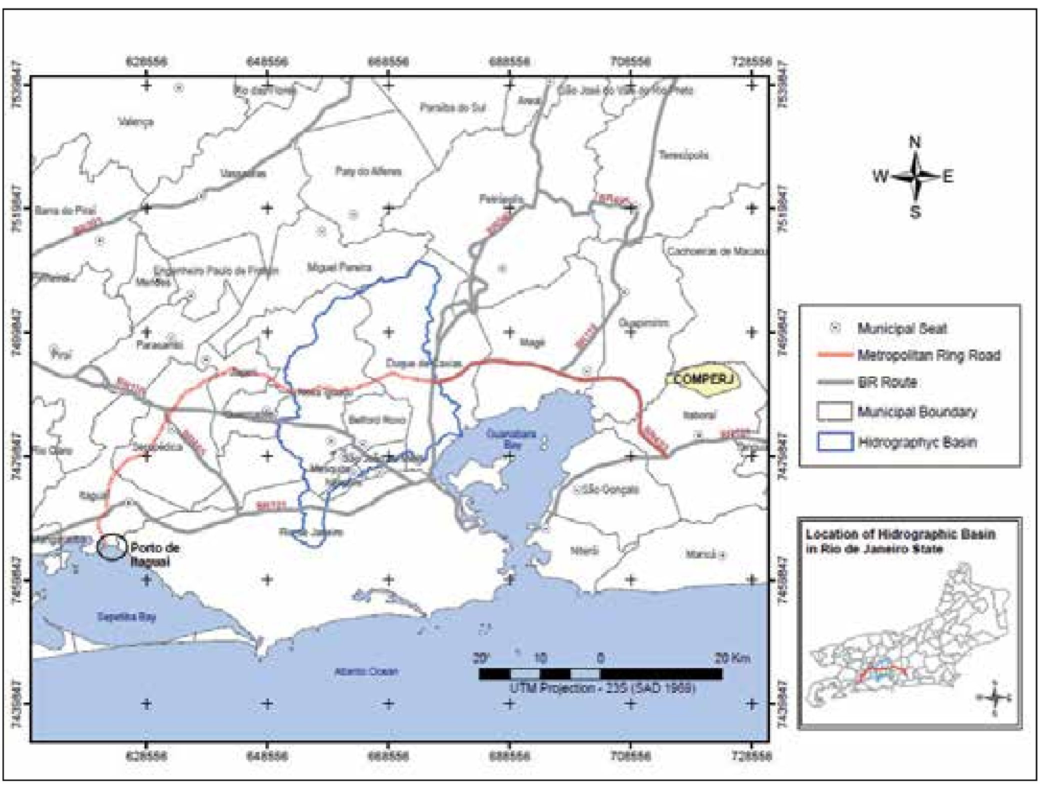


Figure 1. Iguaçu-Sarapuí River Basin

It is in the lower parts of the basin, with elevations near the medium sea level, where it is concentrated mostly of the urban area, with something about 1.5 million people living there. Calculations from IBGE, the Brazilian Institute of Geography and Statistics, show that the incidence of poverty in these municipalities is quite significant, especially in Belford Roxo, Nova Iguaçu and Duque de Caxias, affecting more than half of their populations (Table 2).

Municipality	%
Belford Roxo	60,06
Duque de Caxias	53,53
Mesquita	-
Nilópolis	32,48
Nova Iguaçu	54,15
Rio de Janeiro	23,85
São João de Meriti	47,00

Source: IBGE, Demographic Census of 2000 and Household Budget Survey - POF 2002/2003.

Table 2. Poverty and inequality map – Brazilian Municipalities, 2003- Poverty incidence in Baixada Fluminense Lowlands

The structural analysis of per capita income and the capability to finance investments by municipalities in the region, according to the Observatory of the Metropolis [6], demonstrate the strong differences between the municipalities belonging to the Metropolitan Region of Rio de Janeiro. Such differences constitute obstacles to cooperation in solving common problems. Moreover, the fragile financial structure, coupled with the shortage of technical capacity, particularly in the areas of planning and budget, strengthen the uncertainty, discouraging long-term partnerships in infrastructure projects that could be used to promote social and economic development for the region.

After a century of intense population growth, Brazil has entered the new millennium with quite modest rates of population growth. As shown by the data of the last Census, the Brazilian population grew at an average rate of 1.6% per year in the 1990s, following a decline trend after the strong growth happened from the 1950 to 1970. Projections developed recently estimated that the Brazilian population is growing at rates below 1.3% per year.

The city of Rio de Janeiro has been the centre of services for the Metropolitan region, although this characteristic has not reflected in a high degree of attractiveness for population in recent times. The region remained with the lowest population growth rate among large Brazilian cities. It should be noted, however, that in absolute terms, there was a warming of migration in the last decade towards Rio de Janeiro. Between 1980 and 1991 the total number of migrants towards the metropolitan area of Rio de Janeiro was around 570,000 people, while between 1995 and 2000 (just in five years) the total migration reached 330,000 people. The capital of the state remained the main pole centre, receiving these migration flows and housing 195,000 migrants, i.e. 62% of the total [6].

According to Britto and Bessa [7], historical investments were made in the region by different state governors, like the one of the 1980s, with an amount up to R$ 3 billion, without, however, effectively guaranteeing universal access to environmental sanitation, housing and a better quality of life. Explanations for this are related with: (i) the lack of a profound diagnosis of the dimension of the problem in the region to correctly orient the profile of the interventions; (ii) the discontinuity and non-integration among the programs and projects implemented throughout these years; (iii) the political disputes in the region often decharacterised the projects, again lacking continuity; (iv) the fragility of social control in the process, once the format of the implemented programs have not provided an effective participation of the population (although this component existed in various of these projects); (v) the lack of institutional capacity, allied to the centralizing culture of the state governors in relation to sanitation management; (vi) the strong clientelistic culture in the municipal administrations; (vii) the growing demobilisation of organized social movements, which need members qualification for following up the policies implementation.

3.2. Flood control in the Baixada Fluminense lowlands

Floods in the Iguaçu-Sarapuí River Basin are aggravated basically by the f inadequate land use occupation, in the particular conditions of the lowlands of Baixada Fluminense. In this process, the most important factors are: lack of adequate urban infrastructure; deficiency of the sewage services and solid waste collection; uncontrolled exploitation of mineral deposits, mainly sand for construction purposes; disorderly, illegal occupation of river banks and floodplains; lack of adequate treatment for public roadways pavements; obstruction or strangulation of drainage due to structures built without the proper concerns (railway and road bridges, and water pipelines interferences), as well as walls and even buildings that partially obstruct river channels. At the heart of these problems one always finds either inadequate legislation regarding land use, or, in the great majority of cases, non-compliance with the existing legislation.

It is estimated that floods in the basin directly affect 189,000 people. However, the damage caused and the total number of people indirectly affected by floods are both difficult to estimate. Included in this latter category there are, for example, employees who cannot reach their workplaces and the interruption of traffic and commerce along the flooded roadways or nearby areas that become inaccessible.

In this context, in order to properly discuss the adequate possible planning actions for mitigating these problems, and to figure out the cause-effect process related to future scenarios, a mathematical model will be applied as an aiding tool. The case study alternatives are then introduced in order to allow the development of the discussions in practical terms, using examples of what may happen in the future without the proper concerns. The aim of hydrodynamic modelling was to evaluate the possible impacts of the expansion of urbanisation towards the interior of the basin without the adequate planning process and considering the construction of Metropolitan Ring Road, which is being taken as an urban development inductor factor. Another objective of the modelling consisted of evaluating the impact of an average rise in mean sea level, regarding the drainage system conditions, according to forecasts made by the Intergovernmental Panel on Climate Change (IPCC) [8]. In both situations, which may critically combine effects, planning actions are required in order to control future negative effects, otherwise the human and material losses could become irremediable.

3.2.1. *Brief Description of MODCEL*

In order to proceed with the proposed analysis, it was necessary to choose a mathematical model to support the simulations. With this aim, a hydrodynamic model for representing rural and urban floods – MODCEL [9, 10 e 11] was used.

The construction of MODCEL, based on the concept of flow cells [12] intended to provide an alternative tool for integrated flood solution design and research. MODCEL is a model that integrates a hydrologic model, applied to each cell in the modelled area, with a hydrodynamic looped model, in a spatial representation that links surface flow, channel flow and underground pipe flow, This arrangement can be interpreted as a hydrologic-hydrodynamic pseudo 3D-model, although all mathematical relations written are one-dimensional. Pseudo 3D representation may be materialised by a vertical hydraulic link used to communicate two different layers of flow: a superficial one, corresponding to free surface channels and flooded areas; and a subterranean one, related to free surface or surcharged flow in storm drains.

The representation of urban surfaces by cells, acting as homogeneous compartments, in which rainfall run-off transformations are performed, allows the integration of all the basin area. The cells interact through hydraulic laws, represented by cell links capable to model different possible flow patterns. Different types of cells and links give versatility to the model. The cells, considered individually as units or taken in pre-arranged sets, are capable to represent the watershed landscape, composing more complex structures. Therefore, the task related to the topographic and hydraulic modelling is an important phase of the process. In large floodable areas, when leaving the drainage network, the water can follow any path, dictated by the topography and by the urban built patterns. Marginal sidewalks may become weirs for the spilling waters from the rivers, the streets may act as canals and the buildings, parks or squares may act like reservoirs. In this situation, it is perceived that overflowed waters may have an independent behaviour from the drainage network, generating their own flow patterns. These characteristics are adequately represented in MODCEL.

The modelled area of Iguaçu-Sarapuí River basin extended from Guanabara Bay to Botas River confluence. The upstream reaches of the basin, which were not divided in cells, had their flows determined through a hydrological model called HIDRO-FLU [13].

3.2.2. Simulation criteria

The main objective of the modelling of the lower and middle reaches of the Iguaçu River was to evaluate impacts caused by the expansion of uncontrolled urbanisation towards the middle/upper basin, arising from the development expected from the construction of the Metropolitan Ring Road, an important axial roadway.

The effective rainfall calculation method used was that of the SCS [Soil Conservation Service] of the Department of Agriculture of the USA - USDA. The *Curve Number* (CN), the main hydrological parameter of this method, varied for each of the simulated scenarios in accordance with different stages of urbanisation, as described below:

1. Past situation: the CN values were defined based on soil types and land use mapping from 1994 (LANDSAT satellite images) [14].
2. Present situation: the CN values were determined by land use mapping, made on the basis of images from the 2006 Aster sensor [14].
3. Future situation: assumed that the flat, still rural areas of the sub-basins of the Rivers Iguaçu (upper reach), Botas, Capivari, Pilar and Calombé, and the Outeiro canal will suffer a disorderly process of urbanisation, following the trend of peripherisation in progress in Baixada Fluminense lowlands. This future scenario corresponds to a horizon of approximately 20 years (2030).
4. Controlled future situation: assumed an alteration in the current pattern of urbanisation of these areas, with the introduction of land use control by means of urban planning actions and adoption of more sustainable urban drainage techniques.

Each modelled cell in the basin representation had an individualised CN, depending on its particular characteristics.

Another objective of the modelling consisted of evaluating the impact of the mean sea level rise, as forecasted by the IPCC, on the drainage conditions of the hydrographical basin. The proposed scenarios tested the isolated and/or associated effect of the following variables:

a. different hydro-meteorological conditions, alternating typical tidal situations and the effect of meteorological tide;
b. variation in the soil impervious rates arising from the behaviour of future urbanisation, considering the maintenance of the current rates (without any increase in new urban areas); an increase in the impervious rates due to unplanned urban expansion; and a moderate increase in the rates due to planned control of urban expansion. For each of the simulated scenarios, CN values were adopted as presented in Table 3.

It is important to stress that this paper does not intend to look for final solutions in order to minimise present flood conditions (although this discussion will be considered conceptually in the context of this study, in a nest topic). The main aim refers to the possibility of discussing future conditions worsening due to the inadequate planning process that take place today.

Basin	Past CN	Current CN	Future CN	
			without control	with control
Iguaçu	65	66	77	72
Botas	81	81	82	81
Capivari	67.5	65	77.9	72
Outeiro	72	84	84	84
Pilar	75	76	78.2	76
Calombé	68	79	79.8	79

Table 3. Curve Number (CN) used in each simulated scenario

The return period considered for the design rainfall was 20 years. The hydrologic parameters and rainfall information adopted were based on the Iguaçu Project [15] calculations. Regarding to the impacts caused by alterations in mean sea level, a local tide table was used as the base information. This table was produced by the Diretoria de Hidrografia e Navegação da Marinha do Brasil (Hydrography and Shipping Directorate of the Brazilian Navy), with values ranging from 0.09 to 0.90m, representing the tidal variation on the Rio de Janeiro coast. The meteorological tides were considered to influence this value with a majoring of 0.80m. Besides, a possible increment of 0.60m in the mean sea level was also considered (IPCC forecast), due to climate change expectative. With the values mentioned, the proposed scenarios were simulated, considering the tidal variations, the dynamics of urbanisation, the rise in the mean sea level, and combinations among these variables.

4. Results obtained in the modeling

Figure 2 represents the areas susceptible to flooding for the former conditions of urbanisation (at the time of Iguaçu Project [15]), in the 90's, without taking into account the meteorological tides and the effects of climate change. It is, therefore, a condition of reference for the current and future scenarios comparison, referring to flooding conditions of more than 15 years ago. It is observed that there are significant differences in floods in past conditions from those in the present scenario. The alteration already occurred in the land occupation in the upper reaches of the basin in the period justifies this result.

The flood maps presented in Figures 3 and 4, respectively, were obtained through the following conditions: current situation of urbanisation in the basin, without considering meteorological tides and the effects of climate change (Scenario 1); and future condition of the basin urbanisation, considering disorderly urban expansion, typical tides and without the effects of climate change (Scenario 2).

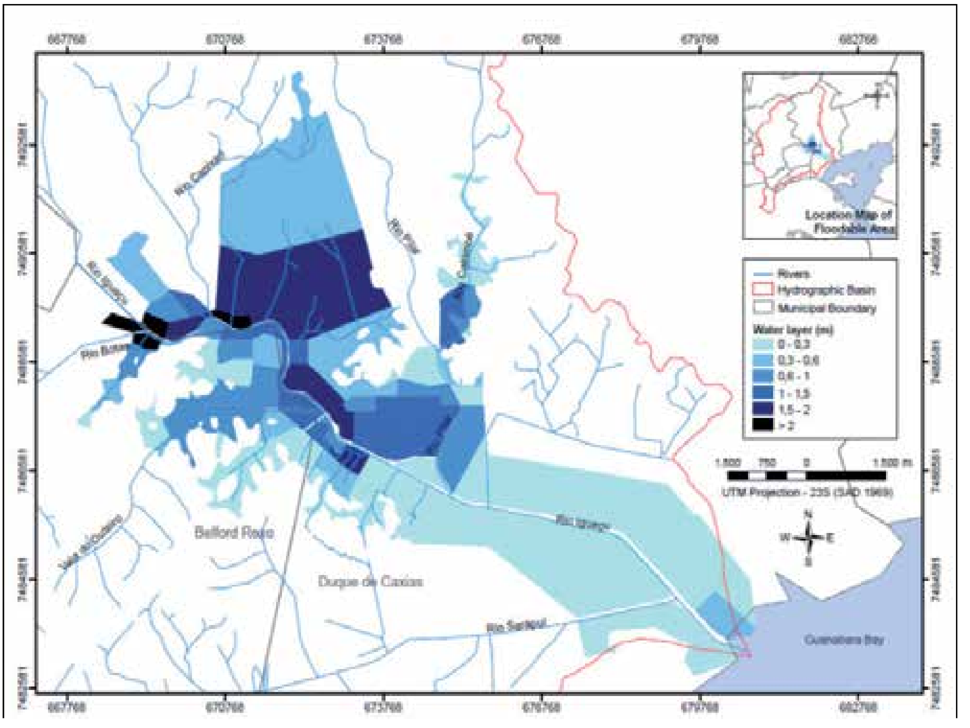


Figure 2. Reference flood map for former urban condition

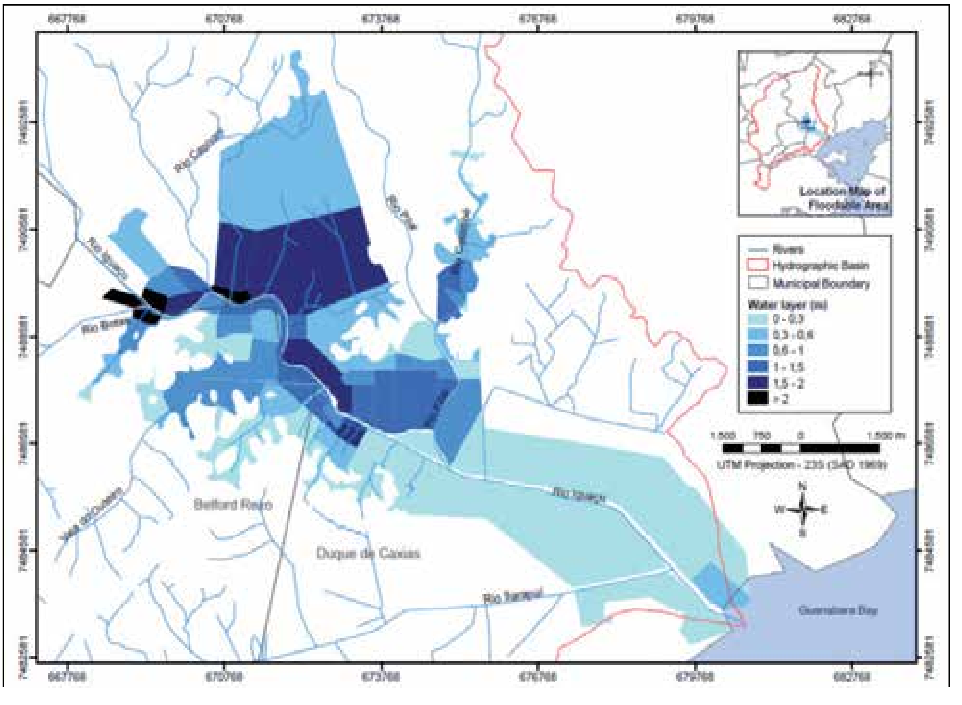


Figure 3. Flood map obtained for the present condition - Scenario 1

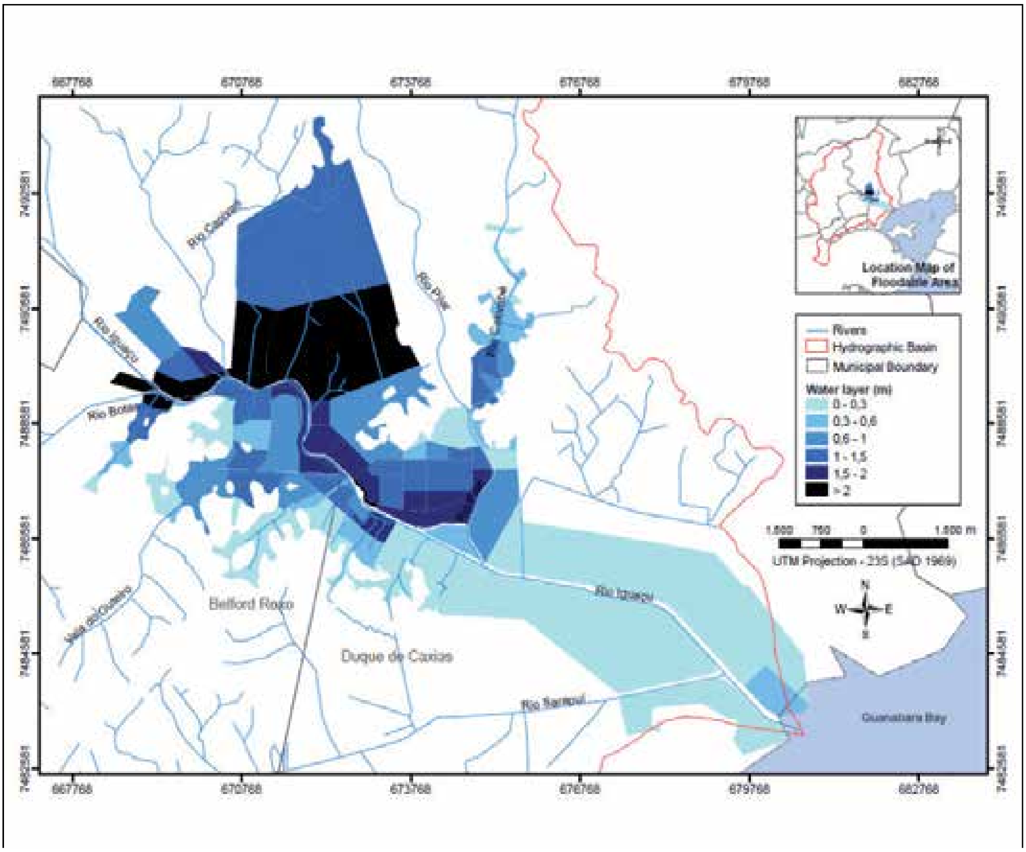


Figure 4. Flood map obtained for future condition - Scenario 2

The comparison among these three scenarios allows the assessment of the isolated effect of the urban expansion in the flooding aggravation. When the CN is altered for the upper reaches of the drainage area, in the simulation corresponding to Scenario 2, a significant worsening is noticed in flood conditions, even without any other worsening factor acting, as seen in the comparison of Figures 3 and 4

If effective measures were implemented for land use development control, in order to prevent disorderly occupation in the middle and upper reaches of the basin, it can be seen, in Figure 5 (Scenario 3), that it is possible to avoid the worsening of floods in the referred sub-basins. It is perceived a reduction in the water levels in the densely urbanized areas, when compared with the previous development situation, without any control over land occupation.

The figures 6 and 7, presented in sequence, correspond to the following scenarios:

- Figure 6: Flood map obtained for the future conditions of basin urbanisation with urban expansion without control over land use; meteorological tide of 80 cm and a 60 cm rise in the mean sea level due to climate changes (Scenario 4);

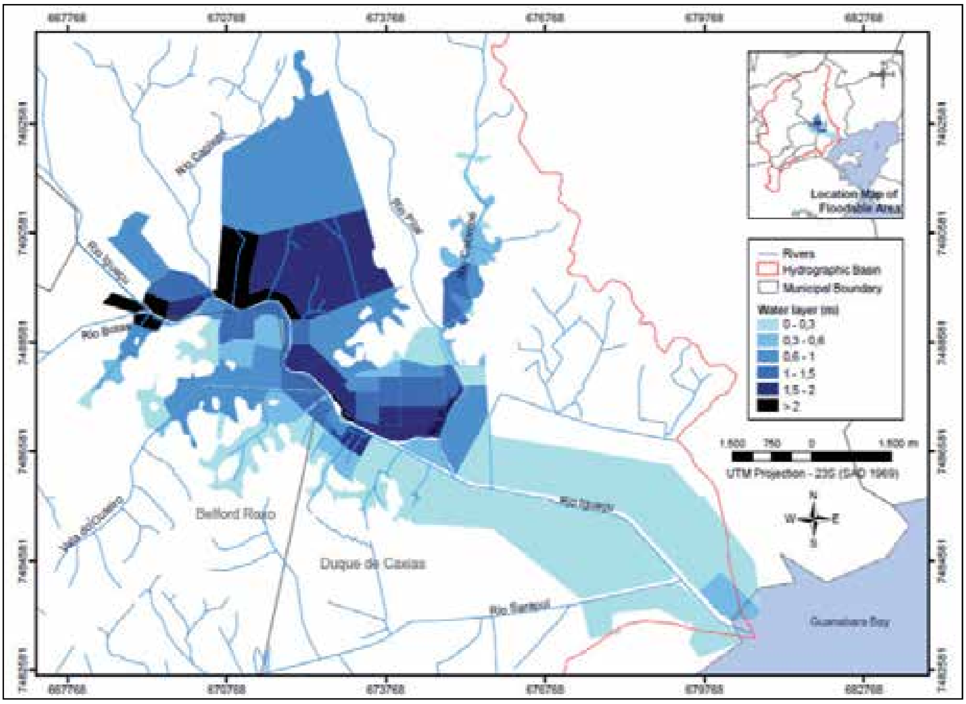


Figure 5. Flood map obtained for controlled future condition - Scenario 3

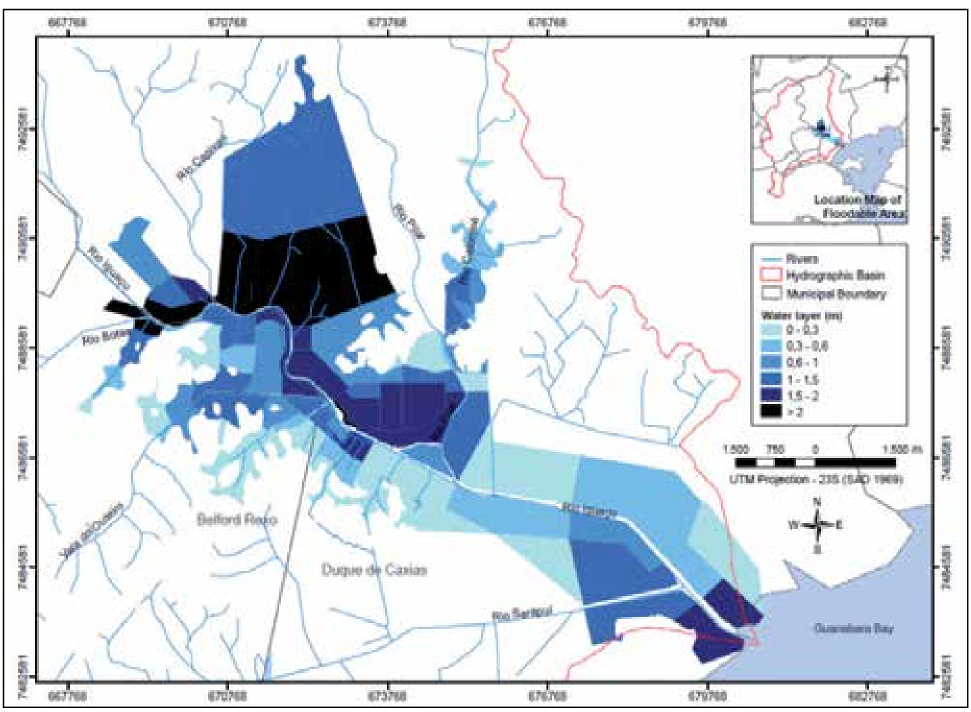


Figure 6. Flood map obtained for future condition, in the context of climate changes - Scenario 4

- Figure 7: Flood map obtained for the future conditions of basin urbanisation, with control over the land use development; meteorological tide of 80cm and climate change effects, with a 60 cm rise in mean sea level (Scenario 5).

