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Precious Forests

Precious Earth

Edited by Miodrag Zlatic

PRECIOUS FORESTS - PRECIOUS EARTH

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Notice

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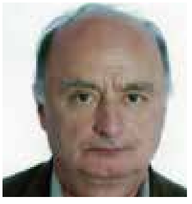
Meet the editor



Miodrag Zlatic was born on 21.10.1953 in Belgrade. He is full professor at the Faculty of Forestry of Belgrade University/Serbia at the Department of Ecological Engineering of Soil and Water Resources Protection. He is chief of the Department for Erosion Control. His fields of research and subjects of lecturing are: Bases of the Environment Protection, Sustainable Natural Resources Management, Erosion Control Economics, Natural Resources Policy, Demographic Aspects of Degradation and Protection of Natural Resources, Risk and Uncertainty of Investments in Sustainable Land Management. He was chairman and co-chairman of several international conferences. He is editor-in-chief, as well as member of editorial board of several international and national journals, books and bulletins. He was coordinator of several national and international projects such as World Overview of Conservation Approaches and Technologies (WOCAT) for Serbia since 2001. He was president of the World Association of Soil and Water Conservation (WASWC) in the period 2005–2010, and is currently councillor of the same Association.

Contents

Preface

From the deep and near past, it is evident that our society is driving our planet along a collision course with environmental crisis. Our economies are consuming much more than the Earth can provide. Humans are using up the capital of the Earth when it should be living from the interest. This is also the case of great natural resources as forests are. Across the world, forests, trees on farms, and agroforestry systems play a crucial role in the livelihoods of rural people by providinge employment, energy, nutritious foods and a wide range of other goods and ecosystem services. Forests have tremendous potential to contribute to sustainable development and to a greener economy. Yet, clear evidence of this has been lacking. This evidence is critical to inform policies on forest management and use, and to ensure that the benefits from forests are recognized in the post-2015 development agenda, not only with respect to the environment, but also for their contributions to broader social issues (http://www.fao.org/forestry/sofo/en/). Through the 4 sections and 12 chapters derived from around the world, this book is adressing the negative and positive human interference on forests (section I), management, governance and policy (section II), economic and social issues (section III) and ecological, environmental and other issues (section IV).

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Immediate Past President of the World Association of Soil and Water Conservation
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Section 1

Negative and Positive Human Interference

Chapter 1

Proximate and Underlying Causes of Illegal Timber Trade in Uganda

Nelson Turyahabwe, Willy Kakuru, Martin Asiimwe and Patrick Byakagaba

Additional information is available at the end of the chapter

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Abstract

Uganda has policies and laws that can foster legal timber trade. This chapter reviews the key sources of timber and current production channels in Uganda. It describes policies and laws governing timber trade and challenges encountered in the quest for legal timber trade. We also show the underlying and proximate causes of illegal timber trade and its impacts on livelihoods, environment, and economy. The sources of timber in Uganda were previously the government-owned forest plantations and natural forests which have dwindled. There is a timber deficit and this has proliferated illegal trade in timber which affects national and local government revenue and forest degradation. Formal, informal, and a mix of formal and informal systems are the main channels of timber production. The responsible agencies that are mandated to ensure legal timber trade are engulfed by institutional weaknesses and socio-cultural and political landscape that is riddled with dishonesty, impunity and lack of transparency. There is need for more engagements to build momentum for promoting legal timber trade and enforcement of rule of law. This can be attained through improved inter- and intra-institutional collaboration, improved accountability and creating incentives for legal timber trade.

Keywords: Timber trade, illegal logging, Uganda, forest governance, forestry policy

1. Introduction

Trade in illegal timber is one of the major causes of global forest deforestation through illegal harvesting operations [1]. In Uganda, the size of the timber market is difficult to estimate considering that the trade is poorly regulated and much of it is undocumented [2]. Illegal timber trade stands at 80% causing an estimated annual financial loss of 23 billion Uganda Shillings ($8 million) through unpaid taxes [2]. Based mainly on updated data from an assessment carried out in 2005 when the forest sector was better regulated and good quality information on the trade was available, the present sawn wood market in Uganda is estimated at 369,000m^3. Most timber is consumed on the domestic market by the construction industry and in furniture manufacturing and other wood products. An estimated 80% is used for roofing with around 10% for furniture and 10% for other uses. In the past, the main sources of timber supply were the government-owned forest plantations and natural forests in the Central and Local Forest Reserves [3]. But due to overharvesting of the natural forests and the lack of enrichment planting and implementation of silvicultural practices, the supply of timber from these sources is declining rapidly. Currently, timber trade is increasingly relying on production from trees and forests on private lands.

The trade in timber from trees on private lands outside the forest reserves is poorly regulated by the District Forest Departments. Most of this timber is illegal as it does not comply with official procedures and regulations of Uganda. Regulations are not adhered to due to a combination of factors such as lack of institutional capacity in the District Forest Departments at the local government level and lack of adequate technical support and guidance from the Forest Sector Support Department (FSSD) at the national level. With the increasing proliferation of districts, many district governments in Uganda are recruiting forestry staff that are inexperienced, ill-equipped and are not well grounded in the official processes and procedures for regulating timber harvesting from private forests.

Regulations are often interpreted differently and the fees and taxes charged are not uniform among districts. Furthermore, the official tax rate of 30% of the value is widely perceived to be excessive and is rarely charged. The official forms and marking hammers required as part of the regulatory procedures are not available in most districts. In the past, the FSSD provided guidance on sustainable harvesting levels based on resource information but this is no longer provided. In most districts the role of the District Forest Officer (DFOs) in regulating timber trade is now limited to collection of taxes and fees. For these reasons, most timber originating from forests and trees outside the reserves is illegal as official procedures and regulations are rarely followed and this has negative implication on the sustainability of forests on private land.

The European Union (EU) defines illegal logging as harvesting of timber in contravention of the laws and regulations of the country of harvest. Using this definition, in line with Uganda regulations, illegal logging would refer to mainly timber cut without a licence, use of banned chain saws, and tax evasion. Regulation of harvesting in the Central Forest Reserves (CFRs) is much easier than on private land since the reserves are directly under the control of National Forestry Authority (NFA), a statutory agency responsible for all forests categorized as CFRs.

However, even in the gazetted government forest reserves, much of the timber harvested could be regarded as illegal since the harvesting is not in line with requirements of the National Forestry and Tree Planting Act of 2003, which requires that an approved management plan should be in place and that harvesting should be in line with the plan [4]. Most forest reserves do not have approved management plans at present. Approving of forest management plans is a prerogative of the minister responsible for forestry in Uganda [4]. This chapter reviews the key sources of timber and current production channels dominating the timber industry in

Uganda. We further describe policies and laws governing timber trade in Uganda and challenges encountered in the quest for legal timber trade. We also show the underlying and proximate causes of illegal timber trade and its impacts on livelihoods, environment, and economy.

2. Materials and methods

Data was collected through review of documents, key informant interviews, and focus group discussions. Documents were reviewed to determine the supply and demand status of timber in Uganda and assessing the policy and legal regime governing the timber industry. The documents reviewed included reports from responsible Government Ministries and Departments and National Forest Agencies such as national forest policies and development plans, operational plans and procedures, and legal frameworks related to forest harvesting and trade. Key informant interviews were conducted to identify existing regulatory framework describing the formal procedures for timber harvest and trade in Uganda. They were further interviewed to describe the link between framework and practice focusing on rights, obligation, and responsibilities. They were also interviewed to identify the challenges hindering implementation of existing frameworks for legal timber trade. The key informants that were interviewed included staff from state forest agencies (National Forestry Authority and District Forest Departments, Uganda Revenue Authority, Ministry responsible for forestry, statutory bodies with relevant legal mandate on forestry; Owners/managers of private forests, Timber producers associations, timber harvesters, traders and consumers. Focus group discussions were conducted with communities living near forests that are harvested and timber dealers to understand the Chain of Custody for Timber.

3. Analysis and synthesis

Narrative analysis was used to analyse and synthesize the data collected from key informant interviews and focus group discussions while content analysis was used in reviewing of documents.

4. Sources of timber in Uganda

Traditionally, the main sources of timber supply in Uganda were the government-owned forest plantations and natural forests in the CFRs. But due to overharvesting of these natural forests and the poor replanting practice after clearing the plantations, the supply of timber from these sources is declining rapidly. Currently, timber trade is increasingly reliant on production from trees and forests on private lands. The most common species for timber in Uganda are *Maesopsis eminii*, *Melicia excelsa*, *Albizia coriaria*, *Chrysophyllum albidum*, *Lovoa trichiliodes*, *Funtumia* *elastic*a, *Entandophragma angolense*, and *Podocarpus latifolius* [5-7]. Recently demand for timber from pine trees (*Pinus caribaea*, *Pinus patula*) is on the rise [6].

In Uganda, forest covers approximately 3,554,594 ha, representing about 17% of the total land area and 15% of the total surface area of Uganda [8]. Out of the total forest cover, 64% of the forests and woodlands are found outside the Permanent Forest Estate (PFE), on private and communal lands, and hence managed by private and local community forest owners. About 17% consists of Central Forest Reserves (CFRs) managed by the NFA, 18% consists of National Parks and Wildlife Reserves (NPs & WRs) managed by Uganda Wildlife Authority (UWA), 0.85% is jointly managed by NFA and UWA, and 0.03% is local forest reserves (LFRs) managed by respective Local Governments [9]. Within a period of 15 years, 1990–2005, the area under natural forests and woodlands had reduced from estimated 4.9 million hectares to 3.6 million ha representing a loss of approximately 1.3 million ha or a loss of 27% [8]. There is no timber production allowed in strict nature reserves but only in production zones of the reserves [10].

Uganda is experiencing a timber deficit, with the demand for timber and associated products fast exceeding supply. There is an increasing demand and decreasing supply of forest products from Uganda's natural forests. Because of the long rotation period/growth cycles, the supply of hardwood from natural forests cannot be expanded rapidly, resulting in further price increase. It has been estimated that Uganda needs at least 100,000ha of timber plantations just to meet the country's projected internal timber demand by 2025 [3]. According to Odokonyero [10], the size of the local timber was 240 000m^3 and this was twice the sustainable annual allowable cut as per the forest plan of 2002. In 2004, replanting resumed and by 2010, approximately 40,000 hectares had been replanted by NFA in partnership with private sector forestry companies and individuals. Increasingly, the private sector is taking over the role of plantation timber production which was traditionally carried out by the Forestry Department and NFA. The plantations established in 2004 will begin to supply the Sawlog market from 2025 onwards, but until then, Uganda faces a shortage in timber supply. NFA records indicate that production from Central Forest Reserves has reduced from a high of approximately 180,000 m^3 of round wood saw logs in 2008, to approximately 40,000 m^3 in 2011. The figure will reduce even further as the remaining mature plantations are cleared. Assuming sawing conversion efficiency of 25%, NFA's round wood production in 2011 is equivalent to 10,000 m^3 sawn wood which was just 3.5% of the estimated market supply in that year.

5. Timber production and distribution in Uganda

Currently, there are three main channels for production and distribution of timber: formal, informal, and a mix of formal and informal [11] (Figure 1).

In channel 1, timber producers mainly saw millers obtain trees from forest reserves through a public bidding system, convert them into timber that is then transported into urban markets.

In channel 3, timber producers, who are mainly pit-sawyers and contractors, obtain a one year concession to harvest timber from designated areas on private land within a District Local

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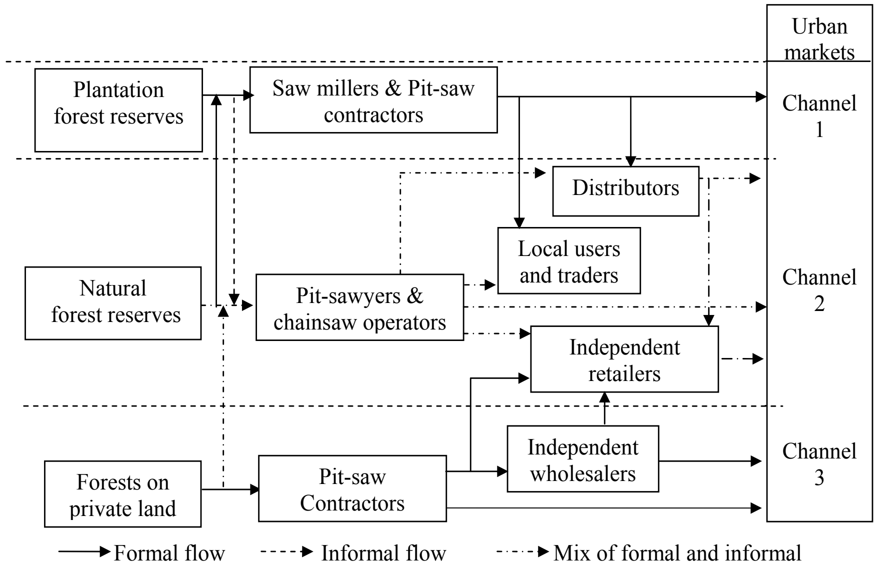

Source [11]

Figure 1. Timber production and distribution system

Government that is transported for sale in urban markets. Channel 2 is the conduit for illegal timber produced by independent pit-sawyers operating either on casual licence or illegally and chain saw operators. These actors operate mainly on private land and intermittently in government forest reserves. After conversion, the timber is distributed locally or traded informally in urban areas as it is a target for confiscation by regulatory authorities. Some traders in this channel transport semi-processed wood disguised as firewood from which they extract low grade timber in end markets using saw benches [11]. The key players in timber markets are the suppliers of trees, primary processors, secondary processors, and consumers [12] and most of the timber is used by the building and construction sector. Timber in Uganda is marketed based on species, size, and quality; however, most consumers are not fully aware of the grading system [13].

6. Policies, laws, and regulations governing timber harvest and trade in Uganda

The Forestry Policy (2001) and the National Forestry and Tree Planting Act (2003) are the overarching frameworks for controlling production, movement, and trade of timber. They define the illegal and legally acceptable practices in timber trade [4].The Act contains several specific provisions relating to timber harvest and trade but also makes provision for development of regulations and guidelines by the forest authorities. These are required to elaborate and operationalize provisions of the Act and to facilitate their implementation. The regulations and guidelines cover issues such as procedures for timber sale, licensing, and fees, the mechanism in which forest products are to be sold from reserves, the approach and circumstances in which a license may be granted, regulations for the sustainable management or utilization of forests, grading of timber and registration of private forests. Most of these regulations have not been developed since the Act was passed in 2003 and this has been a constraint on operationalizing the provisions of the Act. However, a new system for marketing logs and timber was described in a Ministerial Notice of 2004 and this is the system currently being applied. The license fees and other charges have not been updated since the Act was passed in 2003 and the rates described in Statutory Instrument No. 16 issued in 2000 are still in use.

A number of countries have defined standards which must be complied with for timber to be considered legal. The basic requirements are that timber must be harvested, processed, and traded in compliance with national and local laws and regulations, and that the chain of custody procedures must be followed. The requirements can extend beyond forestry laws and regulations and include other national and local laws and regulations such as taxation laws, environmental regulations, labour laws, and health and safety laws.

There are currently three regulatory instruments describing the formal procedures for timber harvest and trade in Uganda. They are a) the National Forestry and Tree Planting Act, 2003 Act, b) the Ministerial Notice issued in 2004, and c) the Statutory Instrument No 16 (forest produce fees and license order) issued in 2000. It specifies felling fees, sawmilling license fees, pit-sawyers registration fees and includes a list of species and valuation rates on which taxes on sawn timber are based. Timber harvest and trade can be regarded as legal if it complies with the provisions of these instruments. Each of these is discussed in the subsections 6.1-6.3.

6.1. Provisions of the National Forestry and Tree Planting Act, 2003 in relation to timber trade

The National Forestry and Tree Planting Act, 2003 contains general provisions requiring timber harvesting to be sustainable, but leaves the detailed descriptions of procedures, chain of custody system, and guidelines to subsidiary rules and regulations to be developed by the authorities and periodically updated. There are several references in the Act to harvesting according to regulations made under the Act. The Act makes a number of references to harvesting in line with management plans which is the key strategy in ensuring sustainability and adherence to best practices. The following sections are of specific relevance:

- Section 21 (2) specifies that in private natural forests, forest produce "shall be harvested in accordance with the management plan and regulations made under the Act."
- Section 28 (3) requires that management plans shall be approved by the Minister or a person designated by the Minister for the purpose.
- Section 32 (1a) requires that in a forest reserve or community forest, harvesting must be "in accordance with a management plan or license granted under the Act."
- Section 41 (1) A responsible body may "subject to a management plan, grant a license" for removing forest produce.

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- Section 42 requires "fair, open and competitive process" in applications for licenses under the Act.

6.2. The Ministerial Notice, 2004

Although many of the regulations under the Act have not been developed as envisaged, the Ministry of Water and Environment in 2004, through a Ministerial Notice, described new procedures for harvest and trade in saw-logs and timber and the chain of custody procedures to be followed.

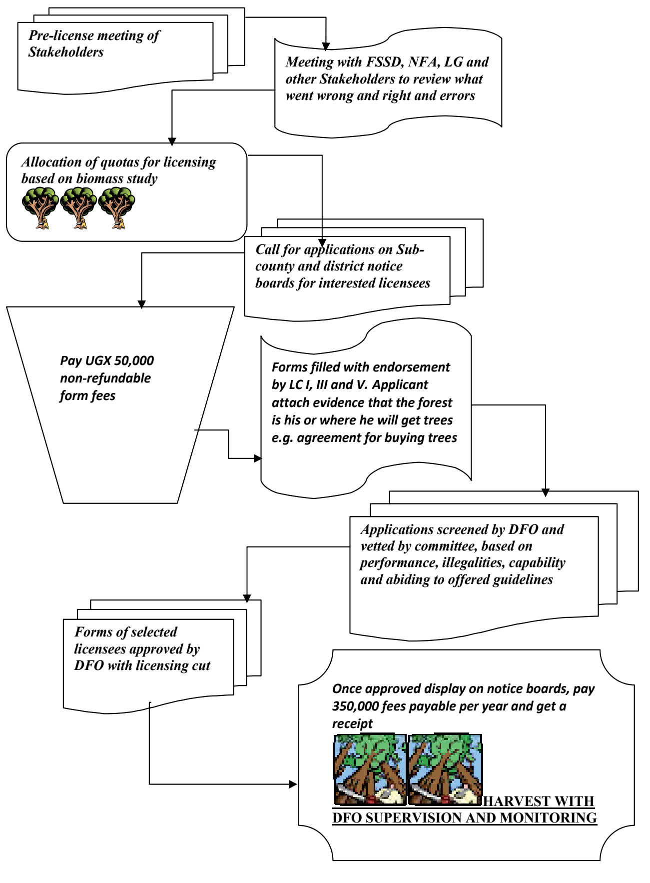
The procedures among others states that harvesting of all forest produce must be carried out under license, issued by a respective responsible body, and volume, weight and length shall be the standard units of measure. The procedure states that forest produce must be well documented and stamped to enable the Forest Produce Monitoring Unit to objectively certify chain of custody and legality of the source. A significant change introduced through this notice was the delegation of responsibility for monitoring the timber trade and law enforcement to NFA. Recognizing the widespread illegal and unregulated timber trade and the lack of capacity in the Forest Sector Support Department (FSSD), the body responsible for formulating policies and regulations of the sector, the Minister delegated the task of law enforcement and coordination of timber trade to the Forest Products Monitoring Unit in NFA. This effectively transferred the functions of timber harvesting and trade to NFA which was well funded and staffed at that time. Through this notice, the unit was designated as a "one-stop-shop" to lead the function of law enforcement with "cross-cutting powers and to serve all responsible bodies, taking into account the statutory duties of each responsible body. The NFA Forest Products Monitoring Unit was to coordinate and work with the FSSD of the Ministry, relevant security agencies, and Uganda Revenue Authority (URA) in regulating the trade. These agencies were expected "to challenge and deter illegal logging and timber trade activities and to implement a system that is simple, easy and cheap to administer, structured, institutionalised, and transparent and to put in place measures that would in due course make the process become self-regulating and self-policing."The new procedures were expected to be simple and easy to administer and to create a chain of custody based on documentation and associated hammer marks. The procedures are still in force.

6.3. Statutory instrument No 16 forest produce fees and license order issued in 2000

The Forest Products Fees and License Order describe the forest fees and taxes. This instruction was issued by the Ministry of Water, Lands and Environment (responsible for forests) in 2000 and is still in use. It specifies felling fees, sawmilling license fees, pit-sawyers registration fees and includes a list of species and valuation rates on which taxes on sawn timber are based. The timber valuations on which the tax is levied are significantly below current timber prices. The tax rate is specified as 15% of the value of timber originating outside forest reserves. After the notice was issued, some timber dealers who were also required to pay Value Added Tax (VAT) on timber purchases complained that those below the VAT threshold were exempted from VAT charges and had an unfair advantage. The Ministry decided that an "equalization fee" of 15% would be charged which was not provided for in the Statutory Instrument and issued a directive accordingly bringing the rate of tax up to 30%. The official tax rate of 30% is now regarded as the standard rate by most DFOs to be charged for timber harvested from trees on private and community lands. These tax rates do not apply to timber from the Central Forest Reserves which is sold by auction by the NFA.

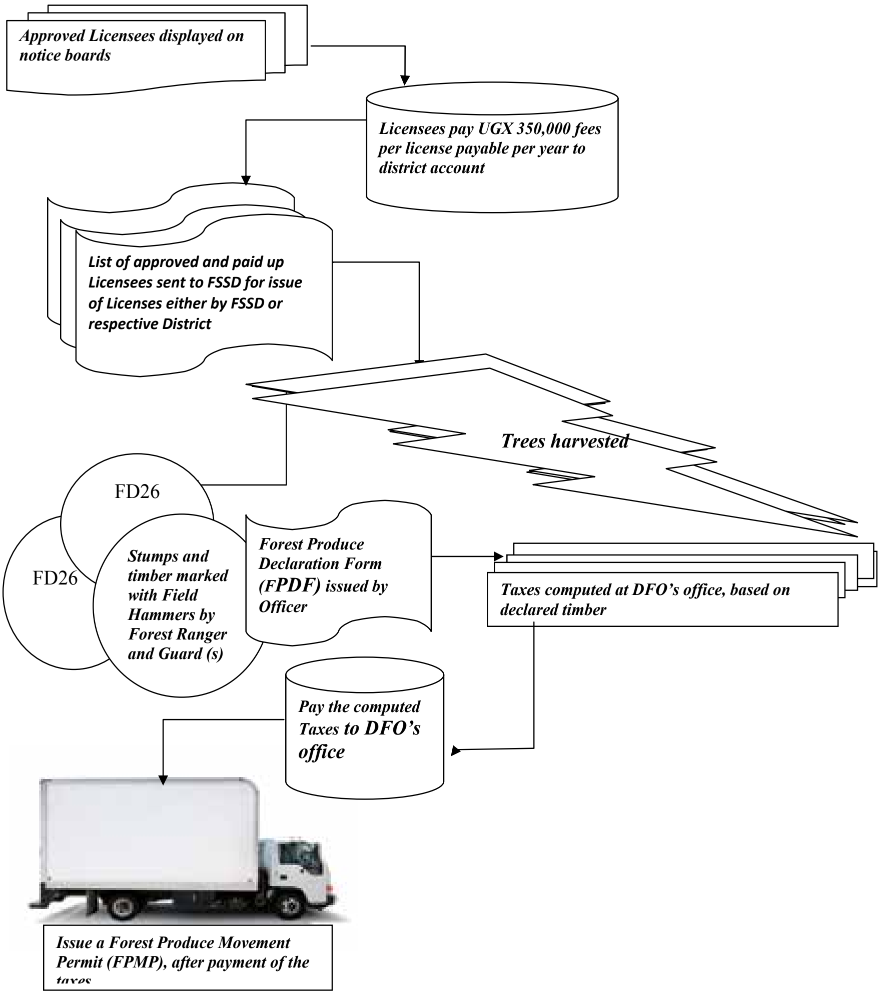
7. The Chain of Custody (CoC) for timber

In Uganda, the responsible bodies have in place a systematic tracking mechanism for timber products from their origin in the forest to their end-use. The systems are supported by implementation with institutional arrangements in the Forestry and Tree Planting Act and related policies and legislation. For the ease of breaking the bulk of the system, this book chapter presents it in two parts: at the stage of assessment, and offer of licenses and actions during the harvesting, declaration, and transport of the produce (Figures 2 and 3). However, the chain of custody is continuous and linked and is implemented in totality.



Source: [14]

Figure 2. Prescribed chain of custody during assessment and offer of licenses for timber



Source: [14]

Figure 3. Chain of custody along the harvesting, taxing and movement of timber

7.1. Conditions applicable to a license

Licenses are recognized as formal documents at the harvest and production level and are used throughout the chain of custody to certify that the products were harvested after authorization. The following conditions hold for forest produce licenses:

i. License should be personal to holder;

ii. The license should not be for sharing and use by more than one person;

iii. The license is limited to use in one sub-county;

iv. For timber harvest, use is limited to hand saws and chain saws are outlawed;

v. The Authorized Officer should hand a list of labourers to District Forest Officer and District Internal Security Officer, for security purposes;

vi. One license should not exceed harvest of 500 cubic meters of round wood, expected to produce 150 cubic meters of timber at about 30% recovery rate.

7.2. License fees

Issue of licenses is subject to payment of fees that are normally fixed through a statutory instrument of Parliament. Currently, payment for license fees is subject to a statutory instrument gazetted in 2000 (Table 1). The fees are relatively too low, given that the forest produce prices have increased more than three times, over the last 15 years.

Type of Fees	Computation Basis	Amount in UGX	Remarks
Non-refundable application fees	Per applicant	50,000	To eliminate unserious people
Pit-sawing license	Per licensed pit-sawyer	350,000	Abused through having one licensebeing shared by different pit-sawyers
Tax on harvested timber	Based on value of timber produced	30%	Not charged in some districts
Re-afforestation fees	Annually for each licensee	300,000	Used for purchase of seedlings a, regardless of where the income was generated. Not charged in some areas
CESS Tax	Charged per piece of timber produced	UGX 50 for soft woods	Some transporters mix up the timber and it becomes hard to differentiate types
		UGX 100 for hard woods	
Source: [15]			

Table 1. Fees charged on licensing for timber in Uganda

8. Formal and semi-formal administrative systems in place for tracking legal timber

In line with the National Forestry and Tree Planting Act, 2003, a number of administrative systems have been put in place for tracking legal trade in forest products in Uganda. The

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different administrative systems are outlined in the chain of custody in Figures 1 and 2. These include:

i. Licensing the timber dealers and receipting the payments done in relation to the timber trade

ii. Hammer marking of the tree stumps and timber after harvest

iii. Verification of the quantities of timber harvested on a declaration form

iv. Payment of the taxes with proof of the general receipt

v. Clearing of the timber by giving timber movement permits

vi. Constant patrols in the forests by district staff from the natural resources sector

vii. Reports by Local Communities in case of any illegality.

Despite the existence of a well-defined theoretical chain of custody; the trend of events in practice changes. Some weaknesses exist within the system that renders a set of challenges to the efficiency and effectiveness of implementation arrangements. The key weaknesses include:

i. Recommendations from Local government Council officials give blanket approval which are not realistic, for example, most indicate that the applicant is excellent and highly recommended and no disapprovals are received or suggestions for weak areas for improvement. This is because these officials do not appreciate the value of legal timber trade and those who are aware are "silenced" through rent seeking and bribes from concessionaires.

ii. Letters of evidence of availability of trees is not accurate and realistic, as evidenced for some few cases, where field verification has been attempted.

iii. Most Licensed pit-sawyers are dishonest. For example, one person fronts an application, which after being successful the license is used by a number of harvesters abusing the provision of licensing being from person to holder and this is exacerbated by poor monitoring of the licenses by the responsible agencies.

iv. Most times, the evidence submitted on ownership of trees for harvesting has been found to be forged.

v. Most often, politicians make directives that applicants have to be issued licenses, irrespective of technical guidance disqualifying or limiting some applicants.

vi. Attempts by some harvesters to evade taxes.

vii. Under declaration of quantities harvested to reduce on taxes to be paid.

viii. Before, the list with licenses would be sent to FSSD, who would issue the licenses and monitor harvesting with DFO. Currently districts issue licenses with no direct involvement of FSSD and therefore there are no checks and balances in the processes.

ix. Charcoal burning/production not taxed/licensed.

x. No field staff based at sub-county, so no marking of trees at harvest.

xi. Computation of taxes is a highly technical process, which makes it difficult to be delegated.

xii. Forest agencies still use rates of the year 2000, even when the prices of forest products have more than tripled over the 15 year period.

xiii. Limited staffing and lack of forest rangers for field verification and declaration to District Forest Officer (DFO). The DFOs relies on *good faith* of the driver/owner of timber, declaring to DFO on what he/she is carrying.

xiv. In some districts field hammers are used for their role and that of a seal, since the district have no seal and at times shares with other districts.

xv. License issuing officials in most cases issue licenses without knowing the biomass available in the sub-county allocated, resulting into harvesters going to other sub-counties to avoid incurring losses.

9. Weaknesses and challenges

The administrative systems for timber trade can contribute a lot to curbing illegalities of trade in forest products if they have been implemented successfully. However, some challenges are often faced in the process of implementing the different measures and they include the following:

a. Low staffing in forestry sector and particularly the District Forest Departments.

b. No staffing in the field to monitor activities related to harvesting of the resources.

c. Most of the illegal timber harvesters and transporters work and transport produce at night or over the weekends, which is hard for the staff to monitor the activity, since there are no provisions for remuneration for working over weekends and beyond office hours.

d. Local Governments do not share the revenue collected from products revenue collections and therefore their teams have no motivation to monitor illegalities of forest products.

e. Budgetary allocation to forestry sector is low at national and local level.

f. Inadequate funds to fuel police vehicles in case a need arises to arrest illegal timber traders.

g. Interests by some politicians in forest produce trade, who influence the licensing process.

h. Licensing instructions and receipts being controlled by FSSD from Kampala and sometimes causing delays.

i. Weak laws on private forest management, while private forests have wider coverage compared to forest reserves.

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10. Drivers of illegal timber trade and its impacts

Economic opportunities and jobs are limited in Uganda but timber is still available and there are traders willing to pay for the opportunity to harvest and supply lucrative markets all over East Africa. Typically, timber dealers bring the power-saws from Uganda and the local communities benefit through various administrative fees and charges and through the employment that the trade creates. Compared to other economic opportunities such as mining, timber harvesting is a relatively easy enterprise for small-scale operators to engage in.

The high demand for timber from Uganda in neighbouring countries is one of the major drivers of the trade. Through their timber trading and procurement policies, neighbouring countries therefore have the ability to improve regulation and governance of the trade by imposing a chain of custody requirement or through procurement policies and trading policies that exclude illegal timber. Procurement policies that exclude illegal timber can have a very positive impact as can be seen with the EU timber law which is already having a positive impact on the activities of the industrial concessionaires in Uganda. Since the ban on the chain sawmilling in Uganda without popularizing alternative efficient options such as timberley, logo sol, guided chain saw, etc., timber trade has continued to be dominated by illegal actors.

The main drivers of the illegal trade are:

i. Weak institutions (in terms of human resource and finances) responsible for regulating the trade, particularly the District Forest Departments that are responsible for regulating timber harvesting from private lands and the Forest Sector Support Department which has overall responsibility for regulating the forestry sector

ii. Obsolete and often difficult to interpret procedures and chain of custody systems that are difficult to follow at present

iii. Lack of appreciation of the official procedures of legal timber trade at district level

iv. Pressures from district local governments to maximize tax revenues from local forest resources

v. Weak law enforcement at district level

Illegal timber trade has been reported by various authors [e.g. 16, 17] as one of the primary causes of forest degradation in natural forests. In Uganda this has mainly been on forests on private land where timber dealers are offered concessions to cut trees that can be converted for timber and the land is opened up for agriculture. Land owners and timber dealers rarely follow the provisions in the law and guidelines of the forest sector department hence rendering most of these forests susceptible to degradation. Concessions offered through illegal means often result into unsustainable levels of forest harvesting which may eventually lead to unprecedented biodiversity loss [18].

Illegal timber trade can lead to losses to the local and national government from under-collection of taxes and fees [19] and this may contribute indirectly to increased poverty because governments fail to have funds to support triggers of development. This is evident in many districts of Uganda such as Kibale, Kyenjojo, Hoima, and Masindi that were previously endowed with natural forests on private and reserved land but the local communities are now living in abject poverty.

The unregulated environment makes investment in efficient sawmilling machinery risky, prolonging the current inefficient and wasteful conversion of round logs to sawn wood. It also puts law abiding loggers, timber traders, and wood users at a disadvantage and cannot compete with illegal loggers and tax evaders and this may result into distortion of timber markets [18] hence reducing the economic viability of operating legally [20]. Illegally traded timber also increases the risks for investors, reducing their willingness to invest in timber processing or timber production and shrinks export market for Uganda's timber.

11. Ecological impacts of illegal timber trade

It is difficult to determine the impact of illegal timber trade in Uganda because of lack of data on the types and scale of illegal activities in the timber industry. Nonetheless, illegal timber trade has been cited as one of the drivers of deforestation and forest degradation especially forest reserves which were gazetted mainly for their high biodiversity value and provision of other environmental services [21]. In some parts of Uganda especially in the Albertine rift, illegal logging has facilitated agricultural encroachment into forest land causing loss of biodiversity and the associated ecological benefits especially sequestering carbon and water catchment protection from both private forests and reserves [22]. Primate diversity has been reported to reduce due to illegal timber trade in some forests [23]. In her studies Baranga [24] found that illegal timber trade was contributing to habitat loss and forest degradation in central Uganda. The population structure and abundance of tree species used for timber have been affected by illegal timber [25].

Trade in forest products was deemed to negatively impact on the forest through illegalities that lead to anarchic exploitation of different products, which in turn lead to deterioration of forest resources. The deforestation rate in Uganda is estimated at 1.9% annually, leading to a loss of 90,000 ha of forests per year [8]. This loss is threatening the future of Uganda's economy, which depends a lot on its natural resources for agricultural production, construction, and manufacturing various commodities. Forests are important in the protection of water catchment areas and forest degradation in the Lake Victoria Catchment Areas has resulted in the reduction of water levels in the lake, which has, in turn, led to lowering of hydro-power output at the Bujagali and Kiira power stations, Uganda's major hydro-electric power sources. This was noted to have severely affected industrial production, with growth in industrial output declining from 10.8% to 4.5% for the period 2004–2005 to 2005–2006 [26]. In turn, most manufacturers were forced to use generators, which are environmentally unfriendly and at a higher unit cost. Furthermore, degradation of forest areas directly affects the communities in the area, for example, through decline in water resources, water pollution and fuelwood, thus making the population incur other costs related to water use. This has an impact on women and children who spend a lot of valuable time searching for water and firewood instead of utilizing the time for agricultural production and other income generating activities.

12. Conclusion

Uganda has a plethora of policies and laws that can foster legal timber trade. However, most timber on the market can be described as illegal. This has implications on not only revenue in form of tax but loss of livelihoods for millions of people and the environment. The source of timber has over the years plummeted and this creates more room for illegal timber trade since the demand has also grown astronomically. The responsible agencies and duty bearers who are mandated to ensure legal timber trade are engulfed by institutional weaknesses and challenges and socio-cultural and political landscape that is riddled with dishonesty, impunity, and lack of transparency across scales. There is need for more engagement among stakeholders to build momentum for promoting legal timber trade and enforcement of legal provisions. This can be attained through improved inter- and intra-institutional collaboration, improved accountability from duty bearers, and creating incentives for legal timber trade.

13. Recommendations

i. There is need to review systems, processes, and regulations for harvesting and trade in timber to be in tandem with the current socio-economic, cultural and political situation.

ii. There is need to review procurement policies and laws of Uganda to provide for incentives of dealers in legal timber and sanctions for illegal timber dealers.

iii. Ensure responsible agencies and duty bearers are transparent and accountable to the public in all timber trade activities.

iv. Advocate for certification of timber in Uganda to promote responsible timber trade

v. Strengthen the capacity of the forest sector department and district forest departments and other enforcement agencies to enforce the regulations and guidelines for promoting legal timber trade.

vi. Improve inter- and intra-institutional coordination and collaboration in the enforcement of regulations and guidelines for legal timber trade.

vii. Mobilize support of local communities and local leaders to guard against illegalities in timber trade.

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Chapter 2

Realities on Deforestation in Tanzania — Trends, Drivers, Implications and the Way Forward

Jafari R. Kideghesho

Additional information is available at the end of the chapter

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Abstract

Deforestation ranks at the top in the global environmental agenda. Its importance is prompted by economic and ecological roles played by the forests and the notable adverse effects caused by deforestation on human and other species. These effects include biodiversity loss, greenhouse gas emissions, disruption of water cycles, increasing soil erosion and disruption of livelihoods. Deforestation rate is more serious in tropical countries where human population growth is high with extreme poverty. Tanzania, one of the tropical countries in Sub-Saharan Africa, is not exempted from these scenarios. This chapter provides some insights on deforestation problem in Tanzania with emphasis on status and trends, major drivers, ecological impacts and current efforts geared towards addressing this problem. Finally, the chapter offers some recommendations to pre-empt further impacts associated with the problem.

Keywords: Tanzania, deforestation, drivers, trends

1. Introduction

Forests play a critical role in enhancing the quality of life, guaranteeing the existence of other species and the functioning of the planet's natural systems. They support the poor in reducing their vulnerability to economic and environmental shocks. The livelihoods of about 1.6 billion people, over 25% of the world population living in extreme poverty are sustained by forests [1]. The World Bank has estimated that medicinal needs of about 1 billion people worldwide are met by drugs derived from forest plants [2]. About 40–50% of these drugs, worth an estimated value of US$108 billion a year, originate from tropical forest plants [3]. In many developing countries, forests provide fuelwood, the primary source of energy, which occasionally meets as much as 90% of energy requirements [4].

The forest products industry alone contributes substantially to economic growth and employment. The global forest products traded internationally was in the order of US$255 billion in 2011 and some 40% of this value is generated in developing countries, where forest-based employment provides 49 million jobs [1]. Worldwide, forestry sector employs over 100 million people in a formal sector [5]. The forestry sector is a major provider of rural employment in many countries. Economic importance of forests is also derived from non-wood forest products. Recent estimates indicate the global value of non-wood forest products (NTFPs) to be less than US$17 billion annually [6]. However, lack of information and relevant assessment tools at the country level makes this value underestimated. According to FAO [5], about 75% of the overall tropical tree species are used for their NTFPs value.

The IUCN's 'Livelihoods and Landscapes programme' classified forest reliance under three levels: (i) modest or special purpose forest reliance (average contribution of forests to livelihoods is around 18%, e.g. transmigrants in Sumatra, parts of China, dry areas of Tanzania); (ii) forests form a major part of livelihoods (average contribution of forests to livelihoods is up to 35%, e.g. in Sahel, North Thailand, rural Guatemala); and (iii) forests are as important as or more important than agriculture (average contribution of forest to livelihoods is 50% or more, e.g. Congo Basin, Indonesian Papua) [7].

Beyond sustaining the household economy, the companies and governments derive substantial commercial benefits from forests. The FAO (as of 2008) estimates that forest industries contribute over US$450 billion to national incomes, nearly 1% of the global GDP, and providing formal employment to 0.4% of the global labour force [8]. Other benefits from forests include incomes and subsistence benefits, informal work opportunities and reservoirs of economic values that help to ameliorate shocks to household incomes – particularly in rural areas of poor countries [9].

Forests are home to nearly 90% of the world's terrestrial biodiversity [1] and are important biodiversity hotspots with several endemic species [10]. For example, the forests of the Eastern Arc Mountains of Kenya and Tanzania contain 1500 endemic plant and 121 endemic vertebrate species in 2000 km^2, the highest ratio for endemics per area of all biodiversity hotspots [10, 11]. The current commitment by world governments to gazette large areas of their land as protected areas (exceeding 10% of the global land) is motivated by growing recognition of the critical role played by forests as the reservoirs of terrestrial biodiversity [9].

Forests play a vital role in carbon sequestration (i.e. locking up atmospheric carbon in vegetation via photosynthesis). They absorb about one third of recent anthropogenic emissions of carbon dioxide (CO_2) to the atmosphere [12]. Estimates put the carbon storage of boreal forest at 703 gigatonnes, tropical forests at 375 gigatonnes and temperate forests at 121 gigatonnes [13].The Amazon Forest alone contains 90–140 billion metric tons of carbon, suggesting that the release of even a portion would accelerate global warming significantly. Rainforests produce over 40% of the world's oxygen [14].

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By reducing the capacity of forests to lock up atmospheric carbon in vegetation, large amounts of carbon are released into the atmosphere as carbon dioxide. The build-up of carbon dioxide along with other greenhouse gases (nitrous oxide, methane, and other nitrogen oxides) in the atmosphere is known as the 'greenhouse effect'. The amount of carbon released into the atmosphere each year as a result of clearing and burning of forests and peatlands accounts for about 15–25% (or 3.7–8.1 gigatonnes of CO_2 emissions) of humanity's total GHG emissions, greater than the total amount released by the entire global transport sector [3]. Through their absorption and creation of rainfall and their exchange of atmospheric gases, forests regulate climate and local weather. For example, the Amazon alone creates 50–80% of its own rainfall through transpiration [15].

More forests are being destroyed today than ever before, suggesting that more greenhouse gases (GHG) are being released into the atmosphere. The 1980–1990 estimates indicate that deforestation was responsible for release to the atmosphere of between 25% and 30%, roughly 1.6 billion tonnes, of carbon each year [16].

Forest species and habitats have major social, cultural and spiritual significance. For example, in northern part of Tanzania some big and small forests known as *Mshitu* and *Mpungi*, respectively, are venerated by different clans of Pare and Gweno tribes [17]. Many cultures around the world have a spiritual connection with different species of trees and few have played an important part in human history. For example, the Romans associated the branches of a fig tree with the cradle containing Romulus and Remus that became caught in the place that was to become Rome while Chinese and Indians held belief that large fig trees are the homes of spirits and demons. The common fig (*Ficus carica*) was the first plant mentioned by name in the Bible, as the source of the leaves that formed the aprons that covered Adam and Eve's nakedness [18].

2. Status and trends of deforestation in Tanzania

About 35.3 million hectares or 39.9% of Tanzania's land is covered with forests [19]. Almost 90% of these forests are woodlands. Other forest types include Montane, Mangrove and Acacia forests and coastal woodlands. About 18 million hectares of Tanzania's forested land is under protection as forest reserves while 4.1 million hectares are managed under Participatory Forest Management (PFM) [19]. Approximately, 50% of forested land falls under village and general land with unclear management regime, thus being subjected to severe deforestation and degradation [19].

Tanzanian forests provide goods and services which are crucial in enhancing the livelihoods of poor households and the national economy. They contribute over 90% of the energy supply through firewood and charcoal [20], 75% of the construction materials [21, 22] and almost all indigenous medicinal products. Over 25% of all plant species used are wild-harvested medicinal plants [23]. The economic value of forest goods and services to the Tanzanian economy in the past ten years were estimated to be around US$2.2 million, or 20.1% of the GDP [24]. Contribution of forest products to the country's registered export earnings ranges between 10% and 15% [25]. However, trade in non-timber forest products (NTFPs) and timber is to a large extent informal and therefore it is difficult to estimate its real value [21]. Tanzania forests provide formal employment to approximately 1 million people (mainly rural), while about 5 to 10 times more are informally employed [25].

Other than economic benefits, Tanzanian forests and other woodlands are critical habitats for a variety of animal and plant species. They are home to about 116 known species of amphibians, 1100 birds, 316 mammals and 335 reptiles [26]. Of these species, 9.0% are endemic and 6.1% are threatened. Over 10,000 species of vascular plants, including 1120 endemics, are found in Tanzania. Scientific evidence from recent studies indicates that these forests contain several species which are yet to be discovered. For example, the latest research findings on the faunal richness of the tropical moist forests of the Eastern Arc Mountains show the discovery of 27 vertebrate species that are new to science; and 14 other species that were previously unknown to exist in the area [27, 28]. The living forest biomass contains about 2019 million metric tons of carbon.

The rationale of gazetting forest lands and other woodlands as forest reserves and other protected areas is derived from the ecological and economic importance of forests to mankind and other species. However, efforts to safeguard these important ecosystems are subdued by human needs. The forests are increasingly being subjected to deforestation and degradation as demand for arable land, fuelwood, furniture and infrastructure increase.

Tanzania is facing unprecedented loss of its forests and other woodlands. Between 1990 and 2010, the country lost an average of 403,350 ha or 0.97% per year. Between 1990 and 2010 (Table 1), the total loss was estimated to be 19.4% (about 8,067,000 ha) of the forest cover [6]. In this period, Tanzania was, among the ten countries that had the largest annual net loss of forest area (Table 2). Recent report indicates that the country has already lost about 38% of its forest cover [29]. According to the report, the rate of loss is 400,000 ha per annum and, the risk is high as the country's entire forests can be depleted within the next 50 to 80 years if the current trend remains unabated.

	Trends in total (net) forest cover, 1990–2010			**Trends in forest loss, 1990–2010**		
Year	**Forest cover (1000 ha)**	**Annual Change rate (1000 ha)**	**Annual change rate (%)**	**Forest* cover (1000 ha)**	**Annual change rate (1000 ha)**	**Annual change rate (%)**
1990	41495	-	-	41345	-	-
2000	37462	-403	-1.02	37262	-408	-1.0
2005	35445	-403	-1.10	35215	-408	-0.99
2010	33428	-403	-1.16	33188	-407	-1.09

*excluding planted forests; Negative numbers represent deforestation.

Source: [6]

Table 1. Tanzania trends in total net forest cover and loss, 1990–2010

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Country	Annual change 1990–2000		Country	Annual change 2000–2010	
	1000 ha/yr	%		*1000 ha/yr*	%
Brazil	–2 890	–0.51	Brazil	–2 642	–0.49
Indonesia	–1 914	–1.75	Australia	–562	–0.37
Sudan	–589	–0.80	Indonesia	–498	–0.51
Myanmar	–435	–1.17	Nigeria	–410	–3.67
Nigeria	–410	–2.68	Tanzania	–403	–1.13
Tanzania	–403	–1.02	Zimbabwe	–327	–1.88
Mexico	–354	–0.52	Congo (D.R)	–311	–0.20
Zimbabwe	–327	–1.58	Myanmar	–310	–0.93
Congo (D.R.)	–311	–0.20	Bolivia	–290	–0.49
Argentina	–293	–0.88	Venezuela	–288	–0.60
Total	**–7 926**	**–0.71**	**Total**	**–6 040**	**–0.53**

Source: [6]

Table 2. Ten countries with largest annual net loss of forest area, 1990–2010

While data for various land cover in Tanzania from 1990 to 2010 indicate the declining trend for forests and other wooded lands, the area used for other purposes such as agriculture, settlements and infrastructure is increasing (Figure 1). Given the escalating human population growth [projected to increase from 44.9 million people [30] to 69.1 and 129.1 million in 2025 and 2050, respectively [31], it is apparent that more forests and woodlands will be lost to meet the increased demand for food, agriculture and settlements.

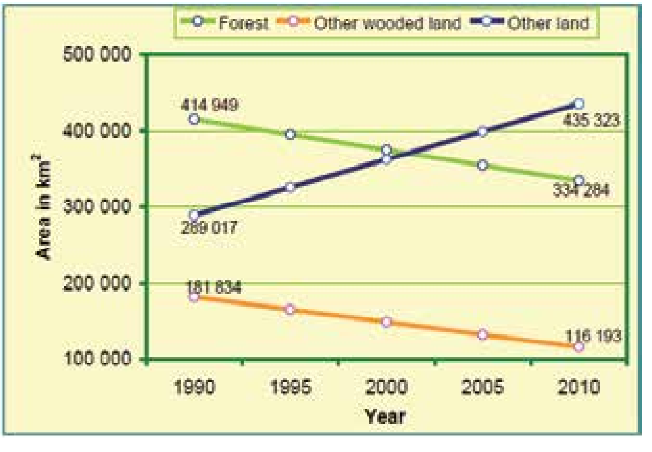
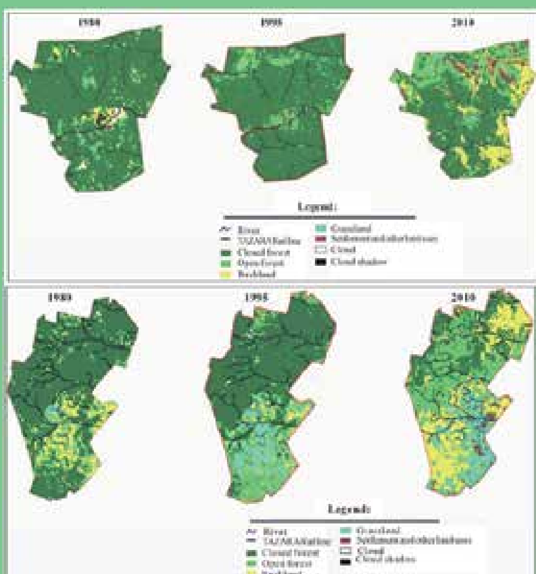


Figure 1. Trends of various land cover in Tanzania, 1990–2010 (Source: [30]).

Box 1: Forest Cover Changes in Pugu and Kazimzumbwi Forest Reserves, Tanzania

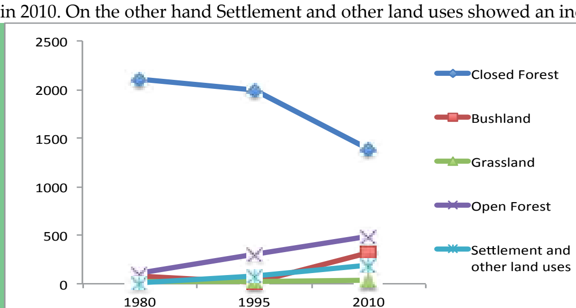
Pugu and Kazimzumbwi Forest Reserves (PKFRs) are part of the coastal forests of Tanzania and are located in Kisarawe District in the Coast region. The two forest reserves are adjacent to each other, one to the north and the other one to the south. The population of Kisarawe District has continued to increase from 95 615 in 2002 to 101 598 in 2012.



PKFRs have experienced significant decline in forest cover over time. During the periods 1980-1995 and 1995- 2010, the forest reserves have shown a significant degradation mainly due to charcoal burning and logging, encroachment for agriculture and pole cutting, expansion of farms and climate change. For the periods 1980-1995 and 1995-2010, Closed Forest in PFR decreased by 4.5% and 25.3%, respectively, while for KFR, Closed Forest decreased by 11.9% and 31.3%, respectively. The maps on the right present the land cover maps of PKFRs for the periods 1980, 1995 and 2010, respectively.

Land cover map for the year 1980, 1995 and 2010 for PFR (above) and KFR (below).

During the period 1980, Closed Forest in PFR occupied 2106.6 ha (87.2%) while in 2010 it declined to 1386.3 ha (57.4%) only. Likewise in KFR, Closed Forest occupied 4050.9 ha (75.7%) in 1980 and declined to 1740.55 (32.5%) in 2010. On the other hand Settlement and other land uses showed an increasing trend (Figure below).



PKFR land cover map for the year 1980, 1995 and 2010 (Source: [34])

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Extent of deforestation differs from one ecosystem or forest type to another. For example, a loss reported for mangrove forests in Tanzania mainland in a period of 25 years from 1980 to 2005 was 18% [32]. In Zanzibar, the loss was estimated to be 50% (Figure 2). The loss of Miombo woodlands since the 1990s is estimated to be 13% [33], while nearly half of the forest cover in the Eastern Arc Mountains, one of the world's biodiversity hotspots, has been lost [28]. The current rate of deforestation and degradation in this important hotspot hints that if the current baseline scenario continues unabated, the remaining 330,000 ha in the mountain belt may be lost within the next 20 years [28]. Land clearing for agriculture expansion and livestock grazing as well as landslides due to logging on steep slopes has caused loss of one third (about 41 km^2) of montane forest of Mount Kilimanjaro during the past 70 years [33]. Pugu and Kazimzumbwi Forest Reserves (Box 1) have recorded significant decline of their cover over time mainly due to charcoal burning and logging, encroachment for agriculture, pole cutting and expansion of farms [34].