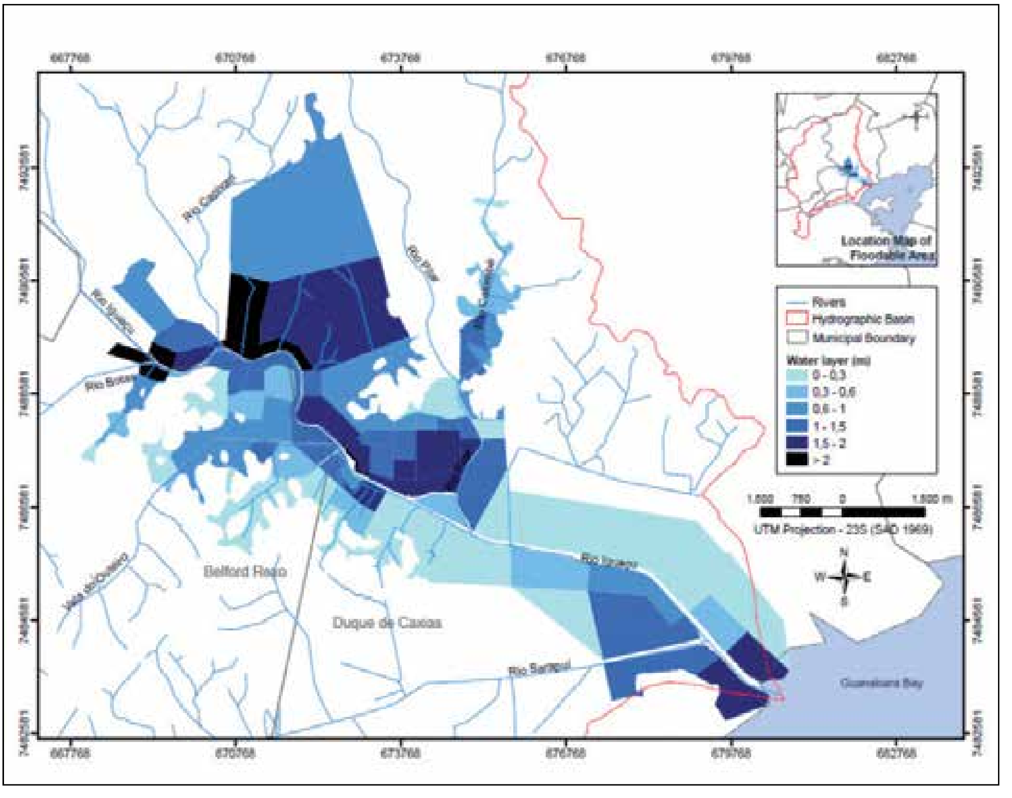


Figure 7. Flood map obtained for controlled future condition, in the context of climate changes-Scenario 5

These two scenarios test the conjugated effect of the three variables considered in the simulations: urbanisation of the upper basin, presence of meteorological tide and mean sea level rise. Based on these scenarios, it is possible to conclude that the disorderly urbanisation of the upper basin causes flooding aggravation in the downstream urban areas already consolidated, while the tidal variations cause even greater floods in the lower reaches (under tidal influence). The sea level rise will worsen the floods in the urban areas situated at low elevations, near the Iguaçu River estuary.

Both the urban expansion and the sea level rise are going to cause great impacts on the urban areas of the basin. Despite having their causes explained by independent variables, these factors, if combined, would lead to serious impacts on the population resident in the basin. If planning measures are not taken in advance, it will be very difficult to mitigate their impacts later.

5. Conceptual discussion

The urban drainage system includes two major subsystems: micro-drainage and macro-drainage. The micro-drainage system consists of the paving of streets, gutters, gullies, stormdrains and channels of small dimensions, intending to collect the runoff and conduct it to the macro-drainage net. Macro-drainage generally consists of natural or built channels of larger dimensions, receiving the input from micro-drainage, concentrating flows and discharging in the receiving water body. A complementary set of structures also take part in drainage systems, among which is possible to mention: reservoirs, protective dikes, and pumping stations. All these structures are arranged and designed to work in an n integrated way, intercepting, conveying, possibly infiltrating or temporarily storing and discharging the generated runoff. Ultimately, the receiving water body is the sea and this is the case of Iguaçu-Sarapuí Rivers.

The urban flooding process, by its turn, is directly associated with the failure of these subsystems, due to lack of maintenance, obsolescence, disordered urban growth or, as stated in recent discussions, due to the possibility of climate changes worsening flow conditions. Specifically to the drainage systems, the negative effects that may arise from the situation of climate changes refer to the increase of extreme rainfall events intensity, and to the restriction imposed by the expected sea level rise at the basin outfall. Evaluating this context, the increase in the mean sea level causes a reduction in the discharge capacity of the system, causing the drainage net to lose efficiency. The worsening of the extreme rainfall events intensity works in the other part of the problem, generating greater volumes to be drained by a system whose discharge capability diminished because of the new outfall restrictions. In this situation, in a context of already serious urban flooding problems, the effects generated by the possibility of climate changes can dramatically increase flooding areas, causing them to reach locations not previously affected by floods, increasing inundation depths and residence times, making the situation even worse.

Understanding how urbanisation affects floods is very important for urban flood control design. In general, it is possible to say that the urban flood control conjugates the adoption of structural measures that change the landscape of the basin, introducing interventions inside and outside the drainage network, to act directly in minimising the problem, and non-structural measures, associated with land use planning, environmental education and several possible other measures that allow a more harmonious coexistence with the phenomenon of flooding. The combination of structural and non-structural measures, in a context of planning integrated with urban growth, allows a composition capable of solving the problem of flooding in a harmonious and sustainable way. This approach, which is relatively recent, is being considered more appropriate to treat the urban flooding problem, by treating the problem in a systemic way and proposing actions that seek to minimize the impacts of urbanization.

This trend, though not motivated by the possibility of climate change, also goes toward this theme, with the possibility of reaching effective results, in opposition to the traditional approach that basically considers propositions of rectifying and canalising water courses. In this perspective, the traditional approach treats the consequence of the problem, related to the generation of exceeding superficial flows. The possibility of the mean sea level rising, however, limits the discharge capacity of the system and makes the traditional approach to fail. Thus, in this context, it is necessary to treat the problem of flow generation, acting in the causes of flooding, while trying to introduce infiltration and storage measures spread over the urban basin landscape in order to reduce and delay flood peaks, allow groundwater recharge and seek to restore the approximate natural flow conditions. This approach introduces the sustainable urbanization concept, proposing that the flood should not be transferred in space or time. This way, storage and infiltration measures may be important measures for sustaining adequate drainage conditions. Storage measures should consider detention or retention reservoirs, acting in-line with rivers or in the base of hill slopes, or combined in multifunctional landscapes in parks and public squares, or even in the plot level, as an on-source control option. By its turn, infiltration measures may involve reforestation actions, the use of pervious paving, or infiltration trenches, among others. All these measures, properly designed in an integrated manner, might be able to work preventively or correctively, if necessary, modifying the spatial and temporal distribution of flows, to face the new challenges.

The storage measures, because of their applicability and diversity of use, in different combinations with the drainage net configuration, are highlighted in this conceptual discussion. The reservoirs are able to attack the problem of flooding worsening, both from the point of view of the uncontrolled urban growth, as well as from the point of view of possible climate changes. The storage capacity of these reservoirs allows facing the larger volumes and to control surface runoff released to the network, minimising chances of system failure, with a time of response that matches the velocity of the critical superficial processes that generates floods. Infiltration measures are very important, because they are able to reduce flow volumes, but infiltration process takes more time and, in this case, time may be a critical factor when trying to control floods. So, infiltration measures are desirable, but may usually they do not prescind from storage measures.

6. Proposed solutions for Iguaçu-Sarapuí River Basin

The Iguaçu Project, related to the first Water Resources Management Master Plan, was the reference scenario used in this study. After more than one decade, the revision of the Water Resources Management Master Plan for Iguaçu-Sarapuí River Basin started in 2007 and finished in 2009. Lack of an adequate urban land use control and unplanned city growth led to several problems, as discussed previously. In the newer version of The Master Plan, the original set of proposed measures was reviewed. Part of these measures was maintained, especially in consolidated areas; however, whenever possible, new concepts on sustainable urban drainage were introduced. The basin was considered in an integrated way and environmental recovery concerns were added to the new plan. Irregular occupations of risky areas, subjected to frequent flooding, and especially riverbanks occupations, were considered not appropriated and people living in these houses without proper safe conditions needed to be relocated.

Both structural and non-structural measures were proposed for flood control purposes, ranging from short to long-term actions. Some of the proposed actions aiming to give more sustainable solutions considered:

- the maintenance of natural spaces free from urbanisation, preventing vegetation removal and the aggravation of flooding at the consolidated urban areas;
- the recovery of lost vegetated areas;
- a land use regulation and control, by means of the establishment of formal Environmental Preservation Areas;
- the implementation of urban parks;
- the creation of public consortiums for integrated planning of policies for multi-counties interests (recognising the importance of the metropolitan planning);
- the revision and adaptation of the municipalities urban planning instruments.

In terms of flood control, riverbanks protection and natural vegetation preservation, three types of parks were proposed, as basic measures to be reproduced in a distributed way over the basin, encompassing the following functions (figure 8):

1. Fluvial Urban Park – longitudinal parks along rivers, with the purpose of protecting river banks from irregular occupation by low income population.
2. Flooding Urban Park – longitudinal parks implemented in low elevation areas to allow frequent inundations, with a storage function intending to help in damping flood peaks.
3. Environmental Urban Park – parks with greater dimensions, flat or not, with the purpose of environmental preservation and land use valuing, aiming to minimise runoff generation and maintaining a buffer of pervious surfaces.

The figures 9 and 10 show two more detailed examples of the proposed parks, in practical conditions, being one for Sarapuí River, and another for Iguaçu River.

Complementary actions held by the State include the articulation with every Municipality in the basin, in order to implement the proposed measures, create local conditions for urban land use control and develop environmental education campaigns, with the financing of the Federal Government, through a specific Program of Developing Acceleration (PAC, in Portuguese). Besides, a habitation program is also being conducted in the basin, in order to support and allow people relocation from risky areas to safer near areas.

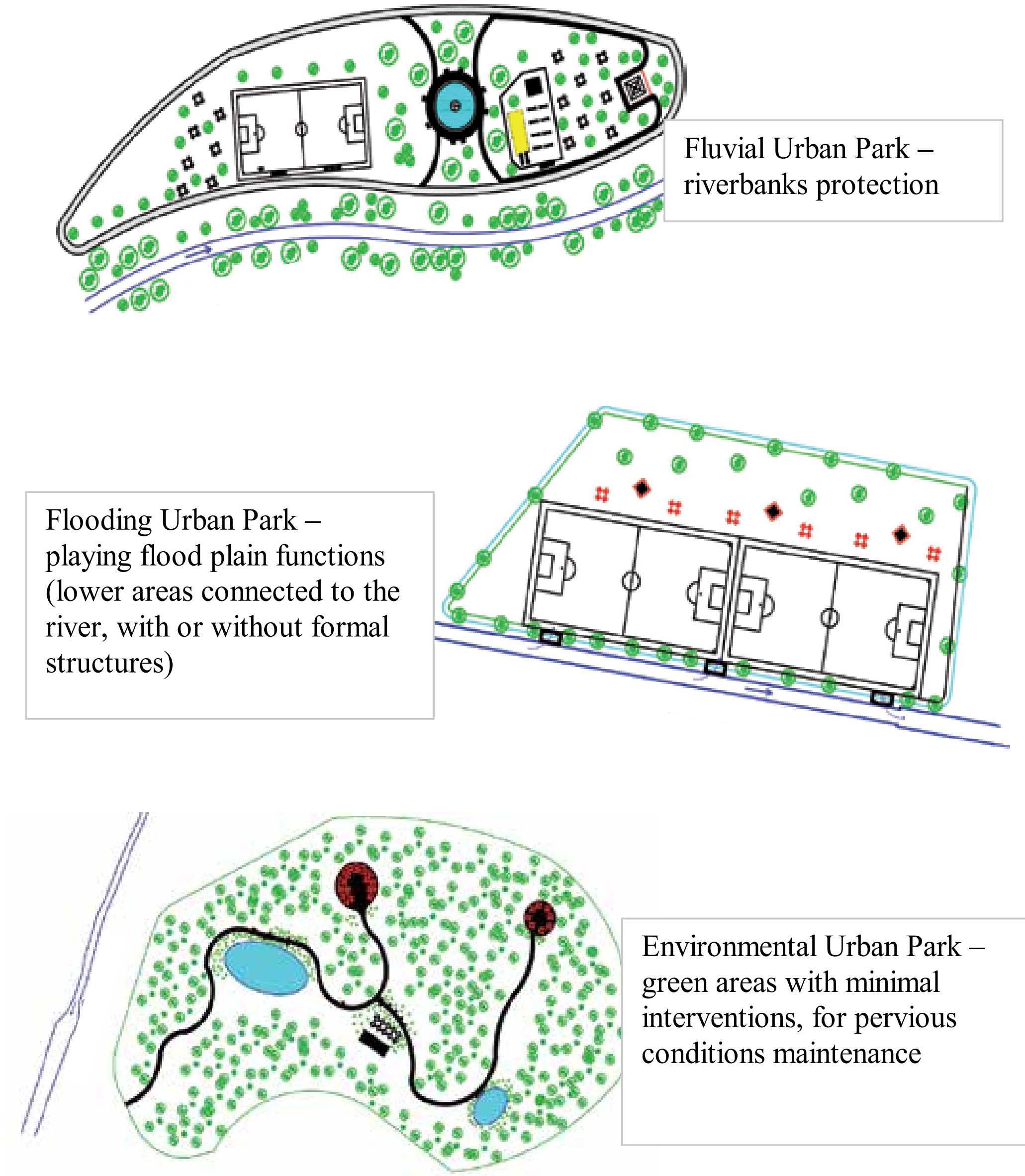


Figure 8. Fluvial parks typology – proposed distributed measures for flood control and environmental recovery

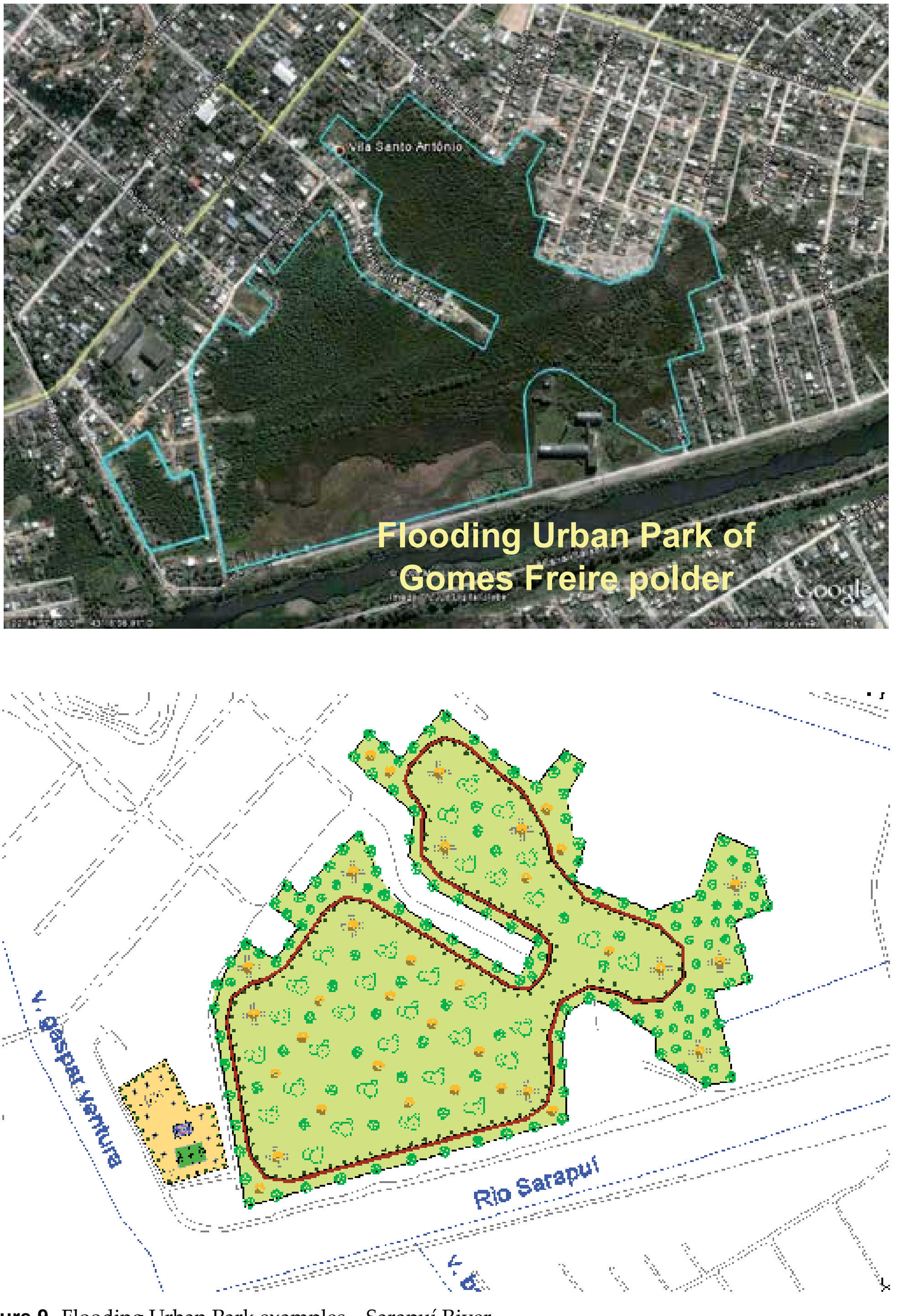
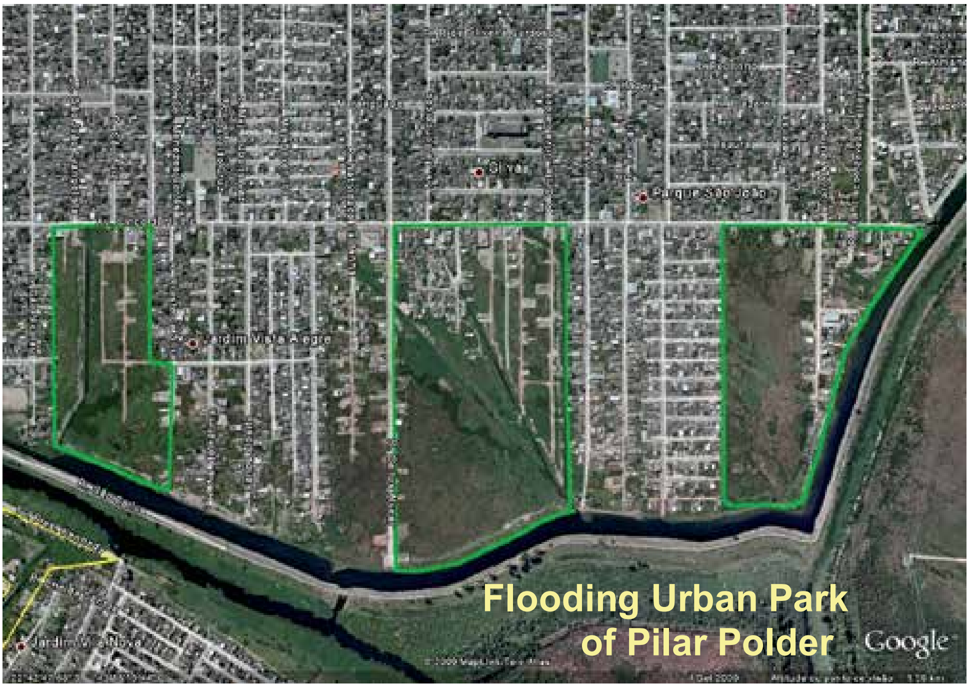


Figure 9. Flooding Urban Park examples – Sarapuí River



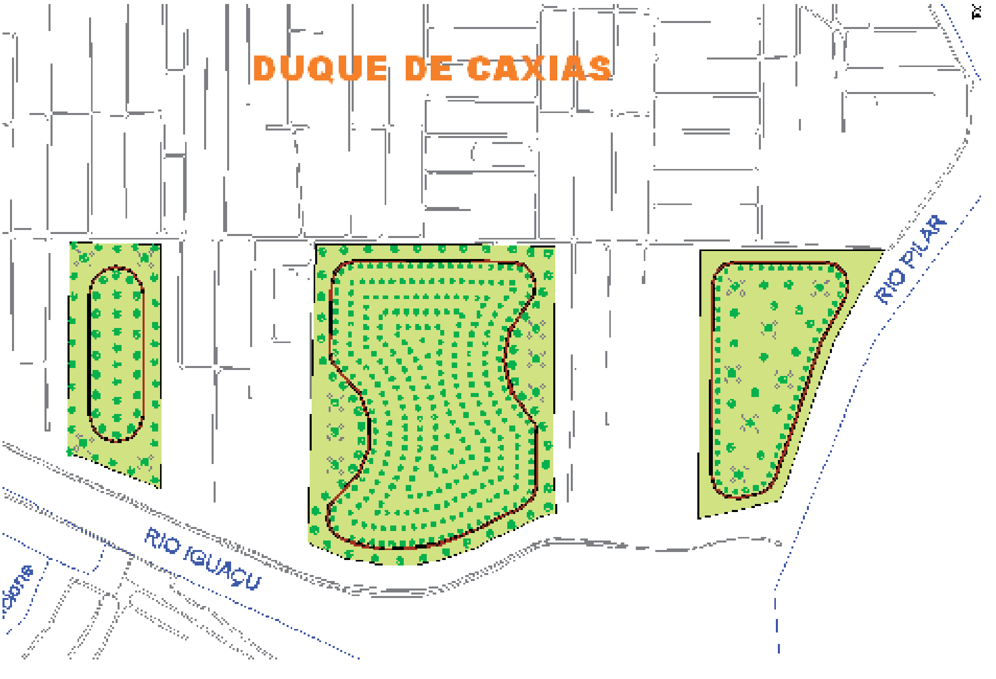


Figure 10. Flooding Urban Park examples – Iguaçu River

7. Conclusion

a. Promoting integration of public policies that interact with the water resources is probably the most urgent and complex task on the agenda of public administrators who are really committed to a sustainable future for the metropolitan areas.
b. There are reasons to believe that the new institutional arrangements in place in the country offer alternatives for the shared responsibilities involving states and municipalities, mainly in the large urban agglomerations. Specifically, in relation to municipalities, there is a vast spectrum of possibilities to be pursued within the Statute of the City. The new Master Plans can and must incorporate more effective mechanisms for land use management, using a greater range of legal, economic and fiscal instruments focused on urban development on a sustainable basis. However, master plans for urban development still lack mechanisms of inter-municipal coordination and regional agreements orientations that may prevent eventual unintended consequences of land use regulations, from one municipality to another.
c. The Iguaçu-Sarapuí River basin still embodies conditions favourable to planning for urban flooding, albeit devised to apply for the long term. A significant part of its territory remains in the form of areas still not incorporated into the urban fabric – notably the areas situated between the mountains that rise abruptly and the lowland itself. This enables the maintenance of areas with high soil pervious rates, provided that the urban fabric does not expand to those areas.
d. The disorderly occupation in Baixada Fluminense lowlands is going to increase the frequency and intensity of the urban floods, causing major damage to the already urbanized areas. The main limiting factor for the expansion of the urban perimeter is the lack of highway connection and regular mass transport lines in the upper parts of the basin, maintaining low occupation rates and rural activities in these areas. It is also worth highlighting the lack of preparation of local administrations to deal with the probable resulting impacts of climate change, above all in urban areas situated at low elevations in relation to the sea level.
e. Some of the actions proposed by this study were:
- maintenance of spaces free from urbanisation, preventing the aggravation of flooding at the consolidated urban areas;
- land use regulation and control, by means of the establishment of formal Environmental Preservation Areas;

f. implementation of urban parks, mainly for storage purposes, minimising flooding impacts and preparing the basin for future worse climatic conditions;
- creation of public consortiums for integrated planning of policies for multi-counties interests (recognizing the importance of the metropolitan planning);
- revision and adaptation of the urban planning instruments for the municipalities.

g. Complementary actions of state responsibility include articulation with every Municipality in the basin, in order to implement the proposed measures, create local conditions for urban land use control and develop environmental education campaigns about the risks of worsening the floods.

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8. References

[1] Dourojeanni, Axel, & Jouravlev, Andrei. Gestión de cuencas y ríos vinculados con centros urbanos. C E P A L - Comisión Económica para América Latina y el Caribe, 1999.

[2] Low-Beer, Jacqueline Doris, Cornejo, Ione Koseki. Instrumento de gestão integrada da água em áreas urbanas. Subsídios ao Programa Nacional de Despoluição das Bacias Hidrográficas e estudo exploratório de um programa nacional de apoio à gestão integrada. Relatório de Andamento. Extrato de resultados preliminares de pesquisa (módulo Institucional). Convênio FINEP CT-HIDRO 23.01.0547.00. Universidade de São Paulo, Núcleo de Pesquisa em Informações Urbanas, 2002.

[3] Jouravlev, Andrei. Los municipios y la gestión de los recursos hídricos. Serie Recursos Naturales e Infraestructura. CEPAL - Comisión Económica para América Latina y el Caribe, nº 66, 2003.

[4] Tucci, Carlos E. M (2004). Gerenciamento integrado das inundações urbanas no Brasil. Rega/Global Water Partnership South América. Vol. 1, nº 1 Santiago: GWP/South América, jan./jun.,2004.

[5] Ibge. Pesquisa de informações básicas municipais – suplemento de meio ambiente, 2002.

[6] Observatório Das Metrópoles. Como andam as metrópoles. Relatório Final – 21 de dezembro de 2005. Disponível em www.ippur.ufrj.br/. Acesso em 8/08/2008. ABRH, João Pessoa, 2005.

[7] Britto, Ana Lucia Nogueira de Paiva, & BESSA, Eliane da Silva. Possibilidades de Mudanças no Ambiente Construído: o saneamento nos novos planos diretores da Baixada Fluminense. ANAIS do IV Encontro Nacional da ANPPAS. Brasília, DF, 2008.

[8] Parry, M.L., Canziani, O.F., Palutikof, J.P., Van der Linden P.J. and Hanson, C.E. (eds). Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2007.

[9] Miguez, M. G. Modelo Matemático de Células de Escoamento para Bacias Urbanas. Tese (Doutorado em Engenharia Civil), COPPE / UFRJ, Rio de Janeiro, 2001.

[10] Mascarenhas, F.C.B.. & Miguez, M.G. Urban Flood Control through a Mathematical Cell Model. In: Water International. Vol. 27, nº 2, p. 208-218, 2002.

[11] Mascarenhas, F.C.B., & Miguez, M.G. Mathematical Modelling of Rural and Urban Floods: a hydraulic approach. In: Flood Risk Simulation. Wit Press, Gateshead, 2005.

[12] Zanobetti, D.; Lorgeré, H.; Preissman, A.; Cunge, J. A. , Mekong Delta Mathematical Program Construction. Journal of the Waterways and Harbours Division, ASCE, v.96, n. WW2, pp. 181-199, 1970.

[13] Magalhães, L. P. C., Magalhães, P. C., Mascarenhas, F. C. B., Miguez, M. G., Colonese, B. L., & Bastos, E. T. Sistema Hidro-Flu para Apoio a Projetos de Drenagem. XVI Simpósio Brasileiro de Recursos Hídricos.

[14] Carneiro, Paulo Roberto Ferreira. Controle de Inundações em Bacias Metropolitanas, Considerando a Integração do Planejamento do Uso Solo à Gestão dos Recursos Hídricos. Estudo de caso: bacia dos rios Iguaçu/Sarapuí na Região Metropolitana do Rio de Janeiro. 2008. IX, 296 p. (Doutorado em Engenharia Civil) Coordenação dos Programas de Pós-Graduação de Engenharia da Universidade Federal do Rio de Janeiro (COPPE/UFRJ), Rio de Janeiro.

[15] Laboratório De Hidrologia E Estudo Do Meio Ambiente Coppe/UFRJ - PNUD. Plano Diretor de Recursos Hídricos da Bacia dos Rios Iguaçu/Sarapuí, com Ênfase no Controle de Inundações. Rio de Janeiro: SERLA, 1996.

The Role of Socioeconomic and Behavioral Modeling in an Integrated, Multidisciplinary Dam-Management Study: Case Study of the Boardman River Dams

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Additional information is available at the end of the chapter

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1. Introduction

The Boardman River flows through Grand Traverse and Kalkaska Counties in Northwest Michigan before flowing into Grand Traverse Bay at Traverse City. Approximately two million recreation user days are estimated to occur on the Boardman River each year. Many of these recreators come to fish the river, others enjoy scenic trails, camping, and paddling.

Beginning in 1867, four small dams were constructed on the Boardman. The dams were constructed primarily to generate hydropower. However, as the dams have aged their commercial viability as hydroelectric stations diminished. As a result, Traverse City Light and Power did not seek to renew the leases of those dams. Because of this, the dams' owners (Grand Traverse County and the City of Traverse City) sought a cost-effective, environmentally and socially responsible dam-management outcome. The resulting process is considered one of the most comprehensive studies of its type ever undertaken in the United States. This process created the Boardman River Dams Committee (BRDC), an inclusive and diverse group of property owners, private citizens, agencies, nonprofits, businesses, scientific experts, and students. The BRDC involved over 1,000 people in 180 public meetings and the assessment of 91 options for the future of the dams. In April 2009, the Traverse City Commission and Grand Traverse County Board of Commissioners reviewed the scientific data and recommendations provided by the BRDC, and voted to remove three of the dams and install fish passage on the fourth.

Simulation modeling was an important tool used to aid transparency and decision-making. The implications of physical changes in conditions on the river were integrated mathematically using the over-arching structure of Figure 1.

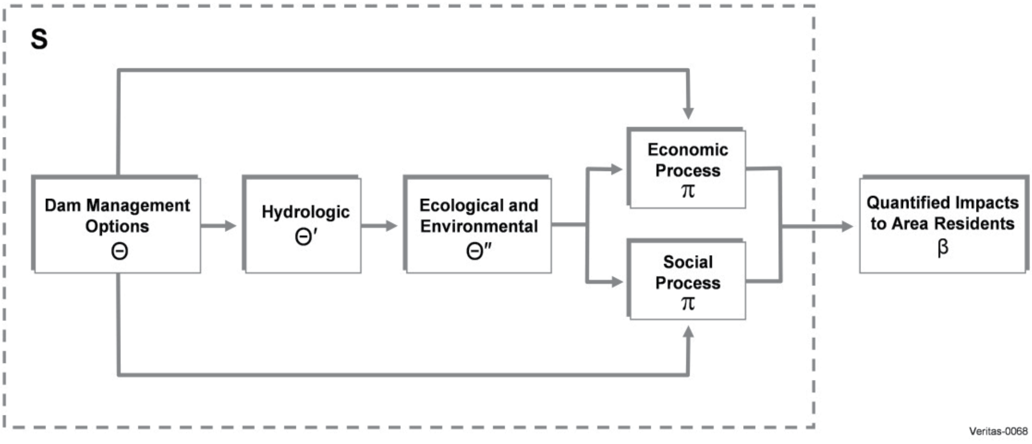

Figure 1. Mathematical notation for the integrated assessment

Mathematically, the Boardman River system was characterized as (S,Θ). In this framework S represents the integrated physical, hydrologic, ecological, environmental, and socioeconomic relationships that link dam management alternatives with socioeconomic outcomes.

Dam-management alternatives that are relevant to local socioeconomic conditions are represented by Θ. Prime notation is used to represent level of control. Factors that can be directly controlled are typically closely coupled to alternative-related physical characteristics such as the existence and operational status of the dams, and presence or absence of fish passage technology.[1] Relevant, indirectly controllable hydrologic, ecologic, and environmental characteristics are represented by Θ ' and Θ".[2] Consequently, the specification of a resource characteristic as Θ means that it is both relevant to socioeconomic processes and either directly or indirectly related to the physical status of the Boardman River dams.

Economic benefit estimates were based on the simulation of observable socioeconomic processes following the structure detailed in [1]. Socioeconomic processes that are impacted by changes to Θ are represented by π. These are specific, continually occurring collections of events. A particular person choosing how to spend a day off is an example of a socioeconomic process as is a real estate transaction.[3] Because the complete properties of socioeconomic processes are rarely observed, quantitatively assessing the system performance requires using indicators. In the mathematical structure, these indicators are identified as β.[4]

[1] By "closely coupled" we refer to changes that can be known with certainty. For example, the removal of a dam also eliminates a portage.

[2] The use of prime notation to represent degree of control (and thus degree certainty) recognizes that expert judgment and reduced form modeling (as opposed to detailed structural modeling) may be used to identify changes to the Θ.

[3] Mathematically this is represented with π, subscripting by i for time periods and j for individuals and superscripting by R for recreation.

[4] These properties are developed as part of the public policy model of [1].

To ensure that they are both mathematically tractable and useful for policy analysis, we require that indicators have the following qualities:

1. They are generated through socioeconomic activities.
2. They are real numbers that can be measured.
3. Evaluating their statistical properties conveys a sense of system performance.
4. Structural simulation modeling allows conducting policy experiments by comparing baseline and counterfactual outcomes.
5. Measures of changes in economic welfare are available from models that simulate changes in the indicators.

Recreational pressure provides an example. Recreational pressure estimates meet requirements 1 and 2 because the number of trips taken to the Boardman River over a particular time period is a measurable quantity that is generated through a socioeconomic process. With respect to requirement 3, recreational pressure does provide an indication of system performance. For example, an estimate of average recreational pressure that is "high" combined with an estimate of variation in pressure that is "low" could indicate "good" performance. As for 4 and 5, behavioral models of recreation site choice are specifically designed to predict both trips and economic welfare under baseline and counterfactual conditions.

With this structure, required information for socioeconomic modeling of the system includes the following:

1. Dam operation characteristics—Θ
2. Recreation site and residential property attributes—Θ
3. Recreational use patterns and values—β
4. Property values—β
5. Dam costs and revenues—β

Because alternatives are evaluated through the identification of changes in Θ and simulation of changes in β, identifying expected changes in β requires characterizing Θ and β in Baseline and mathematically modeling the relationship between Θ and β to allow simulating outcomes under various dam-management alternatives. Following [2], policy implications are identified by evaluating differences across Θ and β in Baseline and counterfactual experiments as a mathematical simulation. This requires identifying Baseline conditions and the mathematical structures that link policies to outcomes.

Information requirements include

1. the population of affected recreators
2. relevant site characteristics for both the site being evaluated and potential substitute sites
3. travel costs from recreator origins to sites.

1.1. The mathematical models

Mathematical models were applied for recreation (fishing, paddling, trails, and camping), economic impacts, hydroelectricity value, and property value.

The mathematical structure applied for recreation is the probabilistic site choice model. This modeling structure, based on choice theory, has the advantages of being professionally accepted, useful for policy-simulation predictions, consistent with economic theory, and capable of identifying resource values.[5]

These models identify the probability of a specific outcome (in this case, the selection of a recreation site), conditioned on the site characteristics of all relevant choices for recreators (e.g., distance from the site to the angler's home, expected catch rates, etc.). In the site choice framework, a recreator chooses a site by comparing characteristics across all sites. The mathematical structure is presented in Equation 1 below.

$$P_i(j) = \frac{\exp(V_{ij})}{\sum_{j=1}^{J} \exp(V_{ik})} \tag{1}$$

where $V_{ij} = f(\Theta, S)$

This equation represents the probability that on any particular recreation choice occasion, a recreator (identified by i) will choose to visit a particular site (identified by j). Note that this likelihood, identified by $P_i(j)$, is determined on the basis of both site characteristics (Θ) and parameters representing the values recreators hold for those site characteristics (S).

This mathematical construct identifies visitation likelihood. However the probability that a recreator will visit a site is not an observable β that can be used to evaluate the performance of the system. Pressure is a closely related and commonly employed β. To estimate pressure for any given site *j*, $P_i(j)$ is summed over all recreators' choice occasions.[6]

The hedonic decomposition of recreation sites into site characteristics and the representation of these site characteristics in the site-choice framework allow an evaluation of important information including changes in visitation probability, changes in site pressure, and changes in resource value. This is accomplished by developing an equivalent mathematical structure with appropriately altered Θ for policy alternatives and finding the difference in trips between this policy simulation model and the base case. Equation 2 presents the mathematics for an individual.

$$AnnualChoiceOccasions_i \left[\frac{\exp(V_{ij})}{\sum_{j=1}^{J} \exp(V_{ik})} - \frac{\exp(\overline{V}_{ij})}{\sum_{j=2}^{J} \exp(\overline{V}_{ik})} \right] \tag{2}$$

[5] The statistical basis for choice theory is the standard conditional logit model [3, 4].

[6] In the simulation context, this is accomplished by multiplying the likelihood of selecting each site (equation 1) by the total number of trips.

where $V_{ij} = \int(\Theta,S)\overline{V}_{ij} = \int(\overline{\Theta},S)$

Aggregating over individuals identifies changes in trips for each site due to the policy that changes Θ to $\overline{\Theta}$.

Estimates of changes in economic value improve the ability to assess resource performance. The distance from an individual's home to a site is a critical variable in a site-choice model because it represents the fuel cost and travel time required to visit each site.

When distance is converted to travel cost, the site-choice framework supports the calculation of monetary changes in value associated with changes in site characteristics. The mathematical form used to identify dollar-based changes in value associated with a policy that changes Θ to $\overline{\Theta}$ is the difference between the utility levels scaled by the relative impact of travel costs. Equation 3 presents the mathematical structure used to evaluate the change in annual value that a recreator attributes to the policy that changes Θ to $\overline{\Theta}$.

$$CV_i = \frac{AnnualTrips_i}{\phi_i}\left[\ln\left(\sum_{j=1}^{J} e_{ij}^{V}\right) - \ln\left(\sum_{j=1}^{J} e_{ij}^{\overline{V}}\right)\right] \tag{3}$$

where $V_{ij} = \int(\Theta,S)\overline{V}_{ij} = \int(\overline{\Theta},S)$

CVi refers to the compensating variation or dollar valued willingness-to-pay that recreator *i* has for the change from Θ to $\overline{\Theta}$. This is the amount of money that would make him indifferent between Θ and $\overline{\Theta}$.[7]

Mathematical structure (S) for property value is the hedonic price approach as developed by [5]. In this structure, property value, identified as market price, is determined according to property characteristics.

$$P = V_i \tag{4}$$

Properties are those with characteristics influenced by the Boardman River dam system

$$V_i = f(\Theta, S) \tag{5}$$

meaning that the expected market price relates to the state of the Boardman River system,

$$P = f(\Theta, S) \tag{6}$$

It is apparent that the change in property value stems directly from the difference in states of the system between current conditions and an alternative.

$$\Delta Value = \int(\Theta,S) - \int(\overline{O},S) \tag{7}$$

[7] This information is useful for evaluating changes via a utilitarian perspective, such as benefit-cost analysis [6].

Under the assumption that identification of partial effects is sufficient, the expected change in value can be determined by identifying the shadow values of any changing property attributes.[8]

$$\Delta\ Value = dP / d\Theta \tag{8}$$

These values are identified as model coefficients in empirical studies that use hedonic analysis to evaluate the relationship between market prices and house characteristics. Given studies that evaluate relevant characteristics, results from these studies can be calibrated and applied in mathematical simulation.

The evaluation of local economic impacts is typically accomplished via a mathematical economic technique called input/output (I/O) analysis [7]. I/O analysis was developed to address policy issues with respect to income, sales, demand, local infrastructure, and plant closing.

In I/O models, changes in final demand for one industry affect other industries within a local economic area.

- *Direct effects* represent the initial change in the industry in question.
- *Indirect effects* are changes in inter-industry transactions as supplying industries respond to increased demands from the directly affected industries.
- Induced effects reflect changes in local spending that result from income changes in the directly and indirectly affected industry sectors.

Multipliers measure total changes in output, income, employment, or value added. Parameters required to specify I/O models include the following:

- *Output multipliers* relate the changes in sales to final demand by one industry to total changes in output (gross sales) by all industries within the local area.
- *Income and employment multipliers* relate the change in direct income to changes in total income within the local economy.
- *Value added multipliers* are interpreted the same as income and employment multipliers. They relate changes in value added in the industry experiencing the direct effect to total changes in value added for the local economy.

Data requirements include outputs and inputs from other sectors, value added, employment, wages and business taxes paid, imports and exports, final demand by households and government, capital investment, business inventories, marketing margins, and inflations factors (deflators). These data are available both for the 528 producing sectors at the national level and for the corresponding sectors at the county level. Data on the technological mix of inputs and levels of transactions between producing sectors are available from detailed input-output tables of the national economy.

[8] The identification of partial effects is most appropriate when expected changes are not dramatic and widespread.

Valuing an asset in financial terms is accomplished by valuing the (net) stream of income resulting from ownership. Because this income occurs at different point in time, values are discounted to present values as indicated in the equation below:

$$NPV = \left(TR - TC\right)r \tag{9}$$

In this equation, total value is the net present value of total annual revenues minus total annual costs.

Total revenues are composed of hourly price and quantity information by service. The various electrical services could include energy, renewable energy, and ancillary services as indicated below.

$$\begin{aligned} TR_{Annual} = {} & \sum_{Hours=1}^{8760} MW_{Energy} \bullet Hours_{Energy} \bullet P_{Energy} \\ & + \sum_{1}^{8760} MW_{renewableEnergy} \bullet Hours_{renewableEnergy} \bullet P_{renewableEnergy} \\ & + \sum_{1}^{8760} MW_{AncillaryServices} \bullet Hours_{AncillaryServices} \end{aligned} \tag{10}$$

Revenues are composed of hourly price and quantity information. Hourly generation quantity is identified as:

$$Q_{hour} = aV_{hour} \tag{11}$$

where Q_{hour} is hourly electricity production, V_{hour} is the volume of hourly flow and a is a positive constant that converts flow to electricity that is specific to technology and hydraulic head.

Annual costs are:

$$TC_{Annual} = Annual\ Cost_{Overhead} + Annual\ Cost_{Government} + Annual\ Cost_{MDNR} + Annual\ Cost_{FERC} \tag{12}$$

Information requirements include hourly electricity quantities and prices going out into the future. Quantities are identified via a combination of river flow and dam-specific information, including head and turbine efficiency.

1.2. Baseline data and transfer studies

The analysis divides the river into 11 segments. The segments were chosen for their distinct characteristics. For example, each impoundment is physically different than the free-flowing sections in between. Each impoundment is represented by its own segment, and each river section between the inlet of one impoundment and the next upstream dam is represented by a distinct segment. Table 1 contains segments used in this assessment. Figure 2 provides a map.

Site number	Location	Size
1	From mouth of Boardman River to Union Street Dam	1,2 miles
2	Boardman Lake	339,0 acres
3	From inlet of Boardman Lake to Sabin Dam	2,2 miles
4	Sabin Pond	40,0 acres
5	Keystone Pond	103,0 acres
6a	From inlet of Keystone Pond to midpoint	6,9 miles
6b	From midpoint to Brown Bridge Dam	6,9 miles
7	Brown Bridge Pond	191,0 acres
8	From inlet of Brown Bridge Pond to Forks	6,0 miles
9	North Branch of the Boardman River	23,5 miles
10	South Branch of the Boardman River	10,0 miles

Sources: [8–10]

Table 1. Boardman River segments

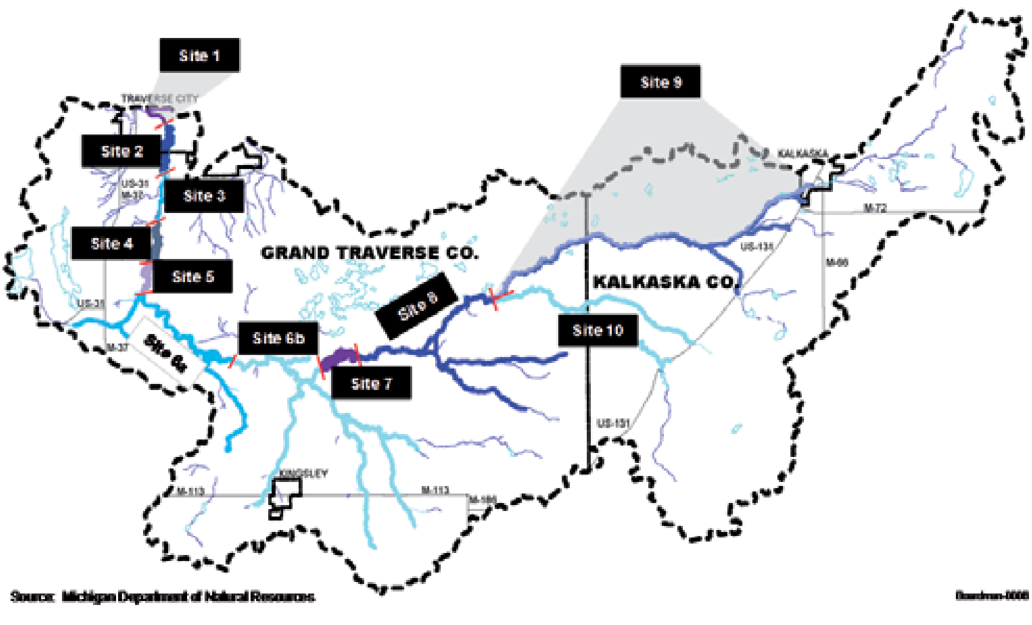

Figure 2. Location of segments 1–10 along the Boardman River

As Table 1 shows, the segments are numbered 1–10, with Segment 6 split into 6a and 6b. Segment 6 is physically homogeneous under our definition of a free-flowing river between impoundments. However, given its location between two impoundments, it has the potential to be affected by one or more of the dam management alternatives. By dividing it, the potentially affected recreation sites are closer in size to each than they would be without this division. Although Segments 9 and 10 are also relatively large when compared to the others, they are less likely to be affected by the dam management alternatives, given their locations well above the Brown Bridge Dam.

Pressure estimates for Boardman River anglers come from an on-site creel study that the Michigan Department of Natural Resources (MDNR) conducted during the 2005 season for Segments 1–8 of the Boardman River. The MDNR data collection included angler counts, as well as the number of fish caught by fish species. From these data, the MDNR developed statistically based seasonal estimates for the Boardman River in terms of the number of angler trips and hourly catch rates by species.

Based on the MDNR results, we developed pressure estimates, by segment, for this assessment by undertaking the following steps:

- Allocate the total number of MDNR days across Segments 1–8 of the Boardman River.
- Extrapolate angler day estimates from Segment 8 to Segments 9 and 10.
- Separate the number of angler days for each segment into resident days and visitor days.

Table 2 contains the resulting allocation of the fishing days across the various segments and residents or visitors.

Segment	Resident days	Visitor days
1	880 to 1 440	220 to 360
2	720 to 1 120	180 to 280
3	800 to 1 200	200 to 300
4	160 to 240	40 to 60
5	320 to 560	80 to 140
6a	1 680 to 2 720	420 to 680
6b	1 680 to 2 720	420 to 680
7	960 to 1 520	240 to 380
8	1 760 to 2 720	440 to 680
9	5 840 to 8 960	1 460 to 2 240
10	2 000 to 3 200	500 to 800
Total	16 800 to 26 400	4 200 to 6 600

Table 2. Annual number of resident and visitor angling days on the Boardman River

To simulate the implication of changes in site characteristics, we employ a recreational fishing study conducted by [11], which covers fishing sites across the state of Michigan and explicitly covers varied fishing experience, including inland rivers and inland lakes, as well as anadromous fishing opportunities, all of which are relevant to the Boardman River analysis. Because this statistical model studies the same activity on the same population, we can use both the site characteristics and the estimated parameters presented in the [11] study and reproduced in Table 3 below.

Characteristic	Mean
Trip cost	-15
Great Lakes warm, walleye catch rate	6,63
Great Lakes warm, bass catch rate	1,45
Great Lakes warm, pike catch rate	0,36
Great Lakes warm, perch catch rate	-2,75
Great Lakes warm, carp catch rate	0,87
Great Lakes cold, constant	-14,75
Great Lakes cold, Chinook catch rate	5,14
Great Lakes cold, Coho catch rate	5,45
Great Lakes cold, lake trout catch rate	3,23
Great Lakes cold, rainbow catch rate	2,19
Inland lakes warm, shore constant	-14,06
Inland lakes warm, interior constant	-7,8
Inland lakes warm, warm lake acres/1,000	21,58
Inland lakes cold, shore constant	-11,43
Inland lakes cold, interior constant	-18,48
Inland lakes cold, cold lake acres/1,000	3,73
Rivers/streams warm, shore constant	-10,09
Rivers/streams warm, interior constant	-11,21
Rivers/streams warm, top quality miles/100	5,35
Rivers/streams warm, second quality miles/100	-3,58
Rivers/streams cold, shore constant	-15,23
Rivers/streams cold, interior constant	-19,24
Rivers/streams cold, top quality miles/100	5,09
Rivers/streams cold, second quality miles/100	0,05
Anadromous runs, shore constant	-10,57
Anadromous runs, interior constant	-7,78
Anadromous runs, Chinook catch rate	3,37
Anadromous runs, coho catch rate	-0,3
Anadromous runs, rainbow catch rate	8,04

Table 3. Parameters for fishing site choice

Site characteristics to populate the model are based on physical site characteristics and MDNR quality and catch rate designations. MDNR [12] sets out its quality designations in the Manual of Fisheries Survey Methods II. The stream miles are categorized based on their quality. Those of high quality are rated either "top quality" or "second quality." Top quality stream miles are characterized by containing good self-sustaining fish populations. Second quality streams are characterized by containing significant fish populations, which are appreciably limited by such factors as inadequate natural reproduction, competition, siltation, or pollution.

Table 4 contains the lake segments, or impoundments, for the Boardman River. The table indicates the types of species in the various segments, based on conversations with representatives from the Grand Traverse Conservation District (GTCD) [13], the MDNR [14], and the fisheries reports prepared for this project [8,15].

Segment	Species type	Acres
2	Warm	339
4	Warm	40
5	Warm	103
7	Warm	191

Table 4. Current conditions of the impoundment fishing sites

Table 5 contains the current conditions for the river segments of the Boardman, Segments 1, 3, 6, 8, 9, and 10. The number of stream miles that are "top quality" and "second quality" refers to the MDNR designation of fishery conditions previously described. Additionally, because Segments 1 and 3 support anadromous runs, the current conditions for these sites includes catch rates (number of fish caught per hour) for Coho Salmon, Chinook Salmon, and Rainbow Trout, based on information from the 2005 Boardman River Creel Survey [16].

Segment	Species type	Anadromous catch rates		Miles of top quality	Miles of second quality
1	Anadromous Warm Cold	Coho Chinook Rainbow	0,001 to 0,014 0,006 to 0,042 0,084 to 0,237	1,2	0,0
3	Anadromous Cold	Coho Chinook Rainbow	0,000 to 0,001 0,002 to 0,006 0,067 to 0,084	0,0	2,2
6a	Cold	N/A		6,9	0,0
6b	Cold	N/A		6,9	0,0
8	Cold	N/A		6,0	0,0
9	Cold	N/A		23,5	0,0
10	Cold	N/A		10,0	0,0

Sources: [13–14,16]

Table 5. Current conditions of the Boardman River fishing sites

The last type of information that completes the picture of current conditions for recreational fishing is a description of the substitute sites. Substitute sites play a key role in the determination of angler satisfaction.

We used three criteria in the selection of substitute sites. The first criterion was that the substitute site be within 150 miles of some portion of the Boardman River. We selected this distance criterion to be consistent with the [11] study. The second criterion was to incorporate a variety of potential fishing opportunities consistent with the real world. Thus, the selected substitute sites include inland lakes, rivers, and Lake Michigan sites. Finally, when possible substitute sites met the first two criteria, we selected those with the most recent data available in terms of the site features identified in the [11] model.

Table 6 contains the number of angler days to the inland lake substitute sites, as well as the current conditions. Table 7 describes the number of days and the current conditions for the substitute sites that are rivers. Table 8 contains information related to the number of days and the current conditions of the Lake Michigan substitute sites. The items in this table correspond to the features used in the [11] study for Great Lake sites. Unlike the inland lake or river sites, the features of these sites that affect angler satisfaction are the catch rates for the various cold and warm water species.

Site	Number of days	Species type	Acres
Houghton Lake	107 000	Warm	20 075
Lake Leelanau	31 000	Warm cold	8 607
Long Lake (Alpena County)	17 000	Warm	5 341
Green Lake	8 000	Warm	1 994
Higgins Lake	26 000	Warm cold	9 600

Sources: [17–18]

Table 6. Current conditions of the inland lake substitute sites

Site	Number of days	Species types	Anadromous catch rates	Miles of top quality	Miles of second quality
Rogue River (Kent County)	20 000	Anadromous	Coho 0,001	7,5	5,0
		Cold	Chinook 0,043		
			Rainbow 0,095		
Manistee River (from Hodenpyl Dam to Red Bridge)	8 000	Anadromous	Rainbow 0,112	12,9	0,0
		Cold			
		Warm			

Sources: [18–20]

Table 7. Current conditions of the inland river substitute sites

	Elk Rapids	E. Grand Traverse Bay	W. Grand Traverse Bay	Leland	Manistee
Angler days	9 930	9 974	21 977	6 294	63 815
Catch rate:					
Walleye	0,0010	0,0000	0,0000	0,0000	0,0001
Bass	0,0038	0,0037	0,0011	0,0031	0,0001
Pike	0,0000	0,0000	0,0000	0,0000	0,0002
Perch	0,4967	0,0465	0,1097	0,0005	0,0153
Carp	0,0000	0,0000	0,0000	0,0000	0,0000
Chinook	0,0141	0,0652	0,0558	0,0897	0,1757
Coho	0,0018	0,0006	0,0014	0,0004	0,0047
Lake trout	0,0087	0,0409	0,0267	0,0083	0,0051
Rainbow	0,0308	0,0014	0,0007	0,0448	0,0061

Source: [21]

Table 8. Current conditions of the Lake Michigan substitute sites

In addition to fishing, the Boardman provides canoeing and kayaking opportunities. Site-specific data on the current number of paddling days along the Boardman River are not readily available. For this reason, we rely on estimates from local individuals with first-hand knowledge of paddling use of the Boardman. These estimates from knowledgeable locals are validated using publicly available data on paddling participation rates and trip-taking frequencies.

The relative proportion of resident to visitor days was used to allocate the total days by segment across residents and visitors. These results appear in Table 9 below.