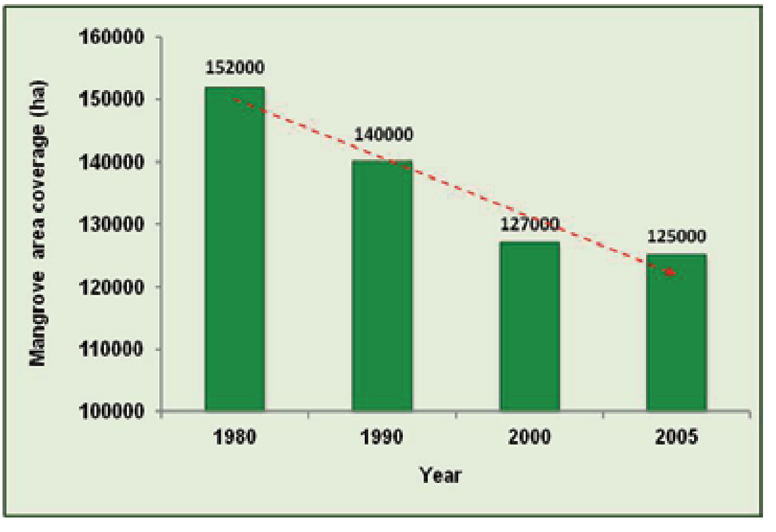

Figure 2. Trends in mangrove area coverage (1980–2005) (Data source: [32]).

3. Wildlife habitats and deforestation

Encroachment is one of the management issues facing the wildlife protected areas. Habitat destruction and, subsequently, local extinction of species emanate from encroachment and deforestation carried out to open land for agriculture and settlements along with obtaining forest products such as fuelwood, timber and building material [35–37]. The situation is worse for wildlife habitats located outside the protected areas where legal protection status is inadequate or lacking.

CORRIDOR/DESCRIPTION	THREATS
1. LOAZI-NTANTWA-LWAFI: Connects Loazi Forest Reserve and Lwafi Game Reserve via open land and Ntantwa Forest. Contains a range of savanna and forest species, the most notable being the chimpanzee.	These forests are rapidly being felled and reduced by charcoal manufacturers, and converted to agriculture. There is not, and has never been, any management of any of these protected areas, and thus illegal activity is commonplace. Many villages across this area (and within the corridor detailed above) consist mainly of Congolese bushmeat hunters who have temporarily settled in Tanzania, and exploit this area's remote and unmanaged status. Bushmeat (including chimpanzee) is exported from Tanzania across Lake Tanganyika for sale in the Democratic Republic of Congo.
2. MANYARA-NGORONGORO (UPPER KITETE/ SELELA): The corridor is utilised by elephants and buffalo moving between Manyara National Park and Ngorongoro Conservation Area.	Outside the southern edge of the Ngorongoro Conservation Area, the increased human settlement and cultivation caused interruption to the movement of elephants, buffalo and other large animals from the northern Highland FR to the lowlands below the escarpment. Even though cultivation was stopped, homes, domestic livestock and cattle dips still exist in the corridor. All areas adjacent to the corridor are settled and cultivated by local people (Mangewa, 2007).
3. UDZUNGWA-SELOUS: Anecdotal evidence indicates that, until recent decades, there was regular and abundant movement of large mammals between the Udzungwa and the Selous ecosystems across the Kilombero Valley. Used by elephants and buffalo during migration between the two ecosystems. Other animals reported from the corridor include the aardvark, Angolan black-and-white colobus, bushbuck, crested porcupine, Harvey's duiker, bushbuck, hippopotamus, leopard, lion, puku, spotted hyena, waterbuck and the Udzungwa-endemic Udzungwa red colobus.	This Corridor is under immediate threat, especially in the Namwai forest area, from rapid destruction of habitat by cutting of timber (including commercially) and burning; pole cutting and charcoaling; new human settlements and conversion of woodland to agriculture; hunting; increased cattle herding. An additional very recent threat is the settlement of Wasukuma immigrants along the western bank of the Kilombero River, with associated large herds of cattle and planting of crops.
4. WAMI MBIKI-MIKUMI: Links Wami-Mbiki and Mikumi National Park (approximately 100 km apart).	Wildebeest are reported to have moved between Mikumi and Wami back in the 1980s, until sugar cane production and human settlements cut off this migratory route. There are signs of elephant and buffalo moving in this direction from Mikumi NP, with elephants raiding small farms.
5. WAMI MBIKI-SAADANI: Links Wami-Mbiki and Saadani National Park. Used by elephants and buffaloes and other animals	The corridor is under increasing pressure due to human settlements, timber exploitation and charcoal burning and Arusha Dar Highway.

Source: Jones *et al*. [37].

Table 3. Wildlife corridors classified as EXTREME (< 2 years before they disappear)

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Despite the critical ecological roles played by wildlife corridors[1], they are inadequately or not legally protected. The wildlife corridors are, therefore, under constant pressure from anthropogenic activities such as logging, cultivation, houses and infrastructure construction and mining operations. While some corridors had already vanished few decades ago [38–40], some still exist but most of them (over 80%) under endangered status [37]. Jones et al. [38] evaluated and mapped the wildlife corridors of Tanzania that existed in 2008. Based on the rate of anthropogenic activities and habitat change, each of the 31 identified corridors was assigned a status as either MODERATE (less than 20 years remaining before they disappear), CRITICAL (less than 5 years remaining) or EXTREME (less than 2 years remaining). Corridors which were under extreme state were seven (Table 3); moderate five and 19 were under critical condition. Due to the fact that this evaluation was conducted in 2008, the chances are slim that all corridors that were under critical and extreme condition still exist, particularly if no management interventions were taken to reverse the trend.

4. Drivers of deforestation

Deforestation in Tanzania is a function of several factors covering social, economic and governance. This section highlights few of these factors: human population growth, poverty, urbanisation, political instability, trade, expansion of agricultural lands, emerging of new economic options and infrastructure development.

4.1. Human population growth

The Tanzanian population increased from about 12 million people in 1967 to 44.9 million in 2012, almost four times (Figure 3). With the annual growth rate of 3.1%, Tanzania's population is projected to reach 69.1 and 129.1 million in 2025 and 2050, respectively [31]. Population growth, both in rural and urban areas, is the underlying factor behind rapid rates of deforestation in Tanzania. Population growth increases the demand for food, settlements, infrastructure development, fuelwood, furniture, building materials and other products. In meeting these expanding demands, deforestation is inevitable.

The impact of population growth on deforestation is worsened by the reality that the increased population remains in poverty with limited livelihood strategies and, therefore, compelled to pursue unsustainable economic options including deforestation.

4.2. Poverty

Poverty has been defined as 'a pronounced deprivation in well-being', characterised by 'low incomes and the inability to acquire the basic goods and services necessary for survival with dignity, low levels of health and education, poor access to clean water and sanitation, inade-

1 The roles of wildlife corridors among others include: allows the movement of wildlife species from one area to another in case habitat in one area becomes unsuitable; allows genetic flow and exchange between species in two habitat patches;

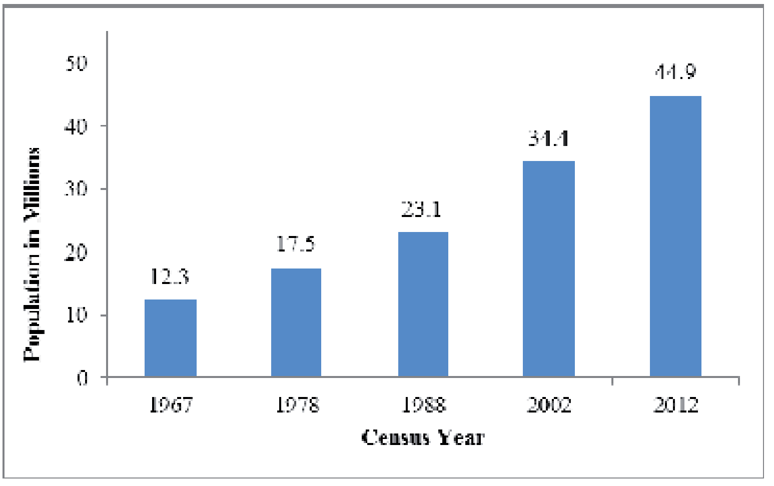

Figure 3. Trends of population growth in Tanzania (Source: National Bureau of Statistics [41]).

quate physical security, lack of voice, and insufficient capacity and opportunity to better one's life' [42].

Tanzania, though endowed with abundant natural resources, has been classified as one of the poorest countries in the world. The World Bank [43] acknowledges a significant decline of poverty over recent years, but this has not exempted the country from being poor. In 2012, Tanzania's average per capita income stood at $570, placing it in the 176th position out of 191 countries of the world. A number of poor people (about 12 million) residing in Tanzania today is almost the same as that of 2001 [43]. The 2011/12 National Household Budget Survey estimates the basic needs poverty line and food poverty line at 36,482 Tanzanian Shillings (US $24) and 26,085 Tanzanian Shillings (US$17) per adult equivalent per month, respectively [44]. Using these two poverty lines, Tanzanian population falling below the basic needs poverty line is 28.2%, while 9.7% falls below the food poverty line.

Poverty has repercussions on natural resources including forests and woodlands. It increases the pressure on forests to meet the basic needs. Its contribution to deforestation can be manifested through: limited livelihood strategies compelling the poor to seek alternatives from the forests, low purchasing power and inability to afford agricultural inputs (e.g. fertilizers) for improvement of productivity of the existing arable land and, therefore, causing agricultural extensification and encroachment into marginal lands, and inability to afford fuel-efficient and environmental-friendly energy, which forces people to rely on forests and woodlands for fuelwood.

4.3. Urbanisation and deforestation

Urbanisation, the process of transforming natural landscapes (such as wetlands and forests) to built environments, is a matter of great concern globally. The UN-HABITAT's report on the State of the World's Cities [45] indicated that half of the world's population was already living

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in cities. The report forecasted 60% to reside in urban areas within a period of two decades. The report forecasted further that, by 2050, the urban population of the developing world will be 5.3 billion. Africa continent, whose urban population is 1.2 billion, will host nearly a quarter of the world's urban population [45].

Tanzania, one of the African countries, is experiencing rapid rate of urbanisation, mainly due to high rates of rural–urban migration. The country's urban population grew almost 17 times, from 6.4% in 1967 to 29.6% in 2012 (Table 4). The urban population has been increasing at a rate of 9.3% per annum for the period from 1978 to 2002. The proportion of the national population living in urban areas increased from 25% in 2002 to over 30% in 2012 [41].

Year	Total population	Urban population	Percent urban	Urban growth rate
1967	12,313,469	786,567	**6.4**	
1978	17,512,610	2,412,902	**13.8**	**10.2**
1988	23,095,878	4,247,727	**18.4**	**5.7**
2002	34,569,232	7,943,561	**23.1**	**4.5**
2012	44,928,923	13,305,004	**29.6**	**5.2**

Source: National Bureau of Statistics [41].

Table 4. The trends of urbanisation in Tanzania (1967-2012)

More towns and cities are growing as economic opportunities are emerging and political decisions are implemented. For example, minerals have acted as the important population pull factor to areas such as Kahama, Mererani, and Bulyankulu while wildlife and tourism have led to the development of towns close to famous protected areas such Ngorongoro Conservation Area, Serengeti, Lake Manyara and Ruaha National Parks.

Similarly, change of administrative units in the country has contributed to urbanisation. In 1975, there were twenty regions in Tanzania mainland. Today, six more regions namely, Manyara, Geita, Katavi, Njombe, Simiyu and Songwe have been designated. The designation of new regions goes hand in hand with the designation of new districts, divisions, wards and villages.

The urbanisation and population growth have implications on forests and woodlands. More lands are cleared in order to provide space for administrative offices, social services, settlements and infrastructures. The effects of urbanization are also felt in areas away from the urban areas. Building materials and furniture (timber) are obtained from rural areas. Furthermore, urbanisation creates high demand for fuelwood, especially charcoal [46] (Figure 4). For instance, using figures from three sources [47–49], Msuya et. al. [50] estimated the amount of charcoal consumed in Dar es Salaam to be 1904 tonnes per day or 694,960 tonnes per year. The analysis indicated further that charcoal consumption in Dar es Salaam in 2009 alone caused a loss of about 105,300 ha of forests, and projected that by 2030 demand for charcoal in Dar es Salaam alone would lead to loss of 2.8 million ha of forests [50].

Figure 4. Urbanisation creates high demand for charcoal from rural areas (Source: [46]).

4.4. Expansion of land under agriculture

Agriculture is the biggest driver of deforestation globally, accounting for about 80% of total deforestation in poor countries. Subsistence agriculture is responsible for 48% of deforestation while commercial agriculture contributes 32% [51].

In Tanzania, the impact of agriculture on deforestation is influenced by a number of factors including human population growth, poverty and government policies. Human population growth translates into the expansion of land under agriculture in forest areas in order to meet the increased demand for food and income (Figure 5). For instance, in Kilwa District of Southern Tanzania the area under cultivation increased to 104,744 ha in 2010 from less than 63,000 ha under cultivation in 2005, an increase of approximately 40% [51].

As pointed out earlier, poverty is linked to the inability to afford the agricultural inputs for more crop production. Consequently, people are forced to abandon the existing farms and clear virgin forests for new farms, the practice commonly known as shifting cultivation. To farmers, virgin forest lands have a number of advantages, making it less laborious. Virgin forest soils are easy to work with; new farms are more fertile and productive; after clearing, the area is burned and is ready for planting; new farms have less weeds for about two seasons, therefore weeding is very much reduced; new farms are less infested by pests; new cleared forest soil is well drained and requires zero or minimum tillage before planting [51].

Government policies and programmes may, in a way, stimulate deforestation as more priority is placed in agricultural production. Tanzania's agricultural sector is regarded as the founda-

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Figure 5. Destruction of mangrove forests for paddy cultivation in Rufiji (Source: [46]).

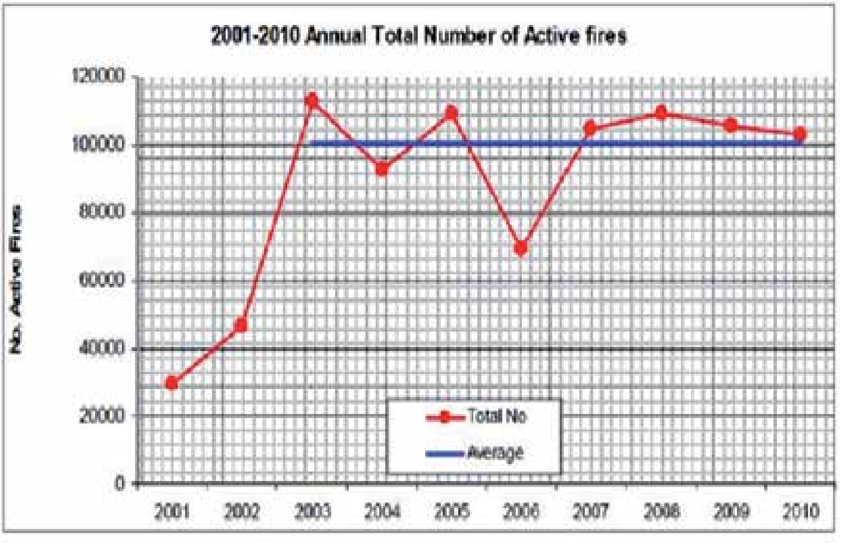
tion of the economy as it accounts for about 25% of the GDP and about 20% of traditional export earnings. Furthermore, it provides 95% of food requirement, employs 75% of the population, controls inflation (since food contributes about 56% of the inflation basket) and has the highest multiplier effect in the economy [52].

Tanzanian government policy firmly supports the development of both large- and small-scale farming, and recognises that large-scale farming has an important role in stimulating agricultural growth. The country has numerous programmes aiming at promoting agriculture and food security. Some of the recent programmes include KILIMO KWANZA (Swahili words for Agriculture First), BRN (Big Results Now) and SAGCOT (Southern Agricultural Growth Corridor). While it is indisputable that agricultural development is important and inevitable, implementation of various programmes may detrimentally affect the forests by encouraging conversion of forests into croplands.

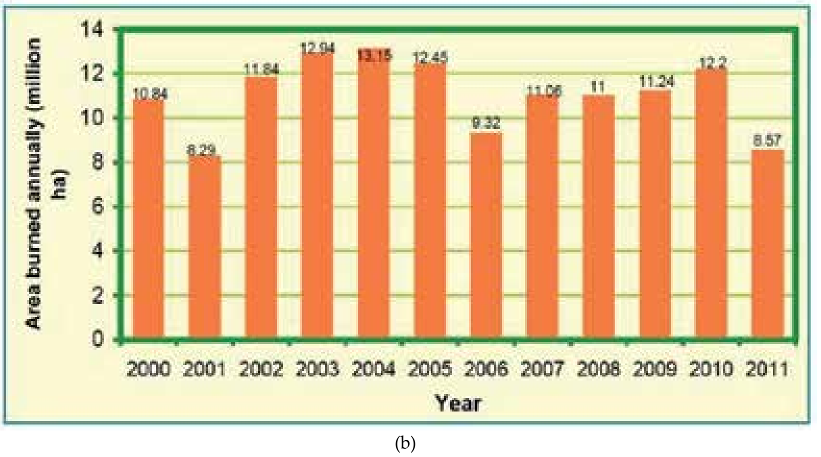
4.5. Incidences of wildfires

Tanzania forests and woodlands are prone to destructive wildfires set for a variety of reasons. Over years, this problem has been growing and, therefore, contributing to increasing rate of deforestation in the country. MNRT [24] estimated destruction of 65,000 ha of forests and other wooded areas per annum. According to FAO [53], the wildfires affected an average of 12% of the area of Tanzania annually between 2001 and 2007. Between 1990 and 2010, Tanzania lost an average of 403,350 ha of forest or 0.97% per annum [5].

The incidences of wildfire (Figure 6a and 6b) have made Tanzania, one of the four most affected countries in the SADC region [53]. Reasons for setting wildfires include needs for improving pasture quality, killing parasites, facilitating wildlife hunting, honey collection, charcoal burning, mining, pit sawing, grazing, opening farms, arson and wildfire attributed to pedestrians.



(a)



(b)

Figure 6. (a) Trends of active fires in Tanzania (Source: [54]). (b) Trend of annually burned area in Tanzania (Source: [54]).

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The growing trend of wildfires is attributed to insufficient plans and programs to control fire, inadequate human and financial resources, insufficient extension programme for local communities and lack of/or weak integration of informal (Indigenous) knowledge and policy implementation relating to forest fires management [54].

4.6. Political instability and the influx of refugees

Unlike several other African countries, Tanzania is one of the few countries which have enjoyed political stability and peace for a long time since their independence. Many African countries have been confronted with civil wars attributed to high levels of poverty, failed political institutions and economic dependence on natural resources [55].

Despite the prevailing peace and political stability, Tanzania had had a share of problems caused by wars waged in the neighbouring countries. One of the problems, among others, is environmental degradation perpetrated by thousands of refugees resulting from these wars (Figure 7). Forests and woodlands are cleared for settlements, fuelwood, building poles and arable land, leading to a dramatic impact on vegetation and wildlife habitats.

Figure 7. Refugees fleeing civil wars from their countries have contributed to population increase and deforestation in western Tanzania. (Source, http://www.intechopen.com).

The western part of the country had been the most refuge-prone area. Although the problem had persisted for several decades before [56], it became more notable following the aftermath of the 1994 genocide in Rwanda. Citing different government reports, Akarro [56] shows that eleven wards in Kigoma region were recipients of 373,213 refugees in addition to 217,095 local people in October 1993. By December 1994, refugees and refuge operations cleared about

20,700 ha of land. In August 1994, about 467,670 refugees formed 64% of the population which lived in 16 wards of Kagera region. Between 1993 and December 1994, 24,000 ha were cleared with addition of 50,000 ha experiencing varying degrees of destruction due to widespread deforestation to meet the demand for fuelwood [56].

In 1994, population in Ngara District increased by 262% following addition of over 500,000 refugees to 191,185 local people [56]. Some months later, the refugee population grew further to 800,000. This population exerted huge pressure on about 95,000 ha of forests and woodlands in the vicinity of the refugee camps. The studies conducted in the area revealed a decline in forest regeneration by 35% following four years of deforestation [57]. This regeneration is quite low to allow quick rejuvenation of the deforested land.

At the peak of the Rwanda refugee crisis, the Kagera region alone recorded very high consumption of firewood amounting to 1200 tonnes per day [58]. In 1997, an average daily fuelwood consumption was estimated to be 300 metric tonnes [59]. The impacts of deforestation were felt some 20 km away from the camps. Nearly 1000 km^2 of land in BENACO Refugees Camp and the adjacent areas were affected by deforestation. Aerial photos taken in 1996 showed that roughly 225 km^2 and 470 km^2 of the affected region were completely and partially deforested, respectively [59].

4.7. Poor governance and corruption

Corruption triggers deforestation by undermining the governance of the forestry sector. Study by the the wildlife trade monitoring network, TRAFFIC, on governance and development of the sector uncovered a large-scale corruption and collusion between national and foreign private interests and government officials [21]. According to study, the emerging dynamics of powerful and organised involvement of senior public officials in timber-related businesses, including members of the executive, obstruct efforts in fighting corruption in the sector. The control over forestry resources is often linked to developing political factions and, therefore, shorter-term decision-making and forms of corruption are very difficult to reverse.

Along with corruption, political intereference on the governance of forestry sector has notable contribution to deforestation. The tendency of political interests to override the professionalism is not uncommon. Some decisions are politically motivated regardless of the detrimental effect they may pose on forests. The efforts by the natural resources officials to check the illegal and destructive activities over forests are often frustrated by the politicians who claim to defend their voters. For instance, currently, there are pending cases where people are living and earning their livelihoods illegally inside the protected areas. However, some politicians are against it and there is a move to pressurise the government to degazette some or parts of the protected areas.

Poverty and poor living conditions among the forestry staff and other civil servants are other drivers of corruption. Until recently, the minimum salary for most of the civil servants was US $85. Bribery and corruption are, therefore, seen as alternative sources of complementing the meager salaries earned by civil servants.

4.8. Growth of trade

Agricultural output and timber prices have been linked to deforestation rates, i.e., when trade affects these prices, it will also affect deforestation rates [60]. As agricultural prices increase, the opportunity cost of conserving forest increases. Farmers react to the opportunity of more profitable cultivation by forest clearing. Furthermore, the extra money earned from agriculture finances more conversion of forestland to cropland [61]. Tanzania, along with Mexico, Thailand, Brazil, Costa Rica, Australia and Brazil, are among the few countries cited to have experienced increased deforestation due to increased agricultural and timber prices [60].

Similarly, timber trade is a lucrative business and, therefore, more people are engaging in this business. The most valuable timber species such as *Milicia excelsa* (Mvule), *Pterocarpus angolensis* (Mninga) and *Dalbergia melanoxylon* (Mpingo) are at risk of extinction due to overexploitation. The factors influencing this trade in Tanzania are accessibility to remote forest areas, corruption and market availability.

4.9. Infrastructure improvement and emerging of new economic opportunities

The past three decades have seen Tanzania investing in developing and improving infrastructures in view of allowing accessibility to different parts of the country. Currently, virtually all parts of the country, previously regarded as remote areas, are easily accessible through good roads. The total classified road network in Tanzania Mainland is estimated to be 87,524 km [62]. The Ministry of Works through Tanzania Roads Agency (TANROADS) is managing the National Road Network of about 29,487 km (33.7%) comprising 10,042 km of trunk and 19,445 km of regional roads. The remaining network of about 58,037 km (69.3%) of urban (5,897 km), district (29,537 km) and feeder roads (22,603) [62] is under the responsibility of the Prime Minister's Office Regional Administration and Local Government. According to TANROAD, the overall road condition assessment at the end of December 2010 indicated that 40% were good, 46% were fair and 14% were poor compared to 25% good, 40% fair and 35% poor in December 2001. Between 30 June 2000 and 30 June 2009, a total of 912 km of trunk and regional roads were upgraded/rehabilitated to bitumen standard [63].

While, on one hand, the improvement of the road network is a credit to the government and important entry point towards social and economic development, it has undesirable consequences on the other hand. These efforts, apart from improving people's living standards, can lead to serious environmental and socio-economic tradeoffs such as a surge in uncontrolled logging and timber trade activities. Areas with intact forests and high-quality timber trees have been subjected to heavy logging to satisfy market demands within and outside the country. For example, forest inventories conducted in 2005 rated most forests in southern Tanzania as *"degraded"* or *"heavily degraded".* The main reason was cited as the completion of the Mkapa Bridge in early 2000s [21, 51]. Similarly the completion of the Umoja (Unity) Bridge (in Ruvuma River) connecting Mozambique and Tanzania has increased logging as the bridge is also being used to transport illegally harvested timber into Tanzania from Mozambique [64]. Moreover, traders use Mozambique as a scapegoat to harvest trees illegally in the border districts of

Tanzania and claim that they are from Mozambique, in order to secure permits for transporting them to Dar es Salaam and elsewhere.

Along with infrastructure improvement, new economic opportunities have emerged in the country, prompting government's decisions to tape these opportunities, regardless of the reservations from some conservationists. Examples of such economic opportunities include discovery of mineral deposits in different parts of the country such as uranium (Namtumbo and Bahi), gold (Buzwagi, Bulyakulu, Nzega and Geita) and gas (Mtwara). Presence of these mineral deposits serves as a major population pull factor to the areas and, consequently, a need to clear huge segments of land to allow mining operations, construction of settlements, opening of roads and other infrastructures. Furthermore, the population increase creates high demand for forest products to satisfy domestic and commercial needs (e.g. furniture, fuelwood, etc.).

5. Implications of deforestation

Considering the role played by the forests, it is obvious that deforestation has serious economic and ecological consequences. Among others, the effects include:

a. Loss of livelihood options among the poor people who rely on forests for food, medicine, fuelwood, building poles and furniture.

b. Reduction or loss of tourism potentials due to destruction of principle resources including charismatic wildlife species and attractive sites. Examples include local extinction of species in some areas due to habitat loss and isolation [37–40]. Recent trend of snow melting in Mount Kilimanjaro presents another detrimental effect on tourism industry (Figure 8).

c. Increased human–wildlife conflicts due to proximity and overlap in the use of space between wildlife, livestock and humans. Incidences of property damage by wildlife, diseases transmission, poaching and retaliatory killings increase with increasing human–wildlife contacts.

d. Increased risk of inbreeding depression among the migratory species due to isolation of protected areas caused by blockage of wildlife corridors;

e. Increased emission of greenhouse gases in the atmosphere and global warming and;

f. Reduced land productivity due to loss of soil fertility and inadequate or unreliable rainfall patterns.

The impacts of deforestation can clearly be elaborated by the Eastern Arc Mountains belt. The area lost almost 50% (approx. 300,000 ha) of its montane and sub-montane forests in a period of 5 years from 2000 to 2005 [28]. As a result of this, 90 million tonnes of carbon have been released to the atmosphere. It is estimated that if the current trend of deforestation will continue unabated, the remaining 330,000 ha will be lost within 20 years time. The impacts of this loss are summarized in Box 2.

(a)

(b)

Figure 8. (a) Deforestation at the base of Mount Kilimanjaro (Photo by Rhett Butler). (b) Snow melting on Mount Kilimanjaro is associated with deforestation.

Box 2: What will happen if Eastern Arc Mountains forests are lost?

• Loss of its ecological role as a carbon sink. The current estimate of the carbon storage of the forests is about 152 million tonnes.

• Increased household poverty to adjacent communities. Firewood, construction material, medicinal herbs, wild fruits and other food materials account for 40% of household consumption.

• Reduced water quantity and quality for domestic and industrial use in big cities such as Dar es Salaam, Morogoro, Iringa, Coast and Tanga.

• Serious electricity interruptions. Over 90% of electricity in Tanzania is hydro-based. The EAM forests provide over 90% of the country's hydroelectric power generated at Kidatu, Kihansi, Nyumba ya Mungu, Hale, Pangani and Mtera Stations.

• Reduced soil fertility and change of rainfall patterns may lower yields for crops such as sugarcane (grown in Mtibwa and Kilombero), rice and tea.

• Tourism potential of the area will be lost due to reduced or extinction of charismatic species found in this forests.

• Loss of the area's repute as one of the world's 24 biodiversity hotspots.

Source: [28].

6. The way forward

This chapter has uncovered a variety of benefits derived from forests. From these benefits, it is apparent that loss of forests is tantamount to putting human life and other species in jeopardy. Unfortunately, in the face of human population growth, poverty, corruption, economic and technological advancement, forests are being depleted at alarming rate, thus threatening the survival of humankind and other species. Tanzania is one of the countries with a notable deforestation rate. Currently, numerous measures are in place to address this problem. However, these measures are either inadequate or are poorly implemented. In reversing the trend of deforestation, there is a need to reinforce these measures and adopt new ones to complement the existing measures. The possible options include the following.

6.1. Enhance conservation education to public

The strategy should aim at educating people about the benefits of forests and adverse impacts that may result from the unsustainable behaviours and actions on forests, sustainable practices that promotes the health of forests and alternative strategies for sustaining their livelihoods beyond those causing damage on forests.

6.2. Addressing the issue of human population growth

Tanzania, like other developing countries, relies on natural resources. Population growth often means farming in marginal lands, migration to urban areas and deforestation, as people try to earn a living. Thus, land use change in this manner causes emissions that contribute to climate change. Addressing the problem of overpopulation will reduce deforestation rates. Some of the strategies, among others, that can be adopted include: empowering women and families to plan the number of children by improving the reproductive healthcare, provision of

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education and job opportunities (especially for women in order to alleviate poverty, gender inequality and overpopulation) and creating awareness of environmental and social costs of overpopulation.

6.3. Adopt sustainable and environmental-friendly poverty reduction strategies

The strategies should target provision or introduction of sustainable economic activities that will make people refrain from ecologically damaging activities. Projects like poultry ecotourism, mushroom farming and beekeeping may provide alternative means of living to people and, therefore, reduce pressure on forests. Introduction of these projects should go hand in hand with assisting the communities to access reliable markets for their products.

6.4. Address the problem of corruption and poor governance

Forestry, like other sectors, is confronted with huge corruption. Acknowledging the magnitude of this problem is imperative in developing the viable mitigation strategies. The war against this immorality should be intensified at all levels by all stakeholders including government organs, religious organisations, NGOs, media and individuals. More emphasis should be directed in strengthening institutions such as legislature and judiciary, strict enforcement of the rule of law, discouraging political patronage, restoring/promoting the independence and professionalism of the public and private sectors, building capacity for the civil society to hold perpetrators to account and increase vigilance in the implementation of the 2003 United Nations Convention against Corruption (UNCAC) at all sectors. The four pillars of the convention – prevention, criminalisation, asset recovery and international co-operation – are essential in promoting open, honest and efficient decision-making, fair competition and ethical procurement systems and supporting effective government development strategies [65]. The Forestry staff should be adequately remunerated to inspire them to resist the temptation of participating in corruption practices.

6.5. Provision of alternative sources of energy

Reduction of the continued widespread dependence of household biomass sources of energy requires provision of alternative sources. Modern sources of energy (electricity, liquefied petroleum gas and kerosene) should be provided at reasonable price which is affordable to poor households. Fortunately, natural gas has been discovered recently in Tanzania. What is required is political will and proper planning so that these discoveries can curb deforestation in addition to enhancing the economy at the household and national level.

6.6. Implement benefit sharing schemes

Benefit sharing arrangements are important in motivating people to refrain from activities leading to deforestation. One of the benefit sharing mechanisms is benefit sharing for REDD. REDD-plus can potentially be a significant source of financial benefits for poor rural communities relying on forests for their livelihoods. Payments consist of compensation for the opportunity costs of land-use changes plus a so-called REDD rent. It entails agreements between stakeholders about the distribution of monetary benefits from the commercialisation of forest carbon. Benefit sharing for RED is built on two premises: it creates effective incentives by rewarding individuals, communities, organisations and businesses for actions that change land-uses and reduce emissions and; it builds wider national (and international) legitimacy and support behind the REDD-plus mechanism. However, implementation of the schemes should identify and address possible contentious issues that may thwart the success of the programme. For instance, one of the controversial issues is ambiguous definition of forests and deforestation, whether plantations should be regarded as forests that deserve consideration under REDD scheme. It is apparent that if the terms are not properly defined, the policy prescriptions may lead to loss rather than saving the forests.

7. Conclusion

The role of forests to mankind and other living organisms cannot be overemphasised. Their role in maintaining ecological functions and sustaining economic development is well acknowledged. However, recent trend of deforestation attributed to rapid human population growth, poverty, poor governance and corruption, among other drivers, puts our life at risk. While this chapter recommends a number of options for reversing the trend, it is an eye-opener for policy-makers, general public and other actors to understand the magnitude of the problem and act accordingly and promptly. The current situation suggests that actions and measures to curb deforestation cannot wait and that the problem calls for multisectoral rather than a single sector approach.

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Section 2

Management, Governance and Policy

Chapter 3

Dynamics of an Urban Forest in Response to Urban Development and Management Initiatives — Case of Bukit Timah Nature Reserve

Kalyani Chatterjea

Additional information is available at the end of the chapter

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Abstract

Singapore, a tropical island of only 716 km², has substantial land under forest. But rapid urbanisation coupled with the scarcity of land has also resulted in extensive land clearance. Though highly urbanised, Singapore has managed to retain 4.5% of the land area under nature conservation, and 2.9% under closed forest. Out of four protected areas, two of these, the Central Water Catchment Forest (CWC forest) and Bukit Timah Nature Reserve (BTNR), are protected under the Parks and Trees Act of 2005 with a total area of 3,043 ha. Though originally connected, these two forests were separated from each other by a major highway, leaving BTNR, the smaller of the two, with a total land area of 163 hectares, surrounded by not just the highways, but also by a fast developing urban residential area. The forest boundaries have seen dense urban development as close as only 50 m from the forest edge. As a result, micro-climatic parameters such as atmospheric temperature, relative humidity, soil surface temperature, light conditions, wind velocity, all have seen significant changes over time and the gradient of such changes are drastic and steep along most forest verges. Currently some ameliorating steps are being taken by the forest management to counter the ill effects of too much encroachment and fragmentation.

Keywords: Fragmented forest, edge effect, edge forest, urban forest, forest degradation, forest micro-climate

1. Introduction

Situated in the tropics between 1º09′N and 1º29′N and longitudes 103º38′E and 104º06′E, Singapore comprises one main island and several small islets and covers an area of 710.2 km². Originally a lowland tropical forested island with mangrove vegetation and mudflats at the coastal verges, Singapore was mainly a fishing island, with little disturbance to the original dense forested land. Since British colonial times in the 19th century, however, inland forests retreated in the wake of clearances made for human habitation and the high rates of deforestation and land clearances continued even after independence, giving in to high demand for a fast growing economy. The thickly forested Bukit Timah Hill, the highest on the island, was recognised as a landmark by European settlers in the 19th century. However, it was rarely visited due to its inhospitable terrain, and was inhabited only by gambier farmers. Its role changed when a main road (Bukit Timah Road) was built to reach it by 1840 and another road linking Bukit Timah to Kranji was built in 1845 [1]. In 1843, a road cutting through the reserve was built from the foot of the hill to its summit. During colonial times, Singapore had its first forest reserve at Bukit Timah in 1883, when the conservation aimed to preserve flora and fauna of the forest. In 1951, under the Nature Reserves Act, Singapore had five nature reserves, Bukit Timah, Pandan, Labrador, and the Catchment Area, when some unique nature reserves were set aside, but without much focused planning and objective [2, 3]. Subsequently, however, even as economic development and demand for space spearheaded large-scale forest clearance, the post-independence period from 1965 actually also saw serious engagement in nature area conservation. The National Parks Board was set up in 1990 to specifically manage the parks and greenery and conserve all nature reserves with legal protection under the Parks and Trees Act of 2005. The National Parks Board was given the responsibility to take charge of not just the many new green spaces created under the greening schemes of Singapore, but also to actively conserve the few naturally green areas that still remained. The city state of Singapore managed to retain 4.5% of the land area under nature conservation and 2.9% under closed forest, in spite of being highly urbanised and in severe demand for land space. Currently, there are a total of four protected nature reserves in Singapore, which enjoy total protection, even in the face of aggressive urban expansion. Tracts of primary and secondary rainforests in the Bukit Timah and Central Catchment Nature Reserves, as well as mangroves and mudflats in Sungei Buloh Wetland Reserve are examples of such nature areas protected even under intense pressure on the already scarce land and in spite of heavy demand for development. Out of these, the Central Water Catchment Forest (CWC forest) and Bukit Timah Nature Reserve (BTNR), with a total area of 3,043 ha, are protected under the Parks and Trees Act of 2005 for the protection and propagation of the native biodiversity.

In spite of these sincere conservation efforts, land scarcity and pressure on the economic front has put forward great demands of land acquisition and development around Bukit Timah and the forest peripheries have seen significant changes. The intense development around the forests in Singapore has opened up new landscapes and altered existing ones. This has created wide zones of non-forested landcover around the originally forested areas. In particular, BTNR and its surrounding areas have seen large-scale and continued change in the environment, making it one of the most impacted locations in Singapore. The most visible impact of similar

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landuse changes close to forest boundaries is the edge effect. Edge effects occur where forested areas come in direct contact with non-forested environments and have been found to extend from 40 m [4] to 500 m [5, 6] into forest interiors. Zheng and Chen [7] agreed that generally the sharper the contrast between two adjacent patches, the stronger the edge effect. In the case of BTNR, the contrast between the forested and the surrounding non-forested environment is drastic, with major highways and roads running along the forest boundaries. Isolation of forests due to landuse change and land conversions is considered to be the biggest threat to biodiversity and have been documented as being the key reason for loss of native species, invasion of exotic species, pronounced soil erosion, and decreased water quality, and collectively, severely affects the integrity of ecological systems [8–12]. In addition to being fragmented, when a forest becomes the centre of urban development as well as a major natural attraction, the pressure of providing eco-system services are increased, as mentioned by Tobias [13]; such demands lead to higher demand for land and amenities such as easy access and proximity to infrastructure, all in turn put excessive pressure on the forest. One direct result of this will be urban sprawl, which is listed as a major impact factor in biodiversity degradation by Gayton [14].

This chapter looks specifically at BTNR in Singapore to follow the pattern of urban expansion around the area and to examine the spatial changes in the surrounding locations. The forest boundaries have seen dense urban residential development that goes as close as only 300 m from the forest boundaries. This not only allows the encroachment of non-forested microclimatic environment to get too close to the forest buffering the interior closed forest, but also allows easy access for people who visit it in large numbers for various recreational, educational, and social purposes. The chapter takes a look at the longitudinal changes the forest boundaries have undergone. It also looks at the various ameliorating steps being taken by the forest management to counter the ill effects of too much encroachment, fragmentation, and overuse.

2. Bukit Timah: The forest

BTNR has some secondary and some primary forest, with a core closed forested area of about 75 ha. Though small, it houses a very high density of flora and fauna and has been documented as having more than 1,000 species of flowering plants, 10,000 species of beetles, and many other organisms indigenous to tropical rainforests [15].

BTNR is situated on the highest hill in Singapore, a steep grano-dioritic batholith (163 m), with a rugged topography and slopes often exceeding 35 degrees. While the fringes of the core forest were disturbed in the past, giving way to scattered forests and some small-scale fruit tree cultivation, much of the interior of the closed forest at BTNR still retains the authentic ‘feel’ of a primeval rainforest. The dense evergreen tropical forest cover is known to house more species of trees than in the whole of North America [15]. Trees as tall as 35–37 m, loaded with epiphytic growth; and in places dense canopy cover retain, in the large part, a typical tropical rainforest environment, complete with little under-growth, dark and moist forest interior, extending lianas, dense but shallow surface root systems, and buttressed trunks (Figure 1).

Source: Author

Figure 1. Inside Bukit Timah Nature Reserve.

The rugged topography in some places leads to irregularities in the main canopy, largely consisting of Dipterocarpaceae. Common species are Seraya (Shorea curtisii), Meranti Tembaga (Shorea leprosula), Meranti Sarang Punai (S. parvifolia), Nemesu (S. pauciflora), and Melantai (S. macroptera). Dipterocarpaceae are by far the most important constituents of the main canopy of BTNR [15]. Another important family of main canopy and occasionally, emergent trees is the Leguminosae, represented by Kempas (Koompassia malaccensis), Sepetir (Sindora wallichii), Petai (Parkia speciosa), and Kerangi (Dialium spp.) [15].

The sub-canopy layer in BTNR grows in light-deficient, micro-climatically constant environment, with little wind movement, constantly moist, and heavily shaded conditions. Most of the vegetation here are simply juveniles, going through the growing stage. Some important species are Euphorbiaceae (Rubber tree family), Rubiaceae (Ixora family), and Annonaceae (Custard apple family).

The 'shrub' layer is the lowest layer of woody plants. Various types of palms are important elements of the undergrowth flora in BTNR, most common being the young rattans (climbing palms).

The ground layer in BTNR is not so conspicuous or abundant, mostly consisting of seedlings. Herbaceous plants are commonest along paths where some light penetrates. Some ferns (*Tectaria singaporeana*) and wild ginger (*Zingiberaceae*) are important ground vegetation in BTNR.

Bukit Timah forest also has an abundance of climbers, some woody lianas, and some herbaceous climbers that grow in shade. Epiphytes are common as well, both on the main canopy as well as under shade. Especially common and characteristic are the fig species, referred to as 'stranglers', which start off as epiphytes and then extend roots to the ground. These roots often coalesce to surround the host tree, often strangling them to form a freestanding fig tree.

3. Bukit Timah: The fast changing landscape

While parts of BTNR still hold a near-original forest condition, it has, over the years, undergone some structural changes brought about gradually by the various changes to the forest interior as well as the forest fringes. The very first such large-scale change was initiated by the construction of the six-lane highway in 1985 through the heart of the forest in the centre of the island, causing divisive fragmentation and separating the smaller Bukit Timah forest from its larger counterpart, the forests of the Central Catchment (Figure 2).

Source: Author

Figure 2. Bukit Timah Expressway (BKE) running through the forest, fragmenting BKE from CWC.

This north-south running highway cut through the central granite country, exposing not just the core of the batholith, but also exposing the core of the forest to the exterior open environment like never before. Suddenly, the usual daily migration routes of the small land animals were interrupted by fast-running traffic. Though no records of animal mortality were kept, numerous experiences of animals stranded along the highway have been related in informal discussions. Although these accounts cannot be verified quantitatively, this is an expected outcome of truncating a forest teeming with small fauna such as the long-tailed macaque, pangolin, civet cats, etc.

The highway development came at a time when economic development and the necessity of fast and efficient transport link between the north and south of the island drove landuse planning. During the 90s, major relocation of original light industries of this area was carried out, clearing land around Bukit Timah hill for high-density, high-rise urban residential development. This left BTNR, the smaller of the two forests, with a total land area of 163 hectares, surrounded by not just the highways, but also by a fast developing urban residential area. Beyond the forest boundaries, BTNR is surrounded by non-forested environments all around and such breaks in the forested landscape include other multiple-lane highways, major roadways, a water pipeline with open service areas, a railway line and vast areas of high-density, high-rise residential developments, and tarmacked car parks. Although the recently expanded surrounding urban landscape also includes a number of green spaces and parks, the manicured greenery have little semblance to the original tropical rainforests that retreated and got truncated because of the urban invasion. Being the highest hill on the island, the forest is not only seen as a much-desired place to live nearby, but also as a place for recreation and outdoor activities by the rising urban population living just a short walk away from it. As a result of the combined effect of rapid urban growth around the forest peripheries and the increasing interest in nature-based recreation among the urban population, the forest is undergoing inevitable changes, both at the boundaries and in the interior. From this perspective Bukit Timah represents the constant dynamic balance between demands of modern urban expansion and sincere conservation efforts to retain it both as a pristine forest as well as the 'Peoples' forest'.

4. Methodology

Inevitable pressure from growing urban development in a land-hungry country puts increasing pressure on the existing forest. Past development initiatives to make way for efficient infrastructure and functionality has had unintended effects on the very forest that has always been at the centre of conservation efforts. But some strategies are being taken to re-establish some of the previous environmental conditions, though many gaps exist. This chapter tries to methodically record the direct impacts of changes over time and also looks at the possibilities of improvements aimed at reinstating some of the original conditions.

To establish the current status and also to examine the dynamic changes the forest has been undergoing, several types of field data have been collected from boundary and interior forest areas over a period of four years and also developments in the surrounding areas and some environmental phenomena have been traced since the 1950s till present to (1) determine changes in landuse at and near the boundaries of the forest, (2) record changes in micro-climate over time in response to landuse changes, (3) record changes in the forest interior surface conditions due to over-use by visitors, and discuss the current ameliorating steps being taken to reinstate and reinvigorate forest trail conditions in the interiors.

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Landuse changes were followed through using landuse maps, topographic maps, as well as by ground surveys. Environmental data such as atmospheric temperature, relative humidity, soil surface temperature, light intensity, and wind velocity were measured in the forest interiors as well as at the forest boundaries, urban landuse at the fringe areas, along roads and railway line along the boundary of the forest, over six phases in four years for comparison of the changing values. Data obtained were plotted using GIS (Geographic Information Systems) to establish spatial patterns of the observed environmental factors over time. This is done to establish the changing responses of the forest interior and exteriors to the altered landscapes.

Forest interiors were also examined to quantify impact on the forest floor due to overuse by visitors. To quantify the impact of hiking and jogging activities on the forest trails a post-impact sampling framework was used and compared with undisturbed sections of the forest (as controls), to establish the degree of impact such excessive use has resulted in over time. Changes to bulk density and surface penetration resistance of forest floor and trail surfaces were measured and status of organic matter content on the same surfaces was determined using the LOI (Loss on ignition) method. These data are aimed at establishing the degree of changes forest interior environment has undergone, specifically due to heavy usage by residents from nearby residential areas.

The study also looked at the current initiatives that are being taken by BTNR forest management to correct some of the problems created due to past urban infrastructure development. The establishment of an eco-link is seen as a major initiative to re-establish the lost connectivity between BTNR and the CWC forest. The eco-link was opened in 2013. Vegetation along the link is still in a state of growth and faces the challenge of being re-established after a period of about 30 years of separation. But management initiatives are set to reinstate indigenous vegetation to facilitate connectivity between the two severed forests. The study will also look at the latest initiative of closing the very popular BTNR from public access to repair and reinstate the forest interior conditions. The closure, repair, and revitalisation of the forest interior conditions will take about two years when the trails will be repaired, improved to reduce visitor impact and increase safety, and in general allow the forest to recover from the prolonged and excessive exposure. The initiatives are seen as direct proactive step taken to ensure sustainability of BTNR as a functioning tropical rainforest, even as it serves as the much-needed nature retreat to the thousands of urban populace living nearby.

5. Data on changes around BTNR

5.1. Landuse change

The Bukit Timah forest prior to independence was part of the central forested zone, with some mixed scattered forests and small-scale orchards surrounding the main forest area [16]. Residential areas were mainly some low-rise bungalows and one single line railway line ran along one of the boundaries. The greatest impacting landuse were the granite quarries around the hill. But these, apart from the areas of actual extraction, did not have much impact on the main forest boundaries or the interiors. All this changed when the Bukit Timah Expressway (BKE) was constructed right through the heart of the central forest, creating a wide divisive landuse interruption. Several other roadworks followed in the wake of more development around the forest. In the 90s, the surrounding areas were cleared of the then-existing light food industries to give way to high-rise condominiums and public housing. A long water pipeline was already in place and with the new roads and buildings, the fragmented BTNR become an island forest, severed from the main forested zone. Figure 3 shows the pattern of landuse changes over time and also the current road and residential developments around BTNR. Though some peripheral areas were added to BTNR to create a buffer around the core forest of 75 ha, some segments of the forest still lie alarmingly close to main roads with heavy traffic, concrete covered surfaces of car parks and the entire forest of BTNR has become a small fragmented tropical rainforest island separated by a 'sea' of inhospitable non-forested landscape, unsuitable for many rainforest organisms. Truncation from the larger counterpart will have obvious effects of lack of migration of species and many more. The full effect of the fragmentation usually takes many decades to unfold, as the existing main canopy trees usually take long time to show the full impact. But when forest interiors are exposed to external ambient conditions, changes to the forest environment can be readily observed.

5.2. Environmental change

The forest interior and peripheral atmospheric conditions were monitored between 2011 and 2014. Data of atmospheric temperature and relative humidity were taken several times during this period from various locations within and outside the forest. Each data set was developed from data collected on the same day and same time frame (between 8 am and 9 am on the same day by several groups working simultaneously at different locations). The objective was to record the existing environmental condition, so that the differences between interior and exterior locations can be fairly compared. This was done to establish the environmental differences resulted from exposing former forested locations to non-forested landscapes. Environmental data were obtained from a total of 1,130 locations over the study period. Measurements for all environmental parameters were taken in six phases between February 2011 and June 2014, with December and February months coinciding with the slightly cooler and wetter months, while March and May corresponding to marginally drier and slightly warmer months. The actual number of measurement stations for all data are given in Table 1.

Year and month of measurement	Forest	Exterior	Total
February, 2011	47	35	82
February, 2012	100	100	200
May, 2012	200	240	440
March, 2013	52	50	102
December, 2013	190	21	211
June, 2014	35	60	95
Total	624	506	1130

Source: Author

Table 1. Number of measurement sites for each observation period.

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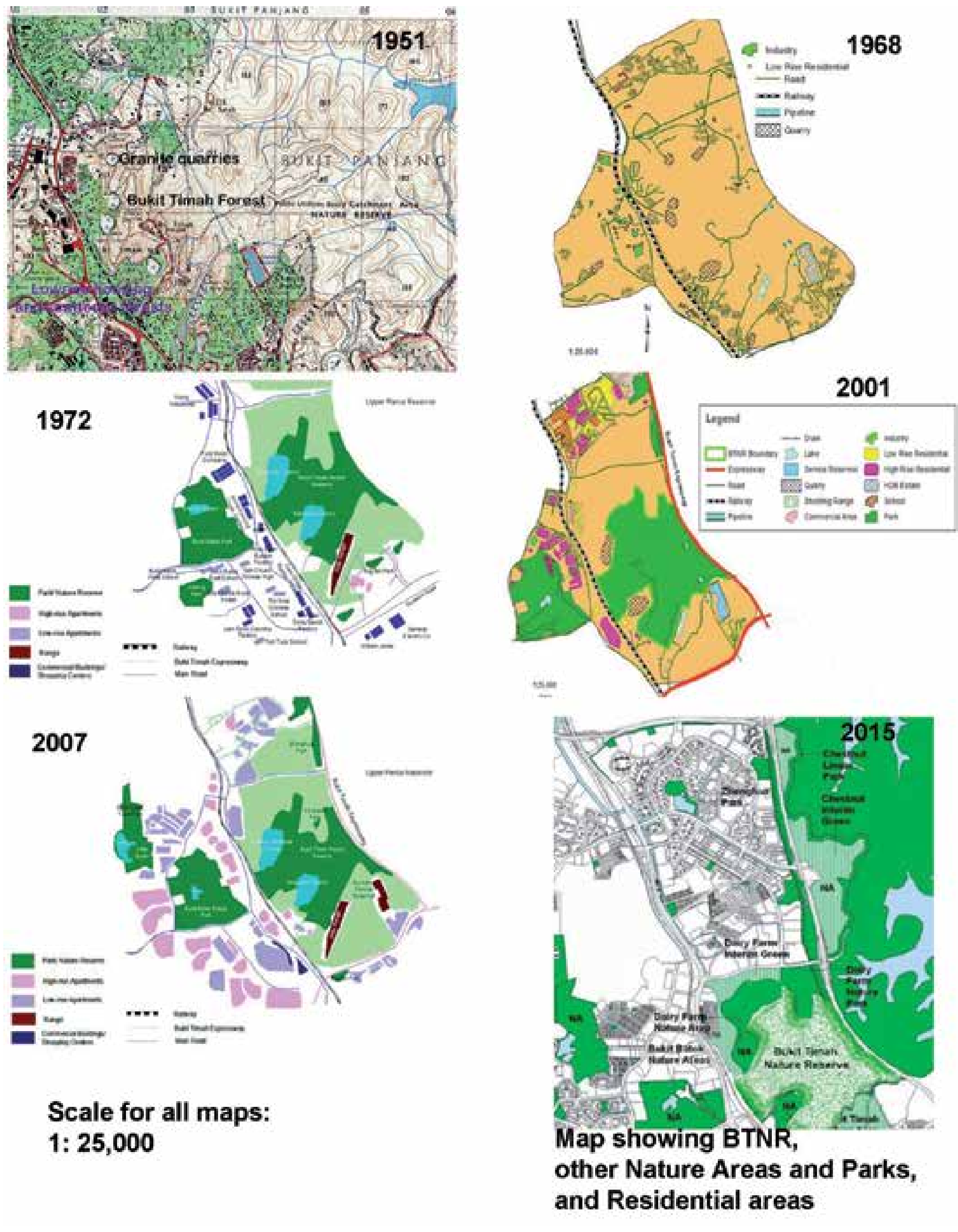


Source: Adapted from various sources and field surveys and created by Author

Figure 3. Landuse changes around BTNR from 1951–2015.