Segment	Resident days	Visitor days
1	120 to 180	80 to 120
2	50 to 60	About 40
3	300 to 1 140	200 to 760
4	50 to 60	About 40
5	30 to 300	15 to 200
6a	600 to 2 400	400 to 1 600
6b	600 to 1 800	400 to 1 200
7	50 to 600	40 to 400
8	1 500 to 3 600	1 000 to 2 400
9	0 to 10	—
10	0 to 10	—
Total	3 300 to 10 160	2 215 to 6 760

Sources: [22–23]

Table 9. Annual number of paddling days on the Boardman River

Parameter	Mean
Whitewater quality	2,82
Parking quality	-2,04
Crowding	2,19
Water quality	-1,39
Scenic rating	2,99
Predictability of water level	-0,92

Table 10. Coefficients calibrated to local conditions and scaled to fishing model

Mathematically modeling site-choice for paddling on the Boardman River requires identifying both site characteristics and parameterization of the relative importance that paddlers attach to each of these characteristics. One study [24] presents a statistical model for paddling; however, it was developed for a different location and population. This study reflects whitewater paddling opportunities in Ireland. Although topography in Ireland is likely more varied than that of northern Lower Michigan, the Irish study considers a range of whitewater sites.

To apply this study [24], we calibrated the parameters to reflect the specifics of the Boardman River and the surrounding area. To accomplish this calibration for site characteristics, we rely on the perceptions of recreators, a tactic which has professional acceptance [25] because it is the recreators' perceptions of the site's characteristics, whether aligned with factual information or not, that drive site selection. The [24] researchers query paddlers' opinions by asking them to rate the rivers they paddle on a 1–5 scale. The relevant site characteristics are:

- perceived whitewater quality
- perceived quality and safety of parking
- perceived crowding
- perceived water pollution
- perceived scenic quality
- perceived predictability of the water level prior to arrival.

We replicate this on the Boardman River by conducting an informal survey similar to the one used by [24], which reveals paddler's opinions on the site characteristics of the Boardman River and other nearby rivers. In the questionnaire, we ask respondents to rate their perceptions of the Boardman's features with respect to paddling on a 1–5 scale. The one exception to this 1–5 scale is the perceived quality of whitewater, which is based on a 0–4 scale.[9] Table 11 below reflects the average of the responses we received, and Table 10 above shows the coefficients calibrated to local conditions.

[9] Although Irish whitewaters are based on a 1–5 scale, we converted that to a 0–4 scale for this assessment to reflect the likely perceived absence of whitewater for portions of the Boardman River.

Seg. #	Description	Current whitewater quality	Parking	Crowding	Water quality (pollution)	Scenic rating	Predictability of water level
1	From mouth to Union Street Dam	0,0	3,8	3,8	3,0	1,8	4,6
2	Boardman Lake	0,0	4,0	3,9	2,9	3,0	4,8
3	Inlet of Boardman Lake to Sabin Dam	0,0	3,1	4,0	4,3	4,8	4,6
4	Sabin Pond	0,0	3,3	4,4	4,3	4,4	4,6
5	Keystone Pond & Boardman Dam	1,0	3,5	4,1	4,3	3,6	3,5
6	Inlet of Keystone to Brown Bridge Dam	1,6	4,0	3,4	4,0	4,6	4,2
7	Brown Bridge Pond	0,0	4,3	4,3	4,4	5,0	4,4
8	Inlet of Brown Bridge Pond to forks	0,4	4,2	3,2	4,2	4,8	4,2
9	North branch	0,0	2,7	4,7	3,7	5,0	4,3
10	South branch	0,0	2,7	4,7	3,7	5,0	4,3

Table 11. Boardman River paddling site characteristics

We used information from Trails.com and the Michigan Atlas and Gazetteer [26] to compile a list of substitute sites. The list included the Au Sable, the Betsie, the Pine, and the Platte Rivers. As part of the questionnaire described above, we included a question about these substitutes and asked respondents to rate them in the same way that they rated the Boardman. Additionally, we provided the respondents with an opportunity to name other substitute sites and rate them. The responses to the questionnaire identified four potential substitute sites for the Boardman.

Table 12 below provides the information on the perceived site characteristics for the substitute sites. The second column of Table 12 contains an estimate of the total number of paddling days for the substitute sites. This number is a necessary input for modeling. We used a similar methodology to the top-down approach using verifiable data. The MDNR provides an estimate of the number of paddling days statewide [27]. Based on an estimate of the miles of navigable river statewide [28], we estimated the average number of days that a typical river mile supports. We applied that number to the number of river miles for the substitute sites. The results appear in Table 12.

The Boardman River enhances the recreation experience for a variety of trail activities, including hiking, walking, biking, and horseback riding. Several segments of the Boardman River support designated trails, particularly around the impoundments. In the segments farther upstream, portions of the Michigan Shore-to-Shore Riding Trail and the North Country Trail follow the Boardman.

Substitute sites	Number of trips	Current whitewater quality	Parking	Crowding	Water quality (pollution)	Scenic rating	Predictability of water level
Au Sable	54 000	0,0	3,7	3,7	4,7	4,0	4,5
Betsie	15 000	0,3	3,7	3,7	4,3	4,3	3,5
Pine River	11 000	2,0	4,7	3,7	4,7	5,0	4,5
Platte River	4 000	0,2	3,2	1,8	4,8	4,1	4,8

Table 12. Current conditions of the representative substitute paddling sites

Public pressure estimates for trail activity days along the Boardman River are not readily available for most segments. We use a "top down" approach to estimate trail activity pressure. This approach starts with a total number of activity days and then allocates these days to sites based on trail miles. The trails along the Boardman River are used not exclusively for hiking, but also for biking, walking, and horseback riding. These latter activities can occur on streets and concrete sidewalks in neighborhoods, paved roads in rural areas, and on land without any developed trails. We have based our estimate of the number of Boardman River trail days on data that primarily reflect day hiking.

Table 13 shows the estimated number of days of trail activities on the Boardman River under current conditions. The number of resident days ranges from about 72,000 to 154,000 days per season while the number of visitor days ranges from about 18,000 to more than 23,000 days per season.

For the visitor days in the other segments, we use a similar methodology as we did for the resident days in these segments. The total number of visitor days is gleaned from tourism studies [29–31].

Segment	Resident days	Visitor days
1	12 000 to 14 000	3 000 to 4 000
2	20 000 to 24 000	5 000 to 6 500
3	1 500 to 4 000	500 to 625
4	4 000 to 11 000	1 000 to 1 250
5	2 000 to 6 000	700 to 875
6a	800 to 2 000	300 to 375
6b	5 000 to 15 000	2 000 to 2 500
7	4 500 to 13 000	1 500 to 1 875
8	5 000 to 14 000	2 000 to 2 500
9	11 500 to 33 000	1 200 to 1 500
10	6 000 to 18 000	900 to 1 125
Total	72 300 to 154 000	18 100 to 23 125

Table 13. Annual trail activity days on the Boardman River

Because no appropriate empirically estimated site-choice model is available for trail activities, we develop site characteristics and parameters, based on expert judgment, and link them to the fishing and paddling model. For site characteristics, we have selected scenic quality and trail miles as the relevant site characteristic. As the paddling model also incorporates scenic beauty, we import the scenic beauty coefficient from the paddling specification, and apply it to the trail activities model. To specify the importance of trail miles, we rely on expert judgment. Table 14 contains the calibrated importance parameters for trail activities.

Parameter	Mean	Variance
Scenic beauty	2,99	0,009085
Trail miles		

Table 14. Coefficients calibrated to local conditions and scaled to fishing model

Recreational spending by residents is not included in this assessment. The rationale behind this distinction is that local spending is transferred from one sector to another in the local economy [32–34]. If, for example, changes in the Boardman River result in increased recreational usage by residents, these residents may spend more money on bait, bottled water, and canoe rentals. However, it also means that locals spend less on other local activities. This specification assumes these local expenditure differentials offset one another with respect to local economic impacts. To estimate current expenditures on the Boardman River, we researched the publicly available information on recreation expenditures, by activity.

Table 15 details the results of our research. For each of the four recreational activities, this table contains estimates of the spending per activity day. In some cases, a range is provided, which is explained below on a study-by-study basis. All estimates have been converted to 2007 dollars using a composite created from various consumer price indices (CPIs) that best reflect the expenditure categories. For example, if the original study provided a breakdown that revealed that one-third of the spending went toward lodging, one-third was spent on gas, and one-third was spent in restaurants, we created a composite inflation factor weighted to reflect the CPIs for lodging, gasoline, and restaurant meals at one-third each.

Recreational activity	Dollars spent per visitor day (U.S. $ 2007)	Source
Fishing	$24,27	[35]
	$23,65 to $74,58	[36]
Paddling	$37,10	[37]
	$96,87	[32]
Camping	$48,34 to $65,29	[36]
	$14,06	[38]
Hiking	$18,87 to $72,47	[36]
	$29,23	[32]

Table 15. Sources of recreational spending estimates

Site-specific data on the pressure of the Boardman River by campers are not readily available. However, an approximation can be developed from publicly available data based on information gleaned from various websites [39–40] and presented in Table 16. Only segments 8 and 9 have developed campsites. With the exception of Ranch Rudolph, all of the campgrounds along the Boardman are State Forest Campgrounds (SFCs).

Based on this information, we use data from the MDNR to estimate the seasonal occupancy for a typical SFC site. The MDNR provides an estimate of the number of SFC campsites throughout the state [27]. The MDNR has also estimated the number of statewide camping nights at those SFCs annually from 2000 through 2006 [40]. Dividing the number of camping nights at SFCs by the number of SFC sites yields the typical number of camping nights that a campsite hosts during the season. Because camping activity likely varies from year to year due to weather differences, we use the range of seasonal days to estimate the occupancy of a typical SFC campsite during the season.

Segment Number	Name of Campground	Number of Campsites
1	None	0
2	None	0
3	None	0
4	None	0
5	None	0
6a	None	0
6b	None	0
7	None	0
8	Forks SFC	8
	Scheck's Place SFC	30
	Scheck's Place Trail Camp (SFC)	50 (based on space for 200 individuals)
	Ranch Rudolph	25
9	Guerney Lake SFC	36
10	None	0
Total		149

Sources: [39–40]

Table 16. Campsites along the Boardman River

According to the MDNR [27], virtually all camping occurs outside of the county of residence. Thus, for purposes of this assessment, we assume that all Boardman River campers are not residents of either Grand Traverse or Kalkaska County. The number of camping nights presented in Table 17 will be used in the tourism expenditures assessment presented elsewhere. This table shows that the number of annual camping nights spent along the Boardman River is between 4 000 and 6 500. The majority of these nights are located in Segment 8.

Segment number	Camping nights
1	0
2	0
3	0
4	0
5	0
6a	0
6b	0
7	0
8	3 000 to 5 000
9	1 000 to 1 500
10	0
Total	4 000 to 6 500

Table 17. Annual number of camping nights spent along the Boardman River

Mean expenditures for each recreation activity are shown in Table 18. The table shows that visitors to the Boardman River spend almost $2 million per year in the local economy. More than half of these expenditures are associated with trail activities by visitors. Table 18 shows the amount of visitor spending for each recreation activity. In total, recreational visitors to the Boardman River spend almost $2 million per year in the local economy.

Activity	Recreational spending (U.S. $/year)
Fishing	$298 200
Paddling	$317 400
Camping	$207 300
Trail activities	$1 110 300
Total	$1 933 200

Table 18. Current level of recreational spending by visitors to the Boardman River

To estimate impacts to the local economy, we used a program developed by researchers at Michigan State University called the Michigan Tourism Spending and Economic Impact Model (MITEIM).[10] As described above, this program estimates economic impacts to the local economy by tracing the flow of the tourism dollars (direct effects) through the local economy. It provides an estimate of the sales, jobs, income, and tax revenues that accrue to the local economy from recreational visitors to the Boardman River.

Tourism spending accounts for over $1,3 million in direct sales to the local economy. Direct sales are less than the tourism expenditures due to the leakages from the local economy described earlier. When indirect and induced effects are included, the addition to the local

[10] Some of these researchers were also involved in the development of IMPLAN (Impact Analysis for Planning). MITEIM is based on the same concept and parameters as IMPLAN. See reference [42]. We selected it for use in this assessment because it is specific to tourism in Michigan. We believe this program provides an impact analysis more tailored to the Boardman River assessment.

economy exceeds $2 million. Almost 40 local jobs can be attributed to Boardman River visitors. Personal income refers to the portion of direct sales that become salaries and wages in the local economy. It is the contribution to the local economy, not counting the costs of non-labor inputs. Finally, the local tax revenue, associated with Traverse City's hotel tax is approximately $7 000 per year.[11]

Changes to the dams on the Boardman River may affect property values, particularly residential property values. Commercial and industrial properties derive their values for their utility in generating an income stream. Changes in the Boardman River are unlikely to affect the income-generating ability of the nearby commercial and industrial properties.

Public lands generate value to society from their public uses, which we will capture through the recreation analyses. We do not anticipate that the current uses that of the public lands surrounding the Boardman River are likely to change with a change in the management strategy of one or more dams. That is, we would still expect these lands to support fishing, paddling, camping, and hiking to some extent even if one or more of the dams are removed. While the public lands have an asset value, it can only be realized through the sale of the land to a private party. Because we do not anticipate that changes in the Boardman River will result in the sale of public lands, we do not believe that a meaningful change in the public lands' asset value will occur.

We rely on a geographic information systems (GIS) database provided by Grand Traverse County [43] to describe the current values and key characteristics of the residential properties near the Boardman River.[12] Table 19 summarizes these key features for residential properties within ½ mile of the Boardman River or its impoundments, by segment. The information in the table includes the number of residential parcels, the number of parcels with frontage, the total number of acres across the parcels, and the total assessed value of all of the properties. This table shows that there are nearly 4 000 residential parcels within a ½ mile of the Boardman River. For these parcels, the total amount of acreage sums to nearly 7 500 and their total value is more than $331 million.

To estimate changes in residential property values associated with removal of one or more of the dams along the Boardman River, we adapt a statistical model developed by [44]. This study investigates the differences in value of residential properties near small impoundments and free-flowing rivers relative to properties near a recently removed impoundment. One of the most important features was that the study contain empirical analysis consistent with predicting changes in value that correspond to the potential dam removal scenarios for the Boardman River. The Provencher, Sarakinos, and Meyer study does so.

[11] To the extent that some visitors stay outside of Traverse City, then this estimate is an overestimate.

[12] Admittedly, the database from Grand Traverse County does not include residential properties in Kalkaska County. However, properties along the Boardman River in Kalkaska County are in Segments 9 and 10, well upstream from any of the dams. Dam removal will not materially affect properties in Kalkaska County.

Segment	Description	Number of residential parcels within ½ mile	Total no. of acres	Total current assessed value (U.S. $ millions)
1	From mouth to Union Street Dam	1 304	233	$137
2	Boardman Lake	1 778	403	$130
3	Inlet of Boardman Lake to Sabin Dam	166	403	$9
4	Sabin Pond	42	305	$4
5	Keystone Pond and Boardman Dam	61	504	$5
6	Inlet of Keystone to Brown Bridge Dam	493	4 759	$40
7	Brown Bridge Pond	8	276	$1
8	Inlet of Brown Bridge Pond to forks	69	576	$5
9	North branch	N/A	—	—
10	South branch	N/A	—	—
	Total	3 921	7 459	$331

Table 19. Residential property near the Boardman River

The study [44] also has other features that correspond to the Boardman River assessment area. For example, the impoundments in this study are relatively small in size, ranging from 8 acres to 194 acres. The sizes of these impoundments correspond fairly well to the sizes of the impoundments along the Boardman River.

Three of the Boardman River dams were used for electricity production. It is possible that they could be used for electricity again.

An equation including the hydraulic head, flow rate of the water, and a horsepower conversion constant is used to calculate the hydropower potential of the Boardman River dams.

$$\text{Power} = \text{Head} \bullet \text{Flow} \bullet \text{Constant}\left(64{,}4\ /\ 550 \bullet 0{,}7457\right) \tag{13}$$

The constant is formed by taking the weight of water, 64,6 lb/ft3, and dividing it by the horsepower constants consisting of 550 ft lbs multiplied by 0,7457 kWh, both values are equivalent to the unit of 1 horsepower.

The head for Sabin Dam (20 feet), Boardman Dam (41 feet), and Brown Bridge Dam (33 feet) were reported in the dam brochure from Traverse City Light and Power. The flow rate of the water is available from the U.S. Geological Survey Surface-Water Daily statistics for the Boardman River, site #04126970, which is located above Brown Bridge Road on the Boardman River at latitude 44°39'24", longitude –85°26'12". The daily flow rate is given in cubic feet per second and is the mean value for each day. This mean value can be used for each of the 24 hours in a day. Current data supported are only from the date 30 September 2007 and earlier. If the rate of flow is below 100 cubic feet per second (CFS), then the efficiency of the power produced is reduced, therefore; any hourly rate that is below 100 CFS, is not calculated and the rate for that hour is zero.

An important feature of the annual profit function is that while hourly quantities of generation are easily identified, hourly prices of electricity and RECs going forward through time. In markets that are expected to transition to deregulation, the uncertainty of future prices and resultant low availability of consistent price estimates further complicates the problem.

2. Conclusions

The socioeconomic impacts associated with alternative outcomes for the Boardman River dams were evaluated by performing counterfactual experiments that simulate changes in the current conditions that arise from various disposition alternatives. These simulations estimate changes in recreational usage, tourism expenditures, property values, and electricity production that result in changes in one or more of the existing dams. Corresponding changes in the river characteristics that influence recreation, property values, and electricity production were estimated for each alternative. These were used to quantify the associated changes in social welfare for various alternatives, providing an empirical basis for decision-making. There were 91 potential management options across the four dams. Of these, the following seven were evaluated most closely.

Alternative 1:

Alternative 1 is repairing and retaining the dams. The repairs to the dams will not materially alter the fishing or recreation opportunities, or the existing nature of the impoundments. We predict no measurable impact on resident recreation values, visitor expenditures, or property values. The characteristics of the existing fishery will not change. Nor will the paddling opportunities. We expect no changes to the existing trails and campsites. Similarly, we predict no changes in property values associated with the implementation of Alternative 1.

Alternative 25:

With the removal of Sabin and Boardman dams, we anticipate that the corresponding changes in stream hydrology and fish habitats will change the recreation opportunities associated with the Boardman River. Under Alternative 25, the impoundments associated with these dams will become free-flowing river segments. The removal of the dams will change the nature of the fishery for several segments. Specifically, anadromous species are predicted to become available as far upstream as the Brown Bridge Dam. In addition, catch rates for anadromous fish species in western Grand Traverse Bay are predicted to improve somewhat. Boardman Lake, however, will continue to offer warm water fishing experiences. Moreover, some segments will offer more “whitewater” under this alternative than current conditions do, consequently changing recreational paddling opportunities. The former impoundments are predicted to become more scenic, as well.

Relative to current conditions, implementing Alternative 25 will increase the welfare of resident recreators by approximately $112 000. This welfare increase represents the present value over 30 years. In addition, we expect tourism spending to increase. The present value estimate of the increase in tourism spending over 30 years is $1,38 million. Finally, once the fishery improvements have realized their maximum potential, we expect that the tourism-based jobs will increase by 4 jobs.

In addition to the recreation and tourism changes described above, Alternative 25 will result in likely changes in residential property values in parcels near Sabin Pond and Keystone Pond. We find that the value of an individual residential parcel in the vicinity of Sabin Pond and Keystone Pond could fall, on average, by as much as 6 percent following removal of the dams, if all other influences on property values are held constant. About two years after the removal, the affected properties are predicted to begin to increase in value. Twenty years after removal, the properties, on average, could increase in value by as much as 18 percent, or approximately one percent per year, relative to current conditions.

Initially if Alternative 25 were implemented, within ½ mile of the Boardman River the aggregate assessed value of the properties could fall by as much as $0,6 million. Over time, the aggregate assessed value may increase by as much as $1,7 million. The present value of the stream of property value impacts is $1,04 million. When considering the results, it is important to keep in mind that calculated changes in value represent the expected change associated only with dam removal. Changes in market values are likely to occur over time for reasons unrelated to dam removal.

In terms of the property value impacts, it is important to understand several aspects. First, the impacts will not be equally distributed across residents of Grand Traverse County. Initially, individual property owners may experience a decline in the value of their individual properties that is proportionally greater than the overall impact. Over time, those same owners may experience a gain in value that is proportionally greater than the overall impact. Second, the statistical model applied for this assessment represents the average impact. Not all affected properties will experience the average impact. Some individual parcels may increase or decrease in value in amounts greater to, or less than, the predicted average impact.

Alternative 41a:

With fish passage modifications on all four dams, we anticipate that recreation opportunities will improve in some of the Boardman River segments. Specifically, these modifications will improve fishing somewhat in the river segments downstream of Brown Bridge Pond. In addition, catch rates for anadromous fish species in western Grand Traverse Bay are predicted to improve somewhat. The dam modifications will permit the passage of anadromous fish species as far upstream as the north and south branches. The existing impoundments will continue to support only warm water fisheries. None of the modifications will result in improvements to the existing whitewater features or scenic quality of the segments. Additionally, we do not anticipate any changes in property values associated with the dam modifications.

Relative to current conditions, implementing Alternative 41 will increase the welfare of resident recreators by approximately $83 000. This welfare increase represents the present value over 30 years. In addition, we expect tourism spending to increase. The present value estimate of the increase in tourism spending over 30 years is $1,44 million. Finally, once the fishery improvements have realized their maximum potential, we expect that the tourism-based jobs will increase by 4 jobs per year.

Alternative 41b:

Alternative 41b adds re-powering each of the dams to the fish passage modifications of Alternative 41a. Because the re-powering does not influence the river differently from 41a, impacts are identical except for the value of electricity generated. Electricity quantities are identified using a combination of river flow and dam-specific information, including head and turbine efficiency as identified in [45]. At the expected level of hourly generation and historical hourly prices annual revenues are estimated at $452 000. Michigan's "21st Century Electric Energy Plan" [46] recommends a portfolio standard that requires load-serving entities to provide 10 percent of their energy sales from renewable energy options by the end of 2015.[13] Load-serving entities can meet the standard in several ways including buying qualifying renewable energy credits.[14] Revenue from renewable energy credits is estimated at $15 per megawatt hour beginning in 2015. With this value and electricity prices that increase at 3% the estimated net present value over 30 years for re-powering the dams is $9 100 000.

Alternative 43:

With the removal of Sabin dam and modifications of Boardman and Brown Bridge Dams, we anticipate that changes in stream hydrology and fish habitats will alter recreation opportunities associated with the Boardman River. Under this alternative, Sabin Pond will become a free-flowing river segment. The removal of Sabin Dam will change the nature of the fishery for this segment. In addition, the dam modifications will permit the passage of anadromous species as far upstream as the north and south branches. In addition, catch rates for anadromous fish species in western Grand Traverse Bay are predicted to improve. Moreover, some segments will offer more "whitewater" under this alternative than current conditions do, consequently changing recreational paddling opportunities. The former

[13] The Michigan Public Service Commission will review the performance of the program before 2015 and decide whether to extend the goal to 20 percent of energy sales from renewable energy options by the end of 2025.

[14] A renewable energy credit is a "unique, independently certified, verifiable record of the production of one megawatt hour of renewable energy."

impoundment is predicted to become more scenic, as well. The existing warm water fisheries for Boardman Lake, Keystone Pond, and Brown Bridge Pond will not be materially affected.

Relative to current conditions, implementing Alternative 43 will increase the welfare of resident recreators by approximately $133 000. This welfare increase represents the present value over 30 years. In addition, we expect tourism spending to increase. The present value estimate of the increase in tourism spending over 30 years is $1,50 million. Finally, once the fishery improvements have realized their maximum potential, we expect that the tourism-based jobs will increase by 4 jobs.

In addition to impacts on recreation values and tourism expenditures, the removal of Sabin Dam will likely affect the property values of residential parcels near the existing impoundment. The above discussion related to Alternative 25 provides the context and caveats associated with estimated changes in property values. Total assessed value of residential parcels within ½ mile of the Boardman River would change if Alternative 43 were implemented. Initially, the aggregate assessed value of the properties could fall by as much as $0,2 million. Over time, the aggregate assessed value may increase by as much as $0,7 million. The present value of this change is $0,43 million.

Alternative 79:

With the removal of Sabin, Boardman, and Brown Bridge Dams, we anticipate that the corresponding changes in stream hydrology and fish habitats will result in changes in recreation opportunities associated with the Boardman River. Under this alternative, Sabin Pond, Keystone Pond, and Brown Bridge Pond will become free-flowing river segments. The removal of these dams will change the nature of the fishery not only for the existing impoundments, but for other segments as well. Specifically, anadromous fish species are predicted to become available as far upstream as the north and south branches. In addition, catch rates for anadromous fish species in western Grand Traverse Bay are predicted to improve. Boardman Lake, however, will continue to offer warm water fishing experiences. Moreover, some segments will offer more “whitewater” under this alternative than current conditions do, consequently changing recreational paddling opportunities. The former impoundments are predicted to become more scenic, as well.

Relative to current conditions, implementing Alternative 79 will increase the welfare of resident recreators by approximately $241 000. This welfare increase represents the present value over 30 years. In addition, we expect tourism spending to increase. The present value estimate of the increase in tourism spending over 30 years is $1,58 million. Finally, once the fishery improvements have realized their maximum potential, we expect that the tourism-based jobs will increase by 5 jobs.

Finally, property values near the current impoundments will likely be affected by the dam removals. The above discussion related to Alternative 25 provides the context and caveats associated with estimated changes in property values that result from the implementation of

Alternative 79. The total assessed value of residential parcels within ½ mile of the Boardman River would change if Alternative 79 were implemented. Initially, the aggregate assessed value of the properties could fall by as much as $0,6 million. Over time, the aggregate assessed value may increase by as much as $1,9 million. The associated present value is $1,18 million.

Alternative 81:

With the removal of Sabin, Boardman, and Brown Bridge Dams and modifications to the Union Street Dam, we anticipate that the corresponding changes in stream hydrology and fish habitats will result in changes in recreation opportunities associated with the Boardman River. However, in the expert judgment of the fisheries biologists working on this project, the measurable changes to recreation opportunities are no different from those that will occur under Alternative 79. The estimated economic value associated with residents' recreation experiences and the estimated increase in tourism spending and jobs are as reported above. Similarly, because the dam removals are the same under Alternative 79 and Alternative 81, the estimated impacts on property values under Alternative 81 are the same as those under Alternative 79, which are reported above.

Based on the results of the integrated process, the dam owners decided to remove the Sabin, Boardman, and Brown Bridge dams and modify the Union Street dam for fish passage. Stated environmental benefits include enhancing and restoring 3.4 miles of native cold water habitat, reconnecting 160 miles of high-quality river habitat, and restoring more than 250 acres of wetlands. Brown Bridge dam has been drawn down, and is scheduled for removal in summer 2012. Environmental permitting for removing the other dams is underway.

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3. References

[1] Vining R (1984) On Appraising the Performance of an Economic System. Cambridge: Cambridge University Press. 220 p.

[2] U.S. Environmental Protection Agency (2010) Guidelines for Preparing Economic Analyses. Report Number EPA 240-R-10-001. Washington, DC: U.S. EPA. 297 p.

[3] McFadden D (1974) The Measurement of Urban Travel Demand. Journal of Public Economics 3(4): 303-328.

[4] McFadden D (1981) Econometric Models of Probabilistic Choice. In: Manski C, McFadden D, editors. Structural Analysis of Discrete Data. Cambridge, MA: The MIT Press. pp. 198-272.

[5] Rosen S (1974) Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition. Journal of Political Economy 82(1): 34-55.

[6] Dower N, editor (1989) Ethics and Environmental Responsibility. Aldershot, England: Avebury. 155 p.

[7] Leontief W (1986) Input/Output Economics. New York: Oxford University Press. 448 p.

[8] ECT (2008) Boardman River Feasibility Study: A Report on the Boardman River Fisheries Habitat Survey & Data Collection. Ann Arbor, MI: Environmental Consulting & Technology, Inc.

[9] U.S. Army Corps of Engineers (2005) Section 506 Great Lakes Fishery and Ecosystem Restoration Preliminary Restoration Plan for the Boardman River Mainstem Grand Traverse County, Michigan. Available: http://dspace.nitle.org/handle/10090/9517. Accessed 2012 March 15.

[10] Michigan Department of Natural Resources (2002) Boardman River Natural River Plan February 1976: Grand Traverse and Kalkaska Counties. Revised 2002 March 12. Lansing, MI: Michigan DNR Fisheries Division.

[11] Lupi F, Hoehn J, Chen H, Tomasi T (1998) The Michigan Recreational Angling Demand Model. Staff Paper 97-58, Department of Agricultural Economics. East Lansing, MI: Michigan State University.

[12] Michigan Department of Natural Resources (2000) Chapter 20: Michigan Stream Classification: 1967 System. In Manual of Fisheries Survey Methods II. Available: http://www.michigandnr.com/PUBLICATIONS/PDFS/ifr/manual/SMII%20Chapter20.pdf. Accessed 2012 April 16.

[13] Largent S, Director, Land Management Services, Grand Traverse Conservation District (2008) Personal communication with Morton A, Veritas Economic Consulting. 2008 March 26.

[14] Kalish T, Fisheries Biologist, Michigan Department of Natural Resources, Traverse City Field Office (2008) Personal communication with Morton A, Veritas Economic Consulting. 2008 March 26.

[15] ECT (2007) Boardman River Feasibility Study: A Report on the Boardman River Fisheries Existing Data. Ann Arbor, MI: Environmental Consulting & Technology, Inc.

[16] Michigan Department of Natural Resources (2005) Survey Report for Boardman River, Summer 2005. Lansing, MI: Michigan DNR Fisheries Division.

[17] Michigan Department of Natural Resources (2006) Study Final Report. Project No. F-81-R-7. Available: http://www.michigan.gov/documents/dnr/230646-Final_191892_7.pdf. Accessed 2012 April 16.

[18] Su Z, Lockwood R, Sutton A (2006) Angler Surveys on Michigan Inland Waters, 2000-2006. Ann Arbor, MI: Department of Natural Resources, Institute of Fisheries Research.

[19] Great Lakes Fly Fishing Company. 2008. Personal communication with Abrams E, Veritas Economic Consulting. 2008 March 26.

[20] Tonello M, Nuhfer A (2004) Manistee River: Hodenpyl Dam to Red Bridge. Available: http://www.michigandnr.com/PUBLICATIONS/PDFS/ifr/ifrlibra/status/waterbody/2004-2Manistee.pdf. Accessed on 2012 April 16.

[21] Goniea T, Biologist, Fisheries Division, Michigan Department of Natural Resources (2008) RE: Question about Data from Study No. 230427 Personal communication with Woodard D, Veritas Economic Consulting. 2008 April 18.

[22] Fred N, Cherry Capital Paddle America Club (2008) Personal communication with Morton A, Veritas Economic Consulting. 2008 February 25.

[23] Goldstein L, Cherry Capital Paddle America Club (2008) Personal communication with Morton A, Veritas Economic Consulting. 2008 February 26.

[24] Hynes S, Hanley N, Garvey E (2007) Up the Proverbial Creek without a Paddle: Accounting for Variable Participant Skill Levels in Recreational Demand Modelling. Environmental & Resource Economics 36: 413-426.

[25] Adamowicz W, Swait J, Boxall P, Louviere J, Williams M (1997) Perceptions versus Objective Measures of Environmental Quality in Combined Revealed and Stated Preference Models of Environmental Valuation. Journal of Environmental Economics and Management 32: 65-84.

[26] DeLorme (2006) Michigan Atlas and Gazetteer. Yarmouth, ME: DeLorme. 120 p.

[27] Cool K, Sobel K, Wood J, Nelson C, Stynes D. 2003. *2003-2007 Michigan Comprehensive Outdoor Recreation Plan*. Available at http://www.michigan.gov/documents/SCORP_164752_7.pdf. Retrieved on February 18, 2007.

[28] Lemberg, David. 2004. "WMU News: First Stage of Statewide Water Trail Opens." Available at http://www.wmich.edu/wmu/news/2004/08/017.html. Retrieved on April 24, 2008.

[29] Michigan State University Tourism. 2001a. "Grand Traverse County Tourism Profile." Available at http://www.tourismcenter.msu.edu. Retrieved on February 6, 2008.

[30] Michigan State University Tourism. 2001b. "Kalkaska County Tourism Profile." Available at http://www.tourismcenter.msu.edu. Retrieved on February 6, 2008.

[31] Fishkind & Associates. 2006. *Tourism Industry Analysis for Grand Traverse County*. Prepared for Traverse City Convention and Visitors Bureau. September 20. Orlando, FL: Fishkind & Associates, Inc.

[32] Southwick Associates Inc. 2007. *State-Level Economic Contributions of Active Outdoor Recreation—Technical Report on Methods and Findings*. Prepared for Outdoor Industry Foundation. Fernandina Beach, FL: Southwick Associates Inc.

[33] English, Donald B.K., and J.M. Bowker. 1996. "Economic Impacts of Guided Whitewater Rafting: A Study of Five Rivers." *Journal of the American Water Resources Association* 32(6):1319-1328.

[34] Moore, Roger L., and Kelly Barthlow. 1998. *The Economic Impacts and Uses of Long-Distance Trails*. Prepared for United States Department of the Interior, National Park Service. Raleigh, NC: North Carolina State University Department of Parks, Recreation and Tourism Management.

[35] U.S. Fish and Wildlife Service. 2008. *2006 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation: Michigan*. Available at http://www.census.gov/prod/2008pubs/fhw06-mi.pdf. Retrieved on March 28, 2008.

[36] Stynes, Daniel J., and Eric M. White. 2006. "Spending Profiles for National Forest Recreation Visitors by Activity." Available at http://www.fs.fed.us/recreation/programs/nvum/spending_profiles_2006.pdf. Retrieved on March 2, 2008.

[37] Bowker, J.M., John C. Bergstrom, and Joshua Gill. 2004. "The Waterway at New River State Park: An Assessment of User Demographics, Preferences, and Economics." Prepared for the Virginia Department of Conservation and Recreation. Available at http://atfiles.org/files/pdf/WNRstudy04.pdf. Retrieved on March 2, 2008.

[38] Nelson, Charles M., Daniel M. Spotts, Denis Auger, and Hector Chiunti. 1995. "Camping, Trails and Dispersed Recreation." Available at http://web1.msue.msu.edu/imp/modsr/03299578.html. Retrieved on February 5, 2008.

[39] Michigan Department of Natural Resources. 2008. "Forks State Forest Campground," "Scheck's Place State Forest Campground," Scheck's Place Trail Camp," and "Guernsey Lake State Forest Campground." Available at http://www.michigandnr.com/parksandtrails/. Retrieved on February 12, 2008.

[40] Michigan Economic Development Corporation. 2008. "Ranch Rudolf." Available at http://www.michigan.org/travel/detail.asp?m=&p=G7353. Retrieved on February 12, 2008.

[41] Humphries, Rebecca A., Dennis Fedewa, Arminda Koch, Jim Wood, Charles Nelson, and Kristen Steger. 2007. *2008-2012 Michigan Comprehensive Outdoor Recreation Plan (Draft)*. Lansing, MI: Michigan Department of Natural Resources.

[42] Propst, DB 2000. Use of IMPLAN to assess economic impacts of recreation and tourism: Chronology and trends. In Proceedings of the Fifth Outdoor Recreation and Tourism Trends Symposium. East Lansing, MI.

[43] Cacciaglia, Ernie, Manager, Grand Traverse County GIS. 2008. Personal communication with Veritas Economic Consulting.

[44] Provencher, Bill, Helen Sarakinos, and Tanya Meyer. 2008. "Does Small Dam Removal Affect Local Property Values? An Empirical Analysis." *Contemporary Economic Policy* 26(2):187-197.

[45] Bingham, M.F., K.E. Mathews, A.R. Morton, D.M. Woodard, E.S. Abrams, and Z. Li. 2008. *Economic and Social Analysis of the Boardman River Dams: Quantification of Existing Conditions*. Prepared for Boardman River Dams Committee. Cary, NC: Veritas Economic Consulting.

[46] Lark, Peter J. 2007. "Michigan's 21st Century Electric Energy Plan." Available at http://www.michigan.gov/documents/mpsc/21stcenturyenergyplan_185274_7.pdf. Retrieved on October 17, 2008.

Section 3

Role of Governments, Community Grants, and Tradable Permits in Environmental Land Use Planning

Community Grants as an Instrument of Planning Practice

Neale Smith

Additional information is available at the end of the chapter

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1. Introduction

Community grants are used by a wide variety of government and non-government bodies at different levels across many jurisdictions. They may be particularly prevalent among local and regional governments and in policy sectors where community development is an approach or goal. Yet there has been little rigorous research into this practice. Few formal evaluation studies have been reported. There is no available synthesis of the rationale behind such programs, effective process designs, or their success in achieving intended outcomes. Planners and other professionals who initiate such programs may have little more than intuition to guide them. Thus, the objective of this Chapter is to review the literature on the use of community grants as a tool for urban and regional planning practice. This review is supplemented with evidence from the author's own experience of these programs within two western Canadian provinces; while these cases are specific to a particular geographic and political context, the findings are likely generalizable to urban governments in (at the least) other Western liberal democratic regimes. The Chapter concludes by drawing on the literature and cases to make suggestions for urban planning professionals about how to effectively use community granting as a community development tool.

A working definition of community grants is as follows: "the provision of funding to community groups or organizations by outside parties through a competitive application process" [1: p. 242]. My focus here is primarily upon what I define as small grants, from several hundred to a few thousand US or Canadian dollars—which is typically a miniscule proportion of the funders' total budget. Micro-grants [2-3] and mini-grants [4-6] are other terms which have been used to describe funding allocations of this size.

2. Community grants in British Columbia: A descriptive overview

There is no exhaustive list or record of community granting programs. Given their widespread use, to prepare any comprehensive inventory is probably a hopeless task and out of date before it is even begun. Nevertheless, to demonstrate how community grants are being used in one contemporary setting, I provide this overview from the province of British Columbia, Canada. A simple web search easily finds these and many other examples.

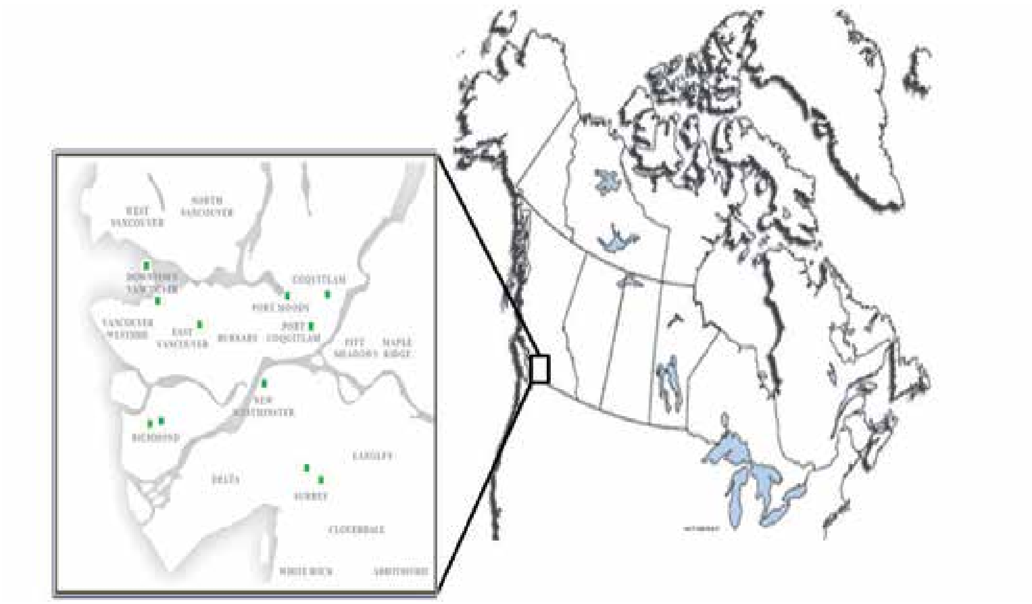

Figure 1. British Columbia's Lower Mainland

A number of local governments in the Lower Mainland region of the province, the metropolitan Vancouver area, have at least one grant program administered by the municipality. For instance, in the city of Vancouver, the Greenest City Neighbourhood Grants[1] most recently funded 16 community groups for projects in areas such as waste reduction, local food, and active transportation. The Community Enhancement Partnership Program in the city of Surrey[2] offers grants of up to $3000 to local groups or residents for projects to beautify their neighbourhoods. Gardens and landscaping, graffiti removal, and decorative lighting are some examples of what might be funded. The city of Richmond has a formal policy which sets aside grants in three areas: arts and culture, parks and recreation, and health and social development[3]. In the city's 2012 budget, the only line item to receive additional money was the grant program[4]. In the city of North Vancouver, an annual grant process distributes money to community groups for both operating expenses and particular project initiatives. Funding is also offered in specific areas such as child care, sustainability, housing, and violence

[1] City of Vancouver, http://vancouver.ca/ctyclerk/cclerk/20110614/documents/a2.pdf
[2] City of Surrey, http://www.surrey.ca/files/cepp_2012_overview.pdf
[3] City of Richmond, http://www.richmond.ca/services/socialplan/citygrant.htm
[4] City of Richmond, http://www.richmond.ca/news/city/2012budgetsapproved.htm

prevention[5]. The city of New Westminster offers grants for arts and culture, amateur sports, environmental awareness and education, and other areas[6]; this is likely quite typical of the range of activities funded by many other local governments across BC and elsewhere.

The Union of BC Municipalities, the peak association representing the province's local governments, oversaw a Community Health Promotion Fund from 2005-2009[7]. This $5 million pool of funds was used to support applications on healthy living and chronic disease prevention projects. Over this period, 146 projects were funded; groups within the city of Vancouver received money in three of the four fiscal years. These were larger grants than in many other cases, being up to $35,000 in some instances. Skill development and partnership creation were some of the outcomes measured across the funded projects [7].

British Columbia's Ministry of Health has also set aside envelopes of funding that could be and were used for community granting. An example is the Community Food Action Initiative, offered in all five of the province's regionally-based health authorities (RHAs). It supports projects related to food security, broadly defined. After a three-year pilot phase (2005-2008) this program was taken up by the health authorities and funded through their core budgets. Some evaluation reports are available [8-10]. Within the city of Vancouver, the Vancouver Coastal Health Authority (VCHA) has offered since 2008 health promotion grants through its Healthy Living Program.

Other sectors, too, such as justice or recreation, are involved in the granting game. Thus, the above is an illustrative rather than a comprehensive overview, but serves to demonstrate the range of granting activity which occurs in different sectors often overlapping within a geographic jurisdiction. As it also suggests, there is extensive commonality between urban planning projects with community development intent and health promotion efforts in the health sector. Many of the projects funded through health promotion community grant projects could have equally easily been supported by grant programs initiated by a city or town planning department; many of the same community organizations regularly receive grants from both areas. The social determinants of health, and social sustainability, are concepts around which urban planning and health promotion overlap [11-12]. That local governments have a crucial role in creating conditions for health is an original premise of the healthy cities/communities movement pursued in Europe, North America, Australia and elsewhere [13-18].

Community Foundations and other not-for-profit, third sector organizations such as the United Way also undertake community granting on an on-going basis. Substantial amounts of money can be involved here. Fifty (50) community foundations across the province of British Columbia belong to the national association, Community Foundations of Canada. Several of these, including the Vancouver Foundation, operate in the Lower Mainland/Fraser Valley region of the province. The Vancouver Foundation disbursed $41

[5] City of North Vancouver, http://www.cnv.org//server.aspx?c=3&i=211

[6] City of New Westminster, http://www.newwestcity.ca/business/grants/community_grants.php

[7] Union of British Columbia Municipalities, http://www.ubcm.ca/EN/main/funding/healthy-communities/community-health-promotion-fund.html

million in its most recent yearly program[8]. It is important to note that not all foundations limit recipients of their largesse to those operating within their own municipality. To the author's knowledge, whether there are or should be significant differences in the rationale for and design of grant programs between the public and not-for-profit sectors is a question that has not been previously studied.

3. Case examples

This section describes in more detail two of the contemporary Vancouver examples of community grant programs noted above. The information is derived from document review, supplemented with some interviews of government managers and grant recipients. This is meant to give a sense of how such programs operate in practice and how they are received by community members.

3.1. City of Vancouver, Greenest City Neighbourhood Grants

In 2011, this initiative funded 16 community groups. A total of 54 community projects were proposed, with funding requests amounting to more than five times the total pool of $100,000 available for allocation. This interest was despite the fact that there were only three weeks between the date when information was publicly posted on the city's website and the submission deadline. City social media channels, such as Facebook and Twitter, were used for publicity. Proposals were reviewed by staff from four city departments, and recommendations on funding forwarded to Council for approval.

Registered not-for-profit organizations and societies based in the city of Vancouver were eligible to apply. Priority was given to proposals that were innovative, included community partnership, leveraged additional resources, and had plans for sustainability. Grants could range between $2000 and $25,000 and projects had a one-year period for implementation—actual allocations ranged from $2000 to $15,500, with an average of $6250. The largest projects were required to submit a completed Outcome Measurement Framework (identical to one used by the United Way and Vancouver Coastal Health Authority). This required identification of inputs, activities, outputs and short-term outcomes, along with associated indicators—that is, a form of logic model [19-20]. For all projects, a written evaluation report is required, including submission of digital photographs illustrating program success.

The Greenest City grants were funded during a civic election year. Because they appeared to be closely associated with the philosophical agenda of Vancouver's governing municipal party, some of the grants were seized upon by the mayor's opponents in an attempt to create controversy. One particular grant of $5000, which had been awarded to the Environmental Youth Alliance for "Lawns to Loaves", was particularly contentious. While this project aimed to educate urban children about agriculture and food production, one component (in which volunteers turned their front lawns into miniature wheat fields) was derided as 'silly', 'wacky' and 'goofy' [21-22]. William Rees, well-known local professor of

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[8] Vancouver Foundation, http://www.vancouverfoundation.ca

community planning, argued that the project had symbolic rather than practical value, in that it might generate conversation about sustainable food systems; one participant called the mini-fields a 'living billboard' [22]. Conversely, the symbolic aspect was precisely what many critics, such as City Caucus blog, attacked[9]. Clearly however, the program fit the criteria established by city staff, and it is enthusiastically championed in some quarters.

3.2. Vancouver Coastal Health Authority, Healthy Living Program: community grants

Since 2008, this program has funded 22 community groups, out of 86 applicants in total. Approximately $134,000 has been disbursed; the available budget for this program has been less than 15% of the amount requested by interested community participants. This substantial response indicates great local interest and support.

Grants are presently available for a maximum of $8000, for discrete project activities to be carried out over a planned one-year time span. Projects are mandated to focus on at least one of the Healthy Living Program (HLP)'s priority areas of healthy eating, active living, and tobacco reduction. Projects must substantially target individuals between 35-64 years of age, from an identified disadvantaged or vulnerable population: e.g., low-income, aboriginal, or high-risk ethno-cultural communities. Eligible recipient organizations are non-profit community-based groups or organizations located in (and/or primarily serving a population within) the geographic boundaries of the city of Vancouver. Applicants are expected to obtain support of community partner agencies. A mid-term report and final report are expected, as is participation in a Showcase event, during which each project can highlight its activities and accomplishments.

HLP initiates each call for proposals 3 months prior to deadline. The grant is promoted through health promotion websites and newsletters as well as by health authority staff. There is some evidence that communications are being re-broadcast through community channels; e.g., community agency blog or Twitter feed. Technical assistance, in the form of consultation with HLP staff members, is available and potential applicants are encouraged to avail themselves of this support, though it is not a requirement for successful application. All received applications are pre-screened by HLP staff to ensure that they address the health promotion pillars and target disadvantaged groups. Projects out of area, asking for ineligible items, or incompletely documented are also excluded at this stage. Those which qualify are further assessed by HLP staff. Applications are ranked on the basis of points, and most highly ranked applications are funded until the available grant monies are exhausted. The current scoring tool consists of 11 questions, of which nine are ranked on a scale of 0-2 and two are rated on a scale of 0-1. The range of possible scores is thus 0-20.

Unlikely the Greenest City grants, the media attention provided to this health authority program has been largely positive. One physical fitness initiative, Healthiest Winner, which

[9] City Caucus Blog, http://archive.citycaucus.com/2011/07/foi-reveals-green-grants-about-thought-experiments-and-symbolism

was aimed to draw non-traditional members to community recreation facilities, was lauded by one newspaper columnist, herself a participant [23-24]. The program manager has suggested that this coverage brought a cascade of interest. The program has been sustained and expanded since its initial funding, but continues to be unable to meet all the public demand.

4. Conceptual rationale(s) for community grants as a planning tool

Previous research has found little documentation or formal assessment of the rationale for and objectives of community grant programs [1, 25-26]. Literature, however, does suggest that the following conceptual arguments can serve to justify community grants as a policy instrument: community organization and mobilization; devolving or decentralizing decision making and increasing public engagement; and social capital formation and community capacity building.

Often, decision makers have issues which they perceive to be priorities (e.g., as identified through social or epidemiological statistics and other forms of scientific evidence). They may wish to garner community and public support for action on this agenda. Grants, then, can be a means to identify others in the community who are concerned about these same issues and willing to put their own efforts towards addressing them. They might also identify those who can be persuaded to adopt these government preferences as their own. That is, grants might be a means of mobilizing the community behind policies and programs focused on the funder's priorities [27]. Many grant programs appear to do this through articulating a handful of areas upon which eligible proposals must be based, such as described above for the Greenest City priorities of transportation, local food, trees/greening and zero waste, or the VCHA Healthy Living Program's emphasis on eating, physical activity and tobacco reduction. Only rarely do grant programs leave problem identification entirely up to community applicants. Those originating in the healthy communities model or focused on broad determinants of health seem to be the main exceptions [15, 17].

Advocates of decentralizing or devolving decision making are constantly seeking ways to bring key choices within the scope of those closest to the 'grassroots'. Grants can do this, in a limited way on particular issues, by giving community groups and organizations some ability to decide how public resources are spent. Of course, because grant amounts are quite small and projects which they fund typically time-limited, they seldom have the potential to result in dramatic community transformation. Grantees are also constrained by the terms of their grant, which typically are aligned in support of existing government or funder preferences, as described above. Peer allocation, or involving community representatives directly in judging the competitive applications, rather than leaving this solely in the hands of paid bureaucrats or political leaders, would be a further step in empowering local decision making but this appears to be relatively less often undertaken.

Community organizations can be an important locus of social capital [28]; they create venues in which citizens can meet, build relationships, and create social networks. Access to grant money can catalyze the formation of new groups and energize existing ones. In this sense, granting programs may be less interested in the nature of projects which are planned and more concerned with bringing people together and building skills [29]. This can fall within the rubric of community capacity building, where generalized skills and problem-solving ability are often highly valued outcomes [30]. It appears to be common in Canada; according to Phillips, "most large municipalities help build community capacity by providing grants to community organizations and by co-production of services" [31: p.66].

Public administration and management literatures in the past years have increasingly concluded that many of the issues facing governments are 'wicked' problems which frequently are beyond the means of any one jurisdiction or sector to resolve. Thus there have been calls for community governance [31], and the strengthening of collaborative and cooperative multi-sector networks which can mobilize resources from many sources [32]. Community grants may be seen as in line with this prescription, though they go only a small ways towards its realization given that they manifest large differences in power and authority between the funder and the recipient. There is similarly literature around the concept of co-production; this argues that it is increasingly necessary for the public and society at large to contribute with formal governments to the design and implementation of services [33]. Again, while community granting accords with this line of thought, it cannot be seen as more than a small step in that direction, as grant projects provide only small-scale and narrowly targeted programs which are supplemental to the established programming activity of governments and institutionalized community agencies.

While community organizations seem most commonly to obtain grants in order to carry out specific activities (for example, to promote active living through walking clubs, or healthy eating through community kitchens and gardens), they can also be awarded for the creation of community plans [6, 34-35]. However the latter is less likely to be a regular feature of grant programs as it would encourage more frequent challenges to the professional expertise of the funders themselves.

5. Common challenges

Based on the experiences above and the literature in general, we next consider some of the key challenges which must be addressed if community grant programs are to be effectively implemented by municipal planning department staff and others.

To begin with, funders must carefully think through the process which they have in mind. Several important aspects should be addressed, only the most prominent of which can be identified here. One of these is timeline. It seems clear that very short timelines between the issue and close of a community grants call will disadvantage the least established community organizations, those with few full-time staff, or those which are least connected to the current political leadership and least likely to be tuned into the themes and language with which it sympathizes. Many granting programs require projects to be implemented and completed within one calendar or fiscal year; however it is important to recognize that preparation, recruitment and other activities can fall behind schedule in under-resourced community groups. Grant recipients, in the author's experience, appreciate flexibility to adjust to unforeseen circumstances.

Clear criteria matter. This allows all potential grantees to develop their best applications in light of what is deemed important by the funder; it allows those determining which projects are to be funded to compare one application against another in a meaningful way; and it makes the decisions transparent to outside observers who might wish to review or question them. But clear criteria matter only when they are consistently applied. Those who rate submitted proposals should, as much as possible, share an understanding of how key ideas are defined and what values they reflect. When committee members bring different and previously unarticulated values to the table, problems ensue [1]. It is probably easier to ensure consistent application when the decision makers come from the same organization, but having intersectoral participation enables a broader range of perspectives to be considered and a wider range of knowledge to be drawn upon. As noted above, community engagement might be most advanced when representatives of potential grantees or their constituencies are directly involved in allocating the available money. However, conflicts of interest might need to be controlled for.

Government spending in the present day is under much more scrutiny than may have historically been the case. New Public Management philosophies have been one source of this change [36]. Offering community grants thus becomes somewhat of a risk because the funder gives up the ability to directly manage projects for success. There are thus many questions about how accountability might be maintained [26]. Public-private partnerships might be one model; these typically are based upon detailed contract specifications with clearly defined deliverables. However, it may be hard to apply the same degree of formalization to agreements with modestly-resourced and semi-professional grantees. Grant programs appear more likely to rely upon requirements for performance measurement and evaluation. But these too can be overly onerous for community groups. In addition, they do not necessarily acknowledge different ways of knowing. Planners and other professionals may prefer quantitative measures which appear to give an objective account of whether or not changes are resulting at the community level, while for lay actors their knowledge of impact may derive from the experience of day-to-day immersion in community life, and the stories it generates—embedded experience to which government employees may not have access [26]. A particular challenge is that grant programs fund many different projects at the same time, efforts which target different audiences and employ distinct sets of activities. What kind of common measure might be applied to assess effectiveness across these contexts? Community capacity building might be specified as a common metric for grantees to report upon.