Table 2 shows the changes in the mean temperature records from a total of 1,130 locations within the study sites during the various phases of data collection.

	Year and month of measurement	Minimum		Maximum	
		Forest	Exterior	Forest	Exterior
Atmospheric Temperature (°C)	February, 2011	25.1	30.9	27.0	34.1
	February, 2012	26.6	28.8	29.5	35.5
	May, 2012	24.5	28.0	29.2	37.8
	March, 2013	25.7	29.0	29.7	34.7
	December, 2013	24.5	30.0	29.6	37.8
	June, 2014	26.5	31.5	27.0	34.1
	Mean	25.5	29.7	28.7	35.7

Source: Author

Table 2. Temperatures (°C) measured for forested and exterior locations.

Apart from atmospheric temperature, relative humidity was also measured from the same locations for both forested and exposed sections. Table 3 shows the values obtained from 1,130 study locations.

	Year and month of measurement	Minimum		Maximum	
		Forest	Exterior	Forest	Exterior
Relative Humidity (%)	February, 2011	88.0	74.2	96.3	89.5
	February, 2012	65.3	52.6	98.2	85.1
	May, 2012	70.7	57.0	94.1	88.5
	March, 2013	65.3	58.0	91.7	78.3
	December, 2013	88.9	78.0	95.6	87.1
	June, 2014	91.4	63.4	99.3	85.7
	Mean	78.2	63.9	95.9	85.7

Source: Author

Table 3. Relative humidity (%) for forested and exterior locations.

Soil temperature measurements were very much in line with the atmospheric temperature distributions across forested and non-forested sites and Table 4 gives the details of the values recorded over the five phases of monitoring.

While forest interiors are generally in shaded conditions, the forest fringes are exposed to too much sunlight, especially in tropical Singapore where days are long and sunshine is generally strong. Light conditions were recorded both inside the forest as well as in exterior zones with

	Year and month of measurement	Minimum		Maximum	
		Forest	Exterior	Forest	Exterior
Soil Temperature (°C)	February, 2011	24.3	27.0	26.8	31.1
	February, 2012	23.9	28.0	28.0	34.1
	May, 2012	23.6	32.5	27.0	34.0
	March, 2013	23.9	26.0	29.0	34.0
	December, 2013	23.5	26.4	27.5	33.5
	June, 2014	22.0	28.0	27.0	34.2
	Mean	23.5	27.98	27.6	33.5

Source: Author

Table 4. Surface soil temperature (°C) recorded at forested and exterior locations.

varying characteristics during the May 2012 and December 2013 surveys. Table 5 gives the results obtained from 651 locations and shows the differences observed.

Classification of Landcover	Locations of Measurement Sites	Light Intensity (Lux)
Forest interior	Forest trails	59–3,088
Fringe forest area	Old scattered forest buffer	322–1,113
	Jalan Asas (scattered forest with old fruit trees)	322–7,811
	Rifle Range Road (through forest cover)	1,113–14,332
Along roads and highways	Along minor roads: Rifle Range Road (open area)	1,398–105,770
	Along major roads: Dairy Farm Road	3,012–104,479
	Major highway (BKE)	104,479–135,710
Open car parks and condominiums	Open car parks	12,696–121,695
	Condominiums	3,433–110,074

Source: Author

Table 5. Light intensities (Lux) recorded inside BTNR and the peripheral areas.

Wind velocities recorded during the study did not reveal dramatic results, mainly as wind is usually an insignificant phenomenon in the humid tropics, except during storms. Most days are sultry, with little or no wind movement at all. In fact, many of the locations recorded less that 1 m/s wind velocity. However, the recorded wind velocity data shows spatial differences that coincide with exposed landscapes, with highest wind velocities recorded along open, major highways at the forest peripheries, as shown in Table 6.

Classification of Landcover	Locations of Measurement Sites	Maximum Recorded Wind Velocity (m/s) Taken on Sultry Days
Forest interior	Forest trails	0–1.8
Fringe forest area	Old scattered forest buffer	2.3
	Jalan Asas (scattered forest with old fruit trees)	2.5
	Rifle Range Road - through forest cover	2.3
Along roads and highways	Along minor roads: Rifle Range Road (open area)	3.0
	Along major roads: Dairy Farm Road	5.7
	Major highway (BKE)	5.3
Open car parks and condominiums	Open car parks	4.8
	Condominiums	3.6
Source: Author		

Table 6. Wind velocities recorded at different locations in and around BTNR.

6. Date analysis

6.1. Landuse change

There has been significant change in the landuse around BTNR since Singapore became independent. Figure 3 shows the landuse in 1951, with BTNR surrounded by scattered pineapple plantation, sundry minor cultivation, tall grass, and small rustic housing. There were a few food processing industries around the neighbouring areas, as well as five granite quarries at the boundary areas belonging to Singapore Granite Quarries and Hindhede Quarry. The Malayan Railway ran at the western verge of the forest. But overall, the peripheries were a low-density rural residential area with low impact on the neighboring forest, providing the buffer protection, with no large-scale disruption of the actual forest environment. Bukit Timah forest was, at that time, a part of the much bigger Central forest. After the 1990 demarcation of the area as a high-rise residential zone, the landscape was altered drastically. New roads, major highways, and cleared land for high density urban development changed the low impact quiet vicinity to one with heavy traffic, large-scale land clearance (Figure 4), and rapid construction work.

This large-scale development made the forest fringe retreat, moved heavy volumes of sediments, and generally established a wide area of non-forested landscape in the surrounding areas of BTNR, now a truncated forest from the larger hinterland forest of the CWC forest. With new residential buildings, new roads and car parks became a part of the landscape. Previously shaded scattered forest zones ceased to exist and the fringe areas now lie juxtaposed with the dense forests of BTNR. Bukit Timah forest lost its effective buffer zone. Some land

Source: Author

Figure 4. Large-scale land clearance and heavy construction work at the forest periphery. BTNR in the background.

was regained as the new buffer, creating a total area of 163 ha, though the interiors were only about 75 ha (Figure 3). The tussle between development and conservation of the forest drove high-density and high-cost land development at the edge of the forest where condominiums were constructed just next to the deep forest, providing much natural solace to the urban residents, but, introducing an invasive, intruding, and often interrupting influence on the forest characteristics (Figure 5).

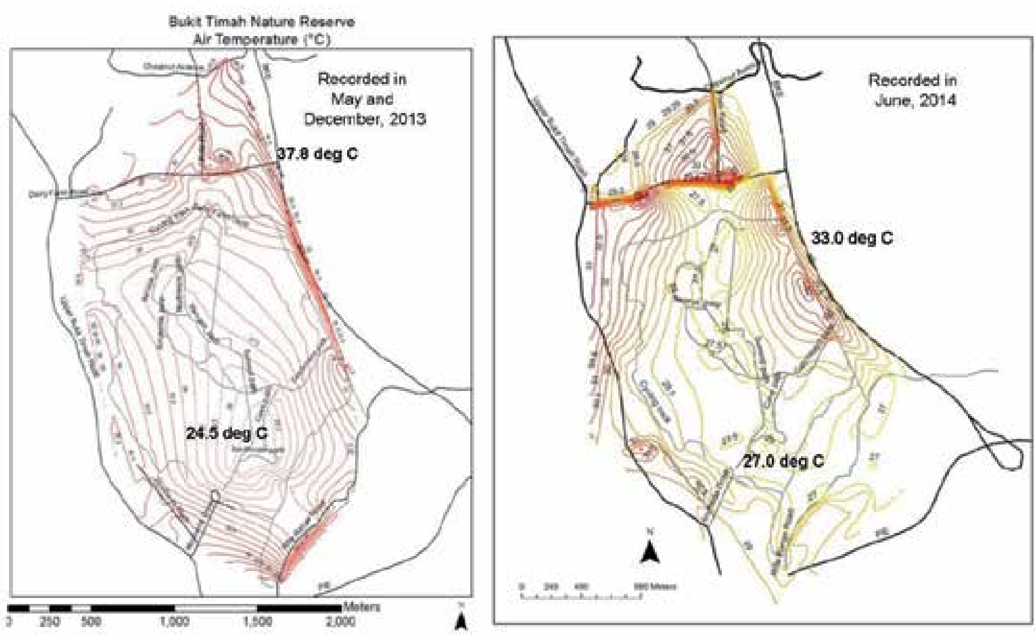
Source: Author

Figure 5. Residential and Infrastructural development less than 50-100m from the forest edge

By the 2000s, the area around BTNR changed permanently, with granite quarries no longer in operation, the railway shut down and given to a green corridor with naturally regenerating vegetation and replaced by clusters of high-rise buildings, car parks, wide roads all around, some less than 100 from the forest fringe. The areas around as well as the forest environment changed permanently. In 2015, there are 81 listed condominiums within a radius of 1–2 km from the forest edge and some new ones are coming up, less than 200 m from the Dairy Farm Road edge of the forest.

6.2. Temperature changes: Temperature distribution

Such large-scale alteration of landuse resulted in changes in the environmental conditions of the forest edge. Atmospheric conditions monitored, such as atmospheric temperature, relative humidity, and soil surface temperatures recorded over four years since the development established permanently, show distinguishable changes in all parameters. Figure 6 shows 8–12°C temperature differences between forest interiors and the peripheries, within a distance of only 1,000–1,500m from the road edges into the forest.



Source: Author

Figure 6. Temperature distribution in and around BTNR, as recorded in 2013 and June2014 (Minimum 24.5°C and Maximum 37.8°C)

Though temperature records were taken on discreet days, since there is only minor variation in monthly temperatures, it is significant to note that in all the six study periods, spanning different months of the year, the temperature of the forest interior and exterior areas maintained similar differences. The 2011 records showed a 9°C difference between the two, while overall, such ranges in temperature varied from 9–13°C, with mean differences of 10.3°C between the coolest and the warmest locations. Alarmingly, this temperature differences occur within distances of less than 300 m and in all records the highest temperatures are recorded along the verge of the forest skirting the main roads and highways (Figure 6). The worst rates of change in temperature are recorded at >4°C within 100 m at the BKE/BTNR, Dairy Farm/ BTNR, and Rifle Range Road/BTNR interfaces. The figure below (Figure 7) shows the pattern of temperature changes from the forest interior to the forest verge. The 300 m at the edge of the forest seem to experience the most drastic change in temperature, making this the 'edge forest' zone, and thus the most impacted belt.

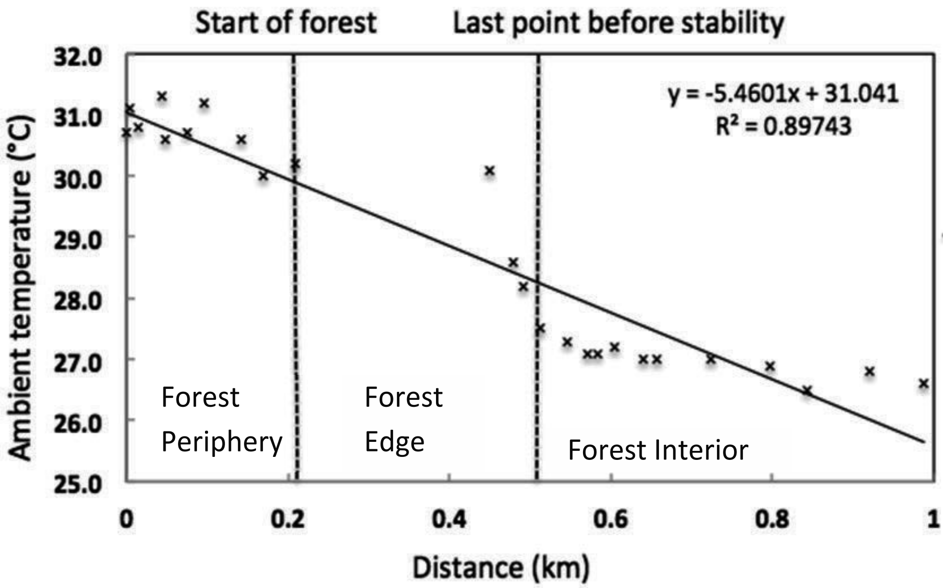


Figure 7. Pattern of temperature change from forest interior to forest periphery.

The temperature distribution recorded over four years around BTNR reveals that urban landscapes, such as major roads, highways, and the car parks adjacent to this major roads have the highest ambient temperatures, with some sites measuring more than 13°C higher than those of the forest interior. Temperature gradients at the forest buffer zones close to roads are considerably steeper. This is in line with previous research that showed that the road width is a significant factor in determining microclimate given the variance in road edge effect [17].

Table 7 shows the temperatures observed and the changes recorded along selected transects drawn across forested to open, exterior boundary areas. There is a mean increase in air temperature of 7.3°C from inside to outside the forest boundaries. Table 7 gives the rates of change along certain locations and it is evident that the sharpest change occurs along the boundary of the forest with the major highway (BKE), while rates of change are negligible across the interior forest sections. This exemplifies the drastic environmental gradients faced by forest peripheral areas when such drastic alterations are made due to urbanisation so close to forest boundaries.

	Forest Interior (FI) n=413	Forest Buffer (FB) n=211	Exterior (E) n=506	Transect I	Transect II	Transect III	Transect IV	Transect V
Maximum temperature (°C)	28	28.1	37.8	33.5	34	37.8	33.5	28
Minimum temperature (°C)	24.5	31	32.2	29.5	29	29	28.5	24.5
Range (°C)	Mean from IF to E = 7.3° C			4	5	8.8	5	3.5

Maximum, minimum, and range of temperature recorded across forest interior, forest buffer, and exterior locations.

Source: Author

Table 7. Temperature changes at the various BTNR study sites in forested and exterior locations.

Description

Temperature

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean: Lower Bound	95% Confidence Interval for Mean: Upper Bound	Minimum	Maximum
FI	107	26.0850	0.92255	0.08919	25.9082	26.2619	24.50	27.50
FB	107	29.0299	0.64064	0.06193	28.9071	29.1527	28.10	31.00
E	107	33.2776	1.00511	0.09717	33.0849	33.4702	32.20	37.80
Total	321	29.4642	3.08158	0.17200	29.1258	29.8026	24.50	37.80

ANOVA

Temperature

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2,797.951	2	1,398.976	1,847.434	0.000
Within Groups	240.807	318	0.757		
Total	3,038.758	320			

Source: Author

Table 8. ANOVA for temperatures recorded in the three categories of landcover: Forest Interior (FI), Forest Buffer (FB), and Exterior areas (E).

The highest temperature range of 4°C within a space of only 62 m is recorded across Transect I. The same trend is recorded along all road margins, indicating that steep environmental gradients are characteristic of areas exposed to highways and open concrete covered surfaces. Specifically, highways/wider roads and car park surfaces demonstrated significantly higher temperature gradients than narrower roads, and this is in line with previous research that showed that the road width is a significant factor in determining microclimate given the variance in road edge effect (Nyandwi, 2008).

Based on data recorded across the all types of landcovers, e.g., forest interior areas (FI), forest boundary buffer vegetated areas (FB), and the open exterior concrete-covered/metalled areas (OE), ANOVA tests are done and the results show very clearly that there is statistically significant difference (F=<.0005) among the three types of landcover in terms of temperatures recorded (Table 8). This is evident in raw data as well, as the highest temperatures recorded on car parks, construction sites, and roads show an increase of 9.3°C from the forest interiors and such increases are consistent around the entire forest boundary.

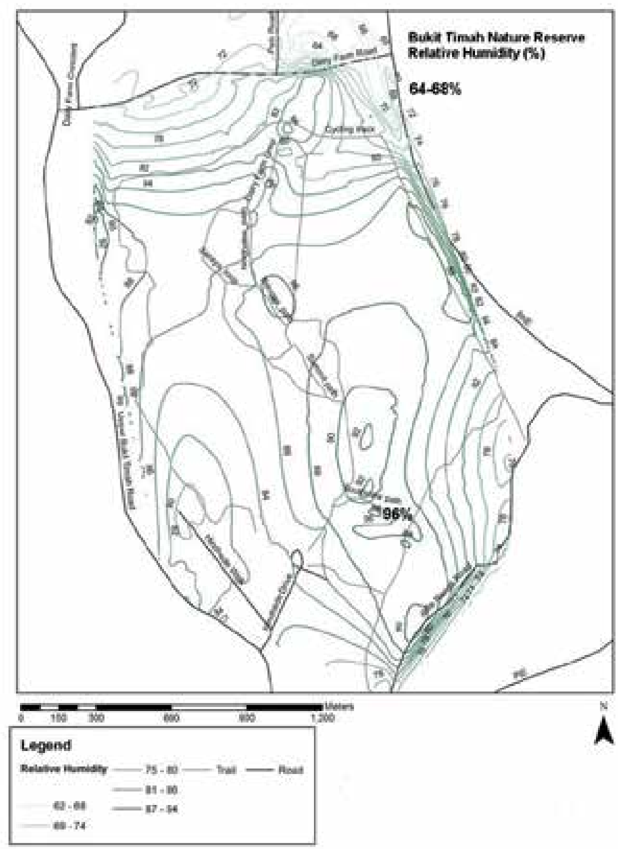
6.3. Relative humidity changes: Relative humidity distribution

Relative humidity (RH) values both inside and at the forest boundary areas were recorded at the same locations where atmospheric temperatures were measured. Figure 8 shows the isohume map of the BTNR area. Similar to the isotherm distribution, the isohume map also shows the forest interiors having the highest RH values (mean of 95.9%), while it dips to lows of 52.6% on some exterior sections of the study area, along expressways.

Similar to the patterns of temperature change, RH distribution in and around BTNR also clearly shows impact of landuse change. Rates of change are high along major roads, along the same sections that recorded high gradients of change in temperature. Along the more vegetated forest verges, such as along Jalan Asas, however, RH variations are gentle, indicating that even when not under characteristic forest cover, denser vegetation does provide adequate protection from desiccation from exposed direct sunlight.

6.4. Soil temperature changes: Soil temperature distribution

Soil surface temperatures recorded at the same sites as atmospheric temperatures and RH show close similarity in distribution pattern. Over the four years and six phases of recordings, forest interiors consistently returned low soil surface temperatures from the heavily shaded, damp forested interiors, with minimum temperatures going as low as 22°C, with a maximum of 27.6°C, while the exposed forest peripheries recorded soil temperatures as high as 33.5°C along open major roadsides along outside boundaries (Table 9). Figure 9 shows the distribution of soil temperatures that follow similar patterns as the distribution of atmospheric temperature. Although Pohlman [18] did not record a significant change in soil temperature with distance from the forest edge, the present study recorded a significant rise of more than 8°C from forest interior to the open forest edge (Table 4).



Source: Author

Figure 8. Distribution of RH in BTNR and surrounding areas

	Forest Interior (FI)	Forest Buffer (FB)	Exterior Areas (E)
Maximum Soil Temp (°C)	28.0	29	34.2
Minimum Soil Temp (°C)	22	26	26.0
Mean Soil Temp (°C)	25.5	27.9	30.7

Source: Author

Table 9. Soil temperatures (°C) recorded from various categories of landcover.

The steepest gradient of soil temperature change is seen along the open stretch of the BTNR boundary with the BKE. The rate of change of the soil surface temperature at this stretch of

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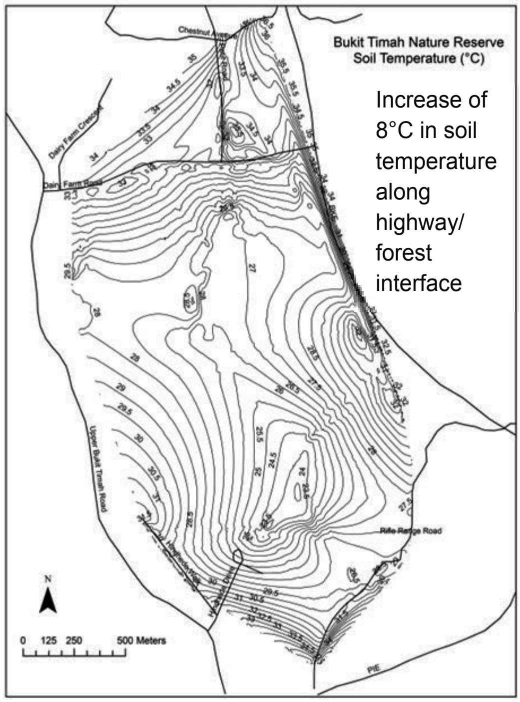


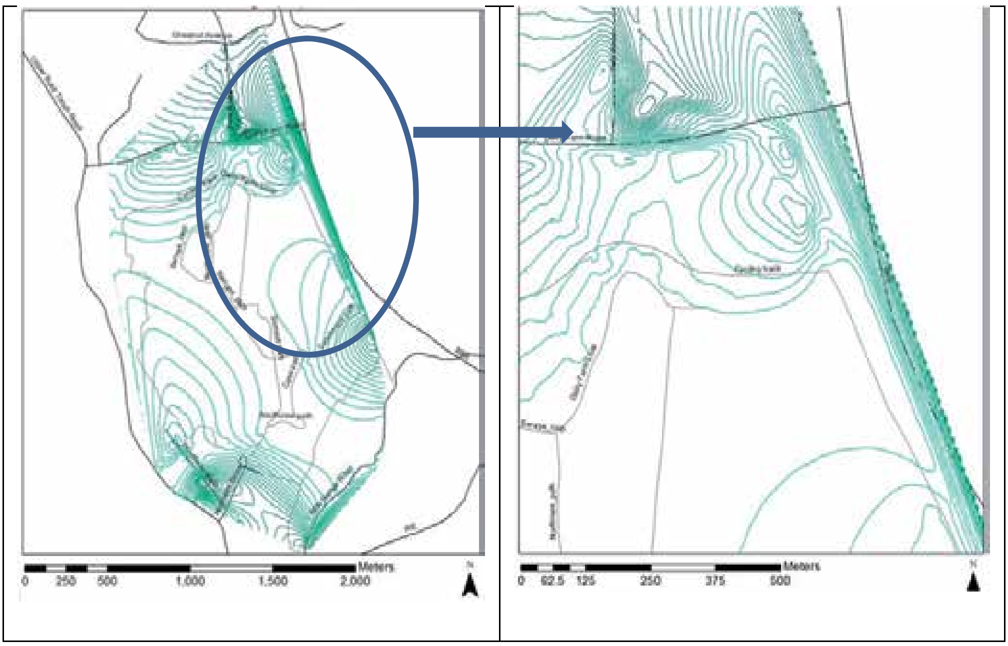
Source: Author

Figure 9. Distribution of soil temperature in and around BTNR.

open ground is 8°C within a distance of only 70 m, where the forest edge sharply interfaces with the open grasscover of the water pipeline service area, next to the highway. Records also show that the surface soil records slightly higher levels, even when full forest cover is not removed. The buffer forest areas showed slight increase in the soil temperatures, perhaps due to the thinner vegetation covers and higher exposure to sunlight.

6.5. Light intensity distribution

The interior sections of BTNR are characteristically in deep shaded conditions, with parts such as the Fern Valley and Jungle Fall in the southwest part of the deep forest being in perpetual dark and humid conditions. Small gaps do exist due to occasional treefalls, particularly on steep slopes [19], allowing some sunlight in. But on the whole, forest interiors exhibit low light conditions. Measurement of light intensities have yielded figures as low as 59 lux, with other parts of the forest recording a little over 1,000 lux (Figure 10). But the situation changes drastically at the highway verges of the forest, with readings as high as 135,710 lux, in full tropical overhead sunlight conditions. The map shows how the high light intensity zones are all along major roads, which is not unexpected. But the gradient of change from low to extremely high light exposures is very steep, with readings changing from a low of around 1,000 lux to the full extent of 120,000 lux occurs within a span of merely 100 m. This sudden change and the resultant exposure of forest vegetation are due to the open highways running too close to the forest peripheries. What is more interesting is that certain sections of the forest periphery, that have some scattered vegetation cover (e.g., Jalan Asas boundary at the western end) recorded low light intensity, merely because of the dense secondary vegetation cover that grew once the forest fringe was cleared. The gradient of change in this location is, therefore, not as steep, providing the inner forest enough protection from exposure.



Source: Author

Figure 10. Distribution of light intensities in and around BTNR.

6.6. Wind velocity distribution

While atmospheric temperature, RH, and soil temperature variations showed consistent patterns of distribution across the different landcovers, wind velocities recorded in and around forest areas did not return consistent results. Figure 11 shows the wind velocity distributions in and around BTNR.

Tropical rainforest areas characteristically do not show significant variations in wind velocities under normal conditions, except during sudden thunderstorms. So wind velocity measurements did not yield any consistent data. However, even in the low wind conditions of a normal sultry day, open stretches of major roads and highways along the forest verge, open car parks, and condominium sites at the periphery recorded wind velocities of 3.6–5.7 m/s. While such measurements are not significantly high, it shows how the forest segments along these exposed locations may be vulnerable to treefalls during frequent thunderstorms.

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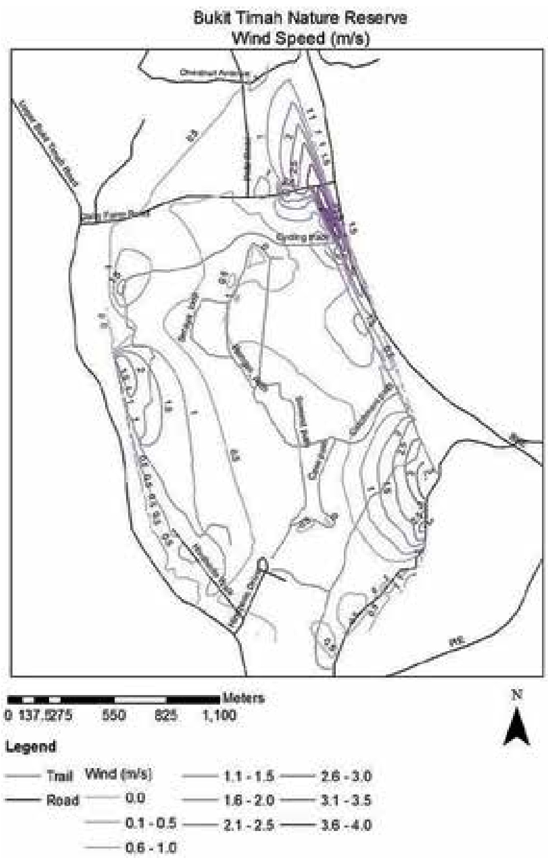

Source: Author

Figure 11. Distribution of wind velocity in and around BTNR

When all parametric values, except the irregular wind conditions, are compared, it becomes clear that the boundaries of BTNR skirting the major roads and highways are impacted heavily in all aspects, making the edge effects very significant.

Table 10 shows the drastic changes in temperature, RH, soil temperature, as well as light intensities within very short distances and the rates are alarming as this sudden change in such essential environmental conditions are bound to have long-term effects on the forest conditions.

It is significant to note that while changes are drastic along major disruptions, locations that have low impact development and some vegetation cover serve as buffer (Jalan Asas area shown below, Figure 12) record milder degrees of change.

This can be an important factor to note as future management of edge effects of the forest can perhaps be rolled out around such findings and buffer areas can be invigorated to provide adequate protection to the BTNR interiors.

Transcect Locations	Rates of Changes Observed (Change per 100 m Distance Across Transect)				Landuse Type
	Temperature (°C)	RH (%)	Soil Temperature (°C)	Light Intensity (Lux)	
At FI to BKE boundary	6.5	33	8.88	>160,000	Exterior (E)
At FI to Dairy Farm Road boundary	3.0	25	2.4	47,800	Exterior (E)
At Dairy Farm Road to paved carpark, construction site boundary	3.0	22.5	2.29	>160,000	Exterior (E)
At FI to Rifle Range Road boundary	3.0	7.5	2.1	21,800	Exterior (E)
At FI to Jalan Asas (vegetated) boundary	0.12	0	0.34	114	Forest Buffer (FB)
Inside Forest	0.02	0	0.1	100	Forest Interior (FI)

Source: Author

Table 10. Rates of change in environmental parameters at forest edges.

Source: Author

Figure 12. Vegetation cover in the buffer areas

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6.7. Impact of visitors on forest surface conditions

Apart from the physical impacts of rapid growth of urban landscape around the forest, residential developments close to the forest boundaries also provide a heavy visitor base to the forest. This sudden rise in the visitorship to the formerly unknown forest has resulted in significant changes to the original forest surface conditions. Changes to the forest interior have been documented by Chatterjea [2, 3, 20].

The forest at BTNR sees more than 400,000 visitors in any normal year, who visit the forest for 1–2 hours and who usually go there for exercise and relaxation. The visitors go through the many laid out forest trails, most of which have natural surfaces and steep slopes (Figure 13).

Source: Author

Figure 13. Visitors and the steep slopes inside BTNR

The systematic degradation of these trails and the resultant impact on the forest conditions due to overuse have been discussed in detail by Chatterjea [20, 21]. The main outcome of such degradation to the interior of the forest is the altered surface condition along the trails, which, due to the severe impact of the pounding by joggers, have become severely compacted. Surface penetration resistances have been measured along all trail surfaces over time and results are shown in Table 11. When compared with undisturbed forested slopes, trails show a staggering 3–15 times higher compaction.

Surface Penetration Resistance (from 600 locations)	Forest	Trail	Trail-side
Maximum Resistance (kPa)	965 .3	2,137.4	2,068.4
Minimum Resistance (kPa)	68.9	1,037.9	68.9
Mean Resistance (kPa)	419.2	1,238.8	912.0

Source: Author

Table 11. Surface penetration resistance, showing compaction of forest and trail sections.

Bulk density figures obtained from a total of 54 trails, trail-side, and forest surfaces along six trails inside BTNR show comparable results and these are shown in Table 12.

Surface type	Bulk Density (g/cm³)	
Forest (n=18)	Maximum:	1.16
	Minimum:	0.60
Trail-side (n=18)	Maximum:	1.45
	Minimum:	1.24
Trail (n=18)	Maximum:	2.38
	Minimum:	1.78

Source: Author

Table 12. Bulk density measured along undisturbed forest, trail-side, and trail slopes.

Bulk density data showing a two to three times increase in density on forest trail soils support the findings of the surface resistance values obtained from similar surface classes, indicating that the trails are several magnitudes higher in surface compaction. As a result of such heavy compaction, trail surfaces often generate surfacewash during the many rainstorm events, generating fast-flowing flows that are potentially erosive. Chatterjea [19, 22] mentioned that such generated surfacewash, though at places restricted by the surface roughness, can be highly damaging to the forest environment, washing off much important soil nutrients and thus negatively impacting the forest biological environment. Figure 14 shows some examples of heavily degraded trails that recorded extreme penetration resistance and thus heavy compaction.

Due to excessive compaction, as shown in the surface penetration data, many trails go beyond repair, disallowing any root penetration even after being left unused for some length of time. It is alarming to record increasing penetration resistance values on trail-sides. These tracts running along the designated trails are initially covered often with indigenous ground vegetation, young saplings, and fresh leaf litter, a major source of nutrients to the forest vegetation. With very high human traffic on the trails, visitors tend to go beyond the designated trails, compacting what was originally beyond the designated trail surfaces. This problem is exaggerated during heavy rains when the trails, with their compacted surfaces, are sites of

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Source: Author

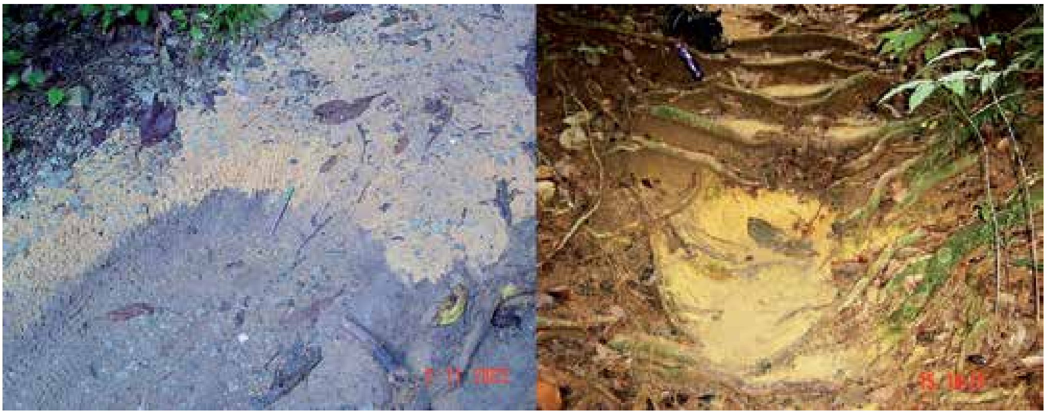
Figure 14. One of the many heavily compacted trails inside BTNR

heavy surfacewash. Top surfaces get muddy and subsequently the slippery surfaces are avoided by the joggers who tend to use the trailsides, thus impacting these the same way (Figure 15).

Source: Author

Figure 15. Trail conditions during heavy storms, with bike marks and surface wash (Note the surface wash on the left)

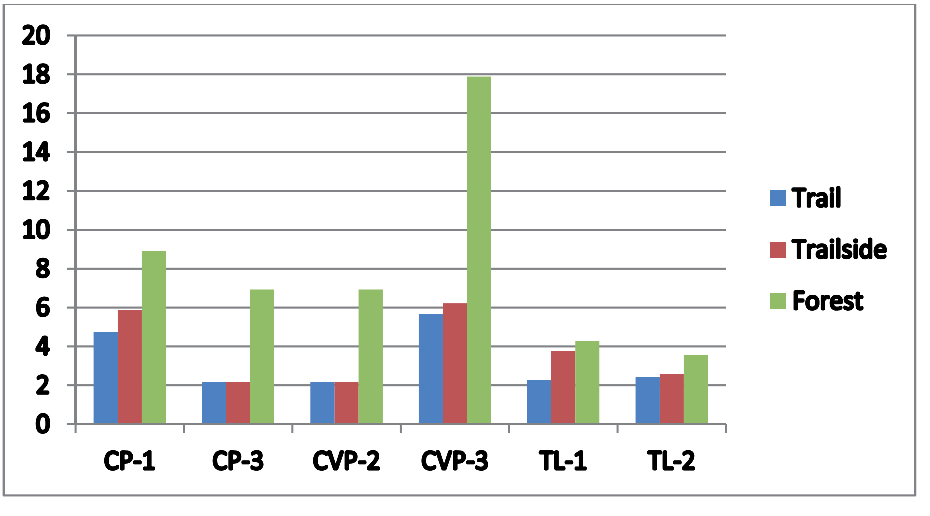
This leads to the widening of the existing trails. Generation of strong surfacewash during rainstorms washes off the much-precious top soil. Figure 16 shows how surfacewash results in topsoil loss, which can affect vegetation regeneration as the soil nutrients are lost, thus affecting growth of forest vegetation.



Source: Author

Figure 16. Trail sections with top soil removed through erosion

The amount of organic matter in soils from undisturbed forested slopes, as well as from trail surfaces was measured using the LOI method. Figure 17 shows that organic matter is reduced significantly in soils on trails. This can be attributed to loss by surfacewash, as well as reduced micro-organism activity within the highly compacted trail soil.

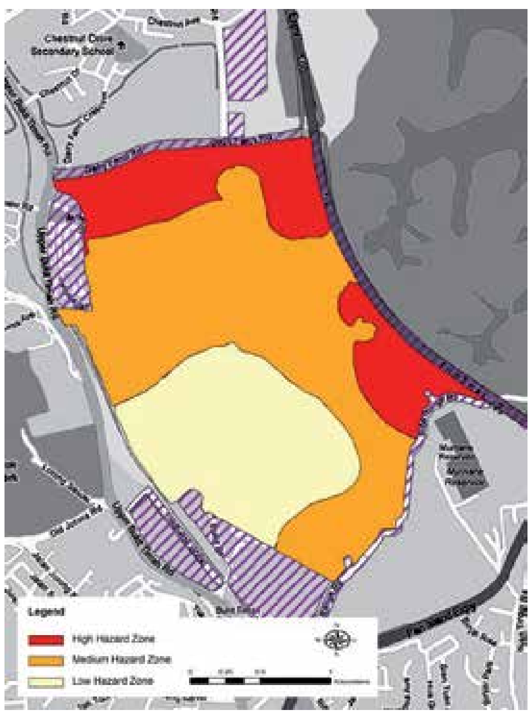


Source: Author

Figure 17. Percent organic matter in surface soils along trails, trail-sides, and on undisturbed forest slopes (CP, CVP, TL are trail names).

7. Management of current conditions at BTNR

During the early years of BTNR as a reserve forest, it was hardly known to the public. There was no formal entrance, no car park or any other amenities to cater to people as it hardly had visitors, except a few researchers and some avid nature lovers. But the situation changed with the landuse alterations in the surrounding areas and with the growing resident population in the many condominiums around. Today, BTNR is a favourite destination for the nearby residents, mostly as the steep slopes provide a rugged topography for outdoor exercise in trying conditions. Surveys done by Chatterjea [2] revealed that 89% of the people went there for exercise, while only 11% went for nature watch. Most went to the trails, which is reflected in the soil compaction results. Degraded trails, as reported by Chatterjea [3], a general thinning of BTNR vegetation [15], the transport disruption by construction of BKE leading to fragmentation of BTNR, the fast-growing residential development around BTNR were some of the many concerns that had counter-effect on the forest that was tagged as Singapore's most prominent conservation icon.

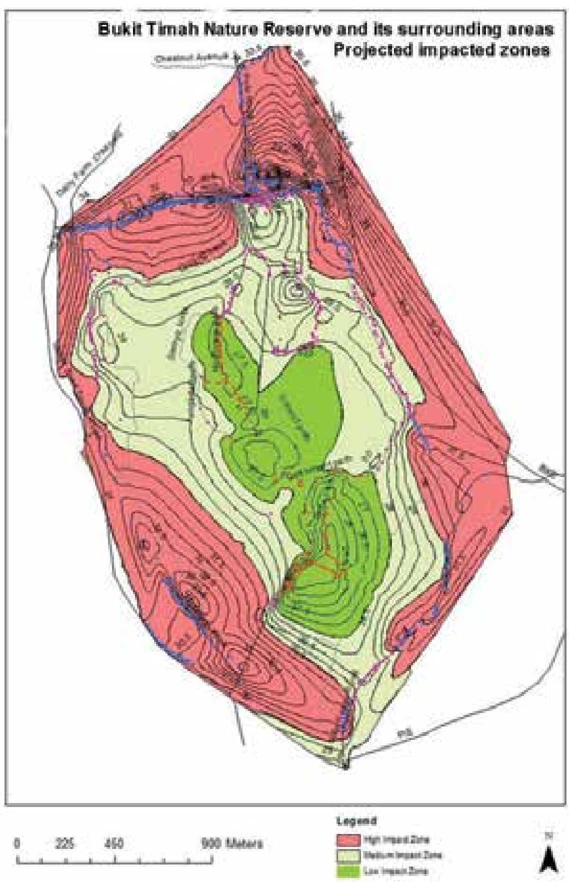


Source: Author

Figure 18. Map showing impacted areas in and around BTNR

If data on atmospheric and soil temperature increase and RH decreases along the forest peripheries are taken into account and superimposed, certain areas can be clearly demarcated as being the most impacted. These will all be along major highways (BKE and Dairy Farm Road). Based on the steep gradients of temperature change along these locations, a spatial zoning can be suggested, indicating the most impacted, and thus the most hazardous areas in the BTNR forest. Figure 18 shows such areas of high hazard, medium hazard and low/no hazard areas.

If the collected field information can be used to draw a possible scenerio for the future trends of forest condition at BTNR, locations of significant edge effects that might have high impact on the forest interior conditions can be demarcated, making these boundary areas hazardous for the sustainability of the forest. Figure 19, based on range of changes of all parameters, shows that the outer boundaries may be extending beyond mere 100 meters, well into the forest. This will, in time have negative impact on the forest interiors, posing concens for the sustainability of the forest, unless some measures are taken to enhance the buffer effect of the boundary areas.



Source: Adapted from Chatterjea [16]

Figure 19. Map showing combined effect of all environmental changes and possible impacted areas within BTNR forest interior

Some initiatives have been taken since 2000 to provide a buffer zone to the forest interior and land was added to the original 75 ha forest to provide some buffer against encroaching urban landuse. But the problem still remained with BKE posing a threat to any possible migration of species across from BTNR to the CWC forest. The increasing number of visitors was the other problem plaguing the forest interiors. In response to these multifaceted problems, the National Parks Board put up a two-pronged management initiative. The first initiative was to construct an eco-corridor across the BKE in an effort to re-establish an eco-link between BTNR and the larger forest at CWC, hoping to re-establish some faunal and eventually some floral establishment between the two initially connected, but subsequently separated forested landscape (Figure 20).

(Photos by courtesy of National Parks Board, Singapore)

Figure 20. The Eco-Link @ BTNR, showing gradual establishment of vegetation cover

The Eco-Link @BTNR was designed to make a safe and easy passageway for ground-moving animals such as pangolins, civet cats among others, and also the long-tailed macaques. The link was established in 2013 and is now in the process of being vegetated with indigenous species to provide natural protection to the resident animals. Figure 20 shows the Eco-Link in two phases, signifying an effort to correct the environmental mistake that had earlier fragmented BTNR. It is not easy to establish if this effort will have any sustainable, positive effect on the forest conditions or whether BTNR will be in a better state because of this corridor. But surely, it shows the conservation efforts and also the zeal to correct past environmental mistakes.

The second initiative, however, is aimed at more definite outcomes, to re-invigorate the forest interior, to re-establish much of the lost forest conditions, while keeping the streams of people satisfied with their daily dose of exposure to BTNR's rugged environment. The forest trails, in their highly degraded conditions, had become dangerously hazardous. So the forest management closed the forest for two years, starting September 2014, to correct the slope disturbances, construct boardwalks over badly damaged trails, reorganising trail locations on gentler slopes, creating trail protection, particularly at the sides, to avoid trail extension, constructing wooden steps over exposed roots to reduce or stop damage to forest vegetation, and generally re-establishing a natural condition that will, in the future, reduce impact on the forest while complying with the heavy demand by the urban visitors. It is expected that with no trampling of the trails in these two years, some of the trails will revive some vegetation cover and regain the soil structure of a characteristic forest surface. If the number of visitors can be controlled and if some of the peripheral forest areas opened for public use can ease the pressure on BTNR, it will help in creating a more sustainable condition for BTNR.

8. Conclusion

Judging from the records shown in Table 10, the heavily impacted locations can be managed with proactive management to reduce the impacts, as found in Jalan Asas boundary. That will provide effective buffer protection to the forest interiors, at least to retain the forest interior environmental conditions. Thus, it might be wise to establish a legally protected buffer zone to effectively protect the forest interiors, without compromising too much on development.

Urban greening is not unknown to Singapore and already there is an active initiative in creating urban forest tracts around both BTNR and CWC, to provide the urban population places for recreation under forest cover. Examples of such are Bukit Batok Nature Park, Hindhede Nature Park, and the new and upcoming Windsor Green Park, where areas surrounding the BTNR and the CWC forests are being deliberately developed and tended to provide forest environment for the increasing appetite of people for outdoor activities. The recently decommissioned railway line running along one edge of BTNR and demarcating that linear land as a green corridor is a positive action towards creating a green buffer and keeping development at bay at the strategic boundary zone. All these initiatives are in line with the requirements that may save the forest at BTNR from being overexposed and overused. Currently, the forest is closed to visitors for about two years. This time will be given for the forest interiors to get revived, with no trampling of trail surfaces. Once the forest is reopened, trails that were marked as heavily impacted and thus hazardous [3] will have boardwalks on some difficult sections so that future trampling will not pose as serious a threat as before.

Bukit Timah forest, being the only surviving primary rainforest in Singapore, is a very important part of the greenscape of Singapore. Due to the conservation efforts, it has been possible to retain some of its natural richness, though it is increasingly under threat. But the current emphasis on its conservation through positive steps at ameliorating some problems is in the right direction to protect this natural heritage of Singapore.

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Japanese Forestation Policies During the 20 Years Following World War II

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Additional information is available at the end of the chapter

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Abstract

During World War II, the area cut annually in Japan exceeded the area planted, and cutover land was common. Within approximately 10 years of the end of the war, however, forestation on cutover land was almost complete. In the 10 years that followed, forestation policies targeted increasing coniferous tree plantations to secure industrial roundwood. Forestation plans and legal systems were developed, and organizations such as the Prefectural Forestry Corporations and Forest Development Corporation were founded to promote the planting of coniferous trees. As a result, approximately 10 million ha of coniferous plantations now exist, roughly 40% of the total forested area, and the area has a growing stock of 3.0 billion m^3. However, some problems resulted from forestation policies. As coniferous trees were planted intensively over a short period of time, the forest age structures became unequal. Many forests have now reached an age class that requires thinning, but the percentage of forests that have been thinned remains insufficient. In addition, all Prefectural Forestry Corporations are now facing serious financial difficulties. Statistics on plantation forests must be improved to create effective management plans, including new reforestation policies.

Keywords: Cutover land, coniferous forest expansion policy, profit-sharing forest, Prefectural Forestry Corporations, plantation forest statistics

1. Introduction

Approximately two-thirds of Japanese land is covered by forests. Since traditional houses were built with wood, and fuelwood was utilized throughout the country, tree planting activities began early. Forest resource control policies were enacted in Japan during the Edo Era (1603–1868) when the feudal domain system (*han*) was developed. Some of the *hans* attached high value to protecting the increase in forest resources, including forestation policies[1]. Shioya classified the planting activities during the Edo Period into six categories: coercive planting by the seigniory, planting as a criminal punishment, voluntary planting for *han*, planting partially covered by the *han* fund, profit-sharing planting, and privately conducted planting [1]. Various types of planting activities were developed during the Edo Period.

After the Meiji Restoration in 1868, the *han* feudal domain system ended, and the forest resource regulations, which were enacted under the feudal system, were deregulated in 1871. In addition, the demand for forest products increased at the beginning of the Meiji Era (1868-1912). Thus, several problems regarding forest resources emerged. In 1897, the first *Forest Act* (Act No. 46 of 1897) was enacted, the main contents of which were a forest protection system and supervision of forest management. The main forest policy focused on forest management of land owned by the government during the Meiji Era; the *National Forest Act* (Act No. 85 of 1899), the *Act on Special Account for Forest Fund of National Forest* (Act No. 85 of 1899), and the *Ordinance on Management Plan of National Forest* (Instruction No. 42, Ministry of Agriculture and Commerce) were enacted in 1899. Using the special account, preparing a forest plan, measuring forested land, forestation, and new plantations on wild lands had been promoted in the national forest until 1921.

Although the forestation policy for non-national forests was not very comprehensive before World War II, it was composed of the following acts and ordinances [1]. In 1907, the *Ordinance on Promotion of Planting* was defined, and planting trees for military and export use was promoted by subsidy. The *Ordinance on Promotion of Planting in Public Forest* (1910) and the *Act on Planting in Public Forest by Government* (Act No. 7 of 1920) were defined and forestation policies for public forests commenced. The *Ordinance on Subsidy for Planting for Watershed Protection Forest* was created in 1927, and the *Ordinance on Promotion of Planting* for general non-national forests was prepared in 1929, which was the beginning of the current system of subsidies for planting in non-national forests. Some forestation policies were introduced during World War II, but the results were generally poor because of overcutting during wartime and the lack of a budget for subsidies for forestation.

The total volume of domestic forest resources decreased in Japan around World War II, which was exacerbated by several severe meteorological events that occurred in Japan at that time. Many of the cutover areas were planted in approximately 10 years after the end of the war. In the 10 years that followed, the main target of forestation policies changed from planting on cutover lands to increasing the area of plantations with coniferous trees such as Japanese cedar (*Cryptomeria japonica*) and Japanese cypress (*Chamaecyparis obtusa*). Legal systems were developed and organizations for planting were founded in order to promote the planting of coniferous trees. This article address the forestation policies and their background in the 20 years following World War II, during which the major issues were the cutover land problem, promoting the planting of coniferous trees, and the promotion of profit-sharing plantations. The current forestation policies on the problems resulting from the postwar intensive planting are referred to in the Discussion.

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1 For English literature on Japanese forestation in Edo Period, see [36].

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Forestation policies[2] are among the most important forestry policies. Reforestation after cutting as well as new planting of past cutover lands and wild land constitute important part of the policies aimed at increasing forest resources. In particular, in order to recover heavy damage to forest resources over a short period of time, one of the important forestation policies is to make a contingency plan and conduct it, including development of a necessary legal system. In this respect, there must be a significant value in analyzing the Japanese experiences during the 20 years following World War II.

2. Methods

The forestation problems, policies, and background of such during the 1940s and 1950s will be clarified using the literature and data, most of which are in government documents and statistics. Several documents of the Bureau of Natural Resource Section of the General Headquarters of the Allied Forces (GHQ), which occupied Japan during 1945-1952, were also used. The three major forestation policies, i.e., planting trees on cutover land, expanding the afforestation, and profit-sharing forestation, will be the focus here. The quantitative aspects of these policies will be discussed using national-level statistics. The current forestation problems caused by the forestation policies during the 20 years following World War II will be explained, and the problems with the forestation policies at that time will be discussed.

While forestation policies are also related to several forestry practices, such as nursery stocks and breeding, we will consider the policies directly related to planting trees. Thus, although the subsidy programs and public-financing systems are generally important on a practical level, they are not covered here. Postwar forestation policy has been conducted in a close relationship with the forest road system in Japan, but references to forest road policies will be minimal for the same reason. The main focus of this article is non-national forests[3], which constitute approximately 70% of the total forested area in Japan.

Traditionally, *cho* and *koku* were utilized as units of area and volume in Japan. The original statistical data were converted to ha and m^3, with the following conversion rates: 1 *cho* = 0.99174 ha and 1 *koku* = 0.2783 m^3. Thus, the approximate planning figures on forestation area or forest product supply and demand include broken numbers in ha or m^3.