Acceptance of community grants also poses both short-term and long-term risks to the recipient. That is, concerns have been expressed in the literature that community agencies might be co-opted by their participation in such programs. For one, they might end up 'chasing dollars' and so directing their efforts toward actions which fit with government funder priorities rather than those which might suit their community and client stakeholders best. Consistency and continuity in programming might be sacrificed in order to grab grant money which is targeted to ever-changing priorities and the desire to back new, innovative, and pilot projects rather than the less exciting task of maintaining existing operations. Secondly, there is concern that community groups become dependent upon government funding and so suppress their political advocacy activities [37-38]—for fear of 'biting the hands that feed them'.

Too much service delivery responsibility cannot be placed upon community grantees – they cannot be downloaded the obligation to assume what governments would normally be called on to do, if they are not also to be given the stable resources and authority required. Program and service delivery grants are prone to this weakness, since they occur outside of community participation in the larger social and economic planning decisions which set the context.

Though seemingly an uncommon opportunity, grant funding might be used for 'counter-planning' – providing community groups with resources to look in broader terms at how systems might be aligned to their needs. Advocacy planning is a historical precedent which urban planners might draw on when considering these issues [39-40]. Social action planning [41] and Alinsky-style organizing are other community-based efforts which tend not to fit within the scope of community grant efforts because they might also produce direct challenges to the funders' own established policy ideas.

Not all community organizations are created equal. A certain degree of organizational capacity is normally needed in order for groups to successfully compete for grants. Being able to interpret requests for proposal and reframe an organization's priorities in those terms – grantspersonship – may be a self-perpetuating skill. Likewise, designing, implementing and evaluating programs to improve community well-being are capacities which are not equally distributing across groups [5]. In recognition of such limits, funders can offer technical assistance to potential grantees. This can take a multitude of forms. One is logic modeling, another may be evaluation planning; many other options are possible. Another way to assist potential grantees is to provide standard data collection instruments. Assistance has been well-received by grantees as reported in the author's experience in both Alberta and British Columbia. Of course, when grant programs incorporate a technical assistance component, they require longer timeframes and more resources contributed upfront on the funders' part. This affects process design considerations as described earlier.

Grant funded programs commonly wrestle with the issue of sustainability [42]. Grants are term-limited – one year for instance in the case of Greenest City and Healthy Living Program funds as described above –and rarely can recipients then apply for continuing or bridging funds. Yet a lot of groundwork is required in order to establish programs which can be taken up and maintained afterward; such work is seldom acknowledged or built into grant systems as an eligible category. Also, what it is that should be sustained?—it may be less important that a program be institutionalized than its benefits be continued [43]. Again, this might be a reason why capacity building is identified as an objective for grant programs. Finally, note that the absence of longitudinal research related to community grant initiatives makes it impossible to reach data-driven conclusions about the nature of efforts which may or may not lead to continuation of funded project efforts.

6. Conclusion

Community grants are widely used by local governments and other jurisdictions in Canada and beyond. Yet there has been very little effort to systematically study these processes and their outcomes. In this chapter, I have looked at the conceptual rationales for why planners and other professionals might wish to use this tool, and the challenges and risks associated with it. I end with the following suggestions for planning professionals who may wish to use community grants as part of a suite of community development instruments.

Targeted dollars – providing community grants for projects that meet a set of priorities determined by the funder – may be the best for community mobilization objectives. Open-ended calls might perhaps better serve community building. This could include ‘counter-planning’, in which grants might be provided for communities to develop their own visions for physical, social or economic development. Restricting grant proposals to topics determined by the funder is more likely than an open call to co-opt the voluntary sector into carrying out a government agenda, while unrestricted competitions may run a greater risk of funding projects that diverge from public and political preferences and are harder to justify from an accountability perspective. Any grant scheme then needs to consider these different risks and possible strategies for balancing them.

Community grants involve the allocation of public money, raised from the taxpayers’ pockets, and so they must not be given out with wild abandon. But community organizations also may have limited skill and time to produce detailed performance measurement and evaluation reports. The sorts of quantitative measures which suit bureaucratic mindsets might be seen as burdensome and irrelevant by grantees. Therefore, planners looking at a grants program might be advised to develop a reporting scheme which combines formal indicators with other forms of evidence, such as stories of significant change [44]. Community capacity building can serve as an outcome measure which may be common to projects which otherwise use distinct approaches to reach divergent audiences. While media attention to community grants might be rare, planners will be best placed to respond to any controversy when the criteria for funding and processes by which decisions are made are transparent and auditable by outside observers.

The overall quality of both applications and funded projects seems likely to be higher when community organizations have access to technical assistance from the grantor. In the author’s experience, recipients are most willing to go on record and express their appreciation for such procedures. This may well help to ‘level the field’ and ensure that more than a select group of organizations can compete for funds available. However, there is a danger that technical assistance might become another way of structuring or controlling what community groups do—that is, it might (unintentionally or otherwise) discourage creative but controversial ideas and steer applicants towards the safe middle road. Offering such support will also demand additional time and resources on the part of the funder and so should be designed into the process from the start.

Grant programs should consider the question of sustainability—will a one-time injection of resources make a long-term difference? For the practicing planner, it is probably most important to decide what should be sustained. If it is the project or program, then options for completing the necessary groundwork of identifying and recruiting on-going sponsors should be built in as eligible expenses. However it is probably more common for transferrable knowledge and skills to be the most desired outcomes. This is likely why community capacity building recurs in the grants literature as both a process objective and outcome.

Done thoughtfully, grant programs can make a difference for individuals and communities. There is no shortage of examples from municipalities around the world. Yet there has so far been little synthesis of experiences or development of best practices in this sphere; this chapter has offered an initial contribution towards that end.

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7. References

[1] Smith, N., & Baugh Littlejohns, L. (2007). A case study in community grant funding: lessons learned. American Journal of Health Education 38, 242-248.
[2] Hartwig, K.A., Bobbitt-Cooke, M., Zaharek, M.M., Nappi, S., Wykoff, R.F., & Katz, D. (2006). The value of micrograntsfor community-based health promotion: two models for practice and policy. Journal of Public Health Management and Practice 12, 90-96.
[3] Paine-Andrews, A., Francisco, V.T., & Fawcett, S.B. (1994). Addressing community health concerns and implementing a microgrant program for self-help initiatives. American Journal of Public Health 84, 316-318.
[4] Forster-Cox, S.C., Wiese, W.H., & MacLean, T.A. (1996). Health promotion mini-grants: grassroots implementation in New Mexico. American Journal of Health Promotion 10, 183-184.
[5] Meit, M., Ettaro, L., Hamlin, B.N., & Piya, B. (2009). Rural public health financing: implications for community health promotion initiatives. Journal of Public Health Management and Practice 15, 210-215.

[6] Miller, E.K., Scofield, J.L. (2009). Slavic Village: incorporating active living into community development through partnerships. American Journal of Preventive Medicine 67, S377-S385.
[7] Union of British Columbia Municipalities. (2008). Community Health Promotion Fund: Status Report, April 2008. Available at: http://www.ubcm.ca/assets/Funding~Programs/LGPS/CommunityHealthPromotion/chpf-status-report-2008.pdf
[8] Social Planning and Research Council of BC. (2011). Vancouver Coastal Health Community Food Action Initiative, Evaluation Report: October 2011. Available at: http://smartfund.ca/docs/eval_vch_cfai_2011_full.pdf
[9] Van der Woerd, KA, Mactier JD, & Lederer, J. (2008). Community Food Action Initiative Evaluation, 2005-2006: Final Report. Vancouver, BC: Provincial Health Services Authority.
[10] Baugh Littlejohns, L., & Smith, N. (2007). Evaluation of Interior Health Community Action Programming in Population Health. Prepared on contract for Interior Health Authority, Population Health, Kelowna, British Columbia. July.
[11] Polese, M. and Stren, R., (2000). The Social Sustainability of Cities. Toronto: University of Toronto Press.
[12] Baugh Littlejohns, L., & Smith, N. (2012). Building bridges between health promotion and social sustainability. In Knowledge Translation in Alberta: Health Research with Impact—KT Casebook, Volume 3. Edmonton: Alberta Innovates -- Health Solutions. 50-53. Available at: http://www.aihealthsolutions.ca/rtna/docs/Casebook03online%20Final%20Version.pdf
[13] Hancock, T. (1993). The evolution, impact and significance of the healthy cities/healthy communities movement. Journal of Public Health Policy, 14 (1), 5-18.
[14] Wharf Higgins, J. (1992). The healthy community movement in Canada. In: B. Wharf, ed. Communities and Social Policy in Canada. Toronto: McClelland and Stewart, 151-180.
[15] Smith, N. (2000). The implementation and evaluation of a healthy communities process in central Alberta: some implications for public health practice. Journal of Public Health Management and Practice 6, 11-20.
[16] Sherwood, D. (2002). The state of the healthy communities movement in Canada. Plan Canada 42, 11-12.
[17] Connor, R., Tanjasiri, S.P., Dempsey, C.L., Robles, G., Davidson, M.B., & Easterling, D.V. (2003). The Colorado Healthy Communities Initiative: Communities defining and addressing health. In Promoting Health at the Community Level. D. Easterling, K. Gallagher, D. Lodwick, eds. Thousand Oaks, CA: Sage.
[18] Twiss, J.M., Duma, S., Look, V., Shaffer, G.S., & Watkins, A.C. (2000). Twelve years and counting: California's experience with a statewide healthy cities and communities program. Public Health Reports 115, 125-133.
[19] McLaughlin, J, & Jordan, G. (1999). Logic models: a tool for telling your program's performance story. Evaluation and Program Planning 22, 65-72.

[20] Kaplan, S., & Garrett, K. (2005). The use of logic models by community-based initiatives. Evaluation and Program Planning 28, 167-172.
[21] Hutchinson, B. (2011). There are plenty of reasons Vancouver no longer the world's most livable city. National Post, August 30.
[22] Stueck, W. (2011). Backyard wheat fields produce food for green-policy debate. Globe & Mail, June 25.
[23] Thomas, S. (2010). Community centre seeks non-LuluLemon wearers for new health program. Vancouver Courier, January 12.
[24] Thomas, S. (2011). Program graduates embrace exercise. Vancouver Courier, April 8.
[25] Smith, N. (1998). Lessons from a comparative study of community grant programs in Alberta health authorities. Paper presented to the Canadian Evaluation Society Annual Conference. St. John's, NL.
[26] Smith, N. (2010). Incorporating local knowledge(s) in health promotion. Critical Public Health 20, 211-222.
[27] Pancer, S.M., & Nelson, G. (1989/90). Community-based approaches to health promotion: guidelines for community mobilization. International Quarterly of Community Health Education 10, 91-111.
[28] Putnam, R. D. (2000). Bowling alone: The collapse and revival of the American community. New York: Simon and Schuster.
[29] Welsch, A., & Heying, C. (1999). Watershed management and community building: a case study of Portland's Community Watershed Stewardship Program. Administrative Theory & Praxis 21, 88-102.
[30] Hawe, P., King, L., Noort, M., Gifford, S. M. and Lloyd, B. (1998). Working invisibly: health workers talk about capacity building in health promotion. Health Promotion International 13, 285–294.
[31] Phillips, S.D. (2010). 'You say you want an evolution?' From citizen to community engagement in Canadian cities. In Local Government in a Global World: Australia and Canada in Comparative Perspective. E. Brunet-Jailley and J.F. Martin, eds. IPAC/University of Toronto: University of Toronto Press. 55-80.
[32] Rhodes, R.A.W. (1997). Understanding governance: policy networks, governance, reflexivity and accountability. Open University Press.
[33] Brandsen, T., & Pestoff, V. (2006). Co-production, the third sector and the delivery of public services: an introduction. Public Management Review 8, 493-501.
[34] Cohen, N. (1995). Technical assistance for citizen participation: a case study of New York City's environmental planning process. American Review of Public Administration 25, 119–35.
[35] GermAnn, K.; Smith, N.; & Baugh Littlejohns, L. (2001). A Healthy Communities Initiative in Rural Alberta: Building Rural Capacity for Health. In Issues Affecting Rural Communities (II): Proceedings of the Rural Communities and Identities in the Global Millennium Conference, J.C. Montgomery & A.D. Kitchenham, eds. Nanaimo, BC: Malaspina University College Rural Communities Research and Development Centre.
[36] Hood, C. (1991). A public administration for all seasons. Public Administration 69, 3-19.

[37] Ilcan, S. & Basok, T. (2004) Community government: voluntary agencies, social justice, and the responsibilization of citizens. Citizenship Studies 8, 129-144.

[38] Casey, J., & Dalton, B. (2006). The best of times, the worst of times: community sector advocacy in the age of 'compacts'. Australian Journal of Political Science 41, 33-48.

[39] Davidoff, P. (1965). Advocacy and pluralism in planning. Journal of the American Institute of Planners 1, 331–8.

[40] Forester, J. (1994). Bridging interests and community: advocacy planning and the challenges of deliberative democracy. Journal of the American Planning Association 60, 153–8.

[41] Rothman, J. (1974). Planning and organizing for social change. New York: Columbia University Press.

[42] Wharf Higgins, J., Naylor, P., & Day, M. (2008). Seed funding for health promotion: sowing sustainability or skepticism? Community Development Journal 43, 210-221.

[43] Green, L.W. (1989). Is institutionalization the proper role of grantmaking? American Journal of Health Promotion 4.

[44] Dart, J., & Davies, R. (2003). A dialogical, story-based evaluation tool: the Most Significant Change technique. American Journal of Evaluation 24, 137-155.

Chapter 10

The Role of Tradable Planning Permits in Environmental Land Use Planning: A Stocktake of the German Discussion

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Additional information is available at the end of the chapter

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1. Introduction

The idea of tradable planning permits is subject to broad discussion in some developed countries such as Switzerland (for example, see [1]), but particularly in Germany (for example, see [2]).

The German federal government intends to reduce the daily land consumption to 30 ha per day in 2020 [3]. In 13 years between 1993 and 2010, land consumption in Germany was significantly higher than 100 ha per day. In the other 5 years, the undershooting of the 100 ha mark has been mostly due to lower economic growth rates or an economic slump [4]. Particularly rural areas were affected by excessive land consumption. Almost 50% of the converted land is sealed [5].

In order to achieve the 30 ha target, there is a broad consensus about the necessity to support planning by means of economic instruments. In this discussion, tradable planning permits turned out to be the instrument of choice, at least among the scientists. In Germany, a lot of research has been underway on this issue for years now (for example, see [6]). Among others, a pilot project is also in preparation [7, 8], as it was planned in the coalition agreement of the current federal government [9].

The idea of tradable planning permits stems from the concept of tradable CO_2 rights, more accurately the cap and trade system. Within the cap and trade regime, pollution rights should be limited in quantity and made tradable. Due to the cap on the pollution possible, the system is considered ecologically effective. If the mechanism is applied to the field of land use planning, the communal development plans are only legally valid if they are backed by planning permits, which have to be held by the communes. The communes – as the planning authorities – and not the land owners are the holders of the planning permits. This is an important difference from "tradable development rights", where private-sector actors are the sellers and buyers (for example, see [10]).

Due to the trade, the scheme is also regarded as being efficient because only those actors with the lowest marginal abatement costs reduce the emissions. The permits can be bought and sold by the communes on an organized trading platform.

The cap on the permits helps to circumvent rationality traps (game theory) which otherwise would appear. In Germany, for instance, communes competed against each other to attract new inhabitants and industries in order to get more tax revenues and higher shares out of the financial equalization scheme. This competition was a race to the bottom in many cases. Among others, the results in many cases have been almost empty residential or commercial areas and high infrastructure costs. However, if a community waives the preparation of new building areas, the neighbouring municipality takes the chance.

Within the cap and trade scheme, such rationality traps might be broken up [11]: Due to the costs of the permits, only such communes whose benefits of land development exceed the costs of the permits will buy planning permits and carry out land development. If land conversion can be avoided at costs below the costs of the planning permits, communes waive the right to further development. Maybe they can also reconvert the land into a natural state. Hence, if there is no need for holding permits, such communes will sell them to other communes (for example, see [12]). If they do not sell the "free" rights, they will suffer opportunity costs. This means that communes with high marginal abatement costs (tax revenues, jobs etc.) are the buyers of the rights, while communes with low marginal abatement costs are the sellers. In the end, all marginal abatement costs equalize at the price of the tradable permits. In the trading planning permits scheme, the secondary market is the institutional heart of the mechanism.

Although it sounds quite appealing at first glance, we want to show that the application of the cap and trade scheme to land use planning is anything but self-evident and not a promising approach per se.

2. Hypothesis: No magic bullet

Tradable planning permits are considered to be a sort of magic bullet. On the one hand, the cap on development permits makes the system effective. On the other hand, only those communes with the highest benefits (additional taxes and shares from financial equalization schemes) carry out the development. Communes with low opportunity costs waive the right to development. Hence the scheme is also efficient, because the planning rights are used at the locations with the highest benefits.

However, contrary to what intuition would suggest, we want to show that effectiveness and efficiency don't harmonize if the concept is applied to land use planning. In contrast, the cap and trade approach cannot meet the goals of efficiency and effectiveness at the same time ("incompatibility thesis") [13]. The argument is based on the following two statements:

- In order to be efficient, a cap and trade system needs wide system boundaries. At least in small or medium-sized countries, such wide system boundaries go hand in hand with a unified planning permit and a unit price.
- In contrast to CO_2, effective land use planning doesn't require control of a scale, but of a structure. A land use structure cannot be controlled effectively by a single planning permission with a single price.

3. Theoretical issues and review of literature

There is a central difference between the cap and trade on CO_2 and the cap and trade on planning permits. Considering the consequences for global warming, it does not matter where the CO_2 is emitted due to the diffusion characteristics of the greenhouse gas. Hence the task is to control a scale (maximal CO_2 emissions anywhere) by capping the quantity of emissions. However, regarding land use planning, not only the scale but also the structure of land use has to be controlled. The quantity of land as a whole can hardly be extended. Instead, the relevant issue relates to changes in the structure of land use, which is for instance forestry, agriculture, industry, settlements etc. It is of central importance where the land use takes place and for which purpose. Hence CO_2 permits are a homogenous good, but land use rights shouldn't be.

3.1. Consensus: Primacy of planning

At present, the structure of land use is controlled by the planning system. According to the proponents of the tradable development rights idea, land use planning should not be substituted but supported by the economic tool ("primacy of planning") [14].

Planning is necessary to break up a possible Nash equilibrium [11] caused by the behaviour of land owners: If, in the absence of any planning, only the willingness to pay decides about land use patterns, a spatial disaster may result and people may run into a rationality trap. If, for example, German people were allowed to realize the favoured model of the detached one-family house in green surroundings, urban sprawl would happen, with negative ecological, economic and social impacts.

At the same time, planning is necessary to protect such forms with weak financial endowments which cause important positive external effects. If no plan provided public spaces e.g. for kindergartens and schools, such forms would have to compete with actors with a high willingness to pay (e.g. banks). Hence they could not be realized. However, without such facilities, the value of the area would often be lower than with them. Good planning should consider the variety of functions of land (e.g. ecological, spiritual). Such forms of land use that move beyond efficiency and profitability are not only important for the cohesion of the social system, but in many cases also for the resilience of the ecological system (for example, see [15]). Planning has to balance the competing demands of various stakeholders, including groups with low budgets and the protection of nature.

3.2. Thesis: Efficiency needs wide system boundaries

Although the primacy of planning is wide consensus, in recent debates it has been argued that tradable planning permits may counteract land use planning [13]. The "incompatibility thesis" is based on the required design of a cap and trade regime. A major justification of the system is its efficiency. The efficiency of the cap and trade system is caused by differences in marginal abatement costs:

- Those communes with high marginal abatement costs buy planning permits on the market at the lower market price. The difference is the benefits from the cap and trade system.
- On the other hand, such communes with low marginal abatement costs reduce their harmful activities and sell the free certificates on the market. The difference between market price and marginal abatement costs is the profit from abatement.

In the end, the marginal abatement costs of all the actors equal the market price of the planning permits. The higher the differences of marginal abatement costs of the acting communes, the higher the efficiency potential of the regime will be.

However, high differences in abatement costs can be achieved by a wide design in terms of space, time, participants and the objects of trade:

- In categorical terms, diverse spatial categories (living, commerce, mixed use, traffic etc.) have to be gathered in one single planning permit ("universal" certificate). This is any land for human settlement and transport infrastructure without regard to its different components;
- Regarding the market participants, the discussion is about also including individuals or NGOs instead of only permitting communes as traders;
- In spatial terms, scientists agree that the trade boundaries have to be as wide as possible (e.g. whole of Germany, no single states);
- Considering the time dimension, banking and borrowing is also discussed in order to use differences in the marginal abatement costs over the timeline.

In Germany, in the last decade the preferred design is characterized by

- A country-wide regime (although the pilot project mentioned above will only comprise selected communes) which incorporates the administrative support of the different states of the federation [16].
- A universal certificate which comprises the whole area for settlement and traffic [16].
- Banking should be allowed (at least the transfer into the following provisional period), in order to allow long-term development strategies for the communes. In contrast, there is much scepticism with regard to providing the opportunity to use the rights before owning them (borrowing) [17].
- Regarding the market participants, an extension of participants beyond the communes has not been discussed seriously so far.

Hence the efficiency potential can only be exhausted if the target is "scale" instead of "structure" (which would make sub-markets necessary). The scale target has to fix wide system boundaries (in contrast to other tradable development rights schemes; for example, see [13]). The scale target and the wide system boundaries are mutually dependent.

There is also another reason why a working trade system would not be possible without wide boundaries: Narrow markets cause high price volatility of the permits. The higher the price volatility, the more insecure the economic success of abatement activities and the less abatement activities will take place. Thus the target is to set the condition for organized trade of the permits.

3.3. Thesis: Controlling structure by economic tools needs tightly segmented sub-markets

Having shown the necessity for wide system boundaries in a cap and trade model, the next question is whether a land use structure – not a scale – can be controlled within such a system. We want to illustrate the problem within figure 1 below. The land use plan sets the allowed land use A (e.g. industry) at the maximum of C_A. The maximal land use B (e.g. housing) is limited by C_B. The marginal abatement costs (MAC) are MAC_A for land use type A and MAC_B for land use type B. For simplification purposes, the illustration doesn't include more land use types.

If a commune waives the right to development of additional sites, it has to suffer marginal abatement costs. Such marginal abatement costs are mainly opportunity costs. If, for instance, a residential area is not realized, a German municipality gets lower shares of the income tax revenues, lower property tax revenues and lower revenues out of the fiscal equalization scheme. If an industrial site cannot be realized, the opportunity costs also comprise lost business tax revenues. Also indirect effects have to be considered, such as income multiplier effects which otherwise would have been initiated by construction activities. All these interrelations and effects are quite complex and include feedbacks within the system. Basically, the scale of opportunity costs is not quite clear. Fiscal impact analysis could provide for more cost transparency, but it is in an early stage. Some fiscal impact tools used so far for residential areas turned out to have quite different performance; for industrial areas no reliable fiscal impact tool is available so far. Also within the above-mentioned pilot model of tradable development rights the development of reliable fiscal impact analysis tools is acknowledged to be important in order to get a better idea about the marginal abatement costs.

However, in the subsequent figure we assume, contrary to the facts, that there is an accurate idea about the volume of the marginal abatement costs of land use type A and B. Hence we can derive a mathematical function of MAC, being dependent on the scale of land use of the different types.

First, let's assume that the caps for land use type A (C_A) and B (C_B) are set according to the land use plans. We assume that the land use planning also properly computes the marginal damages (MD), which are illustrated with the dotted line for both types of land use. With this theoretical "trick" we can take into account that planners care for quantity as well as for quality of land use (for example, see [17]). Therefore, the planning target (C_A and C_B) corresponds perfectly with the intersection of marginal abatement costs and marginal damage of land use type A (E_A) and B (E_B).

Moreover, theoretically the marginal damage of land use type B can be expressed in equivalents of the marginal damage of land use type A. Such equivalents are useful for the definition of a universal cap. Analogous equivalents are also used in the greenhouse gas emission permit schemes. In the Kyoto regime for instance, global warming potentials (GWPs) are used in order to express the global warming potential of the other greenhouse gases in relation to CO_2, whose GWP is standardized to 1. Hence, if caps for different land use types should reflect such equivalents (for simplification purposes a linear function is used below), we get for instance a function such as:

$$C_B = e \times C_A \tag{1}$$

The total cap results by aggregation of the caps of the individual land use types:

$$C_{A+B} = C_A \times e + C_A \tag{2}$$

It is important to note that the equivalents only reflect an average consideration. However, different communes may have different structures of land use; thus the equivalents don't represent their individual situation.

In the subsequent diagram, the added marginal abatement costs (MAC_{A+B}) show the aggregate demand curve, and the aggregated cap (C_{A+B}) shows the aggregate supply curve of all land used for settlement and traffic, set by the planning authorities. The intersection point determines the unit price of the universal development right P* [13]. The illustration holds true for an individual municipality as well as for the aggregation of municipalities.

The figure shows why a unit price causes economic incentives to violate the land use plans:

- Regarding land use type A, the mayor in charge will extend the land use until the intersection point (I_A) of the unit price P* and the marginal abatement costs MAC_A. From this point on, the costs for additional planning permits exceed the benefits from additional land use. However, regarding the land use plan (and the marginal damage), more development of land use type A would be possible (up to E_A and C_A respectively). Insofar there is a loss of welfare, indicated by the gap between M_A and C_A. In order to support the land use planning, price P_A would be necessary instead of the unit price P*.
- Looking at land use type B, the mayor increases land development until his/her benefits of additional development MAC_B equal the unit price of the development P* (in point I_B or M_B respectively). However, this is much more than the land use plans have fixed (C_B). If the caps reflect the intersection point E_B of marginal damage function MD_B and marginal abatement costs MAC_B, this point I_B is also far beyond efficiency (in E_B). In order to get an effective and efficient result, price P_B would have been necessary.

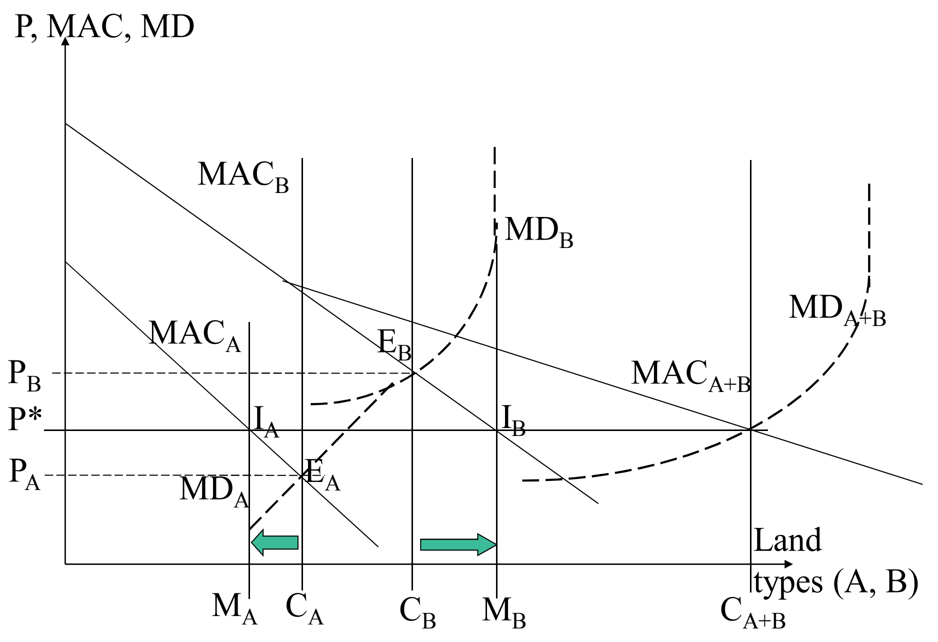

Figure 1. Aberrations with a universal planning permit (adapted from [13])

From the figure above we may derive two important results:

- The trading model, which is based on wide system boundaries and a single tradable planning permit, is not able to support land use planning. With a unit price, it is only able to control scale but not structure.
- Nonetheless, the supporters assert effectiveness. Obviously, they refer to the CO_2 blueprint and only consider the control of scale, but ignore the necessity to control structure. There is no assessment of the welfare losses which are caused by overshooting and undershooting of the planning targets so far (differences between $M_{A,B}$ and $C_{A,B}$). Therefore, also no proper statement about the net efficiency gains (efficiency gains minus the welfare losses, due to overshooting and undershooting) of the cap and trade system can be provided.

Sometimes, supporters suppose that the deviations and aberrations are negligible. Depending on the price of the permits, the position of the caps and the marginal abatement costs, the aberrations and welfare losses can be randomly quite high or low. There is no evidence for a correction mechanism, which might be able to reduce such aberrations systematically. Hence, overshootings and undershootings probably don't equalize in aggregation. The system is as effective as a poor marksman who is currently missing the target in different directions. Aggregating the shooting errors doesn't turn the poor marksman into a champion.

3.4. The "incompatibility thesis"

Against this background, we can describe the central system conflict as follows:

- The rationale of the cap and trade regime is efficiency. However, efficiency can only be achieved within a wide design of the system, among others based on a universal certificate (including all categories of land for human settlement and transport infrastructure);
- In contrast, the required primacy of planning can only be maintained within a tightly structured system. In contrast to the controlling of the scale of CO_2 emissions, the settlement structure cannot be controlled by one cap (certificate) and one price, but needs a diversity of prices with a diversity of certificates.
- If a structure is "treated" with a single price, welfare losses have to be expected due to overshooting and undershooting of the planning targets. Hence the net efficiency gains and net welfare effects of a cap and trade regime for land use policy are not clear at all.

The supporters of the tradable planning permits claim that planning should impose a correcting action if necessary. However, our argument is that precisely due to the counteracting economic signals, planning cannot impose such an action.

The problem could theoretically be solved by a variety of tightly segmented sub-markets with diverse price settings. Sub-markets which adapt the categories of land use planning (market segmentation in categorical terms) have been discussed e.g. by Henger and Schröter-Schlaack [17]. Spatial boundaries which limit the trading rights to regions with similar protection status (market segmentation in spatial terms) have been addressed e.g. by Williams [18], Walz et al. [16], Henger and Bizer [19]. However, in most countries such markets would be too small and thus inefficient [17]. At least in the German discussion, the conflict of goals which appears in the cap and trade scheme was decided in favour of efficiency and against market segmentation. Within a system with wide boundaries, such an incompatibility could perhaps be avoided in a few countries with high population and centralized land use planning systems, such as China. However, so far there is no sound research about the minimum size of such markets and the requirements for the land use planning system.

3.5. Addendum: Initial distribution

Within a cap and trade system, the initial distribution might be done by auction or by providing the permits to the communes without costs (according to alternative allotment formulas). Simulation experiments with German municipalities related to the cap and trade scheme also showed that the initial distribution of rights is quite a critical issue, which may endanger acceptance [20]. In order to guarantee the acquis of the communes, discussions have so far favoured "grandfathering" schemes, in which the status quo of land consumption is not touched. However, such grandfathering schemes are probably less efficient than auction schemes [13, 17].

4. Results and discussion

Basically, the required primacy of planning is not compatible with the system of tradable planning permits. If the basic idea of capping planning permits should be kept, a redesign of the regime is necessary.

4.1. Cap and auction

In order to support the planning system ("primacy of planning"), the planning permits should best be defined in a tight manner which is in line with the categories of the planning system. For instance, if planners are thinking in categories such as residential, industrial or mixed areas, traffic etc., the planning permits should also follow these categories. This also facilitates the handling of the system. Planning permits should basically be mandatory for all sorts of developed areas. For instance, recreational space may have also negative ecological impacts.

The caps could be administered on different administrative levels, e.g. at the level of the states, even at the level of regions (or in other countries: at county level). However, the administration needs a certain human capacity. In Germany, the 30 ha cap might be broken down into lower administrative levels without problems.

However, within a tight definition of a variety of planning permits at a low administration level (e.g. region), the "markets" for each right would be quite narrow. Hence the allocation mechanism shouldn't be based on the secondary market (trade – "horizontal coordination") but on the primary market, namely auctions ("vertical coordination"). The auction of planning permits to the communes could be done periodically. Giving the focus to auction doesn't mean a complete ban on trade but a reduction of its significance. Due to the tight design of the sub-markets, organized trade wouldn't be possible anyway. Instead, over-the-counter trade would be feasible, regulated by the planning permits administration. Within the proposed design, different types of planning rights (residential, industrial etc.) were auctioned and traded at different prices.

The administration should also guarantee that it will take back the planning permits for a fixed price (based on the auction price). Thus communes could also think about changing the land use plans and the redevelopment of shrinking areas into the natural state. Deconstruction would be encouraged, because the communes could be sure about the compensation.

A system which is based on auction might be designed tightly with regard to space, time, participants and objects of the design. The system may work with only a few participants. It may work even at regional level. Within the auction, the development rights are allocated to those communes that can make the best use of them. Moreover, without the overshooting and undershooting of the cap and trade regime, welfare losses also are avoided.

Despite the segregation of sub-markets, the system is also efficient. However, in terms of efficiency it is not clear if such a cap and auction system will or will not compete with a cap and trade system, which is based on a single, universal development right. Nonetheless, if in doubt, recognizing the primacy of planning within the conflicts of goals means subordination of efficiency. From a system theory point of view, economic efficiency shouldn't be a guiding value [15] of superior significance anyway, at least not in land use management. Instead, the guiding value of efficiency has to be balanced with other guiding values.

4.2. Completion by means of a financial equalization scheme

The regime sketched out above has to face some serious counterarguments relating to political viability: In an auction, the powerful communes with a high willingness to pay will prevail. Moreover, the financial situation of the communes would be even more strained and the municipalities' acquis would be encroached (see section 3.5.). Hence the question is how to increase the acceptance of a cap and auction model.

On the one hand, certain transition regulations such as free development rights for existing settlements would certainly be helpful, but not nearly enough on their own.

On the other hand, the view of the discussion about climate policy might be promising. Within the Kyoto regime, it has not been possible to put in place effective caps, mainly because the problems of distribution and "climate justice" have not been solved yet [21]. The regime was based on "grandfathering". Hence those countries with the most aggressive occupancy of the atmosphere and most responsibility for the climate problem got most rights. This was considered as being unjust by countries with developing and emerging economies. Basically, the same holds true in terms of land use permits.

However, many of the objections mentioned above could be countered by establishing a redistribution mechanism. Within such a redistribution mechanism, the money paid by the communes in the auction could be firstly collected in a fund ("land trust"), which is administered by the affected communes. Second, the money is redistributed to the communes, preferably according to the number of their inhabitants (other redistribution keys are also possible). In this respect, all inhabitants are considered as "co-owners" of the planning permits, and thus they should participate in equal shares from the revenues of the auction. Considering the CO_2 emission trading schemes, this idea has been popularized by Peter Barnes [22]. Applied to land use planning, a similar redistribution scheme has already been suggested by Krumm [23]. However, his proposal was based on a price-steering basis: Basically, communes should be charged for any new land conversion using a fixed rate per square meter. The money should be pooled in a fund and redistributed to the communes, preferably according to the number of citizens.

If redistribution to the communes were carried out according to the population, the payments into the "land trust" would be according to the land used per capita, whereas the redistribution would be according to the average use per capita. Hence, besides the cap, an additional incentive for a sustainable land use is implemented:

- If the actual land use per capita is higher than the average land use, the commune in charge is a net contributor to the "land trust";
- If the actual land use per capita is lower than the average, the responsible commune is a net beneficiary;
- If the actual land use corresponds to average land use, there is no difference compared with the status quo.

Because every commune tries to get net benefits out of the land trust, there will be a current dynamic incentive to carry out efficient and effective land use management. In terms of microeconomics, the dynamic incentive is pushed by the substitution effect, whereas the income effect is eliminated by the redistribution scheme ("Slutsky equation", see [24]).

Moreover, within this redistribution mechanism, an average access to the planning permits is granted, also for financially weak communes. The redistribution mechanism serves as an ecological financial equalization scheme between the municipalities. Not unlike a lease mechanism, communes with land consumption rates above average pay to communes with land consumption rates below average.

The effects of the redistribution system are far reaching. To mention just some of them:

- Currently, for instance, some German communes can take some "fiscal rents" due to their location, at the expense of other municipalities. This holds true particularly for the communes in the wealthy commuter belt of bigger cities ("Speckgürtel"). They benefit from the migration out of the bigger cities (e.g. young families), which are "bleeding". In such peripheral communes, land prices are often lower and the environmental conditions are often better than in the big cities. However, a great deal of the attractiveness is caused by uncompensated spillovers. According to the central locations principle [25] the bigger cities provide a variety of public goods at the commuter belt's benefit. Thus urban sprawl is fuelled, and the financial performance of bigger cities gets weaker and weaker. However, in the proposed regime, the whole fiscal surplus will be skimmed off dependent on the type of auction. The willingness to pay of the commuter belt's communes includes the expected fiscal rents (from spillovers). The fiscal rents are redistributed to all communes according to the number of the people, also to the bigger cities. Due to the higher density of population, the redistribution scheme will compensate the bigger cities for their efforts.
- The model is applicable in situations of growth as well as in shrinking areas. In aging societies such as Germany, in particular rural regions are affected by shrinking. However, land conversion and land consumption is highest ex urbia. Urban sprawl turns out to be luxury which is increasingly difficult to finance. The redistribution model may stimulate migration to more compact settlements, with a higher supply of public goods. The system would provide an incentive for renaturation measures in rural communes. This would have positive side effects, considering e.g. vacancy rates and the value of existing properties.
- By skimming off the rents from certain types of land use, communes get more indifferent towards land use alternatives. On a regional level, coordination between municipalities and the allotment of certain functions (industry, tourism etc.) towards different communes is easier than today. Thus, integrated approaches of regional development might be put in place without high resistance of the communes affected.

With regard to the technical implementation of the system, some minor problems have to be solved. For instance, in order to create equal conditions in the auction, the communes should pay into the land trust in the same "logical second" as the redistribution happens. This means the communes are only charged or rewarded by the balances (net position of pay-in and pay-out). Moreover, it has to be figured out on which administrative level the system should be applied. Basically, the redistribution mechanism should be tied to the scope of the cap and auction scheme.

One should be clear about the fact that no money for natural protection would be raised within the redistribution scheme. However, modifications are possible: If, for instance, a natural park as a common public good has to be financed, the redistribution could be carried out after first deducting the expenses for covering the park. Such decisions depend on the land trust and the planning authorities. A legal basis for the cooperation arrangement is necessary.

The proposed model may be appealing, but it is not a "silver bullet". The framework has to be completed by other instruments. For instance, the price of real estate may rise due to successful capping of planning rights. Thus, access problems for socially weak groups might be caused. Hence a suitable land taxation system which transfers shares of land rents and land value to the community would be desirable for example.

5. Conclusions

The concept of tradable planning permits transforms the idea of the CO_2 cap and trade regime to spatial planning. Analyzing the tool, we have at least to refer to effectiveness (planning, ecology), allocation (economy) and distributional aspects (social).

Regarding effectiveness, there is a broad consensus about the primacy of planning. Any economic tool should support planning instead of substituting it. However, planning land is not the same as planning the maximum permissible load of CO_2 in the atmosphere. The former requires a planning of structure, the latter a planning of scale, since it is irrelevant where the emission takes place.

Planning the structure of land use cannot be supported by a unit price, as a result of a universal certificate for all types of land use (for settlement and traffic). In contrast, a variety of sub-markets are necessary, with a different price setting. Meanwhile, more and more planners are also becoming sceptical about the supporting effects of a cap and trade regime.

Supporting the planning of a structure within a variety of sub-markets may be inferior compared with the efficiency of a cap and trade system with wide system boundaries. On the other hand, efficiency losses due to overshooting or undershooting might be avoided. The efficiency losses might be minimized by auctioning the permits to the needy communes on the primary market ("vertical allocation"). Although trade shouldn't be forbidden, an organized secondary market is dispensable (subordination of a "horizontal allocation mechanism"). Moreover, both systems would have to prevent strategic acquisitions of permits (impediment of development in other communes by an artificial shortage of supply), e.g. by a current devaluation of the permits.

Regarding the blueprint of CO_2 trade, a comprehensive arrangement on a global scale has so far failed due to distribution disputes. Also a cap and auction system for planning permits wouldn't be acceptable particularly for communes with a weak financial endowment if there were no correction. This is the reason why the cap and auction regime should be completed by a redistribution mechanism which is based on equal stakes in the scarce land use opportunities.

However, more research is necessary in order to deal with the details of the counter-proposal outlined in this article. So far, in Germany politics has supported the cap and trade approach; as has the allocation of research funds. Critics who pointed out the incompatibility between effectiveness and efficiency in the cap and trade approach have been pushed aside. This also holds true for the combination of caps, auction and redistribution, which couldn't be assessed so far. However, in experimental simulations the acceptance of the cap and trade regime among the practitioners was obviously not very high. Among others, the results of the cap and trade game turned out to be quite sensitive in terms of an increase of the complexity of the framework [20]. In contrast, at least the redistribution approach of Krumm was highly accepted (here, basically, also no fiscal impact assessment is necessary) [26]. Maybe it is time to widen the scope of the research paradigm to extend beyond the cap and trade regime.

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6. References

[1] Zollinger F, Seidl I (2005) Flächenzertifikate für eine nachhaltige Raumentwicklung? – Ein Konzept für Baden-Württemberg und Erkenntnisse aus der Übertragung auf die Schweiz. Informationen zur Raumentwicklung 4/5: 273-280.
[2] Kriese U (2005) Handelbare Flächenfestsetzungskontingente – Anforderungen an ein Mittel zur Beendigung des Landschaftsverbrauchs. Informationen zur Raumentwicklung 4/5: 297-306.
[3] Federal Ministry for the Environment, Natural Conservation and Nuclear Safety (1998) Nachhaltige Entwicklung in Deutschland – Entwurf eines umweltpolitischen Schwerpunktprogramms, Berlin, 147 p.
[4] Penn-Bressel G (2011) Flächenneuinanspruchnahme – Wirkungen auf Umwelt, Städtebau und Ökonomie. Wirtschaftsdienst 11: 800-802.
[5] Frerichs S, Lieber M, Preuß T (2010) Flächen- und Standortinformationen erheben und bewerten – Methoden und Konzepte für ein nachhaltiges Flächenmanagement. In: Frerichs, S, Lieber, M, Preuß, T, editors. Flächen- und Standortbewertung für ein nachhaltiges Flächenmanagement. Berlin: Difu pp. 11-27.
[6] Homepage of the "Refina" research programme, funded by the federal government: http://www.refina-info.de. Accessed: 2012, Mar 15.
[7] Federal Ministry for the Environment, Natural Conservation and Nuclear Safety (2010) Environment research plan (Umweltforschungsplan) 2010. Project Z 6 – 91 054/84, Project Number 3710 16 106.
[8] Homepage of the project "Forum Flächenzertifikate". Available: http://www.ufz.de/index.php?de=21103 Accessed 2012 Mar 15
[9] CDU, CSU, FDP (2009) Wachstum, Bildung, Zusammenhalt, Coalition Agreement. Berlin.

[10] LeJava, J P (2009) Transfer of Development Rights in New Jersey – A background paper, New Jersey. Available: http://www.dvrpc.org/TDR/pdf/2009-10_LeJava_Background_Paper.pdf Accessed 2012 Mar 15.

[11] Nash J F (1950) Non-cooperative Games; Ph.D. Thesis; Princeton University: Princeton, USA. Available: http://www.princeton.edu/mudd/news/faq/topics/Non-Cooperative_Games_Nash.pdf. Accessed 2012 Mar 15.

[12] Krumm R (2004) Nachhaltigkeitskonforme Flächennutzungspolitik – Ökonomische Steuerungsinstrumente und deren gesellschaftliche Akzeptanz, IAW research report, Tübingen: IAW. 136 p.

[13] Loehr D (2006) Handelbare Flächenausweisungskontingente: Eine gute Idee auf Abwegen, in: Zeitschrift für Umweltpolitik und Umweltrecht 4: 529-544.

[14] Bovet J (2006) Handelbare Flächenausweisungsrechte aus Steuerungsinstrument zur Reduzierung der Flächeninanspruchnahme. Natur und Recht 6: 473-479.

[15] Bossel H (1998) Globale Wende – Wege zu einem gesellschaftlichen und ökologischen Strukturwandel, Munich: Droemer. 464 p.

[16] Walz R et al. (2005) Gestaltung eines Modells handelbarer Flächenausweisungskontingente unter Berücksichtigung ökologischer, ökonomischer, rechtlicher und sozialer Aspekte, Final Report. Research Project, funded by the Federal Environmental Office, Project Number 203 16 123/03, Dessau-Roßlau. 170 p. Available: http://opus.kobv.de/zlb/volltexte/2009/7870/pdf/3839.pdf. Accessed 2012 Mar 15.

[17] Henger R, Schröter-Schlaack C (2008) Designoptionen für den Handel mit Flächenausweisungsrechten in Deutschland, Land Use Economics and Planning – Discussion Paper, No. 08-02, University of Göttingen, September. Available: http://www.uni-goettingen.de/en/80714.html Accessed 2012 Mar 15.

[18] Williams R C (2003) Cost-Effectiveness vs. Hot Spots: Determining the optimal size of emissions permit trading zones. University of Texas at Austin Working Paper.

[19] Henger R, Bizer K (2008). Tradable Planning Permits for Land-use Control in Germany. Land Use Economics and Planning – Discussion Paper No. 08-01.

[20] Küpfer C et al. (2010) Handelbare Flächenausweisungszertifikate – Experiment Spiel.Raum: Ergebnisse einer Simulation in 14 Kommunen. Naturschutz und Landschaftsplanung 42 (2): 39-47.

[21] Wicke L (2006) Das Versagen des Kyoto-Protokolls in seiner jetzigen Form und seine strukturelle Weiterentwicklung. Zeitschrift für Sozialökonomie 150: 3-9.

[22] Barnes P, Pomerance R (2000): Pie in the Sky – The Battle for Atmospheric Scarcity Rent, Washington. Available: http://community-wealth.org/_pdfs/articles-publications/commons/ paper-barnes-pomerance.pdf Accessed 2012 Mar 20.

[23] Krumm R (2002) Die Baulandausweisungsumlage als ökonomisches Steuerungsinstrument einer nachhaltigen Flächenpolitik. IAW Discussion Papers 7. Available: http://iaw.edu/iaw/De:Publikationen:IAW-Reihen:IAW-Diskussionspapiere:2002 Accessed 2012 Mar 20.

[24] Varian H (1992) Microeconomic Analysis, 3rd ed., New York: W.W. Norton & Company Inc. 506 p.

[25] Christaller W (1933) : Die zentralen Orte in Süddeutschland. 2nd ed. 1968. Darmstadt: Wissenschaftliche Buchgesellschaft. 331 p.

[26] Preuß T et al. (2007) Perspektive Flächenkreislaufwirtschaft, Vol. 3: Neue Instrumente für neue Ziele. Berlin / Bonn: Difu. 109 p.

Chapter 11

The Role of Government in Environmental Land Use Planning: Towards an Integral Perspective

Noelle Aarts and Anne Marike Lokhorst

Additional information is available at the end of the chapter

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Dynamics and developments in the design and implementation of Dutch nature policies

In 1990 the Dutch parliament accepted the Nature Policy Plan (NPP), designed to conserve and develop nature over the next 30 years. The original plan was developed by ecologists and biologists with little involvement of the agricultural sector. Consequently the plan was about plants and animals, about biodiversity and valuable landscapes and about the realisation of a so-called ecological infrastructure that should connect isolated pieces of nature in the Netherlands. Nothing was said about farmers' behaviours related to nature whereas the implementation of the plan asked a lot from the farmers: they should start working in a nature-friendly way, or sell their land in case it had been located in the planned ecological infrastructure.

The NPP, in its original form, was the result of a centrally organized decide-announce-defend strategy (DAD): internally decided upon, publicly announced, and, because of a fierce public resistance, firmly defended. This strategy has clearly resulted in non-acceptance of the NPP by the majority of the Dutch farmers who did not immediately see advantages for them, but from whom cooperation was needed for a successful implementation. Therefore the government decided to realise the implementation of the NPP by means of participation.

A longitudinal study of such a participation process in the Drentsche Aa area in the north of the Netherlands, has shown that the ambition of Dutch nature conservation policymakers to involve multiple actors (farmers, citizens, recreationists) in nature policy processes has resulted in different patterns of citizen involvement (Van Bommel et al., 2008). A group of citizens appeared who wanted to be involved as stakeholders, but found that they had different views than the decision makers. Even though they were allowed to express their views in discussion meetings, it was clear that these views would not be taken into account. Roughly speaking, citizens who did agree upon the proposals were included, whereas those who did not agree were excluded from the participatory process. As a consequence, the process ended up just reproducing the government's dominant discourse. The citizens with different views and perspectives – not coincidently a group that mainly consisted of farmers - did not feel respected or represented because what was *relevant to them was not part of the so-called formal perspective of the government and thus was ignored. Meaningful participation was no longer possible for them, and this resulted in active, self-organized powerful resistance to the policy.*

Today more and more initiatives can be found involving farmers who organize themselves in interaction with other actors in the countryside, sharing similar problems or similar ideals, and explicitly avoiding the involvement of governments. The reason is that they no longer want to be confronted with policies that have been designed without their involvement and thus do not fit neither daily farming practices nor their identity as a farmer. In addition, they do not want to be dependent on the continuously changing rules and restrictions that they encounter when they, for instance, try to apply for a subsidy such as the Agri-Environment Scheme. Instead, they experiment and invest together, in collective management of nature at their farms, in collective meadow ownership, or in new co-operations for the production of biogas as an alternative energy source. These self-organizing initiatives are characterized by high commitment and responsibility, resulting in responsible and sustainable behaviours that go beyond the individual.

1. Introduction

In search of ways to influence citizens' decision making concerning land use, governments are continuously expanding their repertoire of strategic tools to steer people in the desired direction. These strategic tools range from policy instruments such as subsidies and agri-environmental schemes, that are used to reward desired nature related behaviours of farmers, to forms of participation trajectories in which citizens are invited to participate in policy processes related to the design and use of public spaces (Aarts and Leeuwis, 2010); a phenomenon also referred to as governance (Hajer & Wagenaar, 2003).

While such tools might appear promising and seem to offer a wide range of steering options for governments and policy makers, they each have some serious drawbacks that might hinder or even backfire on effective policy making. In this chapter we critically reflect on the downsides of the so called instrumental approach. Participative policy making is discussed as an alternative way of getting things done. We argue that both approaches have their unique fallbacks and share some features that lead them to be sub-optimal. Therefore the network perspective is added, which implies alternative conceptualisations of change, communication and planning. The chapter concludes with a plea for valuing an integral perspective, based on all three perspectives. Such an integral perspective does not offer a 100% guarantee for successful steering, but does enlarge the space for development of policies for land use planning and rural development that are the result of a process of co-creation between government and societal actors, and that therefore have gradually become acceptable, suitable and effective.

2. The instrumental perspective

A common perspective on implementing governmental policies is the instrumental perspective: governments develop policies that are implemented with the help of a set of strategic tools, also referred to as policy instruments.

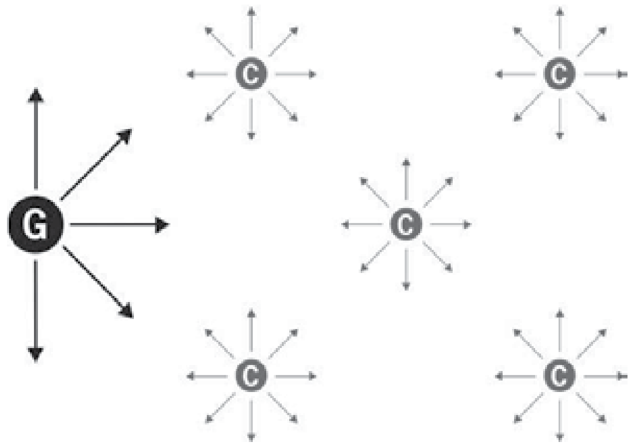

Figure 1. Interaction between government (G) and citizens (C): an instrumental perspective

Let us take a closer look to the instruments a government has available for steering citizens' behaviours.

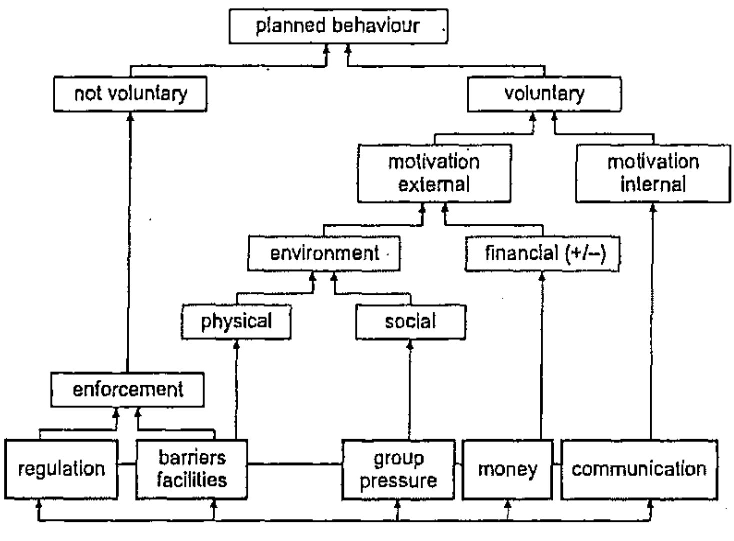

Figure 2. Policy instruments for behaviour change (Van Woerkum et al, 1999)

As can be seen in Figure 2, several policy instruments are available for governments looking to change behaviour. Within this perspective, regulation is not seen as a way to codify existing practices, but rather as an instrument to change the behaviour of people, and to facilitate that change. For several reasons it is not easy to develop and implement new rules. First, developing new regulation takes a lot of time as many different actors are involved in such a process. Second, especially in matters of nature conservation, many citizens, and certainly many farmers, are inclined to react negatively to regulation, for the very reason that such intervention takes place. Regulation undermines their feeling of freedom, ownership, and responsibility for looking after their own environment (Aarts and Van

Woerkum, 1994). The physical environment can stimulate a certain behaviour, for example: playing grounds for children, recreation areas for tourists, museum for learning facilities. It can also hinder undesirable behaviour, for example: fences around valuable natural sites or roadblocks. Governments can try and (re-)design such environments as to promote the desired behaviour. Group pressure can be an important strategy to involve target groups in a policy program, but is hard to organize (for a successful example, see Lokhorst et al., 2010). More often it arises from an effective resonance between the results of other policy instruments. Money can be used as an incentive (subsidies) or as a disincentive (taxes). Finally, communication can be used when not much can be expected from other instruments. Different communication strategies are then applied to persuade people to change their behaviours (Petty and Caccioppo, 1986).