3. Issues related to forestation

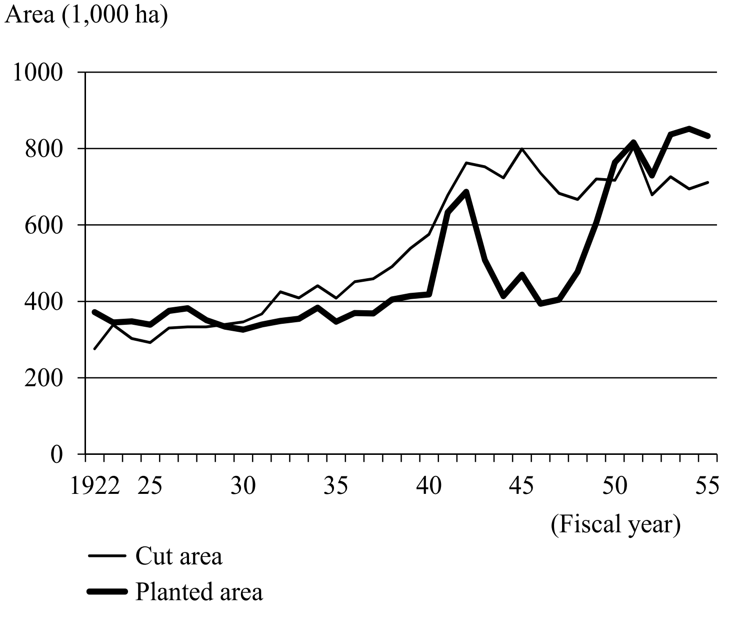
3.1. Divergence between cutting areas and forestation areas

Japan imported forest products before World War II; however, since the start of the war, importation had been generally difficult. The demand for forest products increased during

2 For English literature on Japanese forestation policies after World War II, see [37–38].

3 Forests are divided into three categories in Japan, classified by ownership: national forest, public forest (owned by local governments and so on), and private forest. Non-national forest includes public and private forests.

wartime. Figure 1 shows the cutting and forestation areas in the whole of Japan between 1922 and 1955. In this figure, the cut area includes all kinds of cutting methods, such as clear-cutting and selection cutting, and the forested area is the total planted forest and natural regeneration; thus, the difference between the cut and planted areas is not always the cutover land. However, the cut area was clearly greater than the planted area around 1945. Notably, the divergence between cut and planted areas had begun in the 1930s, when there was a worldwide recession; thus, the economic conditions of many farmers worsened and some cut their trees without following reforestation [2].



Source: [3, 4]
Note: Cut area is the total area cut using all kinds of cutting methods, including clear-cutting, selected cutting, shelter-wood cutting, and final cutting of fuelwood forest, composite forest, bamboo forest, and other types of forest.

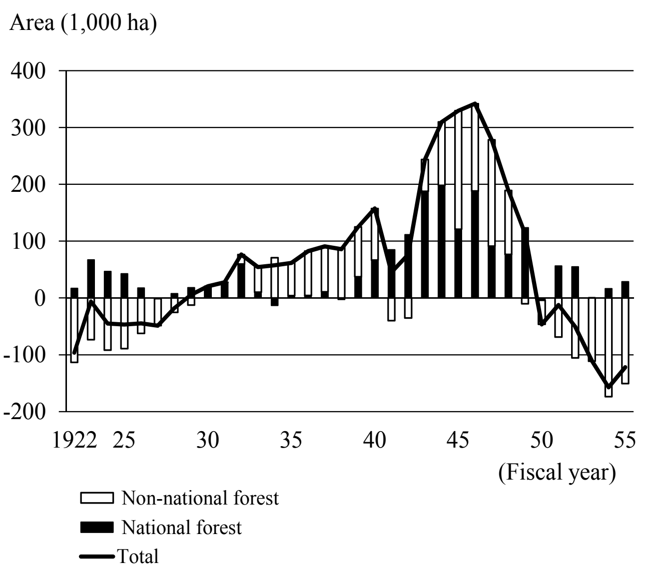
Figure 1. Cut and planted areas.

The cut area had almost doubled by 1940 from that before the war, and the planted area almost doubled in the 1950s. Thus, in the 1940s, forestation activities did not catch up with a rapid increase in cut area. The planted area temporarily increased in 1941 and 1942 owing to a sufficient national budget for forestation programs associated with a national ceremony[4]. Then, the amount of planted area decreased again, mainly due to the lack of a labor force in the farming and mountain villages [5]. Additionally, the planted area remained low during the inflationary period just after the war ended in 1945, and Nihon Ringyo Gijyutsu Kyokai reported nine reasons for this, as follows: lack of planting motivation due to economic

4 In 1940, the Kigen 2600-years Memorial Event was conducted, and planting activities continued with public cooperation across the country [10].

instability, rapid increase in planting costs, anxiety over forest ownership in relation to the agricultural land reform, cultivation problems, lack of nursery trees, lack of labor and related materials, lack of food, lack of money, and the forest tax [2].

The cut area was larger than the planted area during 1929-1949. The excess-cut area (subtracting planted area from cut area) is shown in Figure 2, where the national and non-national forests are divided. The line in the figure is the excess-cut area. Excess cutting occurred in national and non-national forests. The total annual excess-cut area during 1922-1955 was 2.79 million ha, including 1.44 million ha of national forests and 1.36 million ha of non-national forests. Excess cutting occurred earlier in non-national forests, and it occurred in national forests mainly around 1945. Excess-cut areas have disappeared in non-national forests since 1950 due to governmental forestation policies.



Source: [3, 4]
Note: Data was calculated by subtracting the planted area from the cut area.

Figure 2. Annual gap between cut and planted areas.

3.2. Large area of cutover land

Large areas of cutover land emerged throughout Japan around World War II, when annual cut area exceeded annual planted area, reaching approximately 1.49 million ha, including national and non-national forests[5] at the end of 1948 [2]. This area represented approximately 6% of the total forest area of Japan. In particular, trees in optimum locations tended to be cut, and the ratio of cutover land was generally highest in forests near villages. Several severe

5 This estimate includes all cutover land (1.38 million ha) and any other land necessary for planting, such as treeless land, forests with a small number of trees, or wild land.

typhoons damaged these areas, and there were growing concerns about forestation. Planting of trees on cutover land at the earliest possible opportunity was the starting point of the postwar forestation policies in Japan.

The largest segment that needed forestation was that of non-national forests. The Forestry Agency announced that the cutover land area totaled 1.71 million ha, including national forests (0.31 million ha), non-national forests (1.36 million ha), and public forests where forestation was planned by the government (0.04 million ha) [6]. The breakdown for non-national forests is shown in Table 1 [6]. The percentage of forested area that needed to be forested was 8.1% of the entire country, but the percentage had area differences, which were >10% in Hokkaido and Cyugoku. There is almost no difference by holding size for private forests. Notably, the percentage of forested area that needed to be forested was high at the time, regardless of area, ownership, and holding size.

			Total forest area (A) (1,000 ha)	**Forest area necessary for forestation (B) (1,000 ha)**	**Ratio (B) / Total (%)**	**Ratio (B) / (A) (%)**
Area	Hokkaido		1,981	235	17.2	11.9
	Tohoku		2,504	183	13.4	7.3
	Kanto		1,150	77	5.7	6.7
	Koshinetsu		2,421	129	9.5	5.3
	Tokai		1,750	94	6.9	5.4
	Kinki		1,724	170	12.5	9.9
	Cyugoku		2,148	235	17.2	10.9
	Shikoku		1,226	84	6.1	6.8
	Kyusyu		2,026	157	11.5	7.7
	Total		16,931	1,364	100.0	8.1
Ownership	Prefectural forest		914	49	3.6	5.3
	Municipal forest		3,217	324	23.7	10.1
	Private forest	less than 1 *cho*	1,938	152	11.2	7.9
		1-5 *cho*	3,249	245	18.0	7.5
		5-20 *cho*	3,122	260	19.1	8.3
		20-50 *cho*	1,557	130	9.5	8.3
		50 *cho* and over	2,934	204	15.0	7.0
		Subtotal	12,799	992	72.7	7.7
	Total		16,931	1,364	100.0	8.1

Source: [6]

Note: 1 *cho* = 0.99174 ha

Table 1. Forest area in non-national forests that needed to be forested (fiscal 1948).

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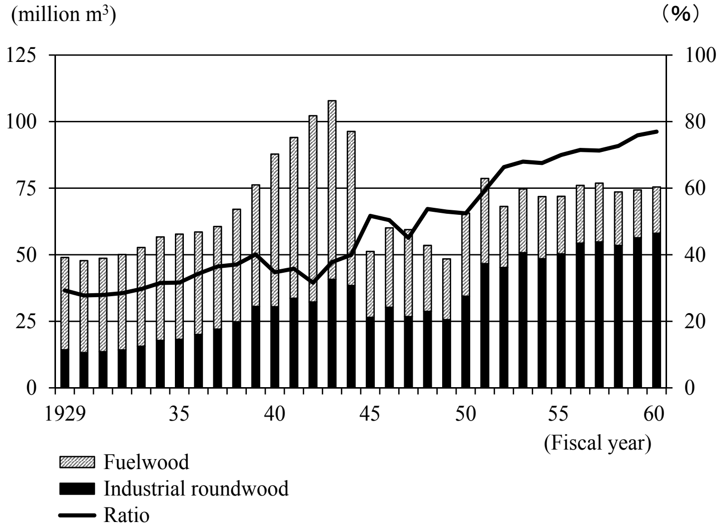
3.3. Divergence between cut volume and growth

Cut volume increased rapidly during the 1930s and 1940s when the cut area was larger than the planted area. The annual cut volume after 1929 is shown in Figure 3. The increase in cut volume during wartime was evident. Cut volume decreased briefly during the latter half of the 1940s. The percentage of industrial roundwood cut volume of the total cut volume tended to increase during the 1930s-1950s.

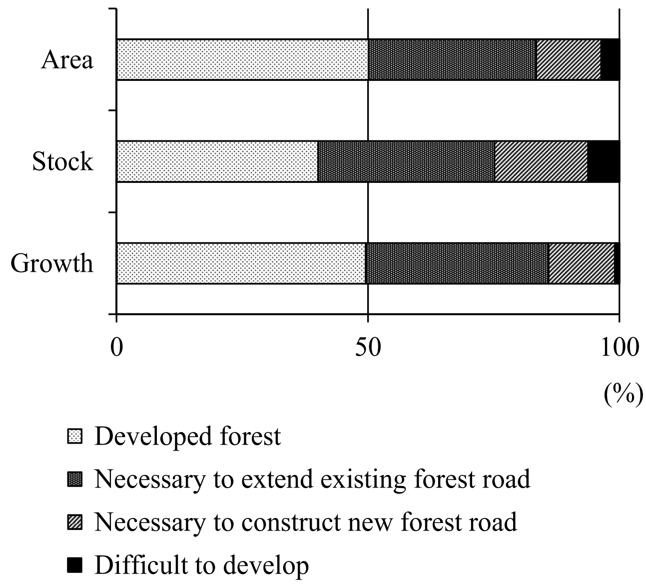
An important comparison is between annual cut volume and annual growth. The data on stock and growth at the time need to be assessed for accuracy because the evaluation was conducted over a short period and under serious financial constraints. In this sense, the growth data provide a sort of reference. Based on the forest resources summary table (1951 for non-national forests and April 1952 for national forests), the growth of coniferous trees was 22.8 million m^3, that of broadleaved trees was 23.9 million m^3, and the total was 46.8 million m^3 in the beginning of 1950s [7]. Growth during the first half of the 1940s, when cut volume was approximately 100 million m^3, is unknown, however, based on the growth in the early 1950s, it is certain that cut volume was larger than growth.



Source: [7, 8]

Figure 3. Cut volume and percentage of industrial roundwood.

A comparison between cut volume of industrial roundwood and growth of coniferous trees would be appropriate, as most industrial roundwood have originated from coniferous trees in Japan. The cut volume for industrial roundwood was at a minimum in 1949 at 25.7 million m^3, but this minimum figure was more than the annual growth of coniferous trees in the whole of Japan at that time. Considering the accessibility, the coniferous forest resource actually available was even smaller. The Forestry Agency estimated the industrial roundwood forest resource, classified by accessibility, in December 1950 [7]. The Forestry Agency divided forests



Source: [7]
Note: As of December 15, 1950.

Figure 4. Area, stock, and growth of coniferous forests.

for industrial roundwood into four categories based on accessibility, and the percentage of each category for area, stock, and growth are shown in Figure 4. In this estimate, approximately half of the growth was available. Therefore, the divergence between cut volume and growth of industrial roundwood was high at that time.

3.4. The dearth of domestic wood crisis

A potential dearth of domestic forest resources was a serious concern following the war due to the long-term forest practices of cut volume exceeding growth, delayed planting after clear-cutting, and the increase in wood demand. Huge amounts of wood were necessary to construct buildings, including wood houses, and to conduct civil engineering projects for war damage reconstruction. The potential dearth of domestic wood was predicted by several reports as follows.

In 1950, the GHQ of the Allied Forces reported that industrial roundwood would be exhausted within 15 years [9]. Another study by the GHQ noted that coniferous wood would be exhausted within 20 years[6] under the following conditions: available coniferous tree resources of 318 million m^3 on a log basis at the end of 1947, and the growth rate of 2%7.

Nihon Ringyo Gijyutsu Kyokai announced in a domestic report[7] that wood stock would be exhausted in 33 years under the following conditions[8]: available stock of 757 million m^3,

6 This is based on “Forestry” of volume XIV (Natural Resources, Part C) of “History of the non-military activities of the occupation of Japan, September 1945 – January 1951,” and the cited page is page 63.

including unutilized forest resources located in remote areas, annual required standing trees of 33 million m^3, and annual growth of 19 million m^3 [2]. Shinrin Shigen Sogo Taisaku Kyogikai calculated that industrial roundwood already developed would be exhausted in 16 years and fuelwood would be exhausted in 10 years [10].

Various calculations were made and published as to when domestic forest resources would be exhausted.The conclusions were the same; namely, the domestic forest resource would be exhausted under the remaining stock and the trend in wood demand. Such estimates impacted subsequent forest policies to some extent, including the necessity for controlling cutting activities in non-national forests, which was an issue in the amendment of the *Forest Act* 1951. Effective utilization of forest resources and an increase in coniferous forest resources through forestation represented target issues of forestry policy to prevent a lack of domestic wood.

3.5. Effective utilization of forest resources

Effective utilization of forest resources was necessary given the existence of a large cumulative cutover land area in Japan at the time. The movement to effectively utilize forest resources started around 1951 [11]. Yokoyama, director general of the Forestry Agency, pointed out several ways to address the imbalance between supply and demand, including recovery of damaged forest, development of remote unutilized forest, limiting consumption of forest products through effective utilization, and importing forest products [12].

As shown in Table 2, the Forestry Agency provided concrete methods for the effective utilization of forests and the efficient use of forest products [13]. The measures fell, basically, into four categories: substituting other materials for forest products, efficient use of forest products, sophisticated utilization of hardwood, and extending the usable years of forest products. All of the forest utilization ideas listed in Table 2 involved the use of 25.8 million m^3, compared to the total consumption of industrial roundwood in the fiscal year 1951 of 31.9 million m^3 [8]. The issue of whether consumption of forest products decreased in the ways listed in the table was not as important as the fact that the Forestry Agency published such a list as a direction for forestation policy.

The proportion of wood utilized for construction of the total consumption is high, as traditional houses are built of wood in Japan. A policy to promote the construction of non-wood buildings was developed under the policy for the effective utilization of forest resources [14]. In 1950, the House of Representatives passed a *Resolution on Promoting Fireproofing of Buildings in Urban Areas*, which stated that new public building construction must be fireproof. In 1955, *Measures on the Effective Utilization of Wood Resources* was issued by the cabinet and included promoting the fireproofing of buildings. National and local governments were required to take the lead and set a good example in fireproofing buildings. A non-wood building construction policy

7 Kobayashi suggested the existence of another report from the Forestry Agency to GHQ, in which the coniferous forest would be exhausted in 12 years in non-national forest and all forest resources, including national forest, would be exhausted in 24 years [39]. The year it was published is uncertain.

8 Within these conditions, figures utilized on stock and growth are based on the report from the Forestry Agency to GHQ [2].

		(1,000m^3)
Item	**Measures of effective utilization**	**Volume**
Change forest products to substitution materials	Utilization of cardboard for packing	1,252
	Utilization of iron poles, steel formwork, etc. for pit props	1,823
	Utilization of bamboo for pulp	50 and over
	Utilization of straw for pulp	334 and over
	Utilization of used paper for pulp	278
	Utilization of reinforced concrete for telephone poles	39
	Change car fuel utilizing charcoal to gasoline	6,818
	Change fuel in urban areas to gaseous fuel	1,344
	Increase production of briquette fuel	0
	Increase production of lignite	612
	Subtotal	12,552
Effective use of forest products	Instruction and promotion in utilizing thin saw blades	1,280
	Utilization of yarders for logging	278
	Establishment of fiberboard factory	1,392~3,479
	Utilization of scrap wood for pulp	250
	Utilization of pulp refuse	165
	Improvement of building construction	417 ~1,670
	Improvement of utilization of hearths and furnaces	3,715
	Improvement of techniques in charcoal production methods	2,054
	Instruction of improvements in combustion appliances	2,505
	Subtotal	12,057
Sophistication of utilization of hardwood		250 and over
Extension of durable years of forest products	By antiseptic treatment	557 and over
	By fireproof building	278
	By waterproof plywood	111
	Subtotal	946
Total		25,805

Source: [13]

Note: This table was prepared from the items and figures listed in [13]. When the original data included a range, the lower figure was used in the table.

Table 2. Wood savings by the measures for the effective utilization of forest resources.

was introduced, and areas where the construction of wooden buildings was prohibited increased on the basis of fireproofing.

Household fuel consumption was the main issue addressed in a government advisory report by Shigen Chosakai [15]. Approximately 80% of household fuel was wood-based at that time, and consumption of fuelwood was associated with broadleaved tree cutting. As the quantity of household fuel consumed by each household was generally small, various species were used as fuelwood, and the actual consumption was unknown. Thus, no comprehensive measure was taken and the problem was ignored. However, the situation seemed even more serious with the population increasing and the living standards improving. The report advised the government that furnaces in rural areas should be improved and the supply of gaseous fuel to urban areas should be increased. As a result, a *Revised 1953-1957 5-Year Plan* to expand and improve town gas facilities was developed by the Ministry of International Trade and Industry, and it was planned that gas facilities would grow from 31.8% in 1952 to 39.9% in 1957.

4. Forestation policies

After the war, approximately 1.5 million ha of cutover land was left and there was a deepening sense of crisis because of the dearth of domestic wood and an increasing demand for forest products. In this section, the major forestation policies for non-national forests, developed by the Forestry Agency, will be described in almost chronological order. The initial policies concerned planting trees on cutover land. However, policies to increase the coniferous forest area were a focus for future self-sufficiency. A profit-sharing forestation system was promoted to increase the forestation area. The results of the policies related to forestation will be shown at the end of the section.

4.1. Planting trees on cutover land

The *Forest Resources Creation Act* (Act No. 52 of 1945) was enacted in 1945, and was a revision of the *Wartime Forest Resources Creation Act* (Act No. 35 of 1945). People purchased planting securities issued by the government at half price, and the government purchased the planting securities at face value after the planting was completed. Thus, this system constituted a substantial 50% government subsidy for planting. Money is usually paid after the work is completed in a subsidy system; however, people who wanted to plant could plant with half the necessary cash in hand under this act. This system ended in 1948 without much impact, mainly due to the high inflation just after the war.

The first full-scale planting plan after the war was the *5-year Forestation Plan* (1949-1953) that promoted planting of coniferous trees on the 1.5 million ha of cutover land area. The *5-year Forestation Plan* is shown in Table 3. The total planted area was scheduled to be 2.82 million ha over the five years.

Planting was necessary on newly cutover land that was added every year after the war, in addition to the previous 1.5 million ha of cutover land. Because of an insufficient budget, the actual work was limited to 60%-70% of the planned area [16].

The *Act on Forestation Extraordinary Measures* (Act No. 150 of 1950) was enacted to effectively promote this planting plan in non-national forests, and the effective period was five years. Prefectural governors could specify the sites to plant, and the governor could conduct profit-sharing planting when planting was not completed at a specified time [1]. Article 1 of the act shows the objectives and effects of the act. The objective was rapid forestation to conserve national land by growing forest resources. It was pointed out in the Act that the forestation subsidy, financial support, preparation of nursery trees, and other related policies must be completed and implemented to realize forestation. The target of this act was to support the rapid planting of the *5-year Forestation Plan*.

				(1,000 ha)
	National forest	**Forestation by government in non-national forest[1)]**	**Non-national forest**	**Total**
Planting	197	23	1,646	1,867
Direct seeding	0	0	25	25
Natural seeding	572	0	312	884
Total	769	23	1,983	2,776

Source: [2]

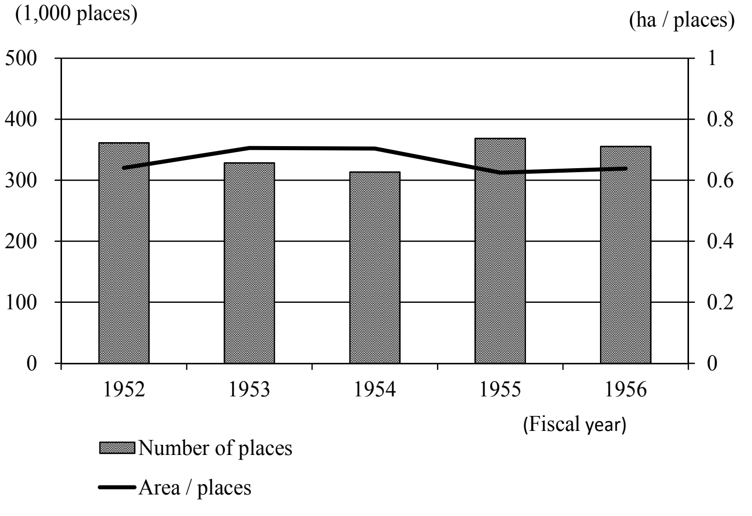
Note: 1) Profit-sharing forest between government and non-national forests.

Table 3. Five-year Forestation Plan (fiscal years 1949-1953).

The *Forest Act* of 1907 (Act No. 43 of 1907) was completely amended in 1951 (Act No. 249 of 1951) and the forest planning system began, which included enforcement measures for planting under some conditions. Under the forest planning system, the prefectural governor implemented an annual plan, which included the forest sites to plant (Article 8, Paragraph 5) and the obligation of the forest owner to plant (Article 14). Such compulsory regulations were exceptional because there had been no obligation to plant outside the restricted forests in the Japanese system.

The number of locations and the area per location among the annual implementation plans made by prefectural governors during 1952-1956 are shown in Figure 5. The number of locations specified for necessary planting was >300,000 every year. The annual mean area per location was small (0.6-0.8 ha).

After the amendment of the *Forest Act* in 1951, the *10-year Forestation Plan for Non-national Forests* ("10-year Plan") was published in 1952 (planning period was 1952-1961). The total



Source: [4, 17-20]

Figure 5. Areas specified as necessary to plant in the forest planning system.

planned forestation area is shown in Table 4. In addition to planting past cutover land, a new rule to replant immediately after cutting was established in the 10-year Plan. As annual cutting activities were necessary due to increased demand for forest products after the war, this new rule was significant, in order to prevent cumulative cutover land. The area to be replanted immediately after cutting was almost half of the total planted area. By planting coniferous trees after cutting broadleaved trees, coniferous forests were expected to expand by 0.8 million ha.

		(1,000 ha)
Category		**Area**
Planting	Past cutover land	879
	Cutover land of previous year	1,611
	Expansion of coniferous forest	838
	Subtotal	3,327
Direct seeding		50
Natural seeding		744
Total		4,121

Source: [16]

Note: The figures are the total forestation area during the 10 planned years. Numbers are the originally newly forested area.

Table 4. Ten-year Forestation Plan for Non-national Forests.

The final goal of the 10-year Plan was to achieve industrial roundwood self-sufficiency by increasing coniferous forest area [16, 21]. Of course, this final objective was an ideal at the time, and this goal was clearly different from that of the *5-year Forestation Plan* (1949-1953), which aimed to plant 1.5 million ha of past cutover land. However, the 10-year Plan was unachievable from the first year due to limited financial resources (the original 1952 budget was approximately 60% of the necessary budget). Regardless of the insufficient budget, reduction of subsidy rate in the fiscal 1954 budget plan made it possible to increase the planted area, and the annual planted area reached its highest level yet in 1954.

Reforestation of the protected forest system also contributed to increasing the planting area. The protected forest system, which is called *Hoanrin*, was introduced in the first *Forest Act* (Act No. 46 of 1897), and categories of the protected forest was expanded in the amended *Forest Act* of 1951. Reforestation of the protected forest was required by law. A new system was introduced in the 1951 amendment in which planting was firstly conducted and the area is specified as a protected forest after forestation. Several large typhoons and floods damaged[9] the whole country in 1953, and the *Act on Temporary Measures concerning Protected Forest Consolidation* (Act No. 84 of 1954) was enacted. The protected forest was promoted to extend according to the consolidation plan for protected forest.

A third plan called the *6-year Forestation Plan* ("6-year Plan") was introduced for the 1955[10]-1960 planning period. During this planning period, the non-national planted forest was scheduled to increase from 4.4 million ha to 6.0 million ha. Planting of coniferous trees after cutting broadleaved trees was emphasized in the 6-year Plan. Quantity was emphasized in the 10-year Plan for war damage reconstruction, whereas quality was emphasized in the 6-year Plan [21], such as utilizing high-grade nursery trees, introducing a seed tree system, and planting under the principle of the "right tree on the right site" [21].

Figure 6 shows the planted area in 1946-1957. The planted area was divided into three categories: planting after cutting, planting on cutover land, and planting coniferous trees after cutting broadleaved trees. The issue of overcut land, which had been a key forestry policy issue, was close to being resolved by 1956.

4.2. Planting coniferous trees after cutting broadleaved trees

After the success of forestation of cutover land, the main objective of forestation policy shifted to expanding the coniferous forest. In other words, the objective of forestation changed from the production of fuelwood to the production of industrial roundwood because the demand for broadleaved trees had decreased drastically as a result of the fuel revolution.

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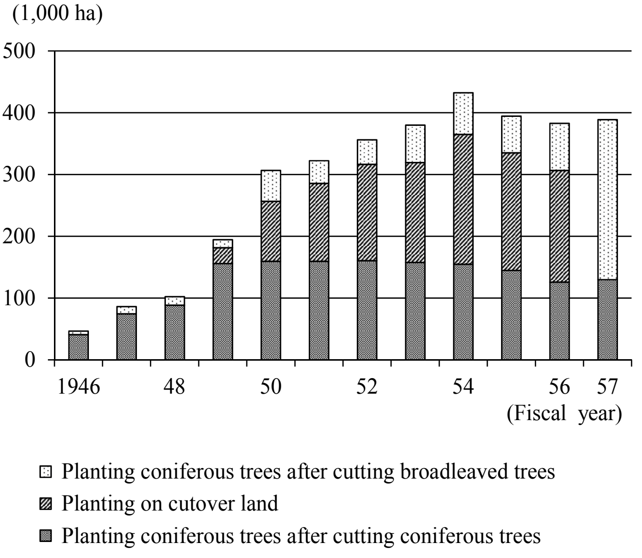
9 Three powerful weather-related events damaged Japan in 1953 [40]. A flood occurred in the Kyusyu area in June. The number of missing and dead came to 1,014, and 3,231 and 11,671 houses were destroyed or half destroyed, respectively. A flood damaged the south Kinki area, mainly Wakayama prefecture, in July. The number of missing and dead came to 1,059, 424 houses were destroyed completely, 4,055 houses were washed away, 4,535 landslides occurred, and there were 106,738 victims. Typhoon no. 13 of 1953 hit in September, with 323 and 276 missing and dead, respectively. The number of injured came to 993 and 4,769 and 13,918 houses were destroyed or half destroyed, respectively.

10 The national forest system made a long-term production plan in 1955, emphasizing the planting of coniferous trees after cutting broadleaved trees. See [41] for details.



Source: [22]
Note: Total national forest and non-national forest area.

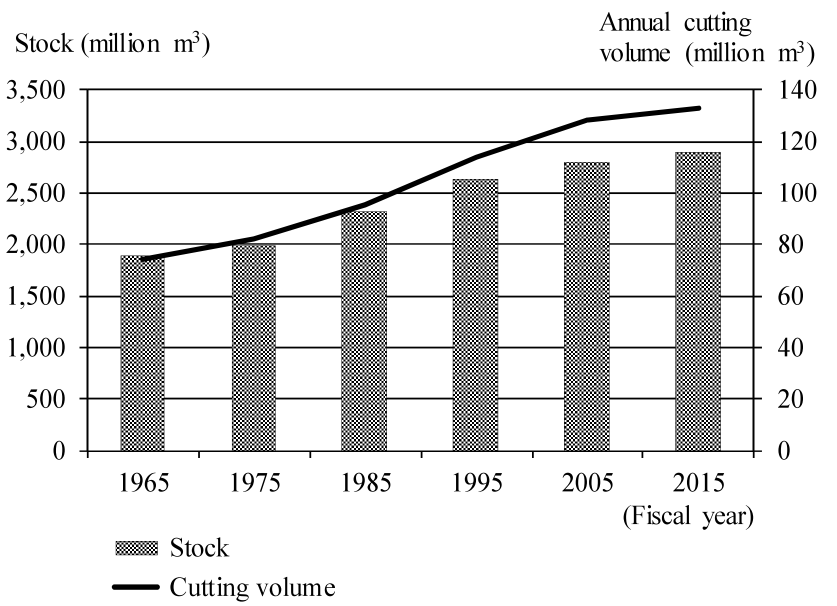
Figure 6. Planted area.

The following laws contributed to this expansion. The *Act on the Profit-sharing Planting Extraordinary Measures* (Act No. 57 of 1958) was enacted, which will be explained in section 4.3. The *Forestry Basic Act* (Act No. 161 of 1964) was enacted, and the main policy goals designated under Article 2 of the *Forestry Basic Act* were to increase forest products, forestry productivity, and forestry worker income. The total area of planted coniferous trees was included in the *Basic Plan on Forest Resources* of 1966 ("1966 Basic Plan"), which was the first plan decided on by the Cabinet under Article 10 of the *Forestry Basic Act* in 1966. The *Act on Advancement of Modernization of Rights in Relation to Forests Subject to Rights of Common* (Act No. 126 of 1966) was enacted, with the main purpose of foresting common forests[11] with coniferous trees.

The "1966 Basic Plan" provided the background for the coniferous forest expansion policy. The 1966 Basic Plan pointed out that although Japan had great potential for increasing forest resources, the current production capacity of industrial roundwood was low due to a lack of forestry roads. There was a concern that the Japanese wood supply and demand would be influenced severely if the low domestic production capacity and dependence on imported wood continued for a long period. It was concluded that actively enhancing domestic forest resources to increase forestry production was necessary. Here, a new logic appeared in the 1966 Basic Plan,which is to secure domestic resources in light of a possible worldwide imbalance in the supply and demand of industrial roundwood. The final goal was 13.4 million

11 See [42] for common forest management and the modernization policy on the rights of common forests in Japan.

ha of planted forest in 2015, which was 50 years after the planned year. The planted forest area was 7.7 million ha at the time the plan was introduced, and 5.7 million ha of new planting was necessary. The percentage of planted coniferous tree area of the total forested area was planned to reach 56% in 2015. The total stock and annual cutting volume were planned as shown in Figure 7.



Source: *Basic Plan on Forest Resources* decided by the Cabinet in 1966, Table 2
Note: The fiscal 1965 cutting volume was the 1962-1964 mean.

Figure 7. Planned stock and annual cutting volume for 50 years.

It was planned that the total stock would increase and reach 2,904 million m^3 by increasing the planting of coniferous trees. In the 1966 Basic Plan, the percentages of annual cutting volume to stock were planned to be 4.1% in 1975 and 1985, 4.4% in 1995, and 4.6% in 2005 and 2015. The percentage was planned to increase; the annual cutting volume was planned to increase to 133 million m^3 in fiscal 2015. As a reference, the actual annual cutting volume of standing trees was 36.5 million m^3 in fiscal 2012, which was substantially below the expected cutting volume in the 1966 Basic Plan. As will be shown later, the main reason was the too optimistic premise of the 1966 Basic Plan, which assumed that the Japanese economic development trend would not change and that the increase in wood demand would continue.

4.3. Profit-sharing forestation

Three resources are required to plant trees in a non-national forest: a forest site, planting labor, and funds for planting. Forestation of cutover land could be conducted by compulsory measures under the 1951 *Forest Act* until 1962. However, no compulsory measures existed for expanding the coniferous forest. The forestation fund was a main problem among the three resources. The planting would not occur without funding by forest owners, even if the subsidizing system and lending mechanism improved.

Various types of profit-sharing forestation began in the Edo Period in Japan, in which forest landowners and planters were differentiated and profits were divided between the landowner and the planter. The *Act on Planting on Public Forest by Government* (Act No. 7 of 1920) was enacted before the war and defined profit-sharing forestation between the government as the planter, and the municipality as the landowner. In a 1924 amendment of the act, it became possible for prefectural governments to plant forest land owned by municipalities and private owners in a profit-sharing system. This prewar profit-sharing system was only applied to the combination of public funds and non-national forests. In order to promote coniferous forest expansion, the *Act on Special Measures Concerning Profit-Sharing Forestation* (Act No. 57 of 1958), enacted in 1958,allowed various combinations of landowners and planters in the profit-sharing forestation system.

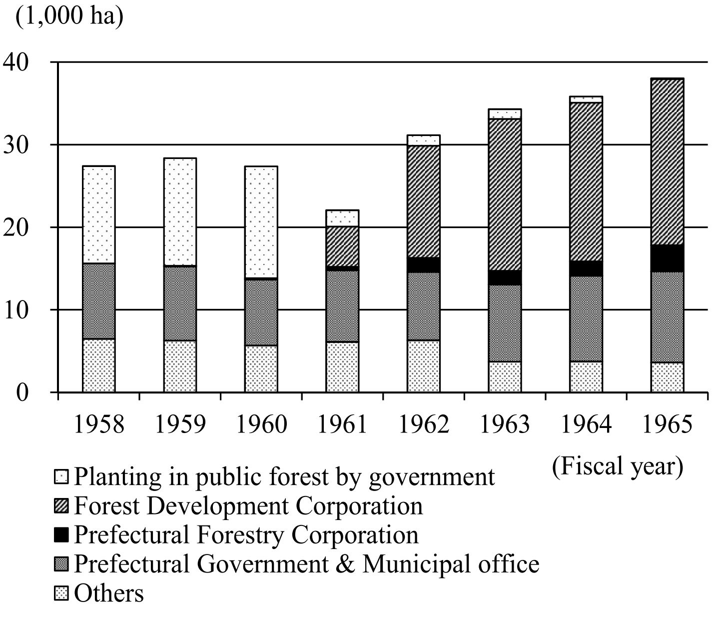
The introduction of private funds from, such as wood-related industries, including the paper and pulp industries[12], was a characteristic of the act of 1958 [1]. However, the area where forestation was actually conducted by means of a profit-sharing system utilizing a private fund was not very large. Forestation utilizing the profit-sharing system was supposed to be conducted on 506,000 ha by fiscal 1980 [23].

Prefectural Forestry Corporations and the Forest Development Corporation played important roles in the profit-sharing forestation system.

The first Prefectural Forestry Corporation was founded in 1959 in Nagasaki Prefecture, and by 1971 all prefectures had established their own Corporations. This organization planted coniferous trees, predominantly Japanese cedar and Japanese cypress, in non-national forests utilizing a profit-sharing system. According to a notification by the Forestry Agency dated April 1, 1965, concerning establishment of the Prefectural Forestry Corporation, the object of the corporation was to rapidly and systematically increase coniferous forestation in undeveloped areas, such as mountainous remote areas and isolated islands, and promote residents' welfare. According to a Forestry Agency administrative circular dated May 11, 1966, the working areas of the Prefectural Forestry Corporation were as follows: areas of poor geographical conditions, areas with a high percentage of broadleaved trees of low economic value, areas with a small number of forest owners who could plant, and municipalities with a high degree of dependence on forestry. Under the policy of the coniferous forest expansion the Prefectural Forestry Corporations were expected to conduct profit-sharing forestation at these poor-condition sites. The total area managed by Prefectural Forestry Corporations was 390,000 ha at the end of fiscal 2007.

12 The paper and pulp industries and the electric power companies were behind the enactment of the Act on Special Measures Concerning Profit-Sharing Forestation [43]. As the price of wood for pulp increased, the Ministry of International Trade and Industry placed a planting obligation on the pulp industries at the time of production facility expansion, and the paper and pulp industries developed a forestation plan. Electric power companies also had an interest in profit-sharing forestation in relation to hydraulic power generation.

The Forest Development Corporation[13] began a profit-sharing forestation program in non-national water source forests in 1961, located mainly in remote mountainous areas. The targeted forests were protected or future-protected forests, and the planted forest land was required to be >5 ha. The total area planted by the Forest Development Corporation is approximately 470,000 ha to date.



Source: [24, 25]

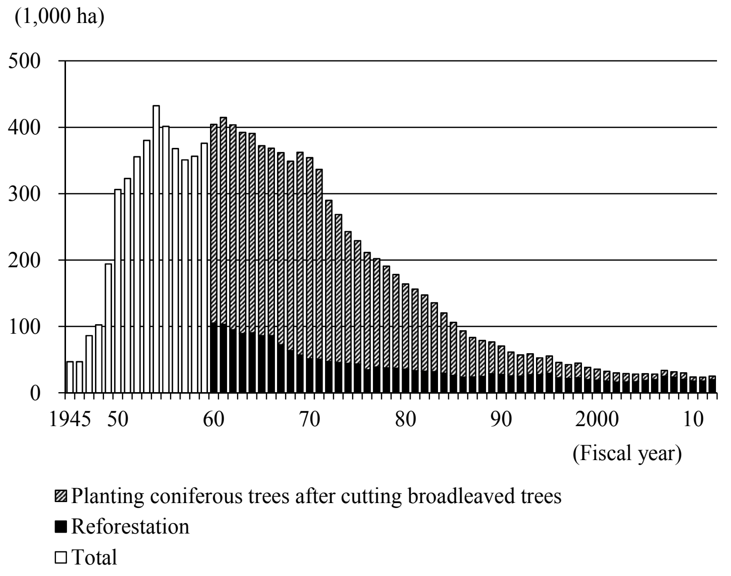
Figure 8. Areas planted through profit-sharing classified by planting organizations.

The area planted by 1958-1965 is shown as Figure 8. The public forest area planted by the government had clearly been reduced since planting by the Forest Development Corporation started. The percentage of Prefectural Forestry Corporations increased gradually. In 1965, the major three planters were the Forest Development Corporation, prefectural governments, and Prefectural Forestry Corporations.

4.4. Results of the forestation policies

The annual planted area is shown in Figure 9. The breakdown figures between the expansion of coniferous forests and other reforestation became available after fiscal 1960. The peak year for total planted area was fiscal 1954, and the annual planted area was >300,000 ha during 1950-1971.

13 The Forest Development Corporation was founded in 1956, following planting activities under the Act on Planting in Public Forest by Government of 1920. The original objective of the corporation was to develop national forest located in remote mountainous areas by constructing forest roads. This corporation was reorganized in 1999, 2002, 2008, and 2015, and is currently called the Center for Forestry Development, Forestry, and Forest Products Research Institute.



Source: [8, 26-29]
Note: Total national forest and non-national forest area.

Figure 9. Annual planted area.

Approximately 10 million ha of planted forests now exist in Japan as a result of postwar forestation policies, which is less than the targeted area of 13.4 million ha in the 1966 Basic Plan, and the major species are Japanese cedar and Japanese cypress[14]. The area of planted forests is approximately 40% of the total forested area and has a growing stock of 3.0 billion m^3. The total growing stock for the whole of Japan was 4.9 billion m^3 as of March 31, 2012. Annual growth was 74 million m^3 in 2010, including all forest resources in Japan, which is just slightly higher than the 72 million m^3 annual demand for wood in Japan. The forest resources that had decreased drastically before and after World War II have largely been recovered, at least concerning total stock.

5. Discussion

As a result of the forestation policies, the issue of cutover land, which assumed once the largest forest-related issue, was solved, and the crisis of the dearth of domestic industrial roundwood was prevented. Now, Japan has 10 million ha of planted forests, with an annual growth of 74 million m^3. Thus, the postwar forestation policies were successful. However, the intense planting conducted over a short period led to current forest policy issues. In this section,

14 The percentages of plantation forest classified by species are as follows: Japanese cedar 44.0%, Japanese cypress 25.5%, other coniferous trees 27.7%, and broad-leaved trees 2.8%.

current issues of Japanese forestry, which could be attributed to the past forestation policies, will be discussed.

5.1. Intense planting under the government's initiative

As coniferous trees were intensively planted over a short period after the war, the age structure of these forests became unequal. Many forests have now reached an age class that needs thinning, but the percentage of forests that have been thinned remains insufficient. Thinning, particularly in a stand >30-40 years, requires forest machinery and a forest road network, but these were not always available. In addition, there tend to be labor force problems due to aging forest owners, forestry workers, and village workers.

Postwar planting of trees, which included planting on cutover land and expanding the coniferous forests, was planned and conducted by national and local governments. Although this was the driving force to realize forestation, it has caused current forest management problems. Postwar forestation policies have connected public work projects with the forest planning system.

The relationship between public work projects, which started in 1946, and planting is explained. Planting, constructing forest roads, and conducting forest conservation projects were included among public work projects because these were related to national land conservation. Although there was a subsidy program for non-national forest planting activities before the war, based on the *Ordinance on Subsidy for Planting for Watershed Protection Forest* (1927) and the *Ordinance on Promotion of Planting* (1929), the government did not actively take the initiative in the planting activity. However, after the war the government has incorporated planting in the public work projects, and strongly promoted planting activities for land conservation in non-national forests.

Next, the relationship between planting and the forest planning system, which started under the 1951 amendment of the *Forest Act*, is described. All forest owners had an obligation to prepare a forest management plan under the previous system, based on the amendment of the *Forest Act* (Act No. 15 of 1939). The management plan was made individually if the holding size was >50 *cho* (almost 50 ha). Forest owners with forests of <50 *cho* had to join the local forest owner's association and the association would prepare a management plan. As above, local governments could supervise non-national forests through the forest management plan. However, this 1939 system failed to work properly during wartime and was discontinued in the 1951 amendment. Under the 1951 forest planning system, the Minister of Agriculture and Forestry had prepared a 5-year plan every five years, and the Prefectural Governor had also prepared a 5-year forest management plan every five years, as well as an annual plan. The basic difference between the prewar and postwar systems was that forest owners had to prepare the forest management plan in the prewar system, whereas the administrative sector prepared the forest plan after the war. In 1968, the forest management plan, prepared voluntarily by forest owners, was added.

Postwar planting projects developed based on strong national and local government initiatives, including public work projects, the forest planning subsidies, as well as subsidies and a public financing system. As a result, the forestation policy was aimed at timber production and national land conservation simultaneously. A considerable amount of planting was conducted without management strategies or forest practice plans by forest owners.

The profit-sharing coniferous forests targeted by the Forest Development Corporation were non-national water source forests located in remote areas. The Prefectural Forestry Corporations contracted profit-sharing planting in non-national forests located in remote areas where almost no one wanted to plant. In such remote areas, no planting would have been conducted due to economic reasons. Thus, it was clear that these administrative corporations had played a significant role. Administrative offices promoted the change from broadleaved forests, which were no longer required as a fuelwood source, to coniferous forests. A number of forest owners had no experience of cultivating coniferous trees, and simply followed the administrative advice.

Although planting and initial tending, such as weeding, were conducted through the initiative of administrative offices, thinning was required as the forests aged. Despite various efforts by national and local governments to promote forest practices such as thinning[15], forest owners tended not to thin or conduct the final cutting. Only a small number of motivated owners prepared forest management plans, without much support from the prefectural government or the local forest owners' association. This situation represents the background for the current forestry issues in Japan.

The compulsory procedure can be found among forestation policies in the 1951 *Forest Act*. The GHQ had basically abolished the compulsory wartime system, but forestation of cutover land was essential to national land conservation; thus, the compulsory policy measures were chosen. The compulsory characteristics were necessary for forestry policy in the 1940s, and to some extent in the 1950s, to maintain forest resources and avoid a crisis arising from a lack of domestic wood. However, such a compulsory approach was terminated after the cutover issues had ended. The forest planting site specifications, specified by the 1951 *Forest Act*, were removed in 1962, but the government-led forestation policies did not change. The government-led forestation program had continued, but the government should have considered about until when it would continue the program and how it would manage the planted forests in next decades. Neglecting these problems has brought about current forest management issues involving insufficient forest practices.

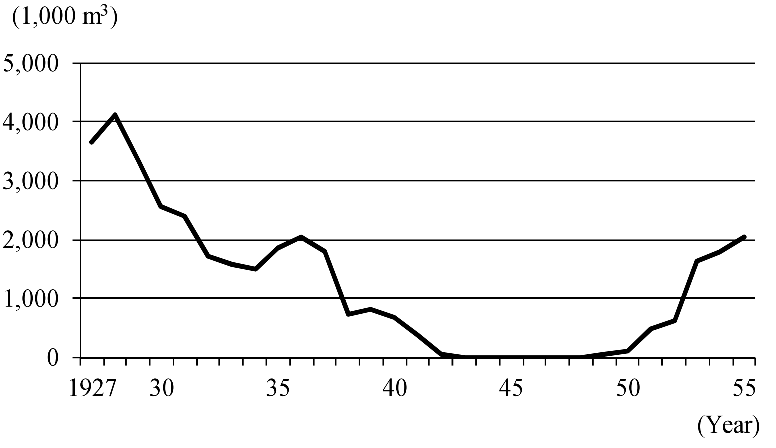
5.2. Industrial roundwood self-sufficiency

The dearth crisis of domestic wood was the main driving force for the postwar forestation policies. The situation that annual cut volume was more than that of growth caused the dearth of domestic forest resources in developed areas. The aspiration for self-sufficiency in industrial roundwood[16] originated from the wartime experiences. Figure 10 shows timber imports from

15 The Forestry Agency secured a budget for thinning associated with measures against global warming, based on the Act on Special Measures concerning Advancement of Implementation of Forest Thinning, etc. (Act No. 32 of 2008).

16 Various analyses on the future dearth of forest resources included both industrial roundwood and fuelwood. However, as fuelwood was expensive to import, it was not considered.

1927 to 1950. As the outbreak of war got closer, the quantity of imported timber decreased, and the percentage of imported timber was zero around 1945, until timber imports from Southeast Asia restarted in 1948. As timber imports were zero or very low at that time, the only way to supply industrial roundwood was from domestic forest resources. The 5-year Plan (1949-1953) was prepared when timber imports were zero. The 10-year Plan (1952-1961) and the 6-year Plan (1955-1960) were developed just after timber imports restarted.



Source: [10] (before 1945) and [30] (after 1946)

Figure 10. Timber imports.

However, timber imports at the time were considered a measure to solve the future dearth of domestic forest resources. GHQ also analyzed the Japanese wood supply and demand based on forest resources and wood consumption at the time. GHQ pointed out three choices: (a) insufficient supply indefinitely but on a sustained yield basis; (b) sufficient supply in the immediate future but ultimate forest bankruptcy; and (c) importation of nearly half of its timber and fuel needs (more as the population rises) to supplement sustained production [31]. GHQ suggested that about 28.3 million m^3 (1 billion ft^3) of timber should be imported, alongside the efficient consumption of forest products and improved forest management to enhance the growth of trees. It was also pointed out that such timber imports would not be a problem based on the domestic foreign currency reserve and international forest resources. Shinrin Shigen Sogo Taisaku Kyogikai reported that possible imports would be from Alaska, the USSR, and Southeast Asian countries [10]. The report suggested that repeated petitions through GHQ and Japanese government would be needed to import wood from Alaska. As revealed in these reports, it was already pointed out that timber imports would alleviate the crisis of the dearth of domestic wood.

Japanese timber trade policy promoted postwar imports. The tariffs on forest products were generally low, and tariffs for logs were dropped to near zero by a 1951 amendment, with the exception of some specific species, and tariffs on forest products were limited to sawn wood. The problem with importing timber was not the tariff, but the foreign exchange allocation policy; however, this exchange control for logs was abolished in 1960. Log imports increased immediately and the import of sawn wood increased recently. The wood self-sufficiency rate has fallen to be 27.9% in 2012 [32][17], although the postwar forestation plan targeted industrial roundwood self-sufficiency. It can be concluded that planted coniferous forest had expanded under the forestation plans, but that the plans had not affected domestic timber production. It seems that the forestation policy for self-sufficiency and the trade policy could be somewhat contradictory. A comprehensive analysis of the policy contradiction remains for future research.

5.3. Financial issues of the Prefectural Forestry Corporations

All the Prefectural governments founded a Prefectural Forestry Corporation ("Corporation") to promote the planting of coniferous trees in non-national forests using a profit-sharing system. Forest owners prepared only forest sites, the Corporation supplied money, and the idea was that the revenues from final cutting would be divided between the forest owner and the Corporation in a contracted proportion. An important characteristic of the Corporations is that profit-sharing forest management was conducted utilizing long-term debt[18]. All costs of planting, tending, thinning, forest road construction, wages, redemption money, and interest, were supposed to be paid from long-term debt. When the organization was founded, it was expected that the amount of long-term debt would be less than the revenue from final cutting.

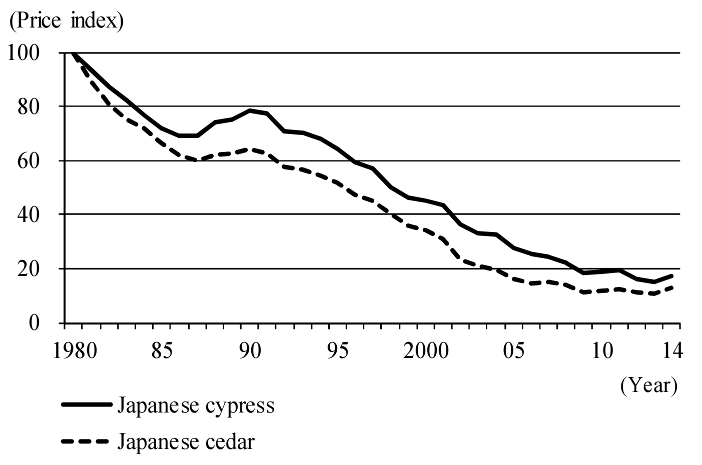
However, a deficiency in future assets was certain for all prefectural corporations. All Prefectural Forestry Corporations have long-term debt of approximately 8.7 billion USD[19] in total, which has become a political issue in all prefectures. Some prefectural corporations have dissolved or have been integrated into the prefectural forest system, or have altered their long-term forest practice contracts. The basic problems related to this financial failure of a Corporation are discussed below.

The first thing to be pointed out is the fact that the Corporation failed to predict log price changes or was too optimistic. Japan was in the middle of a strong economic growth when many of the Corporations were founded. The demand for industrial roundwood and the price of logs were increasing. Such economic conditions provided a precondition for promoting planting policy by founding the prefectural corporations. The 1966 Basic Plan, as shown in section 4.2, was the most basic forestry plan, and the future prospects of forest resources and the long-term prospect of supply and demand for industrial roundwood were estimated under the precondition that timber prices would never change. However, the upward trend in domestic log prices was reversed to downward because of low economic growth, a decrease

17 The minimum forest product self-sufficiency rate (18.2%) was recorded in 2002 but the rate has been increasing gradually since that time.

18 The Corporation provided finances from planting subsidies (approximately 30%), debt from the Agriculture, Forestry, and Fisheries Finance Corporation (AFC; currently the Japan Finance Corporation) (approximately 60%), and debt from prefectural governments (approximately 10%) [43]. The Corporation could easily collect funds from the AFC because the AFC debt was guaranteed by the prefectural government, indicating that the long-term debt of the Corporation could turn out to be the cost the prefectural government must finally bear.

19 1.04 trillion yen was converted to USD at a rate 1 USD = 120 yen.



Source: [29, 33]
Note: Price index was considered to be 100 in 1980, when the highest price was recorded. (As of March)

Figure 11. Stumpage price.

in population growth, decreased housing construction, and increased imports of log and sawn wood. The most drastic change in price was the stumpage price as shown in Figure 11.

Prices for Japanese cedar and Japanese cypress, which are the typical planted coniferous species, have changed to a declining trend since 1980. The price index (1980 = 100) bottomed at 10.9 for Japanese cedar and 15.1 for Japanese cypress in 2013, and the downward trend in price almost stopped. Due to the drastic drop in log prices, revenue from thinning and future final cutting would also decrease greatly, and total revenue could be less than total cost. The Corporations made efforts to extend the final cutting age as a practical measure because no profits would be made at the scheduled final cut age under the long stagnating log price. However, extending the final cutting put off the time when Corporations could collect revenue. The Corporations did not predict such a long-term decline in log prices, and resulting various management issues.

The second problem is that total costs included not only actual costs of planting and tending, but also debt interest and general administrative costs. Figure 12 shows an example of the financial conditions of a Corporation, where the funds invested were divided into actual costs plus administrative costs and interest[20]. The interest percentage has become large in recent years to be >90%. The interest percentage of the total costs during fiscal 1966-2012 without considering the discount rate was 46.4%. Planting activities of this Corporation started in fiscal 1966 and ended in 1998, and since then the Corporation has managed forests planted previously.

20 The detailed actual conditions on the interest of the long-term debt of the Corporation were not open to the public. The case of borrowing from the AFC in the Iwate Prefectural Forestry Corporation was as follows: in the case of subsidized forestation, the simple interest rate was 4.2%, 6.05%, 6.2%, and 6.5%, the repayment grace period was 25 years, and the redemption period was 40 years [43]. In the case of unsubsidized forestation, the simple interest rate was 3.5%, the repayment grace period was 25 years, and the redemption period was 45 years.

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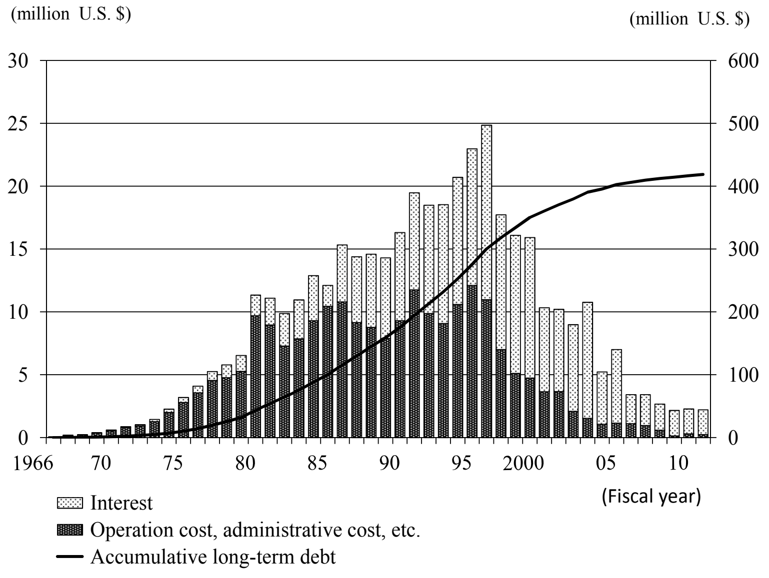

Source: [34]

Note: Total area planted by this corporation was approximately 16,000 ha. Values are converted using 1 USD = 120 yen.

Figure 12. Financial figures on a Prefectural Forestry Corporation.

The management system in which all necessary costs are paid by long-term debt was problematic, given that it takes 40-50 years to produce industrial roundwood in a managed forest. In fact, no revenue was collected from the forest during the 40-50 years after founding the Corporation, except revenue from thinning, which is generally very small or nothing. As a result, interest must have been paid by additional long-term debts. It is unclear whether such a financial problem involved in the management system of the Corporation was completely understood by the stakeholders, and this remains a future research topic. The final goal of planting coniferous forested area was the priority of the 1966 Basic Plan and the forestation policies at the time. It was a serious problem that the finances were completely lacking for the organization to expand coniferous forests based on the national policies.

When log prices started to fall in 1980, people probably expected a price rise again, because the postwar prices of logs and forest products had tended to increase. However, as the downward trend in stumpage has continued over the past 30 years. As for the corporation shown in Figure 12, if it had conducted a fundamental financial reform in the 1980s, it could have avoided some of the accumulating debt. There was little concern about the finances of the local organizations conducting forestation under the national policies at that time.

Although the Corporations have definitely contributed to increasing the area of planted coniferous forests on non-national forest land, their financial failure is obvious. The issues of the Corporation show that forestation policy must be associated with financial policy[21] for long-term forestation investment.

5.4. Forest resource statistics

The first goal of postwar forestation policy was planting trees on cutover land, which was clearly urgent for conserving national land. As shown in section 3.4, the statistical estimates from several calculations suggesting the future dearth of domestic industrial roundwood was the starting point of the policy to expand coniferous forests. Many problems were detected in the calculations made at the time.

Several different estimates were made as to when domestic industrial roundwood would be exhausted, on the basis of available stock, annual growth, and annual cut volume. Correctly estimating stock and volume is generally difficult; thus, an inadequate estimate may have been unavoidable. However, Japan has never actually faced exhausted domestic forest resources.

Kondo criticized the stock and growth estimates for three reasons [35]. First, the calculations assumed that forests located in high mountainous areas and protected forests were unavailable for harvesting. Protected forests were not generally exempt from all cutting activities. Second, he pointed out that the stock of utilized forests was underestimated and that of unutilized forests was overestimated. Third, underestimates of old-aged forests were pointed out. Given the conclusion that the stock available should be larger than the published estimate, Kondo argued that no crisis of domestic forest resources would occur if forest land reform was carried out at the same time. Kondo also pointed out that one of the reasons why the government underestimated forest resources was to stretch forest roads in remote areas.

Among the critical opinions about the calculations regarding the dearth of forest resources, the importance of an appropriate estimation of the forest resources was identified. One of the basic conditions for estimating forest resources was an accurate assessment of the forested area. However, the actual forested area is often larger than the registered area[22] even now, due to a lack of forest land survey data owing to delays in national land surveying. The percentage of surveyed land in the whole of Japan was only 41% at the end of fiscal 2009 [44]. There still remains the serious problem of vast forest area being left unsurveyed.

Given that the dearth of forest resources in the utilized forests is forecasted, when the exhaustion occurs depends on how to define the utilized forest. Furthermore, the area of the utilized forest is changeable with various logging methods and different timber prices. Bearing in mind these factors, the estimate of utilizable forest resources tended to be arbitrary.

In addition to the difficulties involved in defining a utilized forest and evaluating the stock, another problem at the time was the fact that the growth rate was unclear. Shinrin Shigen Sogo Taisaku Kyogikai estimated the number of years until exhaustion to be 33, 46, and 60 years for growth rates of 2.45%, 3.5%, and 4.0%, respectively [10]. It is obvious that efforts to estimate growth rates of the planted forests are required now.

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21 It was problematic that the repayment grace period in the AFC was 25 years, which was shorter than the final cutting age. As no fund was available to the Corporation at the time they were founded, the interest was assumed to be paid by additional loans as a result of such a short repayment grace period.

22 Mokuzai Shigen Riyo Gorika Suishin Honbu reported that the actual area of forested land was two to five times greater than the area written in the land register [11]; thus, the actual stock was considerably larger than the published data.

For example, if stock is underestimated and domestic supply is overestimated, the time to exhaustion would be short, or if stock is overestimated and domestic supply is underestimated, based on overestimating imported timber, there would be no timber shortage. Correct estimation of forest resources, and the forest product supply and demand, still remains important today. At the same time, it is necessary to understand that such estimates can be somewhat arbitrary and that a comprehensive review of past estimates should be conducted.

6. Conclusions

The first major postwar forestation policies were developed as a way to decrease the area of cutover land. These policies were followed by introducing temporary enforcement measures under the forest planning system. Following this, national and local governments prepared forestation plans and related legal systems to increase the planting of coniferous forests, and strongly promoted policies with the same goal by founding planting organizations; policies for a subsidy system were also developed. As a result of policies, the total volume of Japanese forest resources has recovered. However, cutting activities are generally weak, although many of the planted forests have recently reached the final cutting age. In addition, large debt has been incurred by the Prefectural Forestry Corporations. We are facing serious forestation problems today which are different from those experienced just after the war. It is time to discuss how to manage approximately 10 million ha of existing planted forest in a new way.

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Chapter 5

Decentralisation of Forest Management — Is it a Panacea to Challenges in Forest Governance in Uganda?

Nelson Turyahabwe, Patrick Byakagaba and David Mwesigye Tumusiime

Additional information is available at the end of the chapter

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Abstract

Decentralisation of forest management is currently implemented in many countries in Africa, Asia and Latin America as a governance strategy aimed at enhancing forest resource conservation, poverty alleviation and equity in forest resource utilisation. In Uganda, the overarching aim of decentralisation of the forest sector was to shift responsibility of forest management to lower elected local government councils so as to increase participation and accountability in the forest sector. In this chapter, we investigate whether decentralisation has led to transfer of "real" power to local authorities and the extent to which the original objectives of decentralised forest service delivery have been achieved and challenges encountered in the implementation. We used questionnaires, unstructured observations and interviews to collect data from three districts of Uganda. We found that District Forest Departments of local government are mostly involved in revenue generating activities and protection of local forest reserves with only a very limited focus on activities that endear people towards participation in the management of local forest reserves. Power sharing of District Local Governments with lower local institutions and local communities is extremely limited. Contradictory policies about forest resource governance, inequitable sharing of revenues generated from forest resources between the District and Sub-county governments, rent seeking and political corruption amongst actors who are charged with forest law enforcement are the major challenges in dispensing decentralised forest governance. There is need to increase space for citizen participation in the management of forest resources, holding accountable of the duty bearers and equity.

Keywords: Decentralisation, participation, equity, local governments, forest department, forest governance, Uganda

1. Introduction

The past two decades have been characterised by many countries in Africa, Asia and Latin America implementing policies that promote decentralisation of natural resources such as forests [1-3]. Proponents of decentralisation of forest management often argue that if implemented it can lead to forest resource conservation, poverty alleviation, equity and promotion of good forest governance in developing countries [4,5]. Decentralization involves transferring power from the central government to lower-level actors and institutions [6]. In 1997, forestry was one of the sectors that the Government of Uganda (GoU) decentralised [7-9]. The government recognised local governments and community-based organisations as key players in the development of the sector. In order to implement this, the GoU initiated reform processes in the sector and these culminated into the development of the 2001 Uganda Forestry Policy [10], the National Forest Plan [11] and the 2003 National Forestry and Tree Planting Act [12]. The major outcome of the reform was the change in ideology in the management of forests from centralised to decentralised management. Accordingly, local governments under the District Forestry Services (DFS) were mandated to manage Local Forest Reserves (LFRs) and provide technical support to private forest owners while the National Forestry Authority (NFA), which was created by an Act of parliament, was responsible for the management of Central Forest Reserves (CFRs) [13]. The purpose of decentralising forest management was to increase people's participation in decision-making on forest resources and accountability in the forest sector [14,15].

It is still unclear whether decentralisation of forest management has improved forest governance at local government level since these reforms were introduced in Uganda. Most studies on decentralisation have not assessed specific powers transferred to local authorities, yet these are critical for determining the outcomes [16]. The functioning of DFS at various units and extent to which the original objectives of decentralised forest service delivery have been achieved has not been documented. In this chapter, we investigate whether decentralisation reforms that occurred in Uganda from the late 1990s have led to good forest governance practice at a local level. The focus is mainly to explore how District Local Governments in Uganda expedite their mandate and extent to which principles of good forest governance are adhered to by the duty bearers and the local communities.

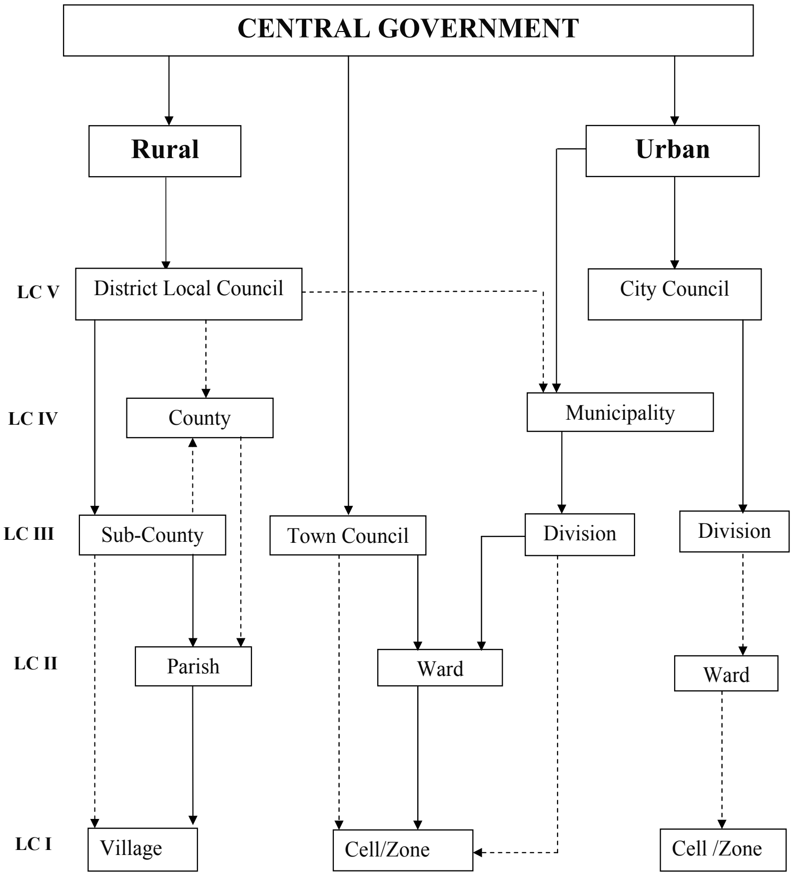
2. History and evolution of decentralisation of forest management in Uganda

Formal management of forests in Uganda started in 1898 when the colonial government's Scientific and Forestry Department was established. A Department of Forestry was established as a separate body in 1917 and renamed as the Forest Department in 1927 [17]. Since then, forest management has shifted from centralisation to decentralisation to address challenges of the time in the forestry sector. The first attempt to decentralise forest management was between 1939 and 1947 with legislation establishing village forests (VFs), LFRs and central forest reserves (CFRs). As the names suggest, the VFs were administered by local villages and all the revenues from them were used for local village development. On the other hand, LFRs were administered by either the District or Kingdoms in areas (e.g. Buganda, Toro, Ankole and Bunyoro) where the latter existed while the CFRs were administered by a central agent, the National Forest Department [18]. By then, each Ugandan District had a District Local Government Council of Ugandan chiefs and councillors. The chiefs had powers over trees on both public and private lands and were mandated to issue licenses, collect revenues, regulate wood extraction and arrest offenders over the same while the Council had powers to make byelaws on use of forest resources [19,20].

However, forestry administration was drastically changed following the attainment of political independence in 1962. The post independence governments of presidents Sir Apollo Milton Obote and Idi Amin Idi Amin changed forestry legislation in ways that diminished the roles of local forest administrators. One particularly significant change was the 1967 amendment of the 1964 Forests Act that sought to improve efficiency and ensure rationality in the sector by centralising provision of forest services hitherto provided by Local Administrators (Hamilton, 1984). Decisions on use of forest resources on public and private land were solely entrusted to a centrally organised Forest Department.

The first step in Uganda's decentralization process was the enactment of the 1987 Resistance Council/Committees (RCs) Statute No. 9 that legalised Resistance Councils (RCs) and gave them powers in their areas of jurisdiction at the local level [21]. Thereafter, the government embarked on an effective implementation programme of decentralization with the enacting of the 1993 Resistance Council Statute [22]. From 1995, Uganda embarked on the process of decentralising delivery of services to local government agencies, including the management of forests [23,24]. After promulgation of the Uganda's Constitution of 1995, the decentralisation policy was legalised by the Local Government Act of 1997, which established the District level Local Council (LCV), Municipality (LC IV) and Sub-county / Division / Town Council (LC III) as corporate bodies of local governments and devolved to them far-reaching powers and responsibilities such as income tax collection, service provision, formulation of policies and laws and managing the environment which were formerly undertaken by the central government ministries [23]. Hence decentralisation in Uganda is based on three inter-linked aspects: (i) political and legislative empowerment of the people, (ii) fiscal devolution and (iii) control of the administrative machinery by the local councils [25]. Local governments were expected to deliver services including management of forest resources on behalf of the central government. Under the 2001 Forest Policy and the National Forest Plan of 2002, the central government recognises local governments and other local community organisations as key players in forestry development [8,11].

The legislative framework for decentralisation in Uganda is provided by the Decentralisation Statute of 1993 and the Local Government Act of 1997 [22,23]. It is based on a district as a unit under which there are lower local governments and administrative units. It introduced the five-tier system of elected representatives called Local Councils (LCs), from level LC1, 2, 3, 4 and 5 or village, parish, sub-county, county, and district, respectively (Figure 1). Each LC has a nine member executive committee, one of whom is designated Secretary for production and environment. The latter oversees forestry activities. According to the 1997 Local Government Act, only the District and Sub-county Councils have powers to legislate. The others are administrative units.



Source: Original

Figure 1. Structure of Local Government in Uganda

The administrative (executive) functions are exercised through a hierarchy of officers supervised at the district level (by a Chief Administrative Officer), county level (by an Assistant Chief Administrative Officer), sub-county (by Senior Assistant Secretaries) and at parish (by Parish chiefs). The executive committee initiates and formulates policies, oversees the implementation of local and central government programmes. The legislative functions are exercised through a hierarchy of elected representatives from LC1 to LC5. These include formulation of policies, ordinances and byelaws for managing the districts' natural resources, including forests [23]. The District Forest Departments manage small areas (about 5000 ha) of Local Forest Reserves (reserves that were decentralised to local governments) distributed in the different parts of the country. They are also mandated to offer advice on sound management of private forests and trees growing on private land, carrying out publicity and forestry extension services. All this work is categorised as district forestry services and the district forest department is mandated to implement them as indicated in the National Forestry and Tree Planting Act, 2003 [12]. In particular, Section 48 of the Act provides for the establishment by District Local Governments (DLGs) of the District Forestry Office (DFO) to function as a decentralised service under the guidance of the District Forestry Services (DFS).

3. Role of forestry in Uganda's national development

The forestry sector is considered as part of the solution to balance economic growth with conservation and ensure sustainable development in Uganda [26]. The total economic value (marketable and non-marketable values) of Uganda's forests is estimated at USD 300 million [27]. According to the Uganda Bureau of Statistics (UBOS), the percentage share of GDP made by the forestry sector in 2009 was 3.5% (1.4% monetary and 2.1% non-monetary). The contribution of forestry to the economy is often underestimated because of conceptual [14] and methodological challenges as some of the resources are accessed in a clandestine manner [28]. A significant part of this contribution is found in the ecosystem service roles of forests including climate change mitigation, watershed services, soil conservation, carbon sequestration, biodiversity conservation and ecotourism. Therefore, forests are indispensable in supporting production of other sectors like energy, health, water, and agriculture. Forestry contributes to a large part of the informal sector through sale of firewood, charcoal, furniture, craft materials, fruits, seedlings and honey [29].

The forest sector is an important employer in Uganda, especially in rural areas. The sector employs about one million people and approximately 100,000 of these are employed in the formal sector [8]. With the current Decentralization reforms, there has been a growth in plantation forestry through the private sector and this has contributed to additional 10,000 permanent jobs and another 15,000 part-time jobs, which translates into approximately USD 12.1 million [30]. Other employment opportunities in the forest sector are in contracting forest operations, supplying forest equipment and inputs, processing of forest products, sawmilling and artisan industries.

Woody biomass is the dominant energy resource for households, and small- and medium-scale industries such as lime, brick and tile making and a number of agro-based industries. About 92% of Uganda's energy needs are met from woody biomass [26]. For example, it is estimated that the nominal value of household expenditure on firewood and charcoal (in both monetary and non-monetary terms) increased from 18 million tons in 1996/97 to 32.8 million tons in 2005/06, or 82% increase over a period of 9 years [31]. The value of charcoal consumption more than doubled, while the value of firewood consumption for the same period increased by 68%.

Forests and trees are an important source of construction materials in Uganda by providing timber, poles, ropes, and other construction materials. Over 42% of dwelling units in Uganda use mud and poles for the walls of dwelling units, and 98% of the dwelling units use timber or poles (with iron sheets or grass-thatch) as a component for roofing [32]. The construction industry has grown at an average rate of nearly 13% annually during the period 2004/05–2008/09 [31], with direct consequence of increasing demand for the forest products.

Forests and trees help to mitigate the effects of climate change. Opportunities for payment for mitigation of the effects of climate change through the Clean Development Mechanism (CDM) and more recently, Reducing Deforestation and Forest Degradation (REDD+) have emerged on the international scene. The product traded is carbon [29]. Uganda has registered a number of projects in both the voluntary and regulated carbon markets, for instance, the Nile Basin Reforestation Project and Kachung Afforestation Projects under the CDM. Other projects on voluntary schemes include Kikonda Forest Reserve Reforestation Project under the climate, community and biodiversity alliance [33].

Catchment forests protect water catchments and thus sustain water supply to homes, industries and hydro energy power plants. Forests and trees play a key role in servicing agriculture through regulation of underground water flows, stopping soil erosion and improving soil fertility. Forests are a source of raw materials for the manufacturing sector (e.g. honey, fruits, medicines and aromatic products). There is a big potential for biodiversity enterprises to contribute to industrial development and competitiveness that is yet to be fully tapped. For instance, herbal medicines are beginning to make inroads, especially as the Natural Chemotherapeutics Research Laboratory progresses in validating the medicinal properties of many tree and shrub species.

4. Methods

This study employed exploratory research design in collecting the data from three Ugandan districts of Mukono, Mpigi and Tororo. The districts were selected based on the presence of decentralised forests and the level of decentralisation. The districts pioneered the implementation of decentralised services in Uganda [34]. These districts were thus expected to provide information on the successes and failures of decentralised forest management in Uganda.

4.1. Sampling procedure

The district and sub-county local governments were selected in the current study because they are the key levels in relation to policy-making, financing and planning for management of forests and other natural resources under the Local Government Act of 1997 [23]. Within the sub-county and district governments, only members of Production and Natural Resources Committees were selected for interviews because they hold decentralised powers and mandate for managing natural resources, including forests [23,24].

In each district local government, at least eight members of the Production and Natural Resources Committee were interviewed. They included four elected local councillors, the Chief Administrative Officer (CAO), the District Environment Officer, the Director of Production

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and the District Forest Officer. The CAO is the accounting officer who supervises and oversees the implementation of district programmes, while the latter three are the technical personnel that implement natural resources management programmes, including forestry. Elected local councillors are mandated to plan and formulate policies at the local government level. At the sub-county government level, at least five elected local councillors and senior assistant secretaries (formerly known as sub-county chiefs) were interviewed. The Senior Assistant Secretary performs similar roles as those of CAO at the sub-county level, while elected local councillors perform duties for the sub-county similar to those of the district councillors.

4.2. Data collection approach

4.2.1. Semi-structured interviews

Semi-structured questionnaires were administered to local government officials mainly from the Production and Natural Resources departments at the district and sub-county in 2010. These included the District Forest Officers, Environmental Officers, Directors of Production, the CAOs, Senior Assistant Secretaries and elected local councillors at the district and sub-county levels. Data were collected on their roles and responsibilities in decentralised forest management, their perceptions and awareness about decentralisation of forest management. Information was also sought on forestry activities undertaken, incentives and disincentives for undertaking decentralised forest management, decision-making powers in the management of forest resources, forest rules and byelaws formulated, and constraints and challenges local governments face in decentralised forest governance.

4.2.2. Key informant interviews

In-depth key informant interviews were held with key people in the NFA, NGOs, Ministry of Water and Environment, staff of the defunct Forest Department, and private sector and with staff from local organisations involved in forestry-related activities at the district and sub-county levels. Interviews focused on how local organisations work with the Forest Department at the district, the kind of powers, resources and technical advice provided by the Department, and experiences from participation in forest governance.

4.2.3. Unstructured observations

During interviews, observations were also made on various forestry activities undertaken by communities and District Forestry Services of local governments. This also acted as a tool for triangulating the information obtained from the questionnaire survey.

4.2.4. Desk review

Records, policy and legal documents at the District Forest Department were reviewed to triangulate information on budgets, institutional conditions and framework for the implementation of decentralised forest governance.

4.3. Data analysis

Data entered into the Statistical Package for Social Scientists (SPSS) version 21 were cleaned and exploratory data analysis conducted to inspect all the entries for possible anomalies including erroneously entered values. Activities implemented, indicators of power relations, and challenges in the implementation of decentralised forest governance were examined through a simple computation of descriptive statistics.

5. Results

5.1. Activities implemented by forest departments under decentralisation dispensation

Forest resource monitoring was the major activity undertaken under District Forestry Services (95.8%), followed by tree nursery establishment and management (87.5%). Local organisations were not much involved in bee keeping, energy conservation and tourism development that were meant to alleviate poverty (Table 1).

Roles and Responsibilities	% Response
Forest resource monitoring (patrols)	96
Tree nursery establishment and management	87
Environmental education and awareness	84
Promotion of tree planting (agroforestry) with households, schools and private institutions	79
Maintenance of forest boundaries	79
Collection of revenue from forests	58
Promotion of collaborative forest management	50
Training of local authorities in forestry planning (development of work plans)	42
Promotion of ecotourism and biodiversity conservation	42
Promotion of energy conservation technologies	38
Promotion of bee keeping	12

Source: Original

Table 1. Activities implemented by District Forestry Services (DFS) of local governments

5.2. Power relations in the management of forest resources at the district level

Limited powers were devolved to sub-counties and village councils to monitor illegal forest resource use, while issuing of permits and prosecuting forest offenders were the responsibility of the District Forest Services of local governments (Table 2).

Activity(s)	% Response
Monitoring the forest resource	63
Making of forest byelaws	50
Apprehending forest offenders	34
Impounding equipment and tools from offenders	33
Recommending Issuance of permits to forest users	8
Prosecuting forest offenders	8

Source: Original

Table 2. Forestry activities for which sub-counties/lower local governments have decision-making powers

5.3. Challenges in implementing decentralised forest governance

Nearly two-thirds of the respondents reported that there were conflicts between local authorities at the district and sub-county level and the Forest Department staff. They reported that local politicians collaborated with illegal forest users to illegally exploit forests and conflicted on the issue of sharing of revenues from the sale of forest produce. Other challenges included unclear tenure of forest resources, overlapping authority and inadequate budget responsibility for decentralised forestry activities (Table 3).

Kind of conflict(s)	% Response
Politicians collaborating with forest offenders	87
Inequitable sharing of revenues from forest produce	67
Lack of clear tenure on forest produce from private forests and trees growing on private land	53
Overlapping authority and unclear chain of command between local councils and the District Forest Department staff	33
Lack of commitment of fiscal resources for forestry activities	25

Source: Original

Table 3. Challenges in implementation of decentralised forest governance in Uganda

6. Discussion

6.1. Activities implemented by forest departments under decentralisation dispensation

Our findings revealed that policies that primarily target increasing revenue and protection of the country’s forest estate from illegal users dominate the roles of the District Forest Departments. The integration of social and economic needs of local users through collaborative forest management, agroforestry, tree planting and ecotourism development is implemented by local government albeit with very remote prioritisation. The findings show some efforts by the District Forest Departments to invest in activities with the potential to improve the livelihoods of the local people, while protecting the forest resources. The Forestry Departments promote agroforestry in order to increase tree products to local people. Farmers are encouraged to establish woodlots for production of poles, fuelwood, fruits, fodder and for soil conservation. Agroforestry can reduce pressure on natural forests, and contributes to poverty alleviation as local community sell forest and agricultural products [35].

The current study reveals that there is very limited focus on activities that endear people towards participation in the management of local forests reserves which are directly under the stewardship of the District Forest Departments. Promoting collaborative forest management which was envisaged in the Forestry Policy of 2001 [8], and National Forestry and Tree Planting Act, 2003 [12], as a pathway through which local communities would participate in the management of local forest is not highly prioritised.

Our findings corroborate [36] who found that most local authorities to whom powers are devolved are systematically structured to be upwardly accountable to the central authorities, rather than downwardly accountable to local populations. In our study, district forest departments were more inclined towards implementing activities that resonate with the overarching aspirations of the central authority as provided in the Forestry Policy, 2001, and Forestry and Tree Planting Act, 2003. The study has shown that the discourse of participation and power-sharing with local institutions and local communities that influenced most forest governance reforms in Africa [37] is not yet pervasive in Uganda.

6.2. Power relations in the management of forest resources under decentralisation

Sub-county and village councils are rarely involved in issuing permits and other activities which are directly linked to exploitation of forest resources. There is a tendency to only decentralise administrative responsibilities to lower governance units. Our findings are in tandem with [16] who found that local people and their representatives rarely engage in activities that define who wields power even when formally forest resource management has been decentralised. It further shows that even when forest management is decentralised to district local governments, lower administrative units are still relegated to activities that do not involve money but to mainly those that require local support such as making of forest byelaws, monitoring forest resource, impounding equipment and tools from offenders. Discussions with LCs revealed that they are not involved in making decisions on how the forest resources are used. This suggests that democratic decentralisation of forest management has not been embraced in Uganda. It is therefore remote to expect equity to be achieved under the current dispensation of forest governance. This situation is exacerbated by the fact that Uganda's Forestry Policy of 2001 and National Forestry and Tree Planting Act, 2003, do not specify guidelines for selecting powers that can be transferred and the local levels that ought to receive them.

Our findings therefore show that in spite of decentralisation reforms taking root in Uganda for the past two decades, the mentality of professional foresters towards local communities at the district level has not significantly changed. They are still perceived as villains who cannot be given power to participate in activities involving giving concessions but are best suited to design and enforce regulations to protect local forest reserves. This may probably be because of fear to be held accountable by the local communities. It has been reported elsewhere [38-40] that in situations where local communities are considered as simply informants as in the current scenario, it may be difficult to attain effective forest governance. It is important that local communities, especially those that are adjacent to the resource, have rights to make decisions on how the forests are used. This builds confidence and also creates incentives for them to invest in sustainable forest management.

6.3. Challenges in the implementation of decentralised forest governance

Local politicians tend to exert pressure on the Forest Department staff to grant permits and licences to indigenes patronage. This situation often worsens during elections because politicians protect forest offenders from being prosecuted as a strategy to mobilise votes from their constituencies. Local politicians are themselves engaged in illegal forest exploitation.

Furthermore, there is increased pressure from some local governments onto the Forest staff to increase revenue, hence more pressure to exploit forest resources. This situation makes the District Forestry staff more vulnerable to undue pressure or even victimisation should they go against the wishes of the local politicians and some state agents. The findings demonstrate that political corruption has become hegemonic in the management of decentralised forest resources. This has been reported to be a major obstacle to successful implementation of decentralised forest governance in most developing countries [41]. The remuneration of the forest staff is generally inadequate compared to the value of the resource being managed and their qualification. As a result, rent seeking by staff in the forest department in districts is common and selective enforcement of the law and guidelines. Other authors [e.g. 15,42-44] have also reported rent seeking and political corruption as obstacles to forest decentralisation. According to [45], widespread bribery and corruption among forest rule enforcers makes their activities susceptible to abuse and not taken seriously by forest users. In other cases, corruption and the lack of respect for rule of law undermines the work of forestry officials involved in the implementation of decentralised forest governance [41,46].

There is also lack of transparency in the process of issuing permits and licences by the District Forest staff. Exploitation of forest produce is often based on political patronage. Records available in most of the district forest offices indicate that licensed timber dealers are not local residents. This situation creates local resentment and makes forest users poachers instead of protectors of resources [47]. Successful decentralised forest management planning should therefore consider the needs of the local forest users.

Benefits from timber and other forest produce are skewed in favour of the district government and commercial timber users. District government takes 60% of the total revenue generated from forest resources, while 40% goes to the lower local governments. Sub-county local governments are dissatisfied with the 40% of the revenue because they believe that the forests are within their jurisdiction. Unequal sharing of benefits is a disincentive for local governments to participate and regulate forest resource use [48,49]. There is no deliberate affirmative action for local communities that are interested in being awarded concessions from forests within their localities. Many of these are won by "outsiders" who have the economic muscle to pay for rent seeking and there is no clear framework for benefit sharing in both the law and the practice. Giving local authorities a fair share and rights to revenue encourages their participation in the protection of the forest resources and instils a sense of confidence and trust among local forest users and forest agencies [45,50].

In Uganda, control of reserved trees that grow on farmers' land, for example, *Milicia excelsa* (Welw.) C.C. Berg, and commercial harvesting of forest produce from private forests and other trees growing on farmers' land require a licence from the District Forest Office. This often is a disincentive to conservation of forests. Legislation and administrative laws must be clear, precise and consistent to avoid misconstruing the provisions. Insecurity of tenure hinders local community participation in tree planting and promoting sustainable forest management [50,51]. According to [52] and [53], individuals are more likely to conserve a resource when they believe they will reap long-term benefits from it.

Local government councils do not prioritise the management of forests during the budget processes probably because of lack of immediate tangible benefits that can bring political capital. Many political scientists argue that local governments tend to focus more on the developmental policies when allocating financial resources necessary to support local economies and to promote the growth of the communities [54,55]. Their major concern is economic growth of the local governments, not forestry protection, which is a common-pool resource that cannot exclude other communities from obtaining benefits from its use [52]. From this perspective, there is competition between local governments in allocating fiscal resources to activities that help to enhance their fiscal capabilities and those for protection of the forest estates; and the competition is likely to lead to reducing regulatory burden that appeal to forest law enforcers in their jurisdictions. Especially, underfunded District Forest Departments have few fiscal resources to support strict forestry regulations. This leaves many forest departments in districts in a dire situation and the staff cannot implement activities that would ensure effective forest governance despite having authority through a legal instrument.

7. Conclusions and policy recommendations

7.1. Conclusions

The central government decentralised functions and responsibilities to local governments to monitor forest resources without devolving adequate fiscal resources. Contradictory policies about forest resource governance, inequitable sharing of revenues generated from forest resources between the district governments and sub-county governments, rent seeking and political corruption amongst actors who are charged with forest law enforcement are the major challenges in dispensing decentralised forest governance in Uganda.

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7.2. Recommendations

1. There is need to establish platforms for citizen participation in the management of forest resources in their jurisdiction and this ought to be done with a perception of a right and not privilege.

2. There is a need to give incentives, secure political will of the lower local governments, ensure equitable sharing of forest resources between the district and sub-county governments and reform forest regulations for successful decentralised forest governance.

3. The role of District Forest staff and local authorities at district and sub-county level in policing and regulating forest resources should be clearly spelt out and reconciled for effective decentralised forest management and systems for demanding accountability from citizens should be put in place and operationalised.

4. Frameworks which can lead to equity in sharing of revenue accruing from forest resources between district and sub-county governments to motivate local governments to monitor forest resources need to be formulated.

5. Local governments need to be supported financially through grants to implement activities that can enhance the vitality and health of forests since most of the benefits that accrue from them are a common good for the whole country and not only for their areas of jurisdiction.

6. There is a need to strengthen the existing collaboration between the District Forest Departments of local governments and other stakeholders engaged in forestry to foster decentralised forest governance and also prioritize forestry in budgetary processes.

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Chapter 6

Creating Modern Community Conservation Organizations and Institutions to Effect Successful Forest Conservation Change

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Additional information is available at the end of the chapter

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Abstract

Despite increased investment, current conservation strategies have failed to stop environmental degradation and loss of biodiversity of the earth's ecosystems with consequent climate change. *Community Conservation's* (CC) 30 years of experience has produced a successful, cost-effective, field-tested flexible formula to catalyze communities to stop deforestation and biodiversity loss. Our method focuses on four concepts: 1) catalyzing projects, leaving ownership to on-site community-based organizations (CBOs) or local nongovernmental organizations (NGOs); 2) encouraging creation of CBOs; 3) helping build complex federations or networks for a stronger community voice; and 4) creating conservation contagion for regional change. Based on trust, we initially make the community aware of their special forests and wildlife and ask their help in protecting them. Then we help them create CBOs and build federations of conservation activists to strengthen and empower them to manage their projects and their natural resources. By bringing community members to interact together from within a large region, we strive to create conservation contagion. Case histories from Assam, India; northern Peru; the Huon Peninsula in Papua New Guinea; Madagascar; Belize; and Wisconsin, USA demonstrate successes based on the formation of CBOs and community federations, allowing communities to play a powerful role in protecting and restoring forests.

Keywords: CBOs, community-based organizations, community conservation, institutions, NGOs

1. Introduction

Despite increased financial resources, current conservation strategies, focused mainly on protected areas, have generally failed to stop environmental degradation, contain the rapid loss of biodiversity [1] and stem deforestation of the earth's forests [2-4] with consequent climate change [1, 5]. Billions of dollars over past decades have yielded few results [2, 5, 6].

The rise of alternative conservation methods involving local communities in the early 1980s generated controversy [7-11] mainly due to lumping of all community-based conservation projects. Yet, small community conservation projects (CCPs) and large integrated conservation and development projects (ICDPs) have very different philosophies, concepts and actions with most controversy and failure attributed to ICDPs [3, 12]. Today, there are thousands of CCPs [13-15] replacing community-based institutions which were once common globally, to manage forests [16, 17], fisheries [18] and water resources [17].

Some social scientists have been critical of community conservation [10, 11]. Others question whether rural communities can manage their forests and natural resources cooperatively [19, 20]. Yet still others question effectiveness of protected areas [21, 22] noting successes in community-based management systems outside protected areas [23].

What has emerged from what we describe in this article is a highly successful, cost-effective, field-tested method of community conservation [2, 3, 24, 25]. Not just an alternative, it can strengthen traditional conservation methods and protected areas that lack financial and human resources to succeed alone. It is a solid solution to environmental degradation [2, 3] of landscapes through building complex community organizations out of small, simpler ones [3, 25]. This is not surprising since many rural communities show favorable characteristics toward reduction of forest loss: 1) they live on-site where deforestation occurs; 2) they once had successful forest management organizations/institutions; 3) they have indigenous knowledge of the area; and 4) their numbers, thought detrimental, are potential conservationists [2, 3]. Indeed, when asked for help they have responded as conservationists.

At the center of successful CCPs is the creation of new conservation organizations or institutions managed by empowered communities. Such institutions in practice [2, 3, 25] and research [26] have proved effective in forest conservation and management [21-23, 26-31].

Since our early work in Belize, *Community Conservation* (CC) has focused on creating community organizations and complex institutions to protect and manage community projects and environmental landscapes (Table 1). Since 1984, we have evolved a field-tested flexible formula to facilitate catalyzing conservation contagion [3] to stop deforestation and biodiversity loss.

Generating conservation contagion [3] encourages local people as on-site conservationists [1, 14]. When conservation practitioners act as catalysts rather than project owners, communities respond favorably and contagion and community activism can emerge [3](see presentations on www.communityconservation.org). Conservation contagion often has a nonlinear effect [32, 33] as described in the following case histories. Our practitioner conclusions have a high

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1986 – Naïve attempt to create Board or Committee to oversee the **CBS in Belize**, eventually leading to the Woman's Conservation Group managing the project in 1998
1988 - Begin work with newly formed Ferry Bluff Eagle Council in **Wisconsin, USA**
1992 – Initiate Kickapoo Reserve to create valley-wide Kickapoo Community Sanctuary in **Wisconsin, USA**
1997 – First proposal to create a formal federation of community-based organizations to co-manage protected areas of **Belize**, resulting in UNDP grant to create the federation. 1999 – Attempt to carry out the project goals curtailed by project steering committee changing project goals
1998 – Creation of successful federation of community groups protecting the Manas Biosphere in **Assam, India** by 2004-2006; creation of two federations of 34 surrounding villages to protect Kakoijana Reserve Forest
2004 – Advising the creation of a federation of clan landowners in **Papua New Guinea** resulting in the Tree Kangaroo Conservation Program initiating the first Conservation Area in Papua New Guinea in 2010
2008 - Using new **Madagascar** laws to create federations of community-based groups to create around protected areas as buffer areas with federation network in Toliara District
2009 – Using new 2002 **Peru** laws, to begin expansion of Yellow Tailed Woolly Monkey Conservation Project to encourage community groups to create community conservation concessions to protect and manage lands with potential to create a network of these groups
2010 – Using new **Ghana** laws, expand existing community-based CREMA of 15 surrounding villages to protect Cape Three Points Forest Reserve

Table 1. Attempts and practices to create complex community institutions.

probability of success and are supported by social science research [26]. This paper discusses the evolution of community organizations and institutions guided by nongovernmental organizations (NGOs) and shaped by historical events using examples from India, Peru, Papua New Guinea, Madagascar, Belize and the USA.

2. Methods

Each project had its own methods of research, education, economic development, and community development integrating community members with the ultimate goal of conservation. They followed a series of 10 stages that we identified: 1) identify the project; 2) initiate or encourage a community-based organization (CBO); 3) train the CBO; 4) collect biological and sociological data; 5) develop community/outreach; 6) develop management and operation plans; 6) develop infrastructure; 7) formalize the plan; 8) implement the plan; 9) formalize management and project components; 10) terminate advisory role [34].

The projects' bases were social: 1) initiate contact with the community and ask their help; 2) build trusting social relationships; 3) participatory education; 4) identification of leaders and 5) supporters; 6) development of a formal infrastructure and plans; 7) form local networks of conservation activists; 8) diffusion from the target village to other communities to generate conservation contagion; and 9) develop vertical contacts with government and other NGOs (for specific project methods see: [2, 3, 25, 35, 36]).

3. Results — Case histories

3.1. Assam, India – Order out of chaos

The Golden Langur Conservation Project (GLCP) was initiated in 1998 to test methods and concepts developed in Belize, in a challenging new political situation in India with a high human population, militants in the forest, ethnic violence and 250, 000 internal refugees [2, 3, 25]. Given the potential for conservation contagion, the project focused on regional change of the entire Indian range of the golden langur, *Trachypithecus geei*. Contagion began first with participating researchers who focused on the flagship species. Following many meetings and workshops involving communities, NGOs and governmental agencies, the GLCP formed the Manas Biosphere Conservation Forum to focus on the main Indian range of the golden langur. As conservation contagion gathered momentum, community groups were catalyzed.

Kakoijana, a 17km^2 isolated Reserve Forest, with 95% deforestation became a model for future regional work. It was surrounded by 34 villages that formed forest committees to replant degraded areas and Self Help Groups to improve villagers' economic condition with micro-enterprises [3, 25; Bose pers.com.]. Interaction of forest committees and Self Help Groups empowered communities to protect specific forest areas. Eventually, all villages patrolled forested areas and formed two federations to protect the regenerating Kakoijana Reserve Forest and its langurs resulting in an increase of forest canopy cover from 5% to 80%, an increase in the langur population from less than 100 to over 500 [3] and an increase of other avian and mammalian species.

Focused on the Manas Biosphere in 2000, new CBOs emerged from conservation contagion generated by community meetings and workshops throughout the Biosphere. Four celebrations within the Manas Biosphere attracted progressively larger crowds of 6, 000 to 35, 000 participants from the government, NGOs and communities. Following a cessation of militant violence, including an accord in 2004 with the Central Government of India by the Bodoland Liberation Tigers and a ceasefire by the National Democratic Front of Bodoland, more conservation gains occurred.

Despite the peace, illegal loggers still threatened government staff and community residents. In response, the late Rajen Islari, coinitiator of the GLCP, and Kampa Borgoyari, Minister of Environment of the newly formed Bodoland Territorial Council, created the first paid community forest protection force to protect the western Reserve Forests of the Biosphere. This stimulated the formation of other community protection forces with 19 CBOs composing the Unified Forest Conservation Network (Table 2, Figure 1). Sixteen of those CBOs protect almost the entire 285, 000 hectare Manas Biosphere. Most illegal logging has ceased although there are still problem areas. The expanded project became the Manas Elephant Protection Project. The total Indian golden langur population increased from 1500 [37] to over 5600 golden langurs [3, 38] with evidence that elephant [39] and tiger [40] populations may be increasing. The combined efforts of government, NGOs and CBOs catalyzed by the GLCP, resulted in the lifting of the "in danger" listing of UNESCO on the Manas Biosphere.

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Community Groups	Date Form	Location	Protected Area	# vol
1. Green Forest Conservation	2006	Kachugaon	Kachugaon RF & helps others	116
2. Jharbari-Nounwgwr Eco-tourism Society	2007	Jharbari	Chirang RF	40
3. Biodiversity Conservation Society	2006	Ultapani	Chirang RF	40
4. Green Earth	2010	Labnypur	Chirang RF	11
5. New Horizon	2006	KoilaMoila	Manas RF	5
6. Raigajli Ecotourism & Social Welfare Society	2006	Kuklung	Manas RF	30
7. Panbari Manas NP Protection & Ecotourism Society	2006	Panbari	Manas NP - Panbari Range	28
8. United Social Welfare Society	2012	Labdanguri Kahitema	Manas NP- Bansbari Range	26
9. Swmkwr Mittinga Onsai Afat	2005	Bansbari	Manas NP –Bansbari Range	40
10. Manas Bhuyapara Conservation & Ecotourism Society	2007	Bhuyapara	Manas NP - Bhuyapara Range	25
11. Manas Maozagendry Ecotourism Society	2006	Koklabari	Manas NP Koklabari	30
12. Manas Agrang Society	2006	Simlibari	Manas NP- Bhuyapara Range	24
13. Manas Souci Khonghor Ecotourism Society	2006	Barama	Dhira RF	69
14. Manas Chowki Eco-Tourism Society	2011	Uttarkuchi Subankhata	Subankhata RF	20
15. Green Valley Forest & Wildlife Protection Society	2011	Nonaipara	Khalingduar RF, Barnadi WS	10
16. Green Leaves Society	2007	Khoragat	Manas NP - Khoraghat Range	21
17. Bodoland Forest Protection Force	2006	Balapara	Manas NP - Rupai & Khoraghat Ranges	59
18. Dwi Bajrum Eco-Tourism Society	2014	Udalguri	Manas NP – Bhairabkunda Area	20
19.Daoka Raja Eco-tourism Society	2013	Chakrasila	Chakrasila WS	
United Forest Conservation Network – BTC (Umbrella Federation)	2009		Manas Biosphere Reserve	Total 614
19. Green Conservation Federation	2005		Kakoijana RF	
20. Nature Guard	2005		Kakoijana RF	

Table 2. Assam, India community groups formed (RF = Reserve Forest, NP = National Park WS = Wildlife Sanctuary).

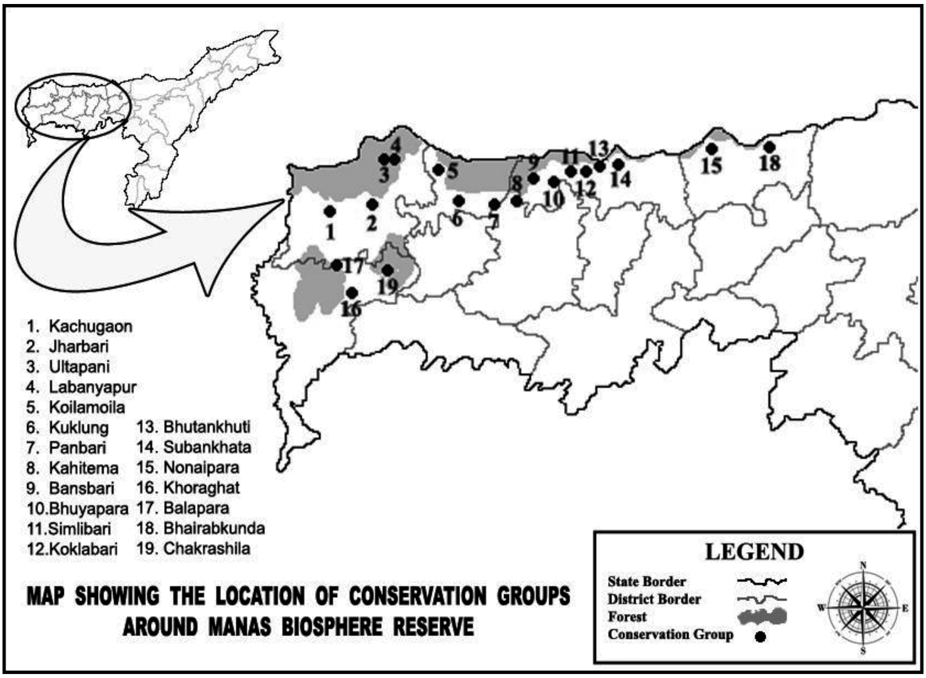

Figure 1. Map of the Manas Biosphere Reserve and other areas protected by community groups (numbers correspond with Table 2). Source: original.

Nature's Foster (NF), our main NGO partner, initiated a new Biosphere project focused on human elephant conflict, under the Assam Haathi Project that focused on a fringe village where elephants damaged village gardens and rice paddies. NF proposed to create a protective electric fence (Figure 2) if the village would provide labor and posts cut from non-protected forests. Participating families would pay a small maintenance fee and maintain the fence. Fifty-three families agreed to the proposal but one group declined to participate.

The complex community institution that resulted was modeled after the Kakoijana federations and the Manas Unified Forest Conservation Network. This institution is a complex multicentric federation built on smaller groups [26]. The fence that was to be maintained included two solar-powered electric stations, and a number of gates to be closed at night when the electricity was turned on. For ease in dividing tasks for fence maintenance, the seven hamlets created nine smaller groups of three or four people to do specific jobs, including maintenance of the power system and wires, opening and closing gates and cutting and clearing vegetation around the electric fence. An administrative committee represented by all hamlets and the two cultural communities, Bodos and Rajbanshis was appointed to administer and maintain the system. Thus far, the 6km fence encircling 2.5km^2 of village area has functioned well for the past four years with no elephant depredations from the adjacent Manas Biosphere forests. The reticent families have since joined the project since they continued to suffer depredations. Other fringe communities have requested similar projects and negotiations are being carried out to interest the Bodoland Territorial Council in more projects.

http://dx.doi.org/10.5772/61133

Figure 2. Aerial photo of the original solar electric fence (omiting the village in the bottom corner). Source: original

3.2. Northern Peru – Law and conservation contagion for community management and protection

The Yellow Tailed Woolly Monkey Project (YTWMP) was initiated by Neotropical Primate Conservation (www.neoprimate.org) in 2007 focused on creating a community reserve corridor between two protected areas in the cloud forest of northern Peru to protect populations of the endemic Critically Endangered yellow-tailed woolly monkey (*Lagothrix flavicauda*). Initially, the community was suspicious of the intentions of foreigners promoting conservation [41]. Rapid progress occurred through conservation contagion from two community-oriented workshops through help from the Ronda Campesina, a traditional CBO that establishes community security where there is not adequate government protection [42]. In all other areas, contagion has worked through word of mouth and media to create situations where the community groups have solicited help from the project.

With conservation contagion, the YTWMP expanded its goals, capitalizing on the 2002 Peruvian laws, by helping communities form CBOs to create conservation concessions and private conservation areas. The YTWMP, using its flagship species, expanded to focus on a landscape of endemism bounded by the Marañón and Huallaga rivers. Table 3 lists the groups the YTWMP is helping with concessions. Figure 3 locates the protected areas. The project is also helping to create local federations to function as community networks to educate themselves to manage their community reserves. As the project expands, it has the potential to incorporate as many as 50 community CBOs, managing an additional 500, 000 hectares of cloud forest and lower tropical rain and dry forests. This Marañón-Huallaga community landscape is a subcenter of endemism within the Tropical Andes Biodiversity Hotspot [43]. Three endemic primates inhabit the landscape: the yellow-tailed woolly monkey, the Andean night monkey (*Aotus miconax*) and the San Martin titi monkey (*Callicebus oenanthe*). The area also contains 13 additional primate and numerous other endemic species.

Group or Towns	**Date Formed**	**Community Protected Area**	**Hectares**	**Stage of Concession**
1,	2009	San Angel's Gardens	7,418	Awarded
2.	2010	Gran Simacache	41,269	Awarded
3.	2009	Iguahuana Dry Forests of Delta	423	Awarded
4.	2011	Hocicon	509	Created
5.	2008	Pampa del Burro	2,700	Awarded
6.	2010	Shitaryacu	1,592	Awarded
7.	2010	Tres Quebradas	4,177	Awarded
8.	2007	Hierba Buena Allpayacu	2.282	Awarded
9.	2010	Copallin	11,549	Awarded
10.	2012	Alto Renaco	3,372	Last stages
11.	2011	El Quinillal	11,540	Awarded
12.	2013	Sacha Runa	2,538	Awarded
13.	2013	Larga Vista 1	22	Awarded
14.	2013	Larga Vista 2	23	Awarded
15.	2014	The Monkeys Jungle	324	Created
16.	2014	Maorna	874	Created
17.	2015	Quiscarumi	11	Created
18.	2010	Berlin	98	Awarded
NGO PA				
19. AMPA	2008	El Breo	113,826	Awarded
20. AMPA	2012	Pucunucho	24	Awarded
21. AMPA	2013	Mangapaquina	14	
Government PA				

Group or Towns	Date Formed	Community Protected Area	Hectares	Stage of Concession
22.Government	2010	Rio Nieva Resrved Zone	36,348	Last stages
23.Government	2009	Cordilla de Colon National Sanctuary	39,216	Created
24.Government community co-management	2009	Chayunain Communal Reserve	23,598	Created
25.Government	1987	Alto Mayo Protected Forest	182,000	Created

Table 3. Peru community groups formed and other protected areas worked with.

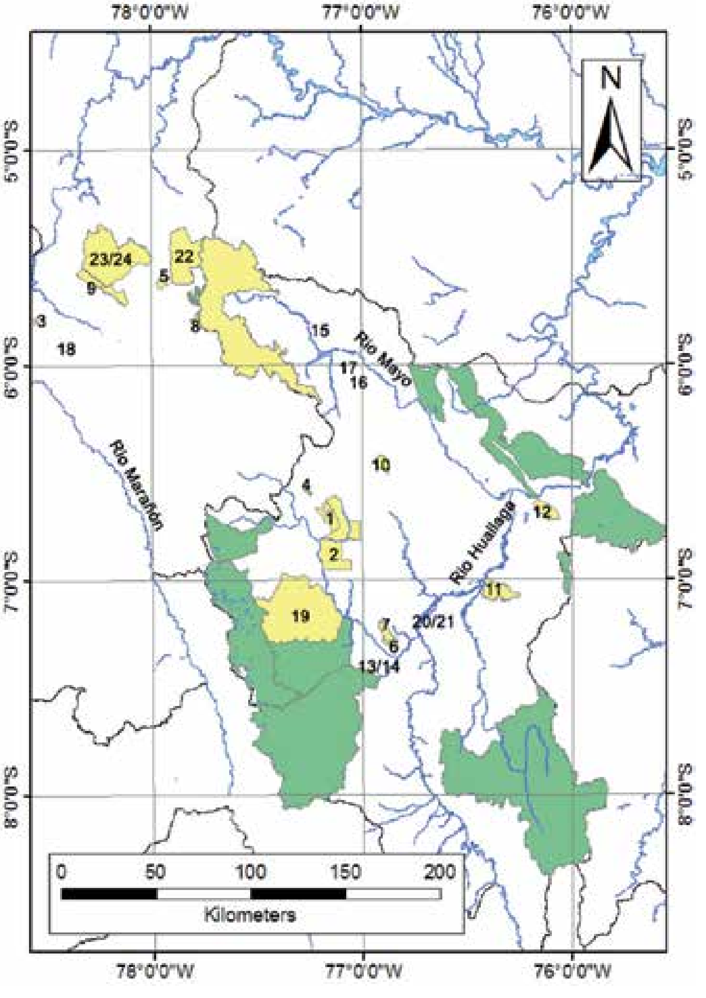

Figure 3. Map of the Mareñón-Huallaga Landscape in Northern Peru indicating the Government Protected Areas (green) , NGO and Community Reserves (yellow) (numbers correspond with Table 3). Source: original

3.3. Huon Peninsula, Papua New Guinea (PNG) - First conservation area

The Tree Kangaroo Conservation Program (TKCP) began in 1996 to study the endangered Matschie's tree kangaroo (*Dendrolagus matschiei*), endemic to the Huon Peninsula and expanded into a community conservation initiative [44], focused on the area defined by the Yopno, Urawa and Som rivers (YUS area). When CC joined the initiative, three clans were participating to create a Wildlife Management Area (WMA) similar to other community-protected areas [45]. However, WMAs had many disadvantages. PNG law draws on Australian law to include customary groups [46] with local land tenure systems and the inherent land rights [47, 48] in which indigenous clans own 97% of the land. By 1991, less than 3% of PNG lands had protected status [49-51] and most (88%) were WMAs created under the Fauna Act of 1966. Thus, novel approaches were necessary to conserve forests and wildlife yet retain clan control of their lands [52].

Papua New Guineans' view of the natural world shows strong attachment to their lands, rivers, and mountains – reflected in the popular saying among many rural Papua New Guineans that "land is life" [53]. Although they have managed their lands for thousands of years, traditional views have been partially supplanted by Christian teachings complicated by modern commercialism [54], with pressure from the Land Tenure Conversion Act that provides a mechanism to convert customary ownership to private land ownership [46]. Recent YUS history laid foundations for clans working together in the TKCP. Originally, Yupno people lived in scattered groups but were moved to create villages after the Second World War with pressure from the Lutheran mission, to establish a "Christian Community" [55]. Thus, clans of different descent groups live together in villages.

After a first visit in 2002, CC wrote a proposal to create a Conservation Area by 1) gathering legal information, 2) facilitating landowner visits to other protected areas, 3) forming a local conservation group, and 4) creating a landowner group to develop a management plan. The Conservation Area has strong objectives similar to National Parks and is more comprehensive than WMAs [52]. Although the Conservation Areas Act was enacted in 1978, it was never previously used since there was no functioning National Conservation Council [56, 57] that determines the criteria, rules and regulations for the Conservation Area. This council was appointed in 2003, perhaps stimulated by the TKCP, opening the way for the YUS Conservation Area [52]. The TKCP and the YUS clans chose the Conservation Area because of its strength and its maintenance of the clans' decision-making rights over their customary lands [52].

By 2003, the TKCP had collected pledges for 36, 363 hectares from 26 clans [58] (Figure 4). The first meeting of clan landowners and the Department of the Environment and Conservation (DEC) occurred in 2004 and a proposal for the YUS Conservation Area was submitted [59]. The TKCP next worked with the YUS Local Level Government, the District Government and the Morobe Provincial Government to gain local government approval. Finally, they worked with the National DEC to develop the proposal for official approval by the PNG National Executive Council (NEC) [59, 60]. The final proposal to the NEC [60, 61], declared over 68, 182 hectares of over 100 clans from 37 villages [61]. The National Government approved the YUS Conservation Area and it was gazetted in January 9, 2009 [60].

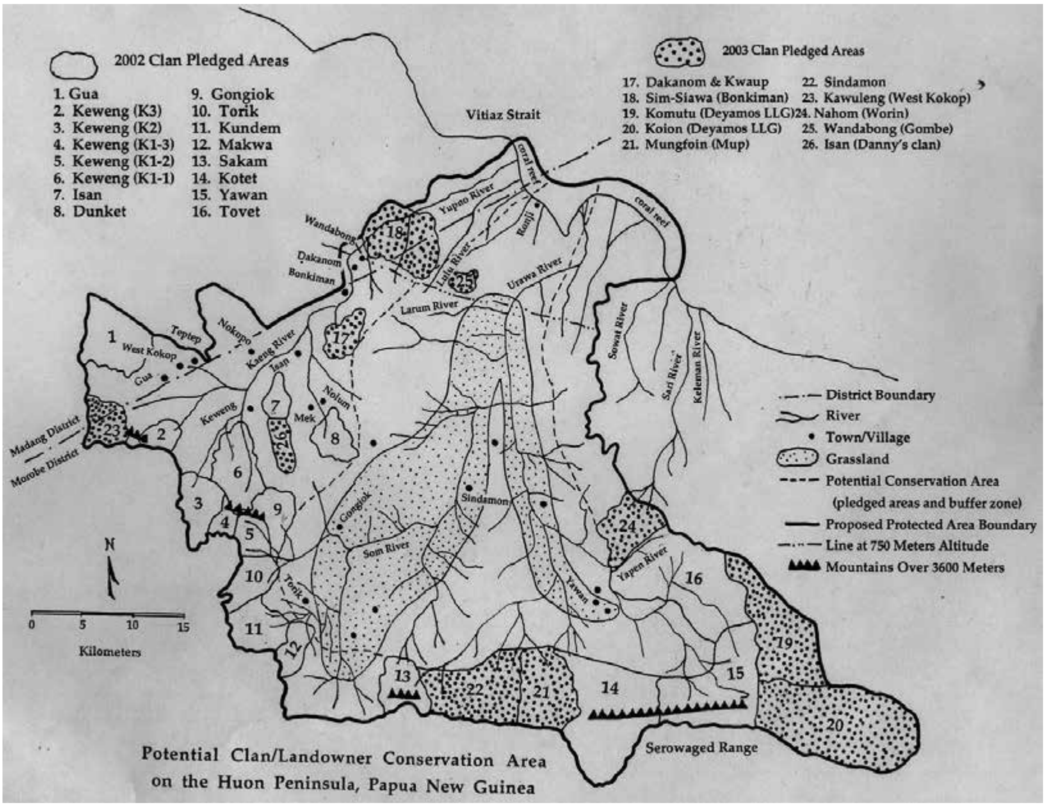

Figure 4. Initial map of the developing YUS Conservation Area in process indicating the 26 clans represented by 2003. Source: original.

Since the state's role has been ineffective in accommodating existing private land ownership [62], the YUS Conservation Area, the first in PNG, and its community comanagement role [63, 64] may strengthen the government's role. Comanagement balances local interests with a legal basis. Although landowners cede some rights, the Management Committee reflects the interests of the landowners as well as the Provincial and National governments [56].

The YUS Conservation Area, a model project [60, 65], now protects 75, 676 (187, 000 acres) hectares and includes 45 villages within the Finisterre and Sarawaged mountain ranges [66] (Figure 5). The TKCP trained landowners to develop management plans and will develop a guide for other communities [60]. It has formed a local CBO to advise the management committee and an in-country NGO and has established a trust fund to maintain the YUS Conservation Area.

Another PNG project, the Tenkile Conservation Alliance, that focused on two other tree kangaroo species has been working steadily in the same direction. Given these two projects, the laws and NGOs supporting the community approach, *Community Conservation* submitted a proposal to Conservation International to use a series of workshops to stimulate conservation contagion for initiating other Conservation Areas in PNG [67].

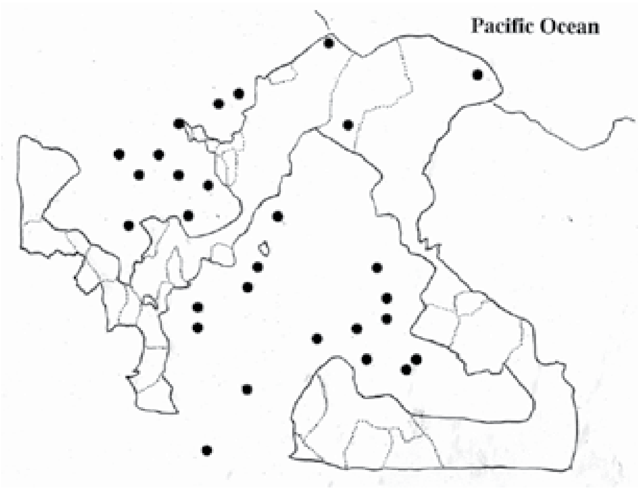

Figure 5. Map of the completed YUS Conservation Area of 187, 000 (75, 676ha) acres. Dotted lines indicate clan boundaries, solid dots indicate villages. Source: [66].

3.4. Southwest Madagascar – A plan laid out

A consortium of government and NGOs made a regional plan to create federations of community reserves to support existing protected areas and to triple the number of protected areas in accordance with the Madagascar National Environmental Action Plan.

In recent times in Madagascar, the local perception that forests belong to the "fanzakana" (government) led to forest degradation from lack of enforcement and loss of respect for the government [68, 69]. In 1996, the government stimulated community-based natural resource management through the GELOSE (Gestation Locale Securise) law that encouraged contracts between the forest service, the local municipality, and a voluntary community association (COBA, Communaté de Base). This cumbersome GELOSE was simplified by Contractual Forest Management (GCF) in 2000 through transference of forest management rights to the communities. Thus, in the third phase of the National Environmental Action Plan (NEAP) that emphasized a landscape approach supported by GELOSE and GCF, over 400 GELOSE contracts were formed throughout Madagascar [69]. By 2009, over 150 such contracts had been signed in the south and southeast alone and the figure is now well over 250 in the south and southwest Madagascar.

Since 2005, after a socioeconomic assessment of southwestern Madagascar [70], WWF and the National Association for the Management of Protected Areas in Madagascar (ANGAP) fostered community comanagement of the dry forest landscape in support of the Durban accord to triple the amount of protected areas in Toliara District [70]. They worked with communities to form village associations and encouraged the GELOSE law for community comanagement [71]. This legal transfer of management responsibility from the state to villages or communes includes a traditional agreement (dina) signed by the village association (COBA), the commune and a government representative, usually the Waters and Forest Service (L'Eaux et Forêts) for forested areas [69, 71].

Once functional and strong associations for land and natural resource management are formed, the areas of community protective influence can be demarked. Then community comanagement federations are formed around community-protected lands often around public protected areas to work with NGOs and ANGAP or other agencies. Coordinators can then strengthen the associations and federations to further their goals by training the community members in the 13 topics [72] relative to both technical and governance aspects of community management. The associated COBAs then elect a coordinator. Coordinators and participating NGOs can train community members with a 1-2 year training course while living in or frequently visiting the villages. Short-term workshops could supplement the long-term on-site training and tutoring. Such a 2-year program would prepare the associations and staff for formal management. The comanagement federation would work with ANGAP or the Waters and Forest Service to create a management plan to include an active forest protection force to patrol and post their lands to discourage encroachers. Associations would set up forestation programs for fuel-wood and other future needs. Plantations would emphasize forest corridors between Federation lands where feasible.

Table 4 and Figure 6 indicate the plan for the following four Regions of south-southwestern Madagascar: Menabe, Atsimo-Andrefena, Androy, and Anosy. This evolving conservation work emphasizes supporting and expanding the areas under protection by having communities work together with ANGAP and NGOs to both strengthen government protected areas and connect them with community protected areas.

Group	Type	State Protected Area	Community PA	Type	Ha
Alokaina Agnalamaitso	OPCI	1 Andranomena SR	2 Menabe Antimena	APC	1. 6420 2. 195000
			3 Allee des Baobabs	APC	small
Hahitamami	AI	4 Kirindy Mite NP			72200
Fimami	AI	5 Mikea NP			250000
Velondriake Fiama	AV		6 Velondriake	APC	80000
Tsifota & Fiherenamasy	AV		7 Honco	APC	>4000
Mitoimafi	AI		8 PK32-Ranobe	APC	77851
Fimihara	AV		9 Jardin des Roses	APC	>200
Filobe	AV		10 Belalanda	APC	.3000
Tamia	AV		11 Tsinjoriake	APC	>15000
Ohemiha	OPCI		12 Amoroni Onilahy	APC	>12000
Club Tsita	AV		13 Ranomay	APC	>300
Fimimano	AI		14 Nosy Ve & marine park Tsimanempesotse	APC	>6000
Tsitinginy Andrangy	AV		15 Honko, Nosy Satrana	APC	>500
Rodobey	AICPM	16 Tsimanampesotse NP			43200 177000

Group	Type	State Protected Area	Community PA	Type	Ha
Hihitse	AI		17 Menarandra Sud	APC	>4000
Komiholo	OPCI		18 Angavo	APC	>8000
Fikasana	OPCI		19 Nord Ifotaka 20 Sud-Quest Ifotaka 21 Corridor PI-PII Andohahela 22 Behara-Tranomaro	APC	>15000
Makarefi	OPCI		23 Ankodida	APC	

Table 4. Madagascar community groups formed in southern and southwestern regions of Madagascar and official or estimated surface areas under national park or community conservation status. (Community group types include Intercommunal Associations – AI; Village Association – AV; Public Organization of Intercommunal Cooperation – OPCI; and AICPM. Protected Area Types include National Park – NP; Special Reserve – RS; Community Protected Area - APC).

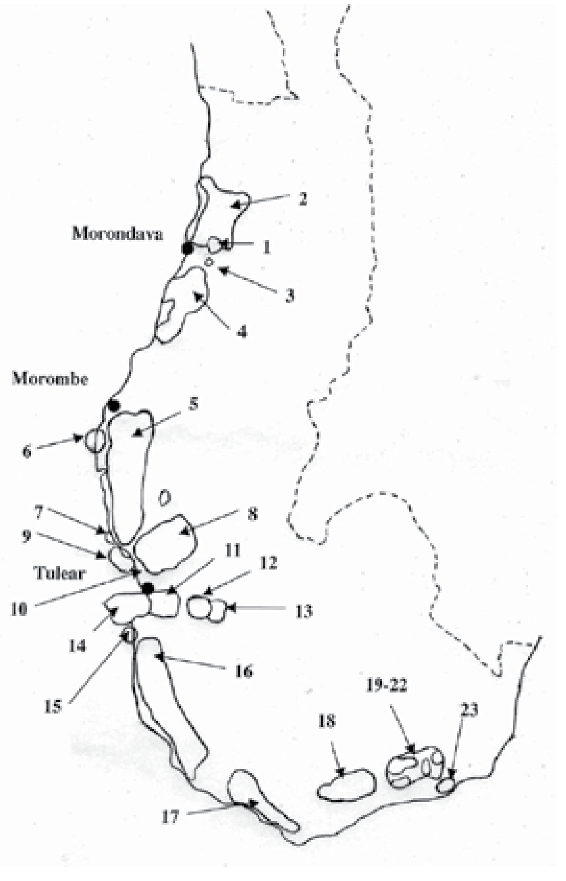

Figure 6. Map of Toliara Province in Southwestern Madagascar showing Community Protected Areas, Government Protected Areas, and Community Groups they are associated with (numbers correspond with Table 4). Dotted lines indicate the provincial border; dots are towns. Source: after WWF by Louise Jasper.

3.5. Belize – Missed opportunity for community comanagement

The Community Baboon Sanctuary (CBS) was initiated in 1985 as an experiment to protect a viable population of black howler monkeys (*Alouatta pigra*) that is endemic to southern Mexico, northeastern Guatemala, and Belize. With the introduction of community conservation to Belize, we first saw evidence of conservation contagion [3]. As a result, many communities sought opportunities similar to what was occurring in the CBS in Belize. Many communities stimulated the Government of Belize to create protected areas and the government, with comanagement experience with NGOs, involved communities in comanagement through signing of memoranda of understanding (MOUs) [73] signing at least 20 community groups as comanagers (Table 5, Figure 7). Eventually, the Government of Belize incorporated community comanagement into government policy [74]. However, despite this, lack of financial support and government motivation [75] left many CBOs struggling to manage their protected areas.

Group Name	Group Form.	Year Form.	PA Name	Ha	Com Stim. PA
1.Women's Conservation Group	1998	1985	Community Baboon Sanctuary	4700	Yes
2.Assn Fr of 5 Blues Lake NP	1993?	1994	5 Blues Lake NP	1846	Yes
3.Aguacaliente Management Team	1996	1998	Aguacaliente WS	2485	Yes
4.STACA	1994	2001	Billy Barquedier NP	745	Yes
5.Assn of Fr of Freshwater Creek	1998?	2001	Honey Camp NP	3533	No?
6.Fr of Mayflower Bocawina NP	1999	2001	Mayflower Bocawina NP	3570	Yes
7.Itzamna Society	2000	2001	Noj Kaax Meen Elijio Panti NP	5753	Yes
8.Rio Blanco Mayan Association	1994	1994	Rio Blanco NP	43	Yes
9.Rancho Dolores EDG	2000?	2002	Spanish Creek WS	2728	Yes
10.Green Reef	1996?	1996	Bacalar Chico NP & MR	7166	Yes
11.Friends of Swallow Caye	1996	2002	Swallow Caye WS	4078	Yes
12.TASTE to SEA	2000	1996	Sapodilla Cayes MR	12500	?
13.FoN to SEA	1993	1996	Laughingbird Cay NP	4600	Yes
14.FoN to SEA	1993	2003	Gladden Spit & Silk Cayes MR	11808	Yes
15.Friends of GraGra Lagoon	1994	2002	GraGra Lagoon NP	600	Yes
16.SATIIM	1998	1994	Sarstoon-Temash NP	19025	No
17.FAMRACC	1998?	1998	Cay Caulker MR	4395	Yes
18.Guardians of the Jewel	2000?	1994	Monkey Bay NP	965	No?
19.GPWSCMC	2003?	1998	Gales Point WS	4135	No
20.SACD	2007	1996	Corozal Bay WS	82049	No
TOTAL				**176,724**	

Table 5. Belize Community Groups Formed (all except CBS are comanaged with the Government of Belize [from 76, 77] (Assn = Association, Fr = Friends, EDG= Environmental and Development Group, NP = National Park, FAMRACC = Forest and Marine Reserve Association of Cay Caulker, FoN = Friends of Nature, GPWSCMC = Gales Point Wildlife Sanctuary Community Management Committee, SACD = Sarteneja Alliance for Conservation and Development, SEA=Southern Environmental Association, STACA = Steadfast Tourism and Conservation Group, TASTE = Toledo Association for Sustainable Tourism and Empowerment).

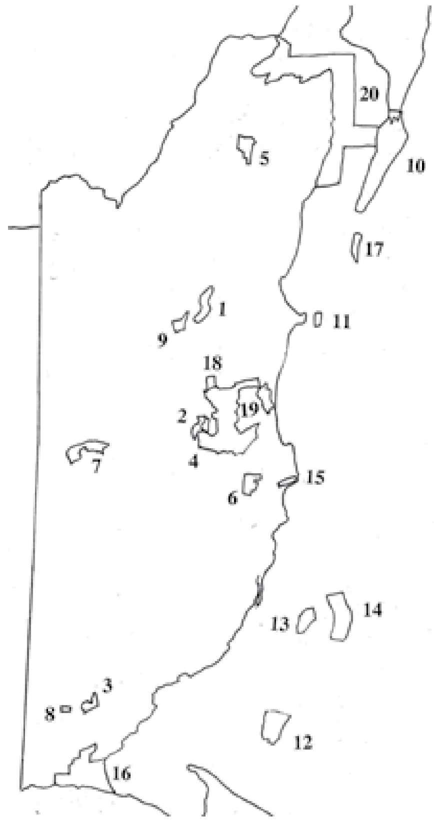

Figure 7. Map of Belize with Community Baboon Sanctuary (No.1) and Protected Areas comanaged with informal and formal agreements with Government of Belize Departments of Forestry and Fisheries (numbers correspond with Table 5). Source: [76, 77].

Seeing the possibilities for creating a strong community comanagement system, CC wrote a proposal to be administered by the Protected Areas Conservation Trust (PACT), a parastatal Belizean organization, for a GEF grant to develop five community projects and a community-based network for all CBOs in the country [78]. The projects selected by PACT included Sarstoon-Temash National Park, Freshwater Creek Reserve Forest, Gales Point Manatee, Five Blues Lake National Park, and Aguacaliente Wildlife Sanctuary. As a result of CC's action to involve communities in the management of the Sarstoon-Temash National Park [3, 79, 80], an indigenous NGO, Sarstoon Temash Institution of Indigenous Management (SATIIM), was initiated and they wrote their own proposal that was consequently funded.

CC's proposal [78] was funded and the project began in 1999, with CC staff as project advisers. After 6 months, the project steering committee changed the project goals [75] and CC staff were eliminated from the project. PACT hired a young Belizean woman with a Masters degree but no community conservation experience and the steering committee acted as project advisers. As a result of these changes, the project was deemed a failure [81] and the $750, 000 and added funds were essentially wasted with no hope of renewal.

After the project completion, CC staff attempted to recreate the community comanaged network. They worked without funding with Matt Miller, a Peace Corps (PC) staff to develop the network through PC volunteers placed in communities managing protected areas [82]. When Miller's PC affiliation ended, it was impossible to proceed, and the communities have been left to struggle on their own. A few years later in 2007, the Association of Protected Areas Management Organizations (APAMO) was formed, perhaps influenced by the idea of creating a community comanagement system, to create a network of protected areas.

A recent trip to Belize in mid 2014 to make a video on the CBS and its legacy as a community model unexpectedly indicated how fickle governments can be on conservation issues and how strong conservationist communities can be. With the discovery of oil prior to our visit, the government and the Minister of Forests, Fisheries, and Sustainability began to put pressure on the Indigenous NGO SATIIM that was comanaging the Sarstoon-Temash National Park to allow drilling for oil within the park, which was essentially illegal. This initiated an uneasy relationship between NGOs and communities toward the government. A new unpalatable contract was promoted by the government and the NGOs, CBOs, and APAMO attempted to negotiate a better contract. The government then stipulated that all comanagers would be restricted from receiving any funding if they did not sign the contract that would give the government power over the protected areas. Most of the NGOs signed the contract or they would not be able to continue their work, but many communities have resisted. Two indigenous comanagers SATIIM and Itzamna Society have been removed by the government as comanagers. SATIIM and some of the Mayan communities have resisted and won some legal battles against the government with the courts stating that these Mayan communities have a right to these lands as their homelands.

The situation is currently in flux. However, the comanagement system which started with the Belize Audubon Society in the early 1980s, had been working well for over 30 years. In many cases, it was the communities that stimulated the government to create protected areas and had worked hard with little training and resources to protect their lands for Belize, with little support from the government. These same communities are now being disregarded by the Minister of Environment. Belize, which had been an early pioneer of successful comanagement for its protected areas is now dismantling it.

3.6. Wisconsin – Rugged individualism blocks community power

While rural southern Wisconsin proved to be fertile ground to stimulate activism and the formation of CBOs, it has proved difficult to catalyze conservation contagion and a sense of regional communalism that has occurred in other countries. This reticence seems to be due to individualism which is a strong element in the American psyche [83].

Community conservation work began in Wisconsin in 1988 with the Ferry Bluff Eagle Council (FBEC) using the CBS as a model [84] (Table 6). However, shortly after successfully working with landowners FBEC discontinued work on the community eagle sanctuary and focused on Eagle Days, an ecotourism project that leaves over $1 million annually in the Sauk-Prairie community from winter eagle viewing [85; Moermond pers. com.]

Group	Date Created	Protected Area	Ha
Ferry Bluff Eagle Council	1987	Private/public lands	NA
Kickapoo Reserve Board	1996	Kickapoo Valley Reserve	3895
Valley Stewardship Network	1999	Private/Public Stewardship	NA
Blue Mounds Area Project	1997	Private Lands	6364
Sauk Prairie Conservation Alliance	1998	Badger Lands	3425
Kickapoo Community Sanctuary	never	Never accepted	NA

Table 6. Wisconsin USA community groups formed.

In 1992, CC created a proposal [86] for a plan to create the Kickapoo Valley Reserve as part of the Kickapoo Community Sanctuary based on the CBS in Belize. The proposal was the resolution to a failed project to create a dam and lake from properties of 144 families by eminent domain that had caused community strife for over 30 years. Much of the proposal was adopted by a committee headed by the Governor's appointee. Through the political process, a 9, 000 hectare reserve was created with a local management board of governor appointees: three members from the adjacent communities, three from the Kickapoo Valley, and three from the state to cover education, environment, and tourism. A few years later, the Ho-Chunk tribe, were given two additional positions on the Board. Although the reserve staff and Board have been successful reserve managers, the community sanctuary idea was omitted from the proposal. Currently in February 2015, another Governor is seeking to dismantle the community-based Kickapoo Valley Reserve Board and place the reserve under the Department of Natural Resources, which has also been considerably downsized. This again shows how changeable government can be.

The initiation of what was to become the Valley Stewardship Network (VSN) originated with the idea of the remainder of the Kickapoo Valley as a buffer zone of the Kickapoo Valley Reserve [84] that harkened back to the creation of the Kickapoo Community Sanctuary, modeled after the Community Baboon Sanctuary in Belize. It led to the creation of a consortium of water quality monitors for the Kickapoo River. VSN has developed a number of programs: to help Kickapoo Valley communities develop management plans, clean up rivers and connect local consumers with local farmers, as well as a strong water monitoring program. VSN's data are used by the Wisconsin Department of Natural Resources and local counties; they have also aided additional conservation organizations that were initiated to fight against factory farms, water bottling initiatives, and frac sand mining.

The Blue Mounds area Project targeted private landowners to protect the biodiversity on their lands with a focus on prairies and oak savannas [84]. It reached ~200 members and 5260 hectares of land through an ecological extension agent and an active education program.

CC used the Kickapoo Valley Reserve as a model to convert the Badger Army Ammunitions Plant (BAAP) lands into a community reserve. CC first approached Citizens for Safe Water Around Badger (CSWAB), an NGO monitoring the BAAP lands [84], but they never fully embraced the Kickapoo model. Eventually, General Services Administration (GSA), whose responsibility was to redistribute the government lands, developed a program for all stakeholders to participate in the process. Community Conservation Coalition for Sauk Prairie (CCCSP) developed to take over project leadership from CSWAB. CCCSP coordinated an education program and produced a proposal to create a natural prairie protected area instead of a chemical-plant-based commercial area. Under a different name, Sauk Prairie Conservation Alliance (SPCA) continued monitoring the land exchange and building demolition process, eventually establishing an office in one of the remaining buildings. The Badger History Group developed as an offshoot of SPCA and helped to gain more community support for maintaining the area as a protected area with a potential recreational role.

The Badger Reuse Committee, established by GSA, worked with the proposed landowners to follow a reuse plan based on the proposal of CCCSP. The lands have been distributed jointly to the Wisconsin Department of Natural Resources, the Ho-Chunk tribe, and the Department of Agriculture who had an experimental farm on the lands. These three landowners signed an agreement with Sauk County, the Department of the Army, and the townships of Merrimac and Sumpter, in which the lands reside, to form the Badger Army Ammunition Plan Oversight and Management Commission. The commission is composed of the Ho-Chunk, Wisconsin DNR, Sauk County and the two townships. There are also stakeholder representatives from CSWAB, SPCA, the Badger History Group, University of Wisconsin-Baraboo, Bluffview Sanitary District, City of Baraboo, Sauk Prairie School District, Village of Sauk City, and the Wisconsin Wildlife Federation with liaisons from The US Army and USDA [87].

The original proposal [86] to create the Kickapoo Community Sanctuary began with the Kickapoo Valley Reserve. However, when the proposal was taken over by a drafting committee of the Kickapoo Valley Advisory Committee coordinated by an appointee of the Governor, much of the community concepts were removed in the revised proposal. When the land was given over to the state the community concept became even more reduced.

Later when we began developing a watershed program with a new proposal [88] to develop a valley wide water quality program, it resulted in Valley Stewardship Network but never developed any concrete interest in unifying the valley into a community sanctuary. In 2007-8, Community Conservation led a workshop to develop community conservation skills in the Kickapoo Valley with the repeated goal of establishing the Kickapoo Community Sanctuary [89]. There was difficulty in getting existing conservation organizations interested in the idea and a yearlong campaign using the Kickapoo Chautaqua, a musical event, to propagate the idea failed. A final push in 2010 resulted instead in developing an annual Earth Day program.

It is puzzling why U.S. villagers, with more formal education, were unable to understand what, presumably, less-educated rural people in India, Ghana, Peru, Belize, and Papua New Guinea, almost immediately grasped. However, this difference became clear considering the individualism that dominates the U.S. psyche [83]. Leopold's Odyssey [83] indicated how, during the late 1930s and 1940s, Leopold struggled with the same problem with U.S. people, that occurs as strong as ever today. In his later life, Leopold saw U.S. conservation losing ground and understood that there were three intertwined elements in U.S. culture that conflicted with conservation and ecological interdependence. He felt that Americans understood themselves as isolated individuals acting in their own self-interest for short-term profit. He stated that the "current doctrine of private-profit and public-subsidy" do not require community obligation from private landowners. Leopold stated "We rationalize these defects as individualism, " "but they imply no real respect for the landowner as an individual." He rather called them "bogus individualism" [83 p. 259], which he believed was based on selfishness and short-sightedness. Leopold believed that industrialization, economic determinism, and individualism were destroying the land. It seems the USA has not progressed much today in this respect.

4. Discussion

4.1. Encouraging community conservation organizations and institutions

Although there is controversy generated around the issue of community conservation on one hand, and a ubiquitous use of the many words connoting community conservation in the literature, there are few definitions of what is meant by the terms [3]. To those that have been successfully working with communities to protect their environment, the controversy is a mute point and only an academic discussion. When carried out with trust between NGOs and communities and when communities are asked for help and given the incentives and responsibilities to protect their environment, they have responded positively. At the center of the success is treating community partners with trust [90], the use of small but adequate budgets used to develop programs, and creating or encouraging the development of simple community organizations as building blocks to develop more complex federations or networks to create an effective solution to stop the spiraling rates of deforestation and loss of biodiversity. Until the conservation community understands and utilizes the numerous rural residents and helps them develop as powerful allies, the world's natural areas will continue to be degraded, fragmented, dwindle and eventually disappear or become ineffective as natural ecosystems.

The basis of successful CCPs is helping communities to create and maintain viable, functional, and empowered community organizations and institutions. By doing this, we are recreating and strengthening new forms of cooperative institutions to replace those that were lost due to colonialism. Community conservation does not replace "traditional" protected areas but strengthens them by creating trusting working relationships between governments, NGOs, and communities and giving communities the power, training, and responsibilities to create a more fulfilled life in relative harmony with the natural world they live in.

In general, community organizations have been based on villages or hamlets as in Belize, Assam, India, Peru, and Madagascar. In Papua New Guinea, clans are the basic unit since villages were a somewhat artificial creation by the Christian missions [55]. Although village units are often heterogeneous in culture and religion, this does not preclude failure [91] and methods can be found to incorporate these variations. Indeed, research on forest management groups shows examples of successful heterogeneous groups [92]. In practice, in the Assam Haathi electric fence project, Bodo and a Rajbanshi, co-developer project leaders work together to inform their respective communities in coordinating the project. In other Assam areas, despite a history of ethnic violence, trusting relationships and positive social incentives help

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diverse communities work together and capitalize on alliances between community members. In the Ultapani-Labanapur villages in the Manas Biosphere, Bodos and Nepalis work together and know each others' languages. In the Kakoijana area, many tribes with Hindus and Christians work together. St Margaret's village, Belize, is composed of refugees from Central America, ex-patriots from the USA and Belizean Creoles that work together. In Peru, the communities involved in these conservation projects are a mix of immigrants from the coast and Andean highlands, with some indigenous.

Although protection of large landscapes is a reason for creating traditional protected areas [23], large landscapes can be protected by community federations [25]. Indeed, there are questions about the effectiveness of traditional protected areas [23]. As in Assam, communities can play a powerful role to support existing protected areas if they are enlisted as full partner conservationists. Communities can also play a major role with nonpublic lands which is important since 90% of forests are outside of protected areas. Indeed, many of the forests in Nepal are being well protected by communities that have been incorporated into a large, complex network of 15, 000 community forest user groups with international linkages [93].

4.2. Conservation contagion

Conservation contagion is a powerful tool that can be encouraged [3]. Existing community networks can be encouraged or new ones created to spread awareness [32]. Workshops and meetings that include people from different areas and cultures can help contagion to jump geographic and cultural gaps. People with extensive contacts are natural net-workers who can propagate contagion across geographical and cultural gaps [32]. Encouraging face-to-face meetings and interactions encourages project dispersal and contagion. Encouraging villagers from one community that has experienced a successful project to inform or help train other communities can be a powerful tool to encourage conservation contagion. We are using villagers in a successful community project in Côte d'Ivoire to influence their neighbors across the Tanoé River in Ghana with the possibility of a transboundary community reserve.

4.3. Laws and government support of community conservation

The strongest conservation option is when government, NGOs, and communities work together. Country laws that support community management are also important. In Assam, there was a change in government when the Bodoland Territorial Council (BTC) took over area administration under the Assam state government. The close working relationship with the Minister of Environment, Kampa Borgoyari, strengthened the situation but funding and other actions were not always continuous since there was no formal law in place directing all actors. Thus, we are working with the BTC to see if we can get the law changed to incorporate the successful community action that has protected Assam's forests in recent times.

In contrast to India, Belize created a mechanism for communities to sign MOUs to comanage National Parks and other protected areas. However, the government agencies have lacked the resources and motivation to help train and encourage the community comanagers [75]. Thus, government and NGOs have worked with their own protected areas but neglected the catalytic role in strengthening community comanaged protected areas. Now, even worse, the government is working against them.

In Peru, legislation exists to promote the creation of protected areas on titled land (Private Conservation Areas) and on government lands (Conservation Concessions). There also exists a formal protected area category for government/community comanagement with indigenous communities (Communal Reserve). The existence of this legislation has been a main factor in encouraging CCPs in Peru, although the complexities of this legislation and the detailed planning required by government agencies means that these mechanisms are in many cases only viable for CBOs connected to outside NGOs [94]. Similar legislation exists throughout Latin America [95] but, as in Peru, CCP success using these mechanisms depends heavily on communal, local and national government willingness.

Forward-looking governments realize the importance of including communities in the conservation process because they understand that they cannot effectively manage and conserve Protected Areas without the help of local communities [96]. For example, in Belize, our work influenced the government to create new policies for community comanagement institutions [74]. In Assam, India we are striving to convince the new Bodoland tribal government to use existing older laws or to create new laws for community comanagement institutions [2]. In Papua New Guinea, we motivated the government to use the Conservation Area law, a powerful law that had not been used before. In Madagascar, Peru and Ghana which have created existing laws to encourage community-based institutions, we are seeking to use those laws to help communities create CBOs and community-based institutions.

5. Conclusions: Practitioner knowledge parallels and is supported by research

As practitioners, many of our independent findings from over 30 years work in 15 countries [3] are supported by social science research [26] and may be considered as important tenets to follow by practitioners of community conservation. Although much of social science on institutions and community organizations has focused on common-pool resource systems, the community-based organizations we have encouraged are not formed for shared resource use but focus on community control and ownership for institutional change to close existing open-access systems and protect resources. The motivation of the CBOs and NGOs and the complex institutions formed by them, focuses on common good or altruistic incentives rather than competitive or self-serving motivations (what social scientists refer to as "rational egoist" incentives). When economic incentives are reduced, other incentives are more likely to emerge. In some cases, economic incentives are even perceived as a hindrance to conservation by CBOs and they refuse to cooperate with outside conservation agents as a protest against the way big conservation is administered [97].

5.1. Conservation contagion

Conservation contagion, observed in Belize, India, and Peru, was noted by a Peruvian villager in a video interview, and similarly Ostrom [26 p.57] noted that "Farm households who

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innovate and are successful or common-property arrangements that increase their joint yield are frequently copied by others. These connections are like a ripple across the landscape rather than strongly linked situations." Conservation contagion shows similar processes to institutional change that happens in small increments or very large changes [26 p.109].

5.2. Communities create CBOs

Most analyses of what is necessary for successful resource management by local people include the ability to create microinstitutions to regulate resource use [95]. From conservation practice, catalyzing communities to create microinstitutions is a high priority and communities will readily create CBOs when given good incentives. Once CBO-NGO trust occurs for conservation methods and solutions, communities are quick to form their own organizations and see the value of creating the large complex institutions. Ostrom [26 p. 221] noted similarly that against conventional theory, many groups have organized on their own [98] or with external help: "local groups of resource users, sometimes by themselves and sometimes with the assistance of external actors, have managed to create viable institutional arrangements for coping with common-pool resource problems." She further notes [26 p. 221] that national governmental agencies have been notably unsuccessful in their efforts to design similar institutions. "Contrary to the conventional theory, many groups in the field have self–organized to develop solutions to common-pool resource problems at a small to medium scale."[98].

5.3. Polycentric institutions

Bringing together people from one or more villages can create simple organizations that in turn can be used to build more complex institutions such as federations or networks to comanage regional areas or landscapes as has been accomplished in the Manas Biosphere and the Kakoijana Reserve Forest [25]. While acting in concert when needed, each CBO functions autonomously and can strengthen each other as similarly noted by Ostrom [26 p.280]. McKean [16] notes that such "institutions for managing very large systems need to be layered with considerable devolution of authority to small components to give them flexibility and some control over their fate." It may function better than centralized government institutions because they utilize local knowledge and can be considerably cheaper [26 p. 281-2]. "By utilizing base institutions that are quite small, face-to-face communication can be utilized for solving many of the day-to-day problems in smaller groups. By nesting each level of organization in a larger level, externalities from one group to others can be addressed in larger organizational settings that have a legitimate role to play in relation to the smaller entities" [99 p.12].

In practice, federations or networks function similarly to what Ostrom has called multi- or polycentric institutions. CC first began encouraging such institutions in the Community Baboon Sanctuary in Belize by catalyzing the seven communities along the Belize River in 1985 to create the CBS Board consisting of members from each village [35, 36]. Later in 1998, CC proposed a more complex community network of all Belizean communities managing protected areas [3] with similar ideas in Madagascar and Ghana, as occurring in Assam and Peru. Ostrom [100] notes that local people may more effectively manage small-scale resources than national agencies because they can better respond to local situations in a field of diversity.

5.4. Focus on altruistic rather than selfish incentives

Whereas much social science research focuses on common pool resources with an assumption of a "rational egoist" mentality for material benefits, CC in practice, emphasizes social, conservation and altruistic incentives to stop an open-access situation. However, in addition to what we have found in practice, there is evidence that community members use altruistic and conservation incentives not just selfish incentives [26 p.102, 110; 101].

The CBOs and NGOs that CC works with seek to protect the common resources from other users who would deplete them. CC encourages simple organizations and complex institutions with the common goal of closing an open-access situation. Thus, all individuals in the group have a similar view. Once protection of the common resource is accomplished then other aspects of common resources pool may occur as the group begins management and seeks sustainable use of some of the resources.

As practitioners, conservation success depends on motivating these aspects rather than economic or self-interest incentives. This may seem counterintuitive, since emphasis in community conservation and ICDP literature has stressed that local communities mainly respond to finances. In practice, that mentality may occur with initial community contact. Researchers are puzzled why communities actively patrol and protect areas even without pay as in Kakoijana, India, Côte d'Ivoire, Peru, and Costa Rica; they do it for the same reason, conservation and the common good. When the communities develop their own institutions and organizations, the rules they place on the community are respected more. Low project finances reduce self-interest incentives and encourages altruistic, cooperative incentives just as external laws and high investment projects do the opposite.

5.5. Trust

Trust is important in response to these cooperative and altruistic values [90]. Positive incentives and motivations increase when people are empowered and their self- determination and self-esteem are enhanced. [26 p. 112].

5.6. Strengthening community partners

Uphoff et al. [102] note three objectives that lead to success in rural development: productivity, well-being, and empowerment. Well-being includes a wide range of attributes that develops a feeling of self-worth. This is the main reason we involve community members and CBOs in livelihood and economic development, to strengthen our rural partners. Well-being in our partners leads to empowerment. Involving them in meaningful work of conserving and protecting their areas develops pride and fulfillment in what they are doing. Helping them to increase their economic status adds to their sense of well-being.

5.7. External sanctions

External sanctions are resisted by communities and are not the best way to proceed and can lead to resentment [26 p. 78-9].

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5.8. Group monitoring

Group monitoring is important [103]. Our rural partners in India, Belize, USA, Ghana, and Peru monitor species, wildlife, illegal activities and other natural resources.

5.9. Funding

Large funding with no local input can be harmful since it promotes a "handout" mentality encouraging local groups to capture the funds rather than pursuing their own goals [26 p. 278] and encourages corruption [103]. As noted elsewhere [3], research has shown that people do not always act rationally and in their own interests. Ariely [104] noted that experiments conducted with rural Indian villagers asked to do various tasks for three levels of pay (one day, two weeks, and five months) did not differ in the first two levels but those who could earn the equivalent of five months pay did the task significantly worse. Ariely [104] also noted that using money to motivate people could be counterintuitive. For tasks requiring cognitive ability, low-to-moderate performance-based incentives can help. But if financial incentives are too high, the attention to the reward becomes distracting and creates stress that reduces the level of performance.

5.10. Support of large institutions

It is important to have the support of large-scale institutions such as government or international or large regional NGOs, to support the community organizations. Uphoff et al.[102] devote a chapter to the importance of rural community organizations working with government and supporting laws. In Assam, success happened with support of the newly formed Bodo tribal government while in Belize lack of government support has left CBOs in need of help. Similarly, Communal Conservancies in Namibia have flourished because of government and large international organizational support [3].

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Section 3

Economic and Social Issues

Chapter 7

Energy Return on Investment (EROI) of Different Wood Products

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Additional information is available at the end of the chapter

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Abstract

Energy cannot be produced without consumption of some part of the energy, and the proportions in which this occurs are a key indicator of the efficiency of the production process. Energy return on investment (EROI) of energy production shows the relationship between obtained and invested energy in the production process. This relationship is a key factor in sustainable global energy supply. Wood chips and one-metre firewood are used to produce thermal energy. Amount of energy obtained by burning depends on the moisture content and the features of the energy plant. This chapter deals with the issue of the amount of energy required to produce in the process of wood chips and one-metre firewood production and its transport to the heating plant. When calculating the energy balance, it is important to include as many input parameters as possible (parameters of energy consumption), which represents an almost impossible task because one parameter directly binds several others. According to several authors, the relationship between obtained and invested energy or EROI for energy wood is 30:1 which is a better ratio than the production of oil, for which relationship between obtained and invested energy is about 20:1. The results of study show that most of the energy during the production and supply of energy wood products from final felling of oak stands is used for fuel for machinery and vehicles in the production process. Ultimately, the relationship between obtained and invested energy is approximately 25:1 in the case of moisture content in the wood chips in the limit (market) value of 35% and the mean distance truck transportation of wood chips of 50 km. The relationship of obtained and invested energy used for one-metre firewood is bigger than 25:1 because of less invested energy which does not include machines like wood chipper. This is a satisfactory relationship, but it decreases with a greater transport distance. Such is the case when chips manufactured in Croatia, due to the lack of heat plants, are transported over long distances to neighbouring countries.

Keywords: EROI, input energy, output energy, wood chips, one-metre firewood

1. Introduction

Energy return on investment (EROI) is the ratio between energy obtained from energy production process and energy consumption during separation, growth, etc., into new forms of energy. EROI is most often applied in energy ratios needed for oil exploration and production of petroleum distillates or in the process of generating and processing biomass (corn, sugarcane, etc.) as well as in biofuel production [1].

The ratio of inputs and outputs in the process of energy production is a key factor of sustainable global energy supply. According to the laws of physics, energy cannot be produced without a portion of it being consumed, and those values are a key indicator of the efficiency of the production process [2].

The term EROI should not be mistaken for conversion utility, which is often found in the literature, for example production (conversion) of one type of fuel to another (production of gasoline from oil, or electricity from diesel fuel). EROI is commonly referred to as an *estimate of the energy gain, energy balance* or *net energy analysis*.

The authors [1] emphasize the importance of obtained energy as a necessary criterion for survival, development and growth of many species including man. It is believed that the survival, military efficiency, wealth, art and even civilization itself are the products of energy gain because without it people through history would not be able to build cities and civilizations and still spend huge amounts of energy on wars.

Plants and trees also generate energy necessary for growth and reproduction. For example, oak as a heliophilous species does not tolerate shade for long and after a few years will die due to lack of sunlight. Also, the trees in open areas have lower green branches distributed on the trunk in relation to those that grow in dense stands. Branches that grow low in the trunk (in dense stands) do not get enough sunlight needed to produce energy throughout photosynthesis, while the energy consumed in assimilation apparatus continues and becomes greater than the energy produced by photosynthesis. Such branches first discard leaves and eventually die off due to the energy loss [3].

Every living creature that wants to survive must satisfy the law of *energy balance evolution* that says that for survival an individual must use more energy than it was required to receive that same energy. Reproduction needs more energy than it is necessary for metabolism processes, while in the process of evolution yet higher energy gain is necessary because energy losses of the majority of individuals in a population that are non-resistant need to be compensated. In other words, each individual (species) that wants to survive must adapt the method of gaining more energy than was invested in obtaining that same energy and as such is successful in evolutionary terms. Only individuals with excess of energy have the ability to spread, progress and develop.

People have eventually learned how to increase control over energy with the help of technology, although, thousands of years for energy production they used human and animal energy as well as processed solar energy (with plant help) for food production. Another, throughout

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history, very important source of energy for people was the energy from wood. However, energy from wood is still an important source of energy for humans, and more recently due to the trend of increasing use of renewable energy sources at the expense of using fossil fuels, energy from wood is gaining more and more attention. Ultimately, all the energy we use on Earth, either directly or indirectly as accumulated energy in the form of fossil fuels, wood, food, etc., was created with the help of solar energy. Solar energy is the basis and starting point for life on Earth.

Proponents of EROI believe that *net energy analysis* offers a realistic consideration of the advantages and disadvantages of production of a certain type of fuel, and provides guidance for the possibilities of production and energy market in the future. Also it is noted that EROI itself is not a sufficient criterion for judgement, even though it has the favour of the majority, especially when one energy source has much higher or lower EROI compared to another. In addition, it is important to take into account the current and future potential need for certain energy source and possible EROI change in case of increased demand for a specific energy source.

EROI can easily be calculated using the following expression [4]:

$$EROI = \frac{Energy\ gained}{energy\ required\ to\ get\ that\ energy}$$

The numerator and denominator are usually in the same measuring unit, so the result is dimensionless, e.g. 30:1, which is expressed as ‘thirty to one’. This means that, for example, the process of wood chips production that has energy value of 30 J requires only 1 J of energy input, starting with the energy required for the production of machines used in the process of obtaining wood chips, fuel for those machines and, of course, manpower invested in the whole process.

The general criterion used in the current debate on EROI and energy production is the question whether energy that returns as fuel is greater than the energy invested in the process of production of that fuel, i.e. whether the EROI is greater than 1.0:1.0. If the energy output is greater than the input then this is the main argument in favour of such production project and vice versa, if the energy input is higher than that the output the project should be rejected. Thus, [5] from comprehensive studies suggests that energy surplus or EROI code for production of ethanol from corn is in the range between 1.2 and 1.6 units obtained for each unit of energy invested. Further, in such production, all the energy output is not contained only in bio-ethanol but also in by-products of that process that can be used as fodder. On the other hand, input energy does not contain depletion of soil nutrients in maize production. Therefore, there is an opinion that most EROI values, including this particular example, currently have a higher ratio between energy inputs and outputs, but when all the parameters of this relationship would be taken into account, ratio reduction would appear [1].

The same authors state that there are several different EROI values from a different data collecting scope and for different energy sources. There is an opinion that for many energy calculations, EROI is too simplified or shallow with the aim of reducing the value of competitive fuel and as such should not be the main criterion for decision making. Many EROI analyses were based with the aim of promoting or protecting certain energy source. The size and significance of the total EROI value should be investigated in terms of getting the total sum of the energy of a nation or society and all energy costs of obtaining it. This is the so-called societal EROI ($EROI_{soc}$):

$$EROI = \frac{Summation\ of\ the\ energy\ content\ of\ all\ fuels\ delivered}{Summation\ of\ all\ the\ energy\ \cos ts\ of\ getting\ those\ fuels}$$

The new way of calculating EROI includes the input parameters as the energy required to transport energy (oil, wood) from the processing point to the end user, while the output parameter is the amount of transported energy. This is the next step of calculating EROI and it is called EROI at 'point of use' ($EROI_{pou}$):

$$EROI_{POU} = \frac{Energy\ returned\ to\ society}{Energy\ required\ to\ get,\ deliver\ and\ use\ that\ energy}$$

Furthermore, the concept of calculating EROI includes not only the energy needed to obtain certain energy-generating product, but also the energy needed to use it (energy needed for building and maintaining infrastructure). Such EROI is called the extended EROI ($EROI_{ext}$):

$$EROI_{\text{ext}} = \frac{Energy\ returned\ to\ society}{Energy\ required\ to\ get,\ deliver\ and\ use\ that\ energy}$$

As it is obvious from expressions presented earlier, there are several ways of calculating EROI, some of which take into account all input and output parameters, while some exclude certain parameters.

According to the last expression for calculating $EROI_{ext}$, for input parameters it includes not only the energy consumption needed, e.g. for the discovery and production of oil, but also the energy needed for oil supply, which means that the calculation should include energy consumption for:

1. Construction and maintenance of vehicles

2. Construction and maintenance of used roads

3. Calculation must contain vehicle amortization

4. Calculation must contain costs of insurance, etc.

In future, $EROI_{ext}$ will probably expand with energy of man and the economic activity that are either directly or indirectly involved in all processes of obtaining energy. Approximately 10%

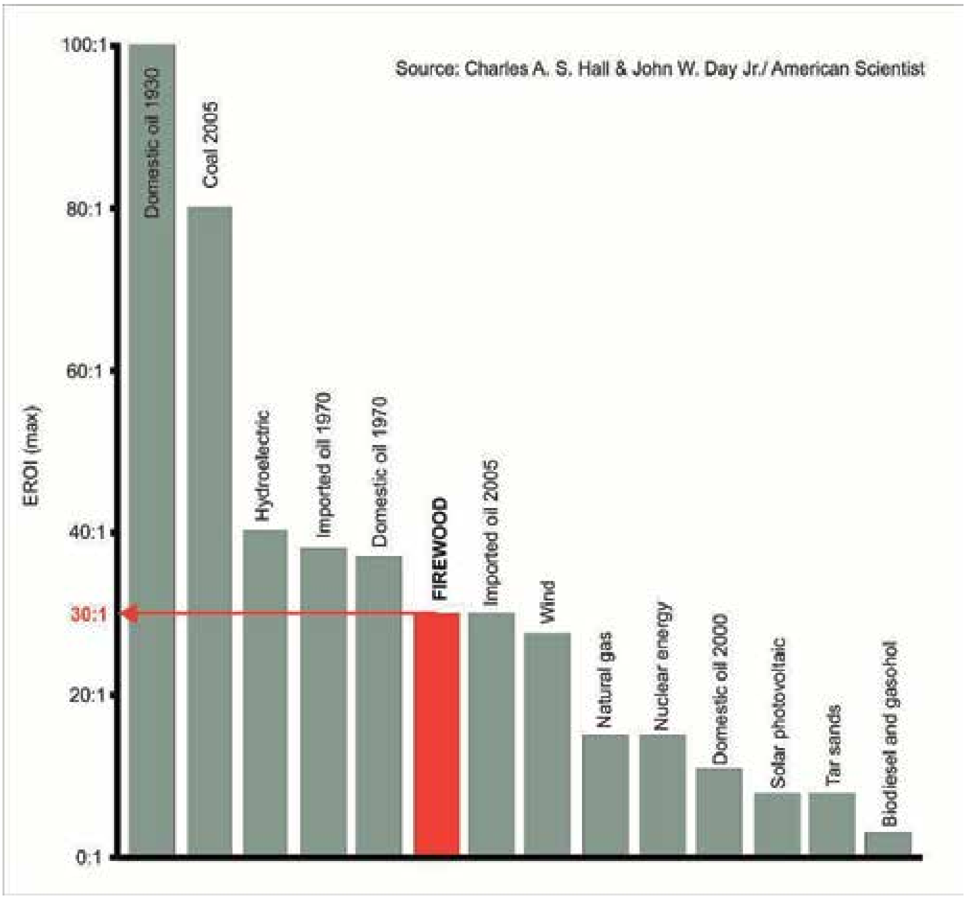

Figure 1. Values of EROI for some energy production processes

of the entire economy is included in the process of obtaining energy, which means that farmers who produce food for workers who produce machines for the transport of oil and so on. In this case, one could say that the denominator when calculating $EROI_{ext}$ contains 10% of the total used energy [1].

The same authors state that in the United States today energy gained from fossil fuels is 80:1 for coal and up to 11–18:1 for gas and oil derived from domestic sites. At the global level, this relationship for oil and gas is 20:1 which means that 1 L of oil is required to obtain 20 L of oil supplied to the society (e.g. petrol stations). Such an energy gain of 20:1 is sufficient for human civilization progress and great industrial expansion. Part of this gained energy is used to further obtain the same energy and other part is used in agriculture which results in huge energy outputs in the form of food transported to the society. It enables people and capital to produce energy outside the energy sector, and such a huge energy gain enables the development of our civilization with both good and bad points of view. The bad news is that the lack of oil began after its first discovery and use while that same oil needed more than 100 million years for formation. Due to decreasing oil reserves, its price began to grow and more and more oil is spent on the search of new bores. Thus its energy gain reduces and the society is looking for new technologies that can replace it, so it can be said that the lack of oil and the development of new technologies is the constant race against time. EROI for oil in the United States during the 1930s was 100:1, in 1970 was 30:1, in 2000 was 11–18:1, and for the rest of the world it is around 20:1.

Referring to figure 1, the ratio of obtained and consumed energy for energy wood is 30:1, which means that 1 L of oil is necessary to produce amount of energy equivalent to 30 L of oil from energy wood (biomass). But if the CO_2 emission is added, whereby it is considered that during the combustion of biomass CO_2 emission is zero because biomass during its growth binds CO_2 in the process of photosynthesis, energy wood is favourable in relation to fossil fuels [6].

The author [7] explores the energy consumption based on fuel consumption in the production chain of wood energy in the form of trunk, thin logs and brushwood and finds that the proportion of energy consumed in fuel is 3.2% for the trunk, 2.8% for thin logs and 2.5% for brushwood in relation to the wood energy value. The largest fuel consumption refers to timber and chip transportation.

The authors [8], on the basis of several studies from Germany, Switzerland and Sweden, offer data on the unit energy consumption. For silvicultural procedures of cutting, bucking and timber extraction, 62 to 135 MJ/m^3 energy is consumed, while for the long distance transport, an additional 92 to 125 MJ/m^3 energy is used (transport distances of 50 km). The overall unit energy consumption is in the range from 180 to 230 MJ/m^3. The same authors report that in 1997 the share of secondary transport amounts between 53% and 57% of the total energy consumption at the level of Sweden.

The author [9] states that for silvicultural procedures, felling and extraction consume 60–270 MJ/m^3, and for secondary transportation 90–223 MJ/m^3, the total energy consumption is 180–395 MJ/m^3.

This chapter presents a detailed calculation of the energy consumption for all machinery and vehicles that were used in the area of Forest Administration (FA) Vinkovci in 2012 with the calculation of EROI for wood chips and one-metre firewood. The total area of the FA is 72,203.27 ha, of which 68,392.48 ha is forest. The total growing stock amounts to 19,717,000 m^3, where common oak participates with 68%, ash with 12%, hornbeam with 10% and other species with 10%.

2. Methods and results of research

All presented data (data on productivity, number of machines, consumptions of fuel, lubricants and tyres as well as consumptions of chains, guidebars and sprockets of chainsaws and quantity of pesticides) were obtained (calculated) by the Department for Production of FA Vinkovci (table 1).

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	Forwarders[1]	Tractor assemblies	Silvicultural tractor[2]	Farm tractor with trailer[3]	Total
			m³		
Logs	142,203	70,124	437		212,764
Long firewood	32,239	19,380	796		52,415
Energy wood	14,396				14,396
One-metre firewood				135,139	135,139
Total	188,838	89,504	1,233	135,139	**414,714**

Source: Original data.

[1] Forwarder extraction includes use of forwarders from other FA's and private contractors.

[2] Silvicultural tractors when not involved in cleaning procedures are equipped with winches and used for timber extraction.

[3] Amount of one-metre firewood includes the amount produced by FA workers (20,693 m^3), while the remaining amount (114,446 m^3) was produced by the local community and private contractors.

Table 1. Share of wood products (m^3) for the period from 1.1.2012 to 31.12.2012 in FA Vinkovci and use of vehicles for timber extraction

When calculating EROI, it is important to include as many input parameters, or in this case the energy required to build all the machines and tools used in forest harvesting operations, construction and maintenance of forest roads, the energy of fuels and lubricants used by machines and vehicles, the energy required to build supplies, such as tyres, chains, guidebars and sprockets of chainsaws, the energy required for the production of pesticides used in cases concerning the forests protection, human energy, etc.

All the energy used in this calculation is expressed in relation MJ/m^3 at the level of year 2012 as well as the energy output, which includes:

- Energy of forest residues that are chipped and transported by trucks to heating facilities
- Energy of one-metre firewood

The final result is the ratio of obtained and consumed energy – EROI.

Output parameter in the calculation is the energy value of wood chips taken from the *Biofuel Handbook* [10] (hereinafter Handbook). Energy value of the energy wood with a moisture content in the amount of 35% according to this Handbook is 11.17 GJ/t, and calculated by the density of oak wood chips at the same moisture (852 kg/m^3) is 9.51 GJ/m^3.

Input parameters for the EROI calculation are distributed to the direct and indirect energy consumptions.

Energy value of one-metre firewood according to the same Handbook is 9.71 GJ/t with the moisture content in the amount of 42% and calculated by the density of oak one-metre firewood at the same moisture (967.3 kg/m^3) is 9.31 GJ/m^3.

Input parameters for the EROI calculation are distributed to the direct and indirect energy consumptions.

Indirect energy consumptions include:

- *Energy required for production of machines and vehicles*

In this the energy included is the energy required for the production of materials for machinery, the energy invested in manufacturing parts and transport of new machinery from place of production to the customer and the energy required for the recycling of waste machines (after amortization period).

In calculation, the energy invested in machinery and vehicles is assumed to be 66 MJ/kg [11, 12].

The author [13] states that the energy required for the production of material embedded in vehicles amounts to average 24 MJ/kg, while manufacturing and assembly of vehicles additionally consumes energy in the amount of 11 MJ/kg for tractors, 9.1 MJ/kg for harvesters, 6.3 MJ/kg for plough, etc. The authors [14] recorded similar results where the calculation for agriculture tractor amounted to 26.04 MJ/kg consumed energy. The authors [15] in their paper provide an analysis of the raw materials used in the forestry equipment and energy needed for production of each of the materials. According to their analysis, based on the vehicles mass, the total energy used in production of materials used in forwarder Valmet 840.2 amounts to 26.79 MJ/kg, respectively, for forwarder Valmet 860.4 is 26.79 MJ/kg and for the agricultural tractor John Deere 8430 amounts to 26.56 MJ/kg.

The energy invested for production of motor cars is calculated according to [16] who used model from [17] and concluded that energy required for production of motor cars is 33.4 MJ/kg.

Masses of machines/vehicles were taken from technical data of manufacturers (forwarders, dump truck, grader, chainsaws, chipper, agricultural tractors) and drivers/owners of vehicles (trucks for transport of wood chips, motor cars), or were determined by direct measuring of axle loads (forwarders) (table 2).

The productivity of each machine/vehicle is presented on an annual basis. Because all the input energy is reduced to unit MJ/m^3 (unit energy consumption), it is also necessary to express energy invested in the production of machine/vehicle on the same way. The total energy input for the production of material, construction and delivery of the machinery/vehicles divided into the depreciation of the machine/vehicle, and the result at the end, is also divided with an annual productivity of the machine/vehicle. For this reason it is necessary to know the depreciation of life of any machine/vehicle, which is 7 years for forwarders and chippers, 10 years for agricultural tractors, graders, trucks, trucks with trailers and semi-trailers, 8 years for tractors with semi-trailers, 7 years for chainsaws and 5 years for motor cars.

For the machines like grader and dump truck for transportation of stone, and the farming tractors and motor cars indirectly linked to the productivity of FA Vinkovci for the year 2012, 414,714 m^3 is the annual productivity of each of these categories of vehicles identified with the total productivity of FA Vinkovci.

Machine/Vehicle	No.	Total weight	Energy	Total energy	Period of amortization	Productivity	Energy consumption
		kg	MJ/kg	GJ	years	m^3/year	MJ/m^3
Chainsaws[1]	405	3,124	66	375.66	5	285,872[1]	**0.26**
Forwarders[2]	8	117,920		7,782.72	7	146,171[2]	**7.61**
Tractor assemblies	22	121,803		8,038.99	8	89,504	**11.23**
Silvicultural tractors	21	126,000		8,316	8	414,714	**2.5**
Truck units[3]	7	141,796		9,358.54	10	51,034[3]	**18.34**
Grader	1	16,200		1,069.2	10	414,714	**0.26**
Dump truck	1	13,350		881.1	10	414,714	**0.21**
Hauling truck	1	16,500		1,089	10	28,380	**3.84**
Farm tractor[4]	1	11,260		743.16	10	40,000[4]	**1.86**
Chipper	1	10,600		699.6	7	40,000[4]	**2.5**
Motor cars	122	146,400		4,889.76	5	414,714	**2.36**

Source: Original data.

[1] Chainsaw productivity does not include 114,446 m^3 (one-metre firewood was produced by the local community and private contractors) and14,396 m^3 forest biomass.

[2] Only timber extracted by FA Vinkovci forwarders.

[3] Only timber transported by FA Vinkovci truck units.

[4] Productivity of farm tractor driven by chipper was calculated based on hour productivity 25 m^3/h (according to: http://www.northernwoodheat.net/htm/Publications/FinnishInfoCard9.pdf), 8 working hours/day and 200 working hours/year.

Table 2. Energy consumption for vehicle and machine production

- *Energy required for production of pesticides*

The energy invested for production of pesticides was calculated according to [13] who estimated average energy consumption of 120 MJ for production of 1 kg of pesticide.

The total energy contained in pesticides was calculated on the basis of four different types of pesticides which were used for forest protection during 2012 on area of FA Vinkovci (table 3).

Direct energy consumptions include:

- *Fuel and lubricant consumptions*

Low heating value H_d is heat (energy) gained from the process of fuel combustion, without additional use of heat from condensing water vapour. Low heating value or the amount of energy gained by combustion of diesel fuel is 41.9 MJ/kg and of gasoline is 42.7 MJ/kg [18]. The amount of energy contained in oil is 35.87 MJ/l [15]. However, with energy contained in fuel and lubricants the energy used to produce them should be included. The author [19] according to [20] states that the total energy contained in mineral oil is 83.5 MJ/l (38.5 MJ/l energy value of oil, 45 MJ/l energy required for the production of mineral oil) or according to [21–23] the total energy contained in diesel fuel is 40.64 MJ/l (36.14 MJ/l energy value and the energy required to produce it is 4.5 MJ/I).

Type of pesticide	Productivity	Quantity	Density[1]	Quantity	Energy	Total energy	Total energy
	m³/year	L	kg/cm³	kg	MJ/kg	GJ	MJ/m³
Artea plus	**414,714**	1,568	1.128	1,768.7	120	212.24	
Match		449.2	0.94	422.25		50.67	
Glifosat		2,110	1.172	2,472.92		296.75	
Difencanum–Sarexa cebo		–	–	11,091.6		1,330.99	
Total				15,755.47	120	1,890.65	**4.56**

Source: Original data.

[1] Pesticides amount in litres was converted to kilograms using density values given by manufacturers.

Table 3. Energy consumption for production of used quantities of pesticides

The values for calculation of total energetic value of fuels and lubricants were taken from [11, 24] which determined values of 55.3 MJ/kg for chainsaw fuel, 51.5 MJ/kg for diesel fuel and 83.7 MJ/kg for lubricants.

Since the energy content of the fuel is mainly expressed in kg/m^3, and fuel and lubricant consumption is measured in L/m^3, all quantities of fuels and lubricants are calculated in kg/m^3 based on density fuel specified by [18]. Density of gasoline is 0.72 kg/L, diesel 0.875 kg/L and lubricant (oil) 0.832 kg/L at 80°C.

The concrete values of consumption in 2011 at the FA Vinkovci were taken to calculate the fuel and lubricant consumptions for the chainsaws. 59,404 L of fuel and 22,798 L of lubricant were spent for the production of technical roundwood and stacked wood in the amount of 282,772 m^3. This means that on the average value 0.21 L/m^3 (0.1512 kg/m^3) of fuel and 0.08 L/m^3 (0.06656 kg/m^3) of lubricant calculated were spent.

The total amount of spent fuel and lubricants was obtained from the database of the production department of FA Vinkovci for forwarders, farming tractors, grader, dump truck and motor cars and chainsaws.

The direct energy consumptions should be allocated per unit energy consumption of fuel, oil and tyres of vehicles that indirectly affect the production. These are the following machines: farming tractors, graders, dump truck and motor cars.

Table 4 shows chainsaw fuel and lubricant consumption for the productivity in 2012. Consumption was calculated based on unit consumption for 2011 that was already explained.

Machine/ Vehicle	Productivity	Fuel	Fuel energy (55.3 MJ/kg)	Fuel energy expenditure	Lubricant	Lubricant energy (83.7 MJ/kg)	Lubricant energy expenditure
	m³/year	kg	GJ	MJ/m³	kg	GJ	MJ/m³
Chainsaw	414,714	62,705	3,467.59	**8.36**	27,603	2,310.37	**5.57**

Source: Original data.

Table 4. Chainsaw fuel and lubricant consumption

Fuel consumption of the agricultural tractor that drives chippers was obtained by direct survey in the field, and the fuel consumption for hauling truck for the transportation of wood chips was gained from conversation with the owner of the truck (table 5).

Machine/Vehicle	Productivity	Fuel	Fuel energy (51.5 MJ/kg)	Fuel energy expenditure	Lubricant	Lubricant energy (83.7 MJ/kg)	Lubricant energy expenditure
	m³/year	kg	GJ	MJ/m³	kg	GJ	MJ/m³
Forwarders[1]	146,171	149,617	7,705.28	**52.71**	7,954	665.71	**4.55**
Tractor assembly	89,504	71,659	3,690.45	**41.23**	6,654	389.56	**4.35**
Silvicultural tractor	414,714	114,340.63	5,888.54	**14.2**	3,627.52	303.62	**0.73**
Truck unit[2]	51,034	161,327.25	8,308.35	**162.8**	1,861.18	155.78	**3.052**
Farm tractor + Chipper[3]	40,000	131,680	6,781.52	**169.54**	100	8.37	**0.21**
Grader	414,714	25,351.38	1,305.6	**3.15**	–	–	**–**
Dump truck	414,714	40,730	2,097.59	**5.06**	495	41.43	**0.1**
Hauling truck[4]	28,380	32,375	1,667.31	**58.74**	133	11.13	**0.39**
Cars and vans	414,714	217,846.4	11,219.09	**27.05**	1,080.43	90.43	**0.22**

Source: Original data.

[1] Only forwarders owned by FA Vinkovci.

[2] Only truck units owned by FA Vinkovci.

[3] Productivity was calculated according to: http://www.northernwoodheat.net/htm/Publications/FinnishInfoCard9.pdf where it is stated that chipper productivity of 25 m³/h, 200 working days and 8 working hour per day, on year basis amounts to 40,000 m³. Fuel consumption was gained by direct field measurements and was 3.29 kg/m³. Oil consumption was estimated on base of engine capacity and need for oil change every 500 working hours – 100 L/year.

[4] Fuel and lubricant consumption was determined based on conversations with hauling truck owner Mr. D. Benšak (UTPR Benšak), and productivity was calculated based on average year transporting distance (100,000 km) and average transporting distance (50 km).

Table 5. Machine/vehicle fuel and lubricant consumption

- *Expenditure of tyres*

Quantity of energy invested in production of tyres was calculated based on values described by [15] according to [25] and [26] and the value is 94.448 MJ/kg of tyre. Mass of some tyre was measured by mobile scales while for the others the mass was taken for technical data of manufacturers (table 6).

Machine/Vehicle	No.	Productivity	Weight of tyres	Energy invested in production of tyres (94.448 MJ/kg)	Tyres energy expenditure
		m³/year	kg/year	GJ	MJ/m³
Forwarders	8	146,171	1,458	137.7	**0.94**
Tractor assembles	22	89,504	2,160	204	**2.28**
Silvicultural tractor	21	414,714	780	73.67	**0.18**
Truck unit	7	51,034	4,875	460.43	**9.022**
Farm tractor + chipper	1	40,000	–	–	–
Grader	1	414,714	–	–	–
Dump truck	1	414,714	1,033	97.56	**0.24**
Hauling truck	1	28,380[1] (100 km)	975	92.09	**3.24**
Cars and vans	122	414,714	1,731.42	163.53	**0.39**

Source: Original data.

[1] Productivity was calculated based on average year transporting distance (100,000 km), average transporting distance (50 km) and average load volume (28.38 m³ of roundwood – calculated based on trailer volume capacity – 90 m³, truck payload – 23,500 kg and common oak density 828 kg/m³ with 30% moisture content).

Table 6. Energy consumption during production of pneumatic tyres based on consumption for each type of vehicle

Annual consumption of tyres for 2012 was taken for database of Production Department of FA Vinkovci for forwarders, agricultural tractors and motor cars. Durability of tyres on hauling trucks for wood chips transport is in average 80,000 km, while truck exceeds an average of 100,000 km/year.

- *Expenditure of spare parts of chainsaws (chain, guidebar, sprocket)*

Consumptions of spare parts of chainsaws were taken from Production Department of FA Vinkovci for 2012. All components are made from steel and energy required for production of steel is 19,742 MJ/kg [15, 25, 26]. It was assumed the mass of guidebar of chainsaw is 1.1 kg, mass of chain is 0.3 kg and mass of sprocket is 0.1 kg in calculation of total invested energy (table 7).

	Productivity	Expenditure				Energy invested in production of steel (19.742 MJ/kg)	Energy expenditure
	m³/year	No./m³	No./year	kg/No.	kg/year	GJ	MJ/m³
Guidebar	414,714	0.00163	676	1.1	743.6	14.68	**0.035**
Chain		0.00934	3,873.4	0.3	1,162.02	22.94	**0.055**
Sprocket		0.00152	630.4	0.1	63.04	1.24	**0.003**
Total					1,968.66	38.86	**0.094**

Source: Original data.

Table 7. Energy consumption for production spare parts of chainsaws

When cutting one-metre firewood, chainsaw fuel consumption is 0.34 L/m³, lubricant consumption 0.17 L/m³, guidebar and sprocket 0.0025 unit/m³ and chain 0.005 unit/m³ [27]. Based on these values, unit energy consumption of chainsaws during cutting one-metre firewood was calculated (table 8).

Chainsaw	Productivity[1]	Fuel	Lubricant	Guidebar	Chain	Sprocket	Total
	MJ/m³						
Energy consumption	0.26	13.54	11.84	0.0543	0.0296	0.00493	**25.73**

Source: Original data.

[1] Energy consumption was taken form table 2.

Table 8. Unit energy consumption of chainsaws during cutting one-metre firewood

Table 9 shows unit energy consumption (MJ/m³) for all machines and vehicles used directly and indirectly in the production of wood products in 2012 in the area of FA Vinkovci. The table also shows energy consumption of each component (production, fuel, lubricants, etc.) for each machine/vehicle specifically.

Figure 2 shows the percentage of unit energy consumption for individual components used in production process (directly or indirectly) in the area of FA Vinkovci in 2012. According to this figure, it is obvious that the largest share of energy input goes on fuel for machines and vehicles in the amount of 86%. Lubricants participate in the amount of 3%, tyres 2%, while the share of energy input for the production of chainsaws spare parts is less than 1%. Amount of energy input for the production of machines, vehicles and pesticides accounts to 9% of the total unit energy consumption.

Energy	Chainsaw	Forwarder	Tractor assembly	Silvicultural tractor	Truck unit	Grader	Dump truck	Hauling truck	Farm tractor + chipper	Cars and vans	Pesticides	Total
						MJ/m³						
Production	0.26	7.61	11.23	2.5	18.34	0.26	0.21	3.84	4.36	2.36	4.56	**55.53**
Fuel	8.36	52.71	41.23	14.2	162.8	3.15	5.06	58.74	169.54	27.05	–	**542.84**
Lubricant	5.57	4.55	4.35	0.73	3.05	–	0.1	0.39	0.21	0.22	–	**19.17**
Tyres	–	0.94	2.28	0.18	9.02	–	0.24	3.24	–	0.39	–	**16.29**
Guidebar	0.035	–	–	–	–	–	–	–	–	–	–	**0.035**
Chain	0.055	–	–	–	–	–	–	–	–	–	–	**0.055**
Sprocket	0.003	–	–	–	–	–	–	–	–	–	–	**0.003**
Total	**14.28**	**65.81**	**59.09**	**17.61**	**193.21**	**3.41**	**5.61**	**66.21**	**174.11**	**30.02**	**4.56**	633.92

Source: Original data.

Table 9. Energy consumption for each machine/vehicle separately and by each component of direct/indirect energy consumption

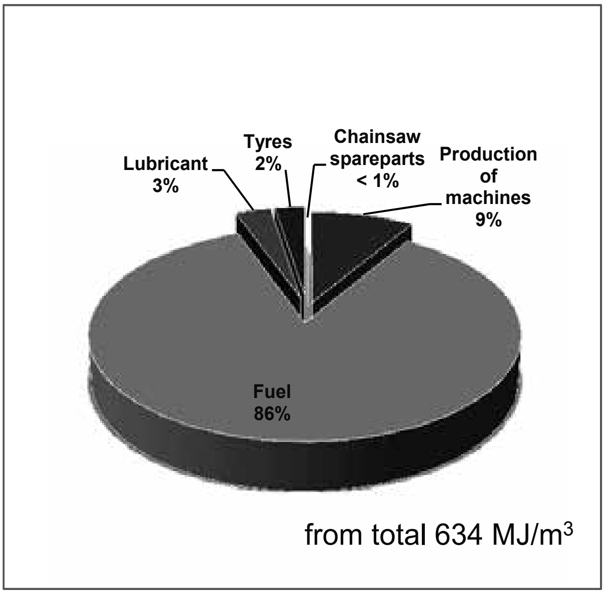

Figure 2. Proportion of unit energy consumption by components (Source: Original data)

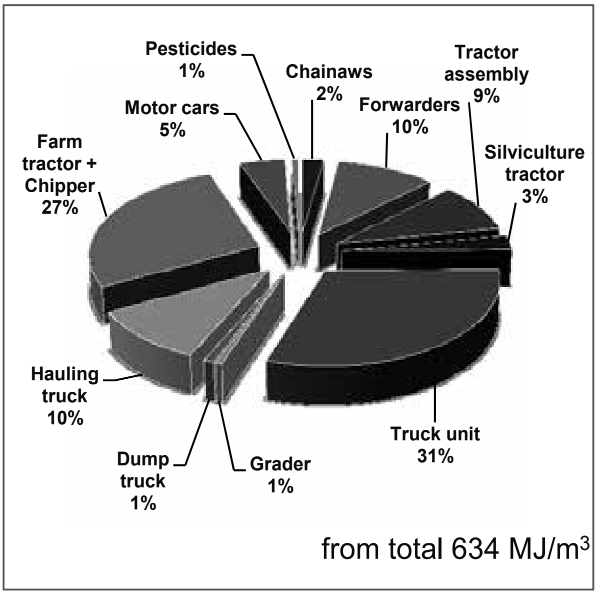

Figure 3. Proportion of unit energy consumption by each machine/vehicle included indirect energy consumption (Source: Original data)

According to figure 3, it can be concluded that the largest unit consumption (in relation to the total unit energy consumption) has truck units during assortment and long firewood transport in the amount of 31%. Chipper driven by farm tractor follows in the amount of 27%. According to table 9, it is visible that these two vehicles also have the highest fuel energy consumption. Fuel energy amounts to a great deal of energy consumption for other vehicles as well.

Average transport distance for wood chips (50 km) was chosen randomly and is in accordance with recommendations of [28], which states that it is the turning point of truck transport of energy wood costs.

Output parameters in this calculation are energy values of different wood products shown in table 10. The energy value of wood for different moisture contents is taken from the Manual of fuels from biomass [10].

Table 10 shows the amount of EROI. This amount was gained based on the relationship of obtained and consumed energy in the process of obtaining that energy. The minimal EROI is 24.97 for production of wood chips, while the maximal EROI is 64.3 for production of one-metre firewood. When calculating the energy consumption for the production of one-metre firewood, transportation to the end user should be included.

The calculated value of EROI in the process of producing wood chips (24.97) is close to values reported by [29] according to figure 1 and [4]. According to [30], mean EROI for wood is 25.

Throughout this process of calculating EROI, energy of workers, which is spent in the production process, is not included, nor is the energy of employees directly involved in the

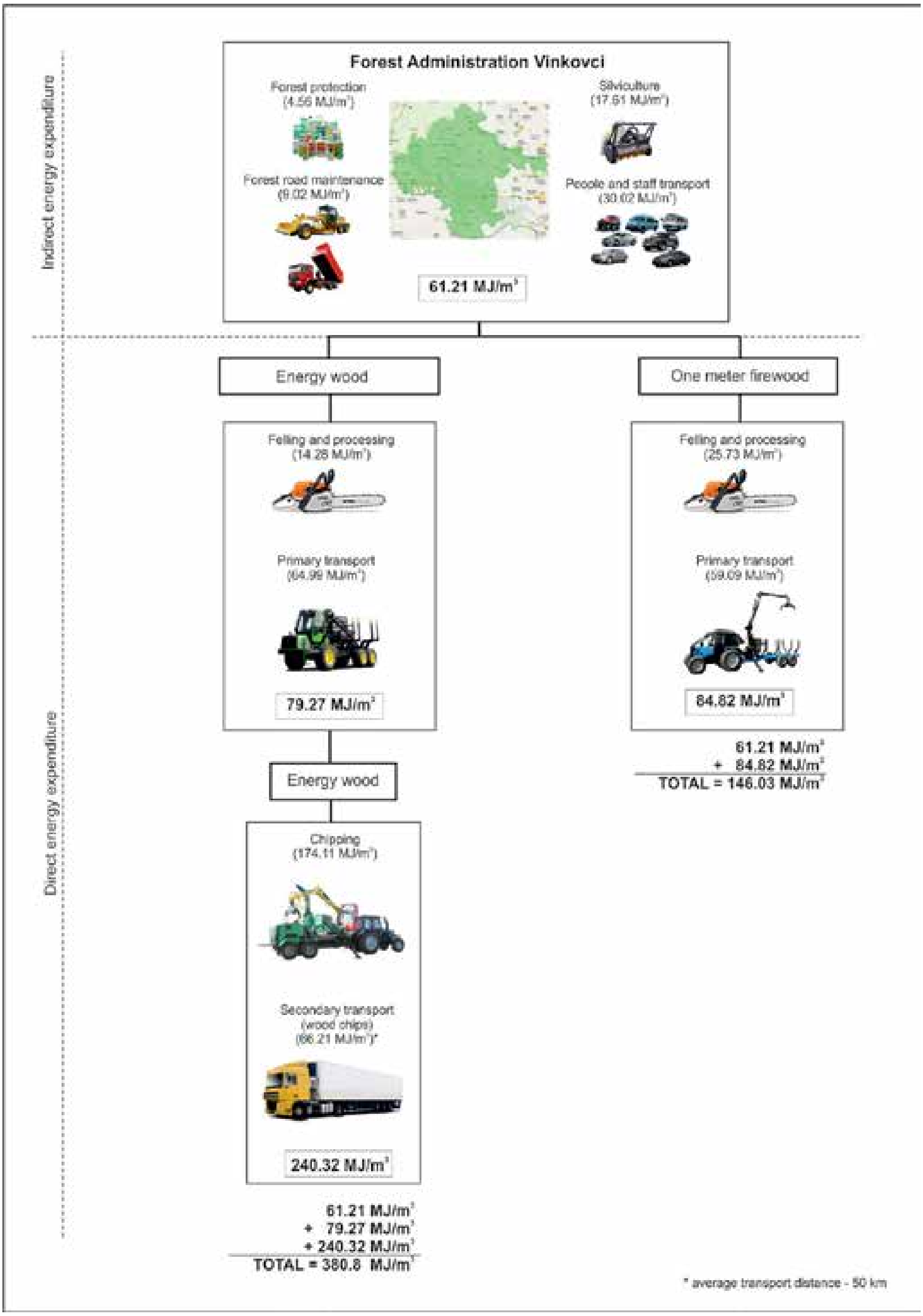

Figure 4. Components of unit energy consumption for both wood products (Source: Original data)

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production process. The calculation does not include either the energy spent for maintenance and overhead of buildings of FA, or the energy that is consumed for their arrival and departure from work (does not include company cars). It is impossible to collect all the data on the energy consumed in the production of these wood products, and that energy would not significantly reduce the estimated amount of EROI.

Wood product	Energetic value			EROI
	Obtained		Invested	
	GJ/t[(2)]	GJ/m³	MJ/m³	
Wood chip (35% moisture. ρ_{oak} = 852 kg/m³)[(1)]	11.17	**9.51**	**380.8**	**24.97**
One-metre firewood (42% moisture. ρ_{oak} = 967.3 kg/m³)[(3)]	9.71	**9.39**	**146.03**	**64.3**

Source: Original data.

[1] Limit value of water in chips (35%) that is requested by market.

[2,3] Manual of fuels from biomass [10].

Table 10. EROI of wood chips and one-metre firewood

Energy consumption in the production of energy wood shows that energy balance of energy wood is not zero, because in its production process a certain amount of energy is consumed (380.8 MJ/m³ – figure 4). Given the amount of energy that is obtained from energy wood (9510 MJ/m³ oak with 35% moisture content), the amount of spent energy is acceptable (EROI = 24.6).

3. Conclusions

The highest energy consumption in the production and delivery of wood chips is based on the consumption of fuels and in the amount of 86%. In doing so, the biggest consumer of energy (fuel) is an agricultural tractor that drives chipper. The production of wood chips should strive to chippers with larger production capacity, and such chippers are generally self-propelled (e.g. Silvator 2000), whose hourly fuel consumption is slightly higher, but productivity is at least more than twice higher in comparison with other chippers, which leads to a significantly smaller unit fuel consumption.

The next solution is transport of energy wood to the stationary chipper which mainly uses electricity as power, and electricity is, from the energy and economic points of view, a better fuel than diesel. When using this method of production of wood chips, the problem occurs with reduced utilization of cargo space of transport means (trucks) because the density of energy wood is very low. But there is a technical solution in the form of bundler machine that compresses energy wood into a round bale. The use of mentioned machine will increase the mass yield of means of transport, but it also leads to increasing energy consumption in the whole process of production and delivery of wood chips.

Wood is a renewable energy source, but it is not completely neutral in terms of CO_2 emissions, because during its production and supply, a certain amount of energy, mostly from fossil fuels, is used. Energy value of wood chips is about 25 times higher (EROI of wood chips in this study was 24.6) of the energy used for its production, and it is considered as an environmentally acceptable energy source.

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Chapter 8

Forestry Entrepreneurs — Research on High Performance Business Model

Étienne St-Jean and Luc LeBel

Additional information is available at the end of the chapter

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Abstract

Over the last 30 years, the forest industry in Eastern Canada has undergone a radical transformation, from a model where larger forestry businesses operated their own production equipment to a model where harvesting, transport, and forest road construction are awarded to contractors. This change in strategy on part of the large corporations has created new start-up opportunities for many forest entrepreneurs. Their dependency on a single large client (wood buyer), however, could hinder entrepreneurial behavior. This study aims to examine the forest Small and Medium-sized Enterprises (SMEs) population, identify the factors that stimulate their performance despite a business environment that may be deemed unfavorable, and draw an overall picture of the existing situation. An analysis of 535 questionnaires filled by forest machine owners suggests that SMEs with four employees or more show better performance results than those with three or fewer employees, considered very small enterprises (VSEs), essentially because these businesses are typically able to work more weeks in a year. Their managers use a significantly higher number of tools to measure performance and attribute greater importance to management duties. The results have enabled us to identify certain performance factors, but suggest that further research is needed to better understand the underlying causes of contract assignment and the relationships that develop between SME managers and large forest product companies.

Keywords: Loggers, SMEs, performance, business model

1. Introduction

The emergence of new actors in the globalized economy has led to increased competition in certain economic sectors, including the forest industry. In Canada, similar to what can be observed in other countries with an important forest sector, logging is mainly the purview of large corporations, which award harvesting, transport, and forest road construction contracts to many Small and Medium-sized Enterprises (SMEs). In eastern Canada, the forest industry has experienced difficult times in recent years, facing challenges that are both structural and the result of unfavorable economic conditions. The increasing cost of fiber, exchange rates unfavorable to exports to the United States (US), a tariff imposed by the US government, increased energy costs, lower prices for softwood and certain types of paper, and increased scarcity of resources have made the industry face many serious problems. Competitive pressure in this industry pushes the large corporations to demand more from their subcontractors, which in turn must improve their performance in order to survive.

The purpose of this paper is to identify factors that could be associated with better performance in a highly competitive business environment. We already know that some forestry SMEs exhibit more diversified activities and a greater number of employees than others (1), which leads us to think that a new business model may be settling up within subcontractors. However, we still do not know if this new way of organizing forestry operations is linked with better performance for the SME. To answer our research questions, we performed statistical analyses on a large sample of forest entrepreneurs active in the province of Quebec, Canada. In this paper, we begin by presenting the business environment in which the forest industry operates, after which we identify a number of specific factors that can affect performance in this sector, and investigate their effects on the population under study.

1.1. Québec's forest industry in context

In Québec, logging is still predominantly controlled by large corporations (2). Forest entrepreneurs essentially provide these companies with logging, forest road construction, or log transport services. As a result, they find themselves in a contractor/subcontractor business relationship, as indicated by Legendre (2005). After studying the evolution of subcontracting in the forest industry, the author notes that risks and responsibilities have been thrust onto the shoulders of small logging businesses, which are "[...] completely dependent economically and financially on the [large corporations] and have almost completely lost all of their organizational independence" [translation] (3). This fact becomes all the more evident when we consider statements by Canadian economic analysts, who view small logging companies as dependent on large organizations, with the main goal of providing these organizations with the flexibility they need to restructure in a post-Fordist economy (4)[1].

Since the emergence of forest entrepreneurs is at least partly the result of a strategic choice on the part of the large forest product companies to focus on their core competencies, it is not

1 This paragraph has been previously published in St-Jean, É. & L. LeBel (2012), "The Influence of Decisional Autonomy on Performance and Strategic Choices – The Case of Sub-Contracting SMEs in Logging Operations". In Okia, C. A. (Ed.), Global Perspectives on Sustainable Forest Management, In Tech, Rijeka (Croatia), pp. 59-74.

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unreasonable to suggest that not all owner-managers of logging companies exhibit entrepreneurial behaviors, such as innovation, or the quest for growth, profits, and opportunities (5-8). Literature on the subject of commercial domination in fact suggests that SME dependency on one or a few clients ultimately attenuates the entrepreneurial behaviours of managers, who may be tempted to settle for a contractor/subcontractor business relationship (9). Furthermore, in the forest industry, primary contractors set various conditions with regard to how forest entrepreneurs carry out their work, for example, by setting restrictions on log length, the amount of wood to cut, or even on work methods or which equipment/machinery to use. Under these conditions, it becomes increasingly difficult for entrepreneurs to innovate, which is often considered a fundamental marker of entrepreneurial action (10). In many cases, as suggested by Holmlund and Kock (11), subcontractors are left with little choice but to comply with the orders of a primary contractor, even if this occasionally results in unprofitable production. However, results from a study by Drolet and LeBel (12) clearly indicates that the owners of logging SMEs have the potential to influence their business' performance. In this context, we still do not know if forestry entrepreneurs took all the leverage they have to manage their business toward a better performance.

Lastly, due to the very nature of their work in this sector, forest entrepreneurs operate in a world of permanent uncertainty, which further amplifies the unstable aspect of production, and in turn, their performance. Factors that contribute to this uncertainty include working outdoors (severe cold temperatures, stifling heat, rain, snow), variable and unpredictable land conditions (slopes, terrain, standing volume, etc.) variable needs for raw material on the part of primary contractors (economic crises, wood substitute products, etc.), workforce scarcity and skills, major mechanical failures, forest fires, and so on. With little or no control over these factors, forest entrepreneurs are faced with more complex budgetary and operational planning and monitoring processes because they can neither reliably predict the number of work weeks for the coming year nor can they anticipate production, earnings, or expenses. With time, however, entrepreneurs learn to operate in a context of uncertainty and not all entrepreneurs are affected equally by uncertainty related to the number of weeks they work. Some proactive entrepreneurs actually take advantage of unplanned work stoppages to engage in preventative maintenance or training, which can have a positive impact on the long-term performance of their business.

Vaillancourt (13) reports that the number of weeks worked is one of their main performance factors for forest entrepreneurs, particularly those operating in forests in the public domain. Forest product companies or primary contractors usually estimate the number of weeks required for an operation on the basis of the amount of wood to be harvested, so they can then distribute production among all of the subcontractors. In the author's sample, 13% of respondents went so far as to identify the number of weeks worked as the main indicator of profitability.

1.2. Factors affecting forest SME performance

SME performance is affected by many factors, particularly due to the multidimensional character of performance, which adds an additional level of complexity to its analysis (14).

SME performance can be measured, monitored, and managed using a variety of methods, tools, and systems. Proper understanding, use and mastery of these tools can also affect performance. Inasmuch as simple performance measurement systems can help owner-managers of logging company-sized SMEs reach their goals, more sophisticated systems, which require resources and expertise that entrepreneurs who are concerned with production rather than management behavior do not always possess, can become a major irritant, only to be abandoned shortly after they are implemented.

Forest entrepreneurs primarily measure their performance in terms of production and cost reduction (15). Other dimensions of forest SME performance, such as human resources or client satisfaction, are not considered in performance evaluation (12). Incidentally, forest entrepreneurs do not use measurement systems or, to an even lesser degree, performance management systems. Few forest entrepreneurs use any tools that are part of a structured performance measurement or management system such as a balanced score card (16). It should be noted that the difference between management and measurement systems is a known source of confusion for many users (17). For entrepreneurs specialized in harvesting, for example, performance is generally measured in terms of stem count, equipment utilization rate, and the amount of fuel consumed. These data, which are compiled in a very informal manner, are used by entrepreneurs for payroll purposes in connection with production and the primary contractor's statements and for overall operational management, rather than for strategic purposes or to improve performance. In addition to their limitations, these indicators constitute "a collection of unrelated data that are scattered about [...]" [translation] (18).

Moreover, several determining factors with a definite impact on harvesting SMEs remain to be explored. These factors could eventually improve the content of balanced management scorecards adapted to the scope of forest SME activities and help owner-managers make better decisions. For example, to what extent does a preventative maintenance program affect financial performance? How do work schedules affect operator productivity? How should these decisions be reflected in the balanced management scorecard? One of the obstacles to the implementation of a balanced management scorecard is the source of the data, from acquisition to compilation, and its connection with the performance management system. Information can come from the accounting system, the forest company or primary contractor, measurements taken by the entrepreneur, or even informal discussions. As was mentioned above, forest entrepreneurs have neither the human resource capabilities nor the expertise of large corporations to develop sophisticated and integrated systems. Research must therefore be used to describe forest SME performance in terms of determining factors and indicators that are simple and tangible. In addition, the energy invested in collecting, processing, updating, and analyzing the information must not exceed the benefits to be generated by the management tool. Under these conditions, the development of a decision-making aid such as a balanced management scorecard, at least with regard to its content, is of limited use by failing to consider dimensions that could have a significant impact on forest SME performance.

Overall, a balanced management scorecard should provide information on several aspects of business activity, and it must especially make it possible to explain a current situation and to detect trends if nothing changes. It must provide entrepreneurs with the ability to anticipate the future of their business in terms of their objectives, which cannot easily be done from a simple reading of the balance sheets. But this kind of management system may be more suitable for businesses with more complex operations and greater number of employees (i.e. business size).

On a different note, the relationship between business size and performance remains unclear. Business size can have an effect on economy of scale, on the effect of scope, the effect of experience, and the effect of learning (19). Empirical analyses, however, do not appear to confirm a relationship between economy of scale and performance (20). It is reported that smaller size, which involves less organizational complexity, positively affects productivity, which is usually associated with performance (21). With more resources, however, larger businesses can more easily incorporate new technologies that stimulate performance (22). It is also noted that smaller businesses show more limited growth because their lack of resources prevents them from developing in a variety of business environments (23). All in all, where business size carries certain advantages and inconveniences with regard to performance, context appears to play a significant role.

It is from this angle that a closer look at forest SMEs becomes interesting. Our preliminary results suggest that smaller forest SMEs are less likely to use performance measurement tools and rely on year-end balance sheets to determine profitability. We attempted to investigate this situation on the basis of the tools that are generally used by entrepreneurs, as opposed to the balanced scorecards suggested in the literature. Moreover, smaller logging businesses also appear to be more severely affected by the crisis that has shaken the Canadian forest industry. We were, therefore, interested in discovering their strategic intentions for the following five years, in order to see to what extent their small size, which necessarily means fewer resources, could affect their survival.

2. Methodology

2.1. Population and sample

Data for this research were collected as part of the *Programme de Recherche sur les Entrepreneurs Forestiers de Récolte et de Transport* (PREFoRT) [Research Program on Forest Harvesting and Transport Entrepreneurs]. In October 2006, a little over 2,500 forest entrepreneurs were invited by mail to participate in a survey, which represents practically the entire forest entrepreneur population of Québec. One month later, a reminder card was sent out to those who had not responded to the first mailing. In December, the questionnaire was sent once again to the non-respondents. In total, 717 entrepreneurs completed the postal survey, for a total response rate of 28%. The questionnaire included more than 80 mostly closed questions, which enabled us to draw a fairly complete picture of the respondents and their businesses. According to Armstrong and Overton (24), it is acceptable to associate the late-respondents with the non-respondents. A partial analysis of the answers provided by the respondents who replied before the reminder card was mailed out revealed that they were not significantly different from those who responded after that date, which suggests the absence of a non-respondent bias.

2.2. Method

Rather than rely on markers normally used to identify business size, we separated the businesses according to size on the basis of the median number of employees, i.e. three (3) employees or fewer and four (4) employees or more. This decision is obviously debatable, but it is supported by an iterative consideration of some of the results obtained. First, not counting the entrepreneur, three employees are usually required to operate a pair of logging machines (processor and forwarder) in the eastern Canadian environment. Second, cross-referencing the number of methods used to measure performance with size (number of employees) reveals that SMEs with four employees or more use at least one (1) method to measure performance, and the maximum number increases radically. Thus, there appears to be a threshold with regard to the use of methods to measure performance. Since this cut-off point also matches the median, it seemed appropriate to continue our investigation on the basis of this number.

2.3. Measures

For *performance*, a relative subjective measure rather than an absolute measure was used. Performance measures can be objective or subjective (25). The use of subjective variation measures is considered satisfactory by some researchers (26). We were concerned about making respondents uncomfortable by asking them to reveal profit numbers, for example. They were instead asked to indicate the extent to which the profit margin had increased, remained stable, or decreased over the previous five years, and if the profits for the last fiscal year were above, comparable to, or below the average for previous years. These two measures were combined to create a *performance improvement index* (Cronbach's alpha of 0.586). Given the fact that forest entrepreneurs are in the midst of a sectorial economic crisis, it appeared to us that a relative measure would enable us to target those who were able to do well under such challenging conditions.

We used performance measures, which reflected the real-life conditions of forest entrepreneurs on the basis of, in particular, an analysis of responses collected from discussion groups. In addition to specific measures such as numbers of trees cut or the primary contractor's statements, we also incorporated financial statements or balance sheets.

To find out about their strategic intentions, managers were asked to identify the strategies that most closely matched their plan for the following five years. Options included "increase the size of your logging business", which reflects a growth strategy in the forestry sector, "diversify your business to conduct activities outside the forestry sector", which reflects a strategy of diversification, as well as other strategies that include either selling, closing, or reducing the size of the business, which indicate a strategy of withdrawal from forest operations.

3. Results

The results reveal significant differences between very small enterprises (VSEs) with three or fewer employees and SMEs with four or more employees. First, SMEs show more improved

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financial performance than VSEs (bilateral t-test, *sig.* = 0.001). Next, as illustrated in Table 1, out of the seven (7) sector-specific performance measurement tools, six (6) are more significantly used by SMEs. They also use more methods to measure performance (Table 2). The relationship between the number of methods used and performance improvement, however, is not significant (correlation = -0.25, sig. = 0.567). We also investigated the relationship between the number of weeks worked and improved financial performance. The relationship is significant and positive (correlation = 0.172, sig. = 0.000). This means that the more weeks a logging business works in a year, the more it improves its performance. There is no significant distinction between VSEs and SMEs with regard to the number of weeks worked (bilateral t-test, sig. = 0.068), which suggests that both business groups have the same amount of work. Business size, however, correlates significantly and positively with the number of weeks worked (correlation of 0.107, sig. = 0.02). In this case, distinguishing between two groups (VSEs vs. SMEs) is somewhat arbitrary and obscures the relationship between business size and the number of weeks worked.

Performance Measure Used		**VSE (≤3)**	**SME (≥4)**	**Total**	**χ2 Test**
Balance sheets or financial statements	Yes	69.1%	76.6%	73.1%	$p = 0.100$
	No	30.9%	23.4%	26.9%	
Number of trips completed	Yes	25.8%	42.6%	34.7%	$p = 0.001$
	No	74.2%	57.4%	65.3%	
Equipment utilisation rate	Yes	25.3%	42.6%	34.4%	$p = 0.000$
	No	74.7%	57.4%	65.6%	
Number of trees cut	Yes	32.0%	44.2%	38.4%	$p = 0.016$
	No	68.0%	55.8%	61.6%	
Primary contractor's statements/log	Yes	19.1%	27.9%	23.7%	$p = 0.045$
	No	80.9%	72.1%	76.3%	
Use of an onboard computer (black box)	Yes	8.4%	29.4%	19.5%	$p = 0.000$
	No	91.6%	70.6%	80.5%	
All activity entered in computers	Yes	6.2%	12.2%	9.3%	$p = 0.046$
	No	93.8%	87.8%	90.7%	

Source: Original

Table 1. Differences in Use of Performance Measurement Tools According to Size

	VSE (≤3)	**SME (≥4)**	***t*** ***-Test***
Number of methods used to measure performance	M = 2.30	M = 3.28	$p = 0.000$

Source: Original

Table 2. Number of Methods Used According to Size

In addition, as illustrated in Table 3, SME managers give greater importance to administrative duties and planning field operations than VSE managers, who focus primarily on personally operating the equipment.

Management Tasks	**VSE (≤3)**	**SME (≥4)**	***t* -Test**
Management and administration	2.54	2.92	0.000***
Planning logging operations	3.34	3.88	0.000***
Operating logging equipment	4.65	3.65	0.000***
Mechanics and equipment maintenance	3.77	3.88	0.250

* = $p \leq 0.05$ ** = $p \leq 0.01$ *** = $p \leq 0.001$

Source: Original

Table 3. Importance Given to Certain Tasks According to Size

Furthermore, not only do SMEs outperform VSEs in the current business environment, some of their strategic choices are different as well. The data reveal that inasmuch as VSEs and SMEs equally wish for their businesses to grow within the forest industry, diversify into other sectors, or train a new candidate to take over the business, VSEs are more likely to wish to close the business and sell off their assets than SMEs (see Table 4). Obviously, fewer VSEs than SMEs wish to reduce the size of their business, since in their case this would be tantamount to closing the business.

Strategic Intention		**VSE (≤3)**	**SME (≥4)**	**Total**	**χ^2 Test**
Grow within the forestry sector	Yes	12.0%	16.0%	12.8%	$p = 0.194$
	No	88.0%	84.0%	87.2%	
Diversify outside the forest	Yes	23.1%	30.9%	24.6%	$p = 0.077$
	No	76.9%	69.1%	75.4%	
Close down the business and sell off assets	Yes	26.8%	12.8%	24.2%	$p = 0.002$
	No	73.2%	87.2%	75.8%	
Reduce the size of the business	Yes	10.8%	24.5%	13.4%	$p = 0.001$
	No	89.2%	75.5%	86.6%	
Train a candidate to take over the business	Yes	19.2%	24.5%	20.2%	$p = 0.248$
	No	80.8%	75.5%	79.8%	

Source: Original

Table 4. Differences in Strategic Intentions According to Size

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Beyond the effects of business size, which could have an influence on strategic choices, better performance influences future choices. Thus, the better a business performs, the more it will strive toward growth and anticipate training a candidate to take over the business, whereas those with poorer performance will seek to reduce their logging operations, or even close down the business (see Table 5).

Strategic Intention		**Performance Improvement Index**						**TauTest**
		2	3	4	5	6	Total	
Grow within the forestry sector	Yes	6.4%	9.2%	13.0%	32.5%	36.8%	12.4%	0.000
	No	93.6%	90.8%	87.0%	67.5%	63.2%	87.6%	
Diversify outside the forest	Yes	27.1%	23.7%	24.2%	20.0%	26.3%	25.0%	0.890
	No	72.9%	76.3%	75.8%	80.0%	73.7%	75.0%	
Close down the business and sell off assets	Yes	38.8%	19.7%	14.9%	5.0%	5.3%	23.8%	0.000
	No	61.2%	80.3%	85.1%	95.0%	94.7%	76.2%	
Reduce the size of the business	Yes	18.6%	10.5%	10.6%	5.0%	5.3%	13.0%	0.045
	No	81.4%	89.5%	89.4%	95.0%	94.7%	87.0%	
Train a candidate to take over the business	Yes	12.2%	23.7%	23.6%	25.0%	52.6%	20.5%	0.000
	No	87.8%	76.3%	76.4%	75.0%	47.4%	79.5%	

Source: Original

Table 5. Relationship Between Performance and Strategic Intentions

4. Discussion

As we have seen, businesses in the forest services sector appear to differ on the basis of their size. Once they are beyond the 4-employee threshold, they use a significantly higher number of performance measurement tools and show better performance. Our research does not enable us to conclude, however, that greater use leads to higher performance; rather, our results suggest there is no such connection. It would appear that some formalization becomes necessary as size increases (27, 28), but this formalization is not necessarily a source of economic performance. This situation results in the manager focusing primarily on managing the business rather than operating the equipment.

One of the keys to understanding forest SME performance factors is the number of weeks worked. This variable is significantly related to performance and size. This means that larger businesses receive more contracts from forest products companies, which leads to better performance since they get a better return on their investments. This opens the door to a host of other unanswered questions. Do primary contractors choose to give more contracts to larger businesses because of their size, estimating, for example, that they need more work, or do other reasons underlie these choices? In other words, does the size of SMEs influence forest products companies as to whether or not to award them contracts? Are larger SMEs more proactive in their search for clients and contracts? We have noted that SME managers give more importance to managing and planning field operations than VSE managers. Does this situation, which is a result of larger business size, help improve the quality of services, and as a result, influence companies into giving them more contracts? Despite our observations to the effect that the number of weeks worked is crucial in explaining performance, we have no knowledge about the factors that influence forest product companies into awarding more contracts to certain SMEs. This suggests that further research is required on the relationship between these forest SMEs and the industry's forest companies, which could explain the performance differences among SMEs operating in this sector.

It is also possible that operations become more efficient once a certain size has been attained, maximizing the return on investments in equipment, beyond the number of weeks worked. It is also likely that managers who can free themselves from operational duties can focus more on their management duties and, as a result, provide better oversight for employees and business practices and thus increase productivity or profitability. These issues should also be explored in the future.

We have also observed that performance shapes future strategic choices. Higher performance logging businesses seek growth and expect to train candidates to take over the business, whereas businesses with poorer performance are more likely to close down the business and sell off its assets, or reduce the size of the company. Our observations to the effect that SMEs with four or more employees show the best performance, even though the specific factors at the root of this performance remain unknown, suggest that additional research be conducted on performance factors at play within this industry, and to investigate whether an optimal size may exist in terms of maximizing operational profitability.

Given that the largest forest SMEs show better performance, and that this is evidently due to a higher number of weeks worked, solutions to improve VSE performance can thus be suggested. Managers of these businesses should foresee growth by adopting a more pronounced entrepreneurial stance rather than a small business orientation (29). As a result, they could transform their management style and become more proactive in seeking work from contractors to increase their number of work weeks.

5. Limitations

Despite having obtained interesting results, several limiting factors must be underlined. First, a subjective (i.e. based on the owner's estimate) and relative (i.e. current compared to past) performance measure was used. While such a measure has its advantages by permitting to more easily collect hidden information, as well as emphasizing performance changes during a period characterized by a profound economic crisis, an objective and absolute measure would have brought a different perspective. In the SME's context, since it is often very difficult to

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obtain objective information with regard to profits and considering that these measures are strongly correlated to subjective measures, it is often the best compromise (25). It must also be noted that we essentially compared VSEs (≤3 employees) to MSEs (≥4 employees). Although we had good reasons to proceed this way, most notably because of the work organization schemes most common in forest operations, this categorization is debatable. Nonetheless, it has allowed for the identification of size thresholds, something a linear measure (i.e. correlation) would not allow. On the other hand, these thresholds do not allow considering the relationship between size and performance. We, therefore, had to complement our analyses with statistical regressions. Considering that identifying factors that contribute to performance is complex, additional analyses are certainly required to understand all possible nuances. Finally, a longitudinal experiment would be beneficial since it could allow understanding the effect of applying certain management practices such as performance measures, in an attempt to improve financial results. Our findings, based on transversal analyses are promising but limited in this regard.

6. Conclusion

This study has led to a better understanding of the effects of certain forest SME characteristics on performance and suggests areas for future research. A better understanding of the factors that improve performance is critical in order to enable them to achieve world-class levels in an industry that is increasingly competitive. These SMEs will also have to transcend the "more work = better performance" paradigm. In a context where logging rates are declining and several entrepreneurs are facing financial difficulties, it is tempting to design procurement policies that would favor certain businesses to the expense of other. The demographic of logging entrepreneurs, with a sample's average age of 51 years, should incite decision makers to develop procurement policies that favor improvement of business practices. Our study indicates that larger harvesting businesses may yield better overall performance. At the same time, they require a different type of involvement from their owners, one that place more emphasis on global business management. Favoring larger businesses without insuring that entrepreneurs are properly trained and experienced may negatively affect performance.

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Chapter 9

Species Selection and Nursery Technique Adoption for Seedling Establishment in Bangladesh — Towards Enhancing Plantation Programme

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Additional information is available at the end of the chapter

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Abstract

Small-scale nursery owners can play a vital role in biodiversity conservation through providing seedlings of forest tree species, horticultural species, flower species and medicinal plants to afforestation, reforestation, social forestry, agro-forestry, shelter belt and home gardening in Bangladesh. The present study of the nursery status of Bangladesh investigated socio-demographic characteristics, farm and farming characteristics, species selection and adoption of nursery techniques by small-scale nursery owners. A survey was conducted of 252 sample nurseries which were selected randomly. The investigation revealed that majority of the nursery owners were mid-aged (30–49 years) male (82.4%) people who took it as primary occupation (86.3%) for more than 20 years (38.1%), but a considerable amount of the respondents had no schooling (34%). Most of the owners rented a small area of land (0.5–5 acre) for the activities on a term basis. About 39.9% of the respondents raised planting materials for horticultural and forest tree species together. The study revealed that fruit-bearing (RF-28.69) and fast-growing species (RF-17.47) were considered as the criteria for species selection. *Mangefera indica*, *Manilkara zopota*, *Zizyphus mauritiana*, *Lichi chinensis*, *Artocarpus heterophyllus*, *Spondia dulcis*, *Citrus citrus*, *Swietenia mahagoni*, *Psidium guajava*, *Cocos nucifera*, *Albizia lebeck*, *Citrus grandis*, *Feronia limonia*, *Averrhoa carabola*, *Dulbergia sissoo* were the top-ranked species preferred by the nursery owners. Majority of the respondents practiced grafting and budding for vegetative propagation and practiced submersion of seeds under water and scarification as pre-sowing treatment for seed germination. On the basis of research findings, it is suggested to facilitate widespread acceptance of forest tree species, along with fruit-bearing species, and take account of small-scale nursery owners' views and preferences for achieving adoption of forest tree-based farming systems in a climate change situation.

Keywords: Seed germination, pre-sowing treatment, vegetative propagation, traditional methods, nursery-based farming system

1. Introduction

Bangladesh is a small and densely populated country with a high population growth (1.32%) [1]. Deforestation and fragmentation of forest land due to shifting cultivation [2], encroachment for agriculture, aquaculture, house and road construction have resulted in greatly reduced biodiversity and consequently have created major challenges for conservation which have made serious imbalance in the ecosystem. The imbalanced ecosystem causes a number of meteorological and health hazards [3-4]. Village forest resources are also depleting at a high rate per annum [5-6]. If this situation continues, the rural homestead forest will be seriously depleted in near future which will affect the demand for food, shelter, fuel and fodder at a geometric rate [7]. Bangladesh has about 17.04% of forestland, but the actual tree-covered area is estimated to be less than 10% [6, 8] where a country needs 25% of forest to its total area. Only seven districts of the country fulfilled the requirements (25% of forest to its total area) of forestland, but there is no state forest at all in 28 districts [6]. In spite of governmental attention to enhance the protected area to 10% of the land [8], conservation of biodiversity in Bangladesh will necessitate main assistance from private, managed patches outside natural and protected area systems.

Under this situation, nurseries can play important roles to make forest cover all over the country. There are about 6000 nurseries all over the country; the majorities among them are situated near the town or city. For this reason, village people get fewer opportunities to reach their homestead with valuable tree or fruit species. If it is possible to establish nursery at grass root level and provide them appropriate technology for species selection, seed germination and seedlings growth at nursery stages, it will be possible to increase seedlings production at the shortest possible time and thereby increase the total forest cover of the country. Indeed, only in a nursery it is possible to provide proper growing conditions to produce healthy vigorous seedlings that nursery can play the fundamental role of the primary stages to increase the forest cover of the country [9]. Many authors discussed about forest nursery status to explore the status of owners and workers, marketing status, species selection, technology adoption for producing better quality of seedlings or clones and thereby enhancing the plantation programme, agroforestry programme, social forestry programme and homestead forestry [10-18]. But there is no information available regarding the basis of species selection and technology adoption of forest nursery in Bangladesh. Therefore, an attempt has been taken to carry on this study. The objectives of the study are: (i) to determine the basis of species selection by the nursery owners at forest nurseries and (ii) to find out the techniques used to generate planting materials and differentiate germplasm access and accessibility.

2. Research method

2.1. Study site

The study was carried out purposively at Phultala and Dumuria upazilla of Khulna district, and Satkhira sador, Debhata, and Kaligong upazilla of Satkhira district Bangladesh. Nowadays, a significant amount of nursery seedlings are supplied from these areas to other parts of the country for agroforestry, social forestry, homestead forestry and other plantation programmes. The study areas are located in the south-western part of Bangladesh and they are the part of the largest delta. In the southern part of the delta lies the Sundarbans, the largest unit of mangrove forest in the world. The study areas are situated primarily in the floodplain landmass lying between 22°12′–23°59′ N latitude and 88°54′–89°45′ E longitude. The landscape of these areas is about 4–6 m above sea level. The climate of this region is sub-tropical, with three distinct seasons: winter (November to February), summer (March to June) and monsoon (July to October). The mean monthly temperature is about 28°C. Winters are relatively mild (temperature 7–12°C) and summer typically 25–32°C but up to 40°C [19-20].

2.2. Data collection

A face-to-face interview was conducted with the head of the forest nursery in the presence of other members (if available). A list of private nurseries in study areas was obtained from the nursery owners' association at Satkhira and Khulna, Bangladesh. A random sample of 252 nurseries was selected for the study. A contextual questionnaire was prepared with a combination of closed and open-ended questions, covering the socio-demographic profiles (age, sex and education) of nursery owners, farm and farming characteristics (tenure status: leased / owned land, nursery size in acre, tenure length in year, categories of species preferences), species selection criteria and technology adoption (source of propagation: seed / vegetative parts, means of seed / vegetative parts security: own production or collection, substrates of seed germination: open bed and / or polybag or others, methods of vegetative propagation: grafting, budding, air layering, etc.) for seed germination and seedling growth. Interviews were carried out by the researchers during October–November 2010, January–February 11, November–December 2011. Follow-up visits were conducted where nursery owners were not available on the first visit, and ultimately all the sampled nursery owners were interviewed. The interview schedule was prepared in English and then translated into Bengali. The questionnaire was tested through personal interview of five nursery owners of the study area, and a revised version was done. The surveyed data were recorded on papers and were tabulated and analyzed using simple statistics and also a weighted score (relative frequency) parameter about species selection, preference and technology adoption by nursery owners.

2.3. Data analysis

Data were analyzed in percentage, frequency, relative frequency and in principal component analysis (PCA). Socio-demographic profiles (age, sex and education) of nursery owners were expressed in percentage. The farm and farming characteristics were also expressed in percentages. Species selection criteria and technology adoption for seed germination and seedling growth were expressed in frequency and relative frequency. Relative frequency was used to rank selected species and to rank the selected criteria. Relative frequency was also used to rank nursery techniques adopted by the nursery owners. PCA was conducted by using past software [21] to find out important components which are correlated with other underlying variables species selection and species selection criteria.

3. Results

3.1. Socio-demographic characteristics

Most of the nursery owners interviewed were male (82.4%) and 86.3% of the respondents mentioned nursery practices as their primary activity, others mentioning agriculture, aquaculture, seed production and grocery selling as their primary occupation. The remaining (13.7%) nursery owners' primary objective was for family subsistence. Income from the nursery sale was a secondary objective. The model age class was 30–49 years. Thirty four percent had no formal education, twenty eight percent had completed primary education only and twenty four percent of the respondents had higher academic or professional education. The median family size was five. Each nursery owner's family had a median of two adult male, two earnings and three literate members (data not shown).

3.2. Farm and farming characteristics

Only 18.3% of respondents conducted nursery activities on their own land and 38.9% of the nursery owners adopted nursery activities on rented land, but almost half (42.8%) operated on both rented and own land (Figure 1a). There were a variety of nursery size, but 45.2% of the respondents implemented it on medium-sized nursery (1–3 acre, 1 acre = 0.4047 hectares). And 37.3% of the respondents had very small to small piece of land for farming and 17.5% of the respondents had a total area of 5 acres (500 decimal) or more (Figure 1b). In terms of tenure length, 38.1% of the respondents were working for more than 20 years though some of them got it by inheritance (Figure 1c). In case of species selection, 35.1% of the nursery owner preferred only horticultural species and 39.9% of the owners desired a combination of forest and horticultural species (Figure 1d). Nearly all nursery owners (97%) managed their nursery with family members. They (86%) spent almost whole day (8–10 h) in peak season (data not shown).

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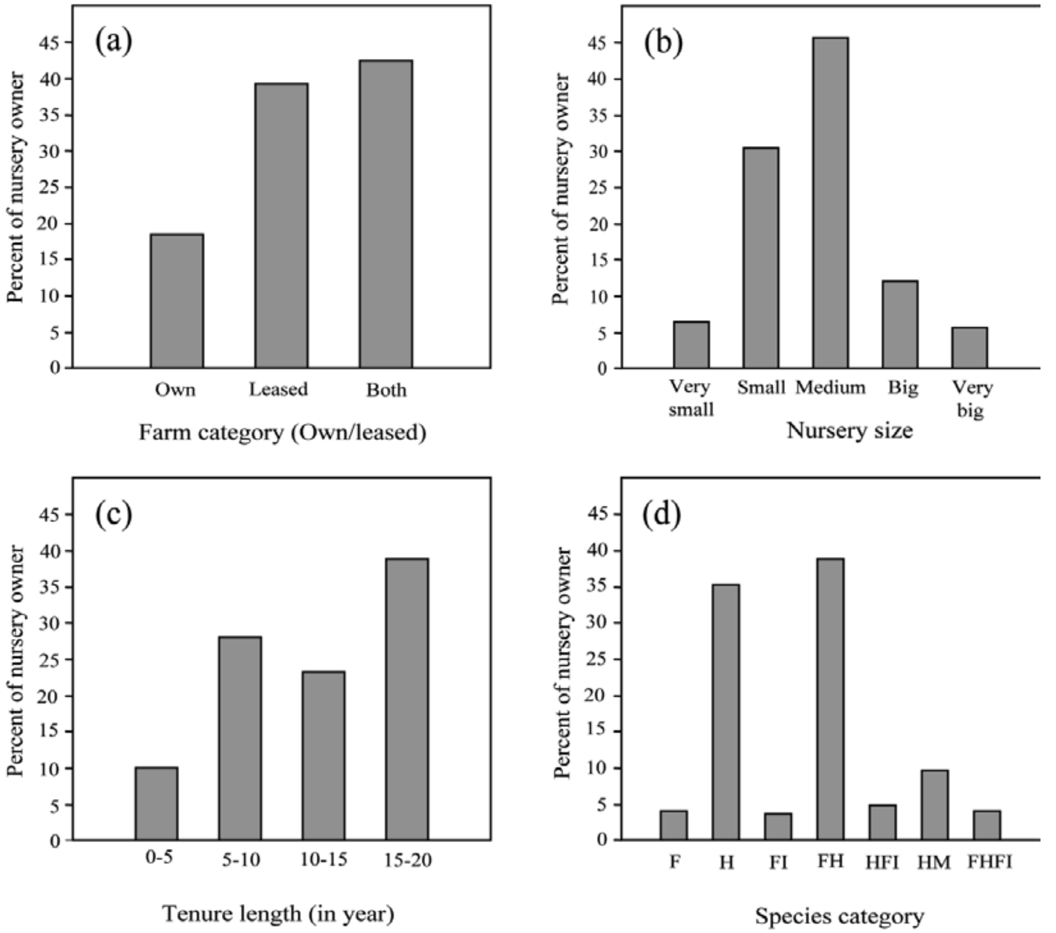

Figure 1. Farm and farming characteristics of small-scale nursery owners in the study area. (a) farm category, (b) nursery size: very small (less than 0.50 acre), small (0.50–1.00 acre), medium (1.00–3.00 acre), big (3.00–5.00 acre), very big (above 5.00 acre), 1 acre = 0.4047 ha, (c) tenure length (d) species category – F: forest species only, H: horticultural species only, Fl: flower species only, FH: combination of forest and horticultural species, HFl: combination of forest and flower species, HM: combination of horticultural and medicinal species, and FHFl: combination of flower, horticultural and flower species.

3.3. Species selection for propagation at nursery

The nursery owners mentioned 57 species growing at the nursery. The most were identified in terms of their scientific name with family, but a few were identified by local names only. The species were ranked according to the relative frequency. *Mangefera indica*, *Manilkara zopot*a, *Zizyphus mauritiana*, *Lichi chinensis*, *Artocarpus heterophyllus*, *Spondia dulcis*, *Citrus citrus*, *Swietenia mahagoni*, *Psidium guajava*, *Cocos nucifera*, *Albizia lebeck*, *Citrus grandis*, *Feronia limonia*, *Averrhoa carabola*, *Dulbergia sissoo*, *Phyllanthus emblica*, *Syzygium samarangense*, *Samanea saman*, *Annona squamosa* and *Syzygium cumini* were the top 20 species according to the given rank.

Sixteen of those were fruit-bearing species and the remaining four were forest tree species. A few medicinal plant and flower species were also mentioned (Table 1).

Scientific name	Local name	Family	Frequency	Relative frequency	Rank
Mangifera indica	Am	Anacardiaceae	246	8.11	1
Manilkara zopota	Safeda	Sapotaceae	231	7.61	2
Zizyphus mauritiana	Kul	Rhamnaceae	221	7.28	3
Lichi chinensis	Lichu	Sapindaceae	208	6.86	4
Artocarpus heterophyllus	Kanthal	Moraceae	187	6.16	5
Spondia dulcis	Amra	Anacardiaceae	180	5.93	6
Citrus citrus	Kagochi lebu	Rutaceae	166	5.47	7
Swietenia mahagoni	Mahagani	Meliaceae	154	5.08	8
Psidium guajava	Peara	Myrtaceae	152	5.01	9
Cocos nucifera	Narical	Arecacea/Palmae	142	4.68	10
Albizia lebeck	Sirish	Fabaceae	121	3.99	11
Citrus grandis	Jambura	Rutaceae	115	3.79	12
Feronia limonia	Katbell	Rutaceae	109	3.59	13
Averrhoa carabola	Kamranga	Oxalidaceae	87	2.87	14
Dulbergia sissoo	Sissoo	Fabaceae	63	2.08	15
Phyllanthus emblica	Amloki	Euphorbiaceae	58	1.91	16
Syzygium samarangense	Jamrul	Myrtaceae	57	1.88	17
Samanea saman	Raintree	Fabaceae	52	1.71	18
Annona squamosa	Ata	Annonaceae	43	1.42	19
Syzygium cumini	Jam	Myrtaceae	39	1.29	20
Gmelina arborea	Gamar	Verbenaceae	34	1.12	21
Melia azedarach	Nim	Meliaceae	32	1.05	22
Terminalia arjuna	Arjune	Combretaceae	27	0.89	23
Shoria robusta	Sal	Dipterocarpaceae	26	0.86	24
-	Asfal	-	19	0.63	25
Albizia lucida	Silkaroi	Leguminosae	18	0.59	26
-	Lambu	-	17	0.56	27
Punica granatum	Dalim	Punicaceae	15	0.49	28

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Scientific name	Local name	Family	Frequency	Relative frequency	Rank
Citrus reticulate	Kamla	Rutaceae	14	0.46	29
Baccaurea ramiflora	Latkan	Euphorbiaceae	13	0.43	30
-	Malta	Rutaceae	12	0.40	31
Polianthes tuberosa	Rajanigandha	Agavaceae	12	0.40	31
Jasminum sambac	Beli	Oleaceae	12	0.40	31
Jasminum auriculata	Jui	Oleaceae	11	0.36	32
Jasminum grandiflorum	Chameli	Oleaceae	11	0.36	32
Gardenia jasminoides	Gandhoraj	Rubiaceae	11	0.36	32
Ixora coccinea	Ranggon	Rubiaceae	10	0.33	33
Cestrum nocturnum	Hasnahena	Solanaceae	9	0.30	34
Artabotrus odoratissimus	Kathalichapa	Annonaceae	9	0.30	34
Hibiscus rosa-sinensis	Jaba	Malvaceae	8	0.26	35
Bougainvillea spectabilis	Baganbilas	Nyctaginaceae	8	0.26	35
Mimusops elengi	Bokul	Sapotaceae	8	0.26	35
Anthocephalus chinensis	Kadam	Rubiaceae	8	0.26	35
Butea monosperma	Pallash	Fabaceae	7	0.23	36
Saraca asoca	Asok	Caesalpiniaceae	7	0.23	36
Delonix regia	Krishnachura	Fabaceae	7	0.23	36
Caesalpinia pulcherrima	Radhachura	Fabaceae	6	0.20	37
Plumeria acutifolia	Katgolap	Apocynaceae	6	0.20	37
Nerium odorum	Karobi	Apocynaceae	6	0.20	37
Lagerstroemia indica	Chotto jarul	Lythraceae	5	0.16	38
Rosa damascena	Golap	Rosaceae	5	0.16	38
Cosmos bipinnatus	Cosmos	Asteraceae	4	0.13	39
Tagetes patula	Gadda	Asteraceae	4	0.13	39
Chrysanthemum coronarium	Chandra mollica	Asteraceae	3	0.10	40
Dahlia hybrida	Dallia	Asteraceae	3	0.10	40
Helianthus annuus	Surja mukhi	Asteraceae	2	0.07	41

* - = Not identified

Table 1. Species selection for nursery practice by the small-scale nursery owners at study area

3.4. Species selection criteria

Table 2 lists the relative frequency of 13 species selection criteria in order of rank based on the respondents' consideration. Fruit-bearing species as the criteria for species selection headed the list, followed by first-growing species and straight bole structure. Medicinal value as the criteria for species selection was listed as rank 13. Fine grain wood, large crown, suitability as fuel wood, suitability for agroforestry, root system (deep or shallow), big and tall tree, branching habit, flower species, branch angle (larger branching angle indicates the chance of self-pruning) were also listed as species selection criteria (Table 2).

Species selection criteria	Frequency	Relative frequency (%)	Rank
Fruit-bearing species	243	28.69	1
Fast-growing species	148	17.47	2
Straight bole structure	136	16.06	3
Fine grain wood	48	5.67	4
Large crown	42	4.96	5
Fuel wood	41	4.84	6
Agroforestry component	38	4.49	7
Root system	36	4.25	8
Big and tall tree	34	4.01	9
Branching habit (many / few)	28	3.31	10
Flower	23	2.72	11
Branch angle	18	2.13	12
Medicinal value	12	1.42	13

Table 2. Species selection criteria by the small-scale nursery owners at the study area

A PCA of top 20 selected species and major species selection criteria showed that the first principal component (PC1) explained most of the variation (46.51%) and the second principal component (PC2) explained 18.23% of the total variation, with a very large difference in eigenvalues between PC1 (5.98) and PC2 (2.52). The ordination of PCA illustrates distinct groups of species selection and species selection criteria. PCA not only provides an illustrated representation of these relationships but also points out species selecting criteria. The ordination of PCA of the present study shows cluster of fruit-bearing species on one side and cluster of timber species on another side of PC2, though every species has multiple characteristics. Fruit-bearing species as the species selection criteria is pointed among the fruit species. Fast-growing species, straight bole structure, fine grain wood, fuel wood, etc. are pointed among the timber species (Figure 2).

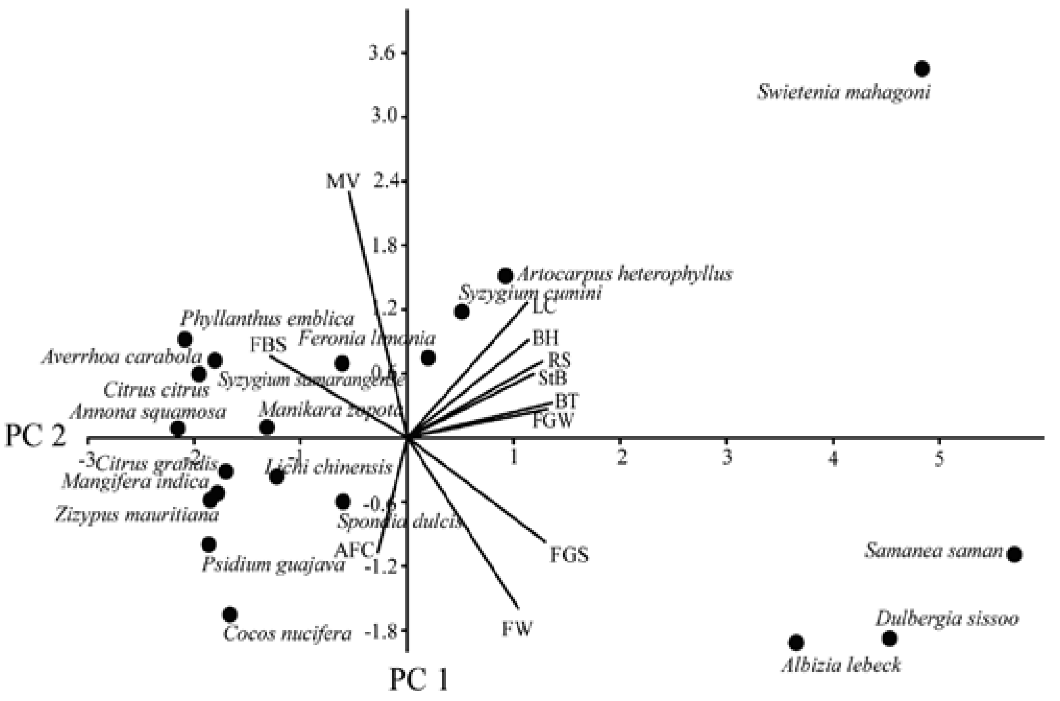

Figure 2. Principal component (PC) ordination of top 20 species and major species selection criteria. The horizontal axis of the ordination plot shows PC1 with an eigenvalue of 5.98, explaining 46.51% of total variation of species selection and species selection criteria; the vertical axis shows PC2 with an eigenvalue of 2.52, explaining 18.23% of total variation of species selection and species selection criteria. Note: FBS: fruit-bearing species, FGS: fast-growing species, StB: straight bole structure, FGW: fine grain wood, LC: large crown, FW: fuel wood, AFC: agro-forestry component, RS: root system, BT: big and tall tree, BH: branching habit (many/few), MV: medicinal value.

Table 3 shows the relative frequency (RF) of different nursery techniques adopted by the nursery owners in order of rank based on the respondents' consideration. Most of the respondents used both seed and vegetative material for propagation (RF – 70.24%), followed only vegetative parts (RF – 26.59) and seeds only (RF – 3.17). For this purpose, most of the nursery owners used their own propagules (seeds and/or vegetative part) to produce seedlings and clones. Open bed headed the list of RF in case of seed-germinating substrates. On the other hand for vegetative propagation, combination of grafting and budding secured highest RF (60.32). Most of the respondents adopted different categories of water treatment as pre-sowing treatment for seed germination purpose.

Items	Category	Frequency	Relative frequency (%)
Source of propagation	Only seeds	08	03.17
	Vegetative propagation (VP)	67	26.59
	Both (Seed and VP)	177	70.24
Means of securing seeds	Own production	121	48.02
	Bought from others	36	14.28
	Both ways	95	37.70
Seed germinating substrates	Open bed	131	51.98
	Polybag	21	08.33
	Both open bed and polybag	88	34.92
	Open bed, polybag and tob	12	04.74
Vegetative propagation method	Grafting	11	04.37
	Budding	06	02.38
	Branch cutting	05	01.98
	Grafting and budding	152	60.32
	Grafting and branch cutting	11	04.37
	Grafting, budding and cuttings	78	30.95
Means of securing vegetative materials	Own collection	134	53.17
	Bought from others	16	06.35
	Both ways	102	40.48
Pre-sowing treatments for seed germination	Hot water treatment	12	04.76
	Cold water treatment	11	04.37
	Sun heated water treatment	06	02.38
	Acid treatment	09	03.57
	Scarification	17	06.75
	Hot, cold, and sun heated water treatment and scarification	163	64.68
	Water and acid treatment	16	06.35
	Water, acid and scarification	18	07.14

Table 3. Nursery techniques acceptance by the small-scale nursery owners in the study area

4. Discussion

In this article, we studied socio-demographic characteristics, farm and farming characteristics, species selection for propagation, species selection criteria and nursery techniques acceptance by the small-scale nursery owners. The result revealed that most of the owners rented small piece of land (0.5–5 acre) for the activities for a long time (10–20 years and above). Only few nursery owners had above 5 acres of land for nursery practices (Figure 1). It may be due to unavailability of land, being a member of the most densely populated developing country like Bangladesh. Horticultural and first-growing timber species were the most preferred species, but some flower species and medicinal plants were also listed at the bottom of the selected species. In case of species selection, nursery owners mentioned 57 species, among them a considerable amount was from fruit-bearing species. From the top-ranked 20 species according to the preference of nursery owner, 16 were fruit species. The top-ranked forest tree species, *Swietenia mahagoni*, was listed at the eighth position and other forest species, flower species, were ranked at the bottom. The PCA ordination also justified the grouping of selected species with species selection criteria. The main factor that affected farmers' adoption was the fruit-bearing species which was in demand as the best in the locality. The other dominant/co-dominant factors like fast-growing species, fine grain wood, agro-forestry component, fuel wood, etc. were in demand in the timber species among the localities. Ahmed et al. [13] discussed urban nurseries in Bangladesh and found similar result. Mercado Jr. and Duque-Pinon [18] conducted a study on tree seedling production systems in Northern Mindanao, Philippines and found that similar combination of forest and horticultural species was preferred by the nursery owners.

In case of nursery technique adaptation, most of the nursery owners used both seeds and vegetative parts for seedling 'and' or 'or' clone establishment. Majority of the nursery owners collected seeds or vegetative parts from their own collection. Only eight respondents mentioned that they used only seed for seedling establishment; on the other hand, sixty-seven respondents used only vegetative part for propagation. It may be due to some of the forest tree species that produce a huge amount of seeds every year. On the other hand, horticultural species and some of the forest tree species have the ability to produce new offspring from vegetative parts. Majority of the respondents used grafting and budding methods for vegetative propagation, especially for the horticultural species. It may be due to the fruiting ability within the shortest possible time. Most of the nursery owners practiced pre-sowing treatment for seed germination to speed up the germination process, breaking the seed dormancy and thereby increase the germination percentages. Majority of the respondents used water (hot, cold and sun-heated water) and scarification as pre-sowing treatment for seed germination. It may be due to water treatment which can be capable of softening the seed coat of some forest tree seed and scarification can be made permeable where imbibitions will start. Literature supported water treatments for seed germination of *Cassia siamea* [22], *Albizia procera* [23], *Albizia lebbeck* [24]), *Xylia kerrii* [25], *Dalbergia sissoo* [26], *Hippophae salicifolia* [27], *Albizia richardiana* [28] and *Melia azedarach* [29]. Literature also supported scarification for seed germination of *Prospis flexuosa* and *P. alba* [30], *Tamarindus indica* [31], *Hippophae salicifolia* [27], *Lagerstroemia speciosa* [28].

5. Conclusion

Nursery owners can contribute a significant role through supplying seedlings to afforestation programme, social forestry programme, agroforestry programme and home garden plantation programme in Bangladesh. Beside these, young educated people can also participate in the nursery sector as there was a crisis of job market in Bangladesh, resulting in the young educated people to be self-dependent; the nursery sector will be promoted and thereby the country will be developed gradually. The investigated results showed that most of the small-scale nursery owners adopted horticultural species due to huge demand of fruit-bearing seedlings 'and' or 'or' clones at local, regional and national levels. Furthermore, fruit trees are involved in achieving farmer's manifold domestic objectives, producing food and other products and providing a defending measure in environmentally fragile landscapes. But at the same time, the demand of forest tree species should also be increased in a country like Bangladesh, critically hazardous to climate change effects. The government, non-governmental organization and policy makers should come forward to assist widespread acceptance of forest tree species, medicinal plants with fruit-bearing species and there is need for recognition of small-scale nursery owners' views and preferences for achieving adoption of forest tree-based farming systems. From the overall findings of the study, it can be concluded that the small-scale nursery owners have diverse ideas about nursery practices, but their diversity of ideas does not fully assure the success of the farming system because their practices were not scientific; furthermore, they rely on the knowledge from experiences. Short courses and trainings on nursery practices may be helpful for the development of the nursery sector.

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Section 4

Ecological, Environmental and Other Issues

Integrating Wildlife Conservation with Commercial Silviculture — Demography of the Swainson's Warbler (*Limnothlypis swainsonii*), a Migrant Bird of Conservation Concern in Southern Pine Forests, USA

Donata R. Henry, Darren A. Miller and
Thomas W. Sherry

Additional information is available at the end of the chapter

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Abstract

Intensively managed pine (*Pinus* spp.) forests encompass over 15.8 million hectares in the southeastern United States and provide an important source of wood products and an economic return to landowners. Given the extent of this landscape and the diversity of management goals and stakeholders, understanding how these forests can also be managed for biological diversity is important. Swainson's warbler (*Limnothlypis swainsonii;* SWWA), a species of high conservation priority, has been documented occupying young, unthinned pine plantations (a novel habitat type), but demographic assessment is lacking. We compared breeding phenology and reproductive success of SWWA in commercial loblolly pine (*Pinus taeda*) stands versus bottomland hardwood forest (the historical habitat type). Timing of nesting, clutch size, and hatching rates were not significantly different with 59% (n = 32) of eggs hatching in pine versus 69% in bottomland hardwood (n = 52). Mayfield estimates of nesting success were similar in pine (27%) versus hardwoods (32%) within and across years. These results indicate that closed-canopy, short-rotation pine stands can provide suitable breeding habitat for SWWA. We also review the value of intensively managed pine landscapes for avian conservation in general.

Keywords: Silviculture, biodiversity, habitat conservation, biodiversity, Swainson's warbler, *Limnothlypis swainsonii*

1. Introduction

Globally, plantation forests are increasing by an estimated 13 million hectares annually [1], comprising approximately 264 million hectares, and predicted to reach 345 million hectares by 2030 [2]. These forests are critical for meeting global wood supply demands as forests dedicated to wood fiber production produce substantially more volume of wood per hectare than natural forests [2,3]. Although the primary management objective of these forests is to provide commodities, they can simultaneously contribute to conservation of biological diversity [4-7].

For perspective, the southeastern United States has produced more timber than any other country in the world since 1986, yielding more than a million jobs and $51 billion dollars (USD) to the economy in 2009 [8,9]. Contributing largely to this productivity are intensively managed pine (*Pinus* spp.) forests, which increased in area from nearly none in 1952 to approximately 15.8 million hectares in 2010 [9]. These plantation forests currently comprise about 19% of the forested area in the region, 86% of which are privately owned [9], and are expected to stabilize in area, thus remaining an important component of forests in the southeastern United States [10,11]. Although forested area has remained relatively stable from the early 1900's to 2007, urbanization is increasing and is considered the greatest threat to this forest cover [10,11].

Intensively managed pine forests contribute to the conservation of biological diversity, including habitat conditions for diverse avian communities [12-16], albeit with limitations [13, 17,18]. Conservation value of intensively managed forests depends on the silvicultural regimes, including rotation length, stand establishment methods, stocking density, thinning regimes, and intermediate treatments (e.g., prescribed fire, herbicide application, and fertilizer use); landscape context; physiographic region; resemblance to natural forest structure; landscape scale features such as corridors and edges; and other factors. Given the extent of this silvicultural landscape, its importance to forest conservation, its economic value, and a diversity of management goals and stakeholders, it is critical to understand how commercial forests can simultaneously be managed to conserve biological diversity, particularly on private land.

Bird communities respond predictably to changes in vegetation structure in different silvicultural regimes and stand ages. Some species occupy young pine forests following clear-cuts, whereas others prefer more mature stages of succession within these broad classes [12,14,15,19,20]. For example, species of high conservation concern inhabit even-aged, thinned pine plantations in response to prescribed fire and herbicide applications [14]. Migratory bird species typically found in deciduous forests may occupy mature, even-aged pine plantations, primarily in the presence of a well-developed understory. In southeastern US pine plantations these species include Acadian flycatcher (*Empidonax virescens*) [21], red-eyed vireo (*Vireo olivaceus*), wood thrush (*Hylocichla mustelina*), worm-eating warbler (*Helmitheros vermivora*) [22], ovenbird (*Seiurus aurocapillus*), and Swainson's warbler (*Limnothlypis swainsonii*) [12,23,27,37]. Thus, pine plantations are not just occupied by habitat-generalist birds.

Recently, Swainson's warblers (SWWA), a species of conservation concern [24], have been documented occupying intensively managed pine stands in the southeastern United States [25-27]. SWWA are attracted to high stem densities and thicket-like conditions within unthinned pine plantations, which are similar structurally to switch cane (*Arundinaria gigantica*) thickets in bottomland hardwood forests [25-27], the habitat complex in which this species was first documented and remains best studied. However, understanding effects of forest management on avian species such as SWWA necessitates understanding treatment impacts on demographic parameters, and not just abundance [28,29]. To better understand use of a novel habitat condition by a conservation priority bird species, we compared breeding phenology and reproductive success of SWWA between intensively managed loblolly pine stands versus cane thickets within bottomland hardwood forests. Given abundant evidence that SWWA use pine plantations in Louisiana [25-27] we tested the hypothesis that the species experiences demographic success (based on abundance and nesting characteristics) in pine stands comparable to that in bottomland hardwoods. We discuss our results in the context of how contemporary silvicultural practices in southeastern pine plantations are likely to impact species of conservation concern such as SWWA.

2. Methods

Study areas – We conducted this study during five breeding seasons, 1999-2003, in southeastern Louisiana, United States in five of the Florida Parishes (counties) north of Lake Pontchartrain (Figure 1). In this region, lower elevations associated with river systems and drainages supported both extensively forested and highly fragmented tracts of bottomland hardwood forest. More upland areas, once dominated by longleaf pine (*Pinus palustris*) savannahs, have been converted to agriculture, towns, and suburbs, and over 80,000 ha of loblolly pine plantations. Elevation above sea level did not exceed 150 m in any of the study sites.

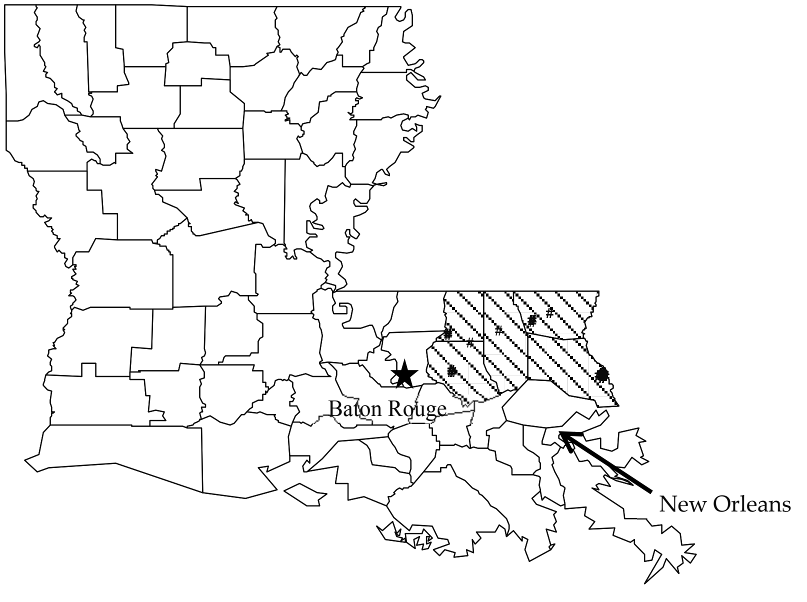
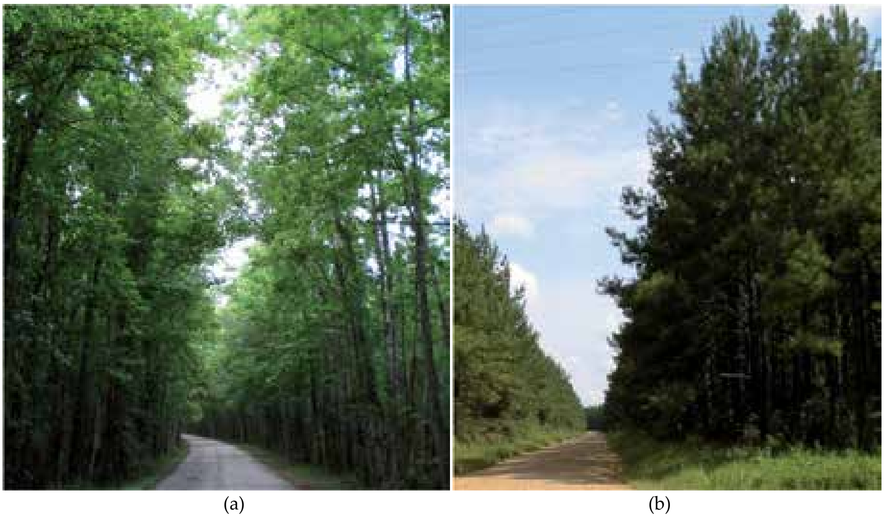


Figure 1. Map of Louisiana, USA showing Parishes (cross-hatching) where study sites were located (black circles).

Our bottomland hardwood site was located in the Honey Island Swamp unit of the Pearl River Wildlife Management Area (PRWMA) in St. Tammany Parish (30˚23′N, 89˚43′W; managed by the Louisiana Department of Wildlife and Fisheries; Figure 2a). Honey Island Swamp is a floodplain that was extensively logged in the 1940-1950s, and strip-type thinned in 1987-88 for a more selective harvest of specific tree species. During our study, most of this area was mature second growth with canopy trees of water oak (*Quercus nigra*), basket oak (*Q. michauxii*), laurel oak (*Q. laurifolia*), sweetgum (*Liquidambar styraciflua*), black gum (*Nyssa sylvatica*), bald cypress (*Taxodium distichum*), hickories (*Carya* spp.), and magnolias (*Magnolia* spp.). Midstory trees included red maple (*Acer rubrum*), ironwood (*Carpinus caroliniana*), swamp dogwood (*Cornus foemina*), hollies (*Ilex* spp.), buttonbush (*Cephalanthus occidentalis*), and silverbell (*Halesia diptera*). The understory was interspersed with southern switchcane, arrowwood (*Viburnum dentatum*), wax myrtle (*Myrica cerifera*), Chinese privet (*Ligustrum sinense*), dwarf palmetto (*Sabal minor*), blackberry (*Rubus* sp.) thickets, and occasionally dense stands of water oak and/ or other hardwood saplings. Numerous bayous and smaller drainages (often containing cypress and gums) dissected the study area, and flooded most frequently during spring and summer. We surveyed over 25 km of roads, trails, and drainages within approximately 2,300 ha. We considered Honey Island Swamp to be high-quality breeding habitat for SWWAs due to its higher density of breeding pairs compared to other large tracts of hardwood forests that we surveyed (including Bogue Chitto National Wildlife Refuge contiguous with PRWMA and Sherburne WMA in the Atchafalaya River Basin).



(a) (b)

Figure 2. Bottomland hardwood (a) and commercial loblolly pine (b) forests where Swainson's warbler nests were located in St. Tammany Parish and Washington Parish, respectively, southeast Louisiana, USA. Photographs by Donata R. Henry.

We surveyed pine plantations (n = 35) located in Washington (30˚46′N, 90˚12′W), Livingston (30˚24′N, 90˚47′W), St. Helena (30˚40′N, 90˚48′W), Tangipahoa (30˚42′N, 90˚27′ W), and St. Tammany (30˚28′N 90˚ 02′W) Parishes of Louisiana on land owned and managed by Weyerhaeuser Company for pine sawtimber production (Figure 2b). Pine stand size ranged from 50

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to 200 ha. Typical management of these stands included clear-cut harvest of existing stands followed by mechanical and chemical site preparation, planting of loblolly pine seedlings at approximately 1,700 seedlings/ha, herbicide release treatment, thinning, and then final harvest at 25-35 years of age. Pine stand canopies were composed of loblolly pine, with hardwood species in the midstory including crab apple (*Malus* spp.), red maple, and sweetgum. Typical understory shrubs included yaupon (*Ilex vomitoria*), wax myrtle (*Myrica cerifera*), and huckleberry (*Gaylussacia* spp.). Sites in Livingston Parish also contained abundant dwarf palmetto in the understory.

Study species – Due to its small wintering range and specialized habitat requirements in tropical forests, SWWA has been ranked among the Neotropical-Nearctic migratory wood warblers most vulnerable to tropical deforestation [30]. Simultaneously, its primary breeding grounds have undergone a history of habitat decline due to high agricultural demands for alluvial soils of southeastern US floodplains [31]. The breeding and wintering ranges of SWWA largely overlap those of Bachman's warbler (*Vermivora bachmanii*), a species now presumed extinct [32]. Of 19 species of bottomland hardwood breeding birds in Louisiana, SWWA was determined to have the narrowest niche breadth [32] as a patchily distributed, ground-foraging insectivore that maintains large territories (up to 2.5 ha) and builds open cup nests approximately 0.3 – 3 m off of the ground [33,34] (Figures 3 and 4). Long considered a species restricted to mature bottomland hardwood forests of the Gulf Coastal Plain, in the 1930s SWWA were discovered in low elevation *Rhododendron* thickets of the southern Appalachian Mountains [35]. More recently, SWWA have been reported in loblolly pine plantations in Texas [36], North Carolina [12], and Louisiana [25-27, 37].

Figure 3. Swainson's warbler nest with adult and two nestlings in a bottomland hardwood forest in the Pearl River Wildlife Management Area, St. Tammany Parish, southeast Louisiana, USA. Photograph by Walter C. Clifton.

Figure 4. Swainson's warbler nest with two nestlings in a commercial loblolly pine forest in Washington Parish, southeast Louisiana, USA. Photograph by Donata R. Henry.

SWWA distribution surveys and nest searches – Each field season, we extensively traveled in vehicles and on foot to survey and locate stands containing breeding pairs of SWWA across both study areas with playback songs and chip notes of SWWA along all accessible roads, trails, and drainages during late March-late April. Prior to our study, the highest number of detections of SWWA in pine plantations in the Florida Parishes had been in unthinned, closed canopy, pole-stage (8-14-year old) stands [26]. Thus, we extensively surveyed stands that both met these criteria and were reliably accessible for nest searching.

We determined number of breeding pairs/km^2 in both habitat types by mapping territory locations on area maps. Thus, estimates provided herein are based on observed pairs per area surveyed rather than extrapolated statistically from point counts (distance sampling) or transects, and our estimates did not include nonbreeding individuals. We marked territorial boundaries with flagging tape by following singing males, using song playback (minimally), observing aggressive interactions of territorial males, and observing color-banded males.

We searched for nests in all stands where evidence of breeding pairs was found based on our extensive distributional surveys. We eliminated stands with too few territories or with recent history of thinning. We revisited and surveyed stands annually, and included them in nest searching as long as evidence of breeding was found (n = 12 stands).

Nest searching extended from the last week of April to first week of August all years. We located nests primarily by searching entire territories systematically, examining all nest-like vegetation clumps and potential nest sites within the range of potential nesting heights. Males typically did not sing near nests, although we followed them and flagged singing positions to help establish territorial boundaries and determine search areas. We also used cues such as adults carrying nesting material, food, or fecal sacs. However, due to the elusiveness of SWWA and shrub density within nesting areas, these cues tended to be uncommon or difficult to detect. Once we located a nest, we checked it every two-four days until the nesting attempt failed or young fledged. We used different paths to approach nests during nest checks to decrease predator cues, and we used binoculars at a distance (3-5 m) to confirm presence of nestlings when appropriate. In some instances, we delayed nest checks due to extreme flooding. We considered nests successful that fledged at least one chick. If we could not locate fledglings when a nest was checked on the anticipated fledge date, we considered a nest successful if it contained feather sheathing and/or castings, and fecal material on the rim of the nest cup, as these signs are characteristic of fledged nests [38]. We considered nests failed if (1) we found nests empty or destroyed before the anticipated fledge date; (2) if remains of nestlings were found in nests; or (3) if nests were found empty on the anticipated fledge date and we could find no sign of recent fledgling activity in the nest cup (described above), fledglings, or adults carrying food.

Statistical analysis – We quantified clutch size, clutch start and completion dates, duration of incubation and nestling stages, percent of eggs hatched, percent of nestlings fledged, and length of breeding season. We calculated nesting success with direct comparisons of nest fates (successfully fledged nests/total nests) and the Mayfield method [39] in both habitat types. Although other methods for estimating or modeling nesting success are available, we found little difference in these models for this species [40] particularly with short intervals (2 days) between nest checks [41]. We used 25 exposure days (14 incubation days plus 11 nestling days [33]) in calculating Mayfield estimates, and the midpoint method [39] for determining the last active date of nests when nestlings fledged or nests failed prior to the last nest check. We tested the hypothesis that habitat type and year affected mean clutch size using a two-way analysis of variance with habitat type (pine or hardwood), year, and a habitat-by-year interaction term. We used chi-squared tests to examine the hypothesis that clutch size, number of hatched versus failed eggs, fledged versus failed nestlings, and fledged versus failed nests differed within years between habitat types. We also used program MARK [42] to compare reproductive success between habitat types. We set an *a priori* alpha level of 0.05 for statistical tests.

3. Results

We detected SWWAs in 15 of 35 pine stands surveyed. In 2001-2003, we found 171 nests: 138 of known fate and 33 of undetermined fate. We found 53 nests (31%) in pine and the remaining 118 in bottomland hardwoods. Additionally, we included reproductive data from 14 bottomland hardwood nests in 1999-2000 (Table 1). Density of breeding pairs in both habitat types varied with site heterogeneity; SWWAs were consistently patchily distributed and clustered in areas of dense understory vegetation. Densities ranged from 3 to 10 breeding