Most plans in the domain of spatial policies consist of a combination of instruments. They encompass regulation, facilities (like roads, water supply, etc.) and financial measures. As far as subsidies are involved, there is reason to be careful. Lokhorst et al. (in press a) critically review financial compensation in the domain of nature conservation. In Europe, these conservation measures are stimulated by agri-environment schemes (AES). However, as Lokhorst et al. (in press a) argue, financially rewarding conservation practices may create a dependency that is self-sustaining, costly, and therefore vulnerable. First of all, such financial policies are dependent on the current political climate and are thus susceptible to change. Indeed, many schemes on both the country and the European level have been altered or have even ceased to exist over the past years. Second, rewarding a behaviour can cause a decline in intrinsic motivation for this behaviour, a process called the "crowding out effect" (Frey, 1997). In this scenario, receiving a reward for performing a behaviour leads people to attribute their behaviour to this reward, causing a shift from intrinsic to extrinsic motivation. Should the reward then be taken away, people will no longer be motivated to perform the behaviour. Therefore, the vulnerability of financially dependent conservation practices are a threat to their continuity over longer time spans. Preliminary evidence for this idea was found in a study on the social psychological underpinnings of both subsidized and non-subsidized conservation (Lokhorst et al., 2011). In this study it was found that farmers' intention to engage in non-subsidized conservation was better explained by psychological aspects of their motivation than their intention to engage in subsidized conservation. While their motivation to perform subsidized conservation was driven mainly by their attitudes, when it came to non-subsidized conservation, feelings of moral obligation and self-identity played an important role. That is, farmers who saw themselves as the kind of people who conserve nature, and who felt that this was the right thing to do, were more likely to engage in non-subsidized conservation. For these farmers, conservation had become part of who they are, and their behavior is less likely to be affected by (changes in) financial policies.

Policies that have been developed without involving the people who are responsible for the implementation are not easy to implement. Such policies will only be accepted when people have the impression that they will benefit from the policy. This may be the case when subsidies are applied, however, as we have shown, this leads to a risky and unstable implementation. We should thus search for different ways of policymaking. Instead of the instrumental perspective in which the government is both the initiator and director of the policy process, the participation perspective, involving stakeholders in the process of policy-development for problem solution, has become a leading paradigm.

3. The participation perspective

The participation perspective can be seen as a response to conceptualizations of steering that reflect great confidence in the malleability of society, but nevertheless do not often give the expected results (Glasbergen, 1995; Aarts and Van Woerkum, 2002; Arts and Van Tatenhove, 2005). Governments invite citizens with the aim to let them contribute to the development and implementation of policies.

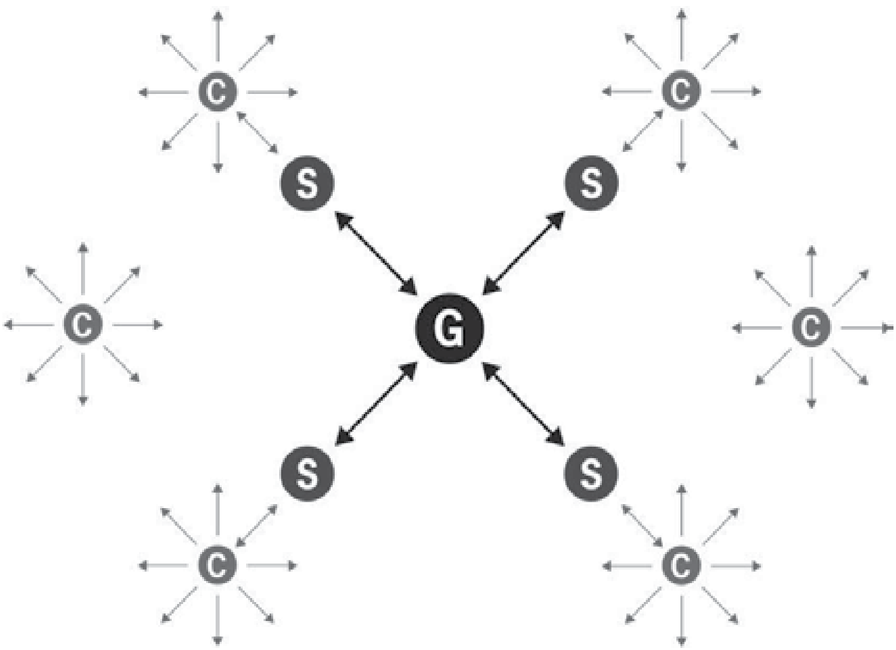

Figure 3. Interaction between government (G), statkeholders (S) and citizens (C): a participation perspective

The idea of public participation is not new. Since the late 1980s, public participation in land use issues has become the dominant discourse, in the Netherlands, but also outside the Netherlands (see Idrissou et al, 2011). Public participation may take place at (or across) various government levels. At the Dutch national level for instance, public meetings have been organized to discuss with citizens issues such as genetic modification of food products and nature conservation policies. In addition, citizen panels of the Ministry of Food and Nature are regularly consulted for the development of policies for sustainable food production. At the local level it is common that citizens are consulted for the design of public space in their neighbourhood.

Practices of public participation, however, do not always result in success. In the first place, we can notice a limited reach in society. Concrete efforts to organize participation in most cases do not involve more than a selected group of citizens, namely the so-called stakeholders that have an interest in the problem domain of which representatives are invited by the government to discuss and negotiate problem-definitions and possible solutions. There are many citizens who are not willing or not able to get their problem perceptions on the agenda of the government. Research of the way governments act in cases of conflict in public space shows that several preconditions have to be met before policy-windows are opened (Van Lieshout et al, 2008; see also Kingdon, 2002). The problem should be well-defined and solvable, and the political context should ask for dealing with the issue. We touch upon the phenomenon of self-referentiality as an inherent characteristic of governments, reducing reality to what is measurable and solvable (Wagemans, 2002).

Second, related to public participation, both in literature and in reality, a rather limited view on how people actually behave can be experienced. Public participation often starts from rather simplistic and prejudged ideas concerning people's motivations, possibilities and restrictions as well as how they behave in groups. Very limited attention is paid to what actually happens between people, including, for instance, processes of community development, processes of inclusion and exclusion, and processes of changing power-relationships, both within and between different groups in society. In addition, the reasonability and intelligence of people are systematically underestimated. Instead people are more often than not viewed as if they always behave in a completely selfish way, only concerned about money. For problems to be solved people only should change their behaviour: they should be open, honest, perfectly listening to each other and be ready to give in. In other words, it is not about understanding actual behaviours of people, but about striving after a sort of ideal behaviour that has to bring solutions.

Third, within the public participation model, instead of capitalizing on differences and diversity, we find a striving after consensus. In cases of complex land use issues this is in most cases neither realistic nor does it contribute to effective problem-solving because it takes away a lot of creativity and easily results in unsolvable impasses (Aarts and Leeuwis, 2010).

Finally, and maybe most important, efforts of public participation keep showing an obstinate illusion of central steering. It is still the government who defines the problem, including the direction for solution. The most important dilemmas of steering by participation concern matters of responsibility for the final result and of realizing ambitions, mainly expressed by the plea for the so-called ‘primacy’ of democratically elected bodies which is vested in the constitution. In the context of land use planning these dilemmas are often solved by simply denying people who bring in ideas that do not fit with the ambitions that have already been formulated by the government beforehand (Van Bommel et al, 2009; Turnhout et al, 2010). This may result in citizens that do not want to participate anymore, and instead start organizing themselves to realise their own ambitions in their own way. In other words, on the one hand, the government, in spite of their participation initiatives sticks to their power to decide what to do. On the other hand, by simply placing them outside the formal process, groups of citizens regain what Foucault has called productive power (Van der Arend, 2007: 53), referring to a certain amount of autonomy and freedom. The risk is that governments who apply public participation as an additional form of instrumental steering - which is the case when space for negotiation is lacking – create their own powerful antagonists (Turnhout et al, 2010).

It can be concluded that both the instrumental perspective and public participation that starts from a fixed policy tend to neglect the idea of citizens being active agents, interacting with each other and organizing themselves in order to attain their goals, for themselves and for others in their environment (Aarts & Leeuwis, 2010). A more advanced form of participation is the organizing of public commitment, in which an individual is asked to make a commitment to certain behaviour(s) in the presence of other people. In the social psychological literature, commitment-making is generally seen as a promising intervention technique (Abrahamse et al. 2005; De Young 1993; Dwyer et al. 1993; Katzev and Wang 1994) and has been shown to influence, a wide range of behaviours. Public commitment can influence behaviour in a number of ways (Lokhorst et al., in press b). First, it can change people's self-image such that the new behaviour becomes a part of their self- identity. Second, it can evoke a willingness to conform to either a societal or personal norm to engage in the behaviour in question. Third, it can set in motion a process generally referred to as cognitive elaboration (Petty and Cacioppo 1986), a process whereby the individual elaborates on the possible reasons to engage in the behaviour and strategies to accurately perform the behaviour, resulting in a strong positive attitude towards the behaviour.

In the domain of nature conservation, commitment making has been shown to affect people's intention to engage in conservation. In a study by Lokhorst et al. (2010), farmers were invited to participate in study groups in which they received feedback on their current conservation efforts. In this setting, farmers were asked to publicly commit to improving these efforts. A year later it was found that those who had made such a commitment showed actual improvement in terms of intention to conserve and area of (semi-)natural habitat. Commitment making seems like an effective tool, but requires working together with local groups and small-scale networks in order to truly be effective. It needs, in other words, to be realised in direct interaction with the people involved. This invites us to explore a third perspective: the network perspective.

4. The network perspective

Already in the seventies the policy-scientist Scharpf (1978) argued that governments would lose their central and steering role. Scharpf referred to the tendency of increasing interweaving and organizational fragmentation within society. He predicted that governments would not be able to function without the co-operation of countless organizations and institutions. As a result, policy processes would have a 'network-like' structure (Scharpf, 1978).

Today, the idea that policies are shaped by 'pulling' and 'pushing' in complex interactions between different stakeholders has become commonly understood. Policy-processes are considered as on-going negotiation processes of which it is difficult to predict the results. Not only do circumstances change continuously, the figurations that people form on the base of their mutual dependences, continuously change as well (Elias, 1970). They shift, according to what is happening between them and in the world around them.

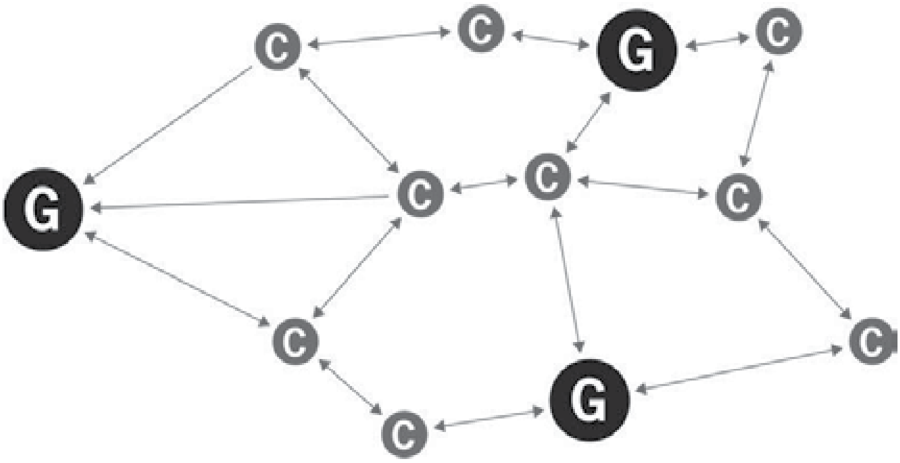

Figure 4. Interaction between government (G) and citizens (C): a network perspective

In view of unexpected developments decisions can (and will) be revised continuously. Thus, policies will eventually take shape in the interactions between different parties, involved in a network of a specific policy-domain and constantly trying to influence the process. This insight asks for further exploring the significance of a network perspective for the development and implementation of land use policies.

The network perspective refers to an endless collection of what Manual Castells (2004) calls 'interacting nodes', either people who have a special position or a combination of roles and functions that enable them to connect different networks, or specific technologies or policies that make different networks become active (Van Dijk et al, 2011). Such networks are neither centrally steered nor fixed, but instead constantly shaped through the pushing and pulling by different stakeholders who continuously do efforts to influence the situation. The network perspective thus starts from the assumption that people, instead of being passive and opportunistic, are active agents, interacting with each other and organizing themselves in order to get things done. In this perspective the role of governments is not to organize and manage a top-down or bottom-up process, but rather anticipate and make use of the self-organizing ability and initiatives of people. Operating in this mode has important implications for how a government interacts with society in order to get things done. It implies that governments must be alert, and constantly gather information about what happens in society, paying attention to informal networks. In doing so, it must develop a sensitivity for coinciding developments, and create room for experimentation especially 'where rules are not applied or are not yet developed' (Hüsken and De Jonge, 2005: 7). It may also need to redirect emergent developments at an early stage in case these are likely to go against the public interest and / or have unacceptable effects for specific groups of future generations. This requires a pro-active attitude in contacting societal actors and opening negotiations with them. In short, governments must, on the one hand, 'set free' and, on the other hand, 'stay connected'. This third mode of operating is in part an alternative to the instrumental and the participation perspective, in that there may be domains in which a government wants to delegate responsibility to societal forces without the deliberate organization of a participatory process. However, even when a government chooses for an instrumental mode or wants to organize a participation trajectory (e.g for reasons of creating legitimacy and / or formal commitment), there will be a need to make use of a network perspective. As we have seen, self-organizing dynamics will emerge, whether a government likes it or not. Hence, governments will have to develop the capacity to apply the three perspectives in an alternating way, and forge connections between them when needed.

In sum, integrating the three perspectives results in a set of relevant points of attention for governments when relating with society in order to develop and implement environmental land use policies:

1. being constantly alert, by watching and being continuously informed about what is happening in society;
2. providing the opportunity for coincidences to take place, by promoting and valuing diversity;
3. creating room for experimentation, by leaving some space between rules and reality;
4. connecting to what moves people, by co-constructing recognizable and understandable stories;
5. problematizing the issue of societal accountability, instead of being focused only on rules and legislation;
6. intervening if needed which implies a clear feeling of direction (see Aarts et al., 2007);
7. working together with existing local groups and small-scale networks

5. Alternative views on change, communication and planning

In line with the dominance of the instrumental approach, we have become used to interpreting processes of change as goal-oriented activities where the use of a certain set of instruments will lead to the desired effect. However, most changes come about in a very different way. When looking to society from a network perspective we become aware of the fact that in many cases it is not as much the causality that determines the course of things, but rather the confluence of events at a certain point in time. In other words, it is the specific context that is the deciding factor. Moreover, whether it is a marriage, an economic crisis, the image of an organisation, or the design and use of land, structures and changes cannot be understood or explained by the behaviour of an involved individual (Elias, 1970, p. 148). Mutual interdependence between people and the way in which this is formed ultimately determine the course of things. People's activities and behaviours must therefore be understood and explained from the social bonds they have formed via the networks they are part of. In the words of Norbert Elias:

'From this intertwining, from the interdependence of people comes an order of a very specific nature, an order that is more compelling and stronger than the will and reason of each individual person that forms a part of the entwinement' (Elias, 1982, p. 240).

The focus on interdependence and interaction in relation to change also creates the necessity for a broader view of communication. Thinking in terms of individual senders and receivers, messages and channels, misses the target when we aim for an integral perspective on land use planning. In a broader view of communication, the interactions between people and groups of people are the unit of analysis. It is in such interactions that meanings are constructed, confirmed or contested. The dynamics brought about by communication are part of a whole variety of networks in which meanings are continuously negotiated.

The emphasis on interactions as the source and carrier of change stands in sharp contrast with the tendency to plan in terms of goal / means that characterises our society and in which many planners still seem to believe. It is high time that we start applying the alternative planning models that have been developed by now (Whittington, 2001; Stacey & Griffin, 2005; Stacey, 2001). The common essence of these models is that they encompass context and dynamics.

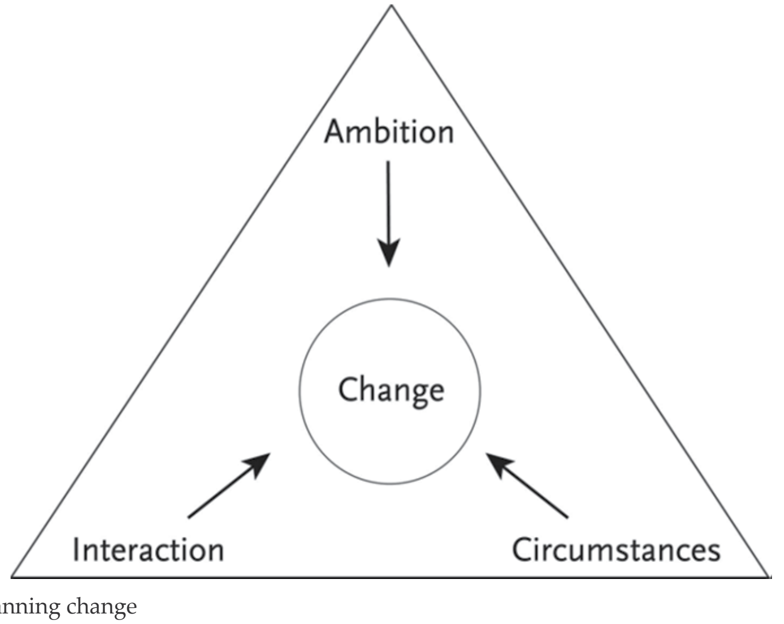

Figure 5. Planning change

Contingency planning is a well-known concept, the basis of which is concrete situations and work is done from one moment to the next. Related to this is incremental planning, dubbed 'muddling through' by Lindblom (1959). The thought behind this is that causal patterns in both social and physical reality are so complicated that centrally driven, top-down interventions have too many unintended and therefore undesired effects. Such encompassing interventions are also undesired from a normative perspective because they assume that there is one regulating point of view and preclude all other rival views.

Incremental planning is based on the presumption that we may make mistakes and miss things (Frissen, 2007). With processual planning, we do have a goal (strategic intent), but the way to get there is not determined. We bet on probable situations, act and reflect on the outcomes. Furthermore, creativity, empathy, a sense of timing and even humour are important preconditions for a constructive process.

These views of change, communication and planning make clear that there are no recipes or methodologies for strategic planning, nor are there guarantees of success. However, if we take dynamics and relative unpredictability as our basis, we are better able to act consciously and respond to specific contexts more adequately. In other words*, we can become better planners if we take into account our limited ability to plan*. A good strategist is like a coach who follows a game closely, looks at what the players are doing and, based on that, gives instructions for moments at which action can be taken. After all, ambitions are realized in interactions with the players, and optimal use is made of the circumstances as they occur at particular moments.

6. Conclusion

Governments will never be 100% successful in steering their citizens; self-organized dynamics and other unexpected developments will continuously emerge. Therefore governments need to recognize the added value of an integral perspective and develop the capacity to apply this perspective. Although a lack of control may be uncomfortable for planners and governments, unpredictability is also an opportunity for the emergence of unexpected perspectives and ideas that may support the solution of problems in the domain of environmental planning. Several developments in the world of planning are already oriented to a broader perspective on society. Our contribution is meant to support this new thinking in a meaningful way

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7. References

Aarts, M.N.C. & C.M.J. van Woerkum (1994). *Wat heet natuur? De communicatie tussen overheid en boeren over natuur en natuurbeleid (What is nature? Communication between*

[*] Corresponding Author

government and farmers over nature and nature policies). Wageningen: Wageningen University, Communication Strategies Group.

Aarts, N. & C. van Woerkum (2002). Dealing with uncertainties in solving complex problems. In: Leeuwis, C. & R. Pyburn (eds.) *Wheelbarrows full of frogs. Social learning in rural resource management.* Van Gorcum, Assen,. 421-437.

Aarts, N. , C. van Woerkum & B. Vermunt (2007). Policy and Planning in the Dutch Countryside: The Role of Regional Innovation Networks. *Journal of Environmental Planning and Management.* 50, 6, 727-744.

Aarts, N. and C. Leeuwis (2010). Participation and Power: Reflections on the Role of Government in Land Use Planning and Rural Development. *Journal of Agricultural Education and Extension*, 16, 2, 131-145.

Abrahamse, W., Steg, L., Vlek, C., & Rothengatter, T. (2005). A review of intervention studies aimed at household energy conservation. *Journal of Environmental Psychology*, 25, 273-291.

Arts, B. & Van Tatenhove, J. (2005) Policy and Power: A Conceptual Framework Between the 'Old' and the 'New' Policy Idioms. *Policy Sciences*, 37, 339_356.

De Young, R. (1993). Changing behavior and making it stick. The conceptualization and management of conservation behavior. *Environment and Behavior*, 25, 485-505.

Dwyer, W. O., Leeming, F. C., Cobern, M. K., Porter, B. E., and Jackson, J. M. (1993). Critical review of behavioral interventions to preserve the environment: Research since 1980. *Environment and Behavior*, 25, 275-321

Elias, N. (1970) *Was ist Soziologie? (What is Sociology?)* München: Juventa.

Elias, N. (1982). *Het civilisatieproces. Sociogenetische en psychogenetische onderzoekingen (2) (The civilization process. Sociogenetic and psychogenetic studies).* Utrecht, Het Spectrum

Frey, B.S. (1997). On the relationship between intrinsic and extrinsic work motivation. *International Journal of Industrial Organization*, 15, 427-439.

Frissen, P. (2007). *De staat van verschil. Een kritiek van de gelijkheid (The existence of difference. A critique of eguality).* Amsterdam, Van Gennep

Glasbergen, P. (Ed.) (1995) *Managing Environmental Disputes. Network Management as an Alternative.* Dordrecht: Kluwer Academic Publishers.

Hajer, M. & Wagenaar, H. (2003) *Deliberate Policy Analysis. Understanding Governance in the Network Society*. Cambridge: Cambridge University Press.

Hüsken, F. & De Jonge, H. (Eds) (2005) *Schemerzones & Schaduwzijden. Opstellen over ambiguïteit in samenlevingen (Twilight Zones & Flipsides. Essays on Ambiguity in Societies)*. Nijmegen: Roelants.

Idrissou, L., N. Aarts, A. van Paassen & C. Leeuwis (2011). The Discursive Construction of Conflict in Participatory Forest Management: The Case of the Agoua Forest Restoration in Benin. *Conservation and Society*, 9, 2: 119-131.

Katzev, R. D., & Wang, T. (1994). Can commitment change behavior? A case study of environmental actions. *Journal of Social Behavior and Personality*, 9, 13-26.

Kingdon, J.W. (2002) *Agendas, alternatives, and public policies*. Longman, New York.

Lindblom, Ch.E. (1959). The Science of Muddling Through. *Public Administration Review*, 19, 79-88

Lokhorst, A. M., Staats, H, Van Dijk, J., Van Dijk, E., & De Snoo, G. (2011). What's in it for me? Motivational differences between farmers' voluntary and subsidized nature conservation practices. *Applied psychology – an International Review*, 60, 337-353.

Lokhorst, A.M., Van Dijk, J., Staats, H., Van Dijk, E., & De Snoo, G. (2010). Usingtailored information and public commitment to improve the environmental quality of farm lands: An example from the Netherlands. *Human Ecology*, 38, 113-122.

Lokhorst, A. M., Staats, H., Van Dijk, J., & de Snoo, G. R. (in press a). Biodiversity on farmlands: the crucial role of the farmer. In: Kruse, L. (Ed.). *Naturschutz und Freiseitgezellschaft*.

Lokhorst, A. M., Werner, C.M., Staats, H., Van Dijk, E., & Gale, J. (in press b). Commitment and Behavior Change: A Meta-analysis and Critical Review of Commitment Making Strategies in Environmental Research. *Environment & Behavior*.

Petty, R. E., & Cacioppo, J. T. (1986). *Communication and persuasion: Central and peripheral routes to attitude change.* New York: Springer-Verlag.

Scharpf, F.W. (1978) Interorganizational Policy Studies: Issues, Concepts and Perspectives. In: Hanf, K. and Scharpf, F.W. (Eds). *Interorganizational Policy Making: Limits to Coordination and Central Control*. London: Sage, 345 - 370.

Stacey, R.D. (2001). *Complex responsive processes in organizations. Learning and knowledge creation.* London, Routledge

Stacey, R.D. and D. Griffin (eds) (2005) *A complexity perspective on researching organizations.* London, Routledge.

Turnhout, E., S. Van Bommel and N. Aarts (2010). How Participation Creates Citizens: Participatory Governance as Performative Practice. *Ecology and Society* 15, 4: 26. [online] URL: http://www.ecologyandsociety.org/vol15/iss4/art26/

Van Bommel, S., Turnhout, E., Aarts, M.N.C. & Boonstra, F.G. (2008) Policymakers are from Saturn . Citizens are from Uranus. Involving Citizens in Environmental Governance in the Drentsche Aa Area. Wageningen: Statutory Research Tasks Unit for Nature and the Environment.

Van Bommel, S., N. Röling, N. Aarts & E. Turnhout (2009). Social learning for solving complex problems: a promising solution or wishful thinking? A case-study of multi-actor negotiation for the integrated management and the sustainable use of the Drentsche Aa area in the Netherlands. *Environmental Policy and Governance*, 19, 6, 400-412.

Van den Arend, S. (2007). *Pleitbezorgers, procesmanagers en participanten. Interactief beleid en de rolverdeling tussen overheid en burgers in de Nederlandse democratie (Advocates, Process Managers and Participants. Interactive Policy and the Role Division between Government and Citizens in Dutch Democracy).* Delft: Eburon.

Van Dijk, T., Aarts, N. & De Wit, A. (2011). Frames to the Planning Game. *International Journal of Urban and Regional Research*, 35, 5, 969-987.

Van Lieshout, M. & N. Aarts (2008). "Outside is where it is at!" Youth' and immigrants' perspectives on public space. *Space and Culture*, 11, 4, 497-513.

Van Woerkum, C.M.J., M.N.C. Aarts & M.M. van der Poel (1999). Communication in policy processes: reflections from the Netherlands. *European Spatial Research and Policy,* 6, 75-87.

Wagemans, M. (2002) Institutional conditions for transformations. A plea for policy making from the perspective of constructivism. In C. Leeuwis and R. Pyburn (eds) *Wheelbarrows full of frogs. Social learning in rural resource management.* Koninklijke Van Gorcum BV, Assen, 245 - 257

Whittington, R. (2001). *What is strategy and does it matter?* London, Routledge

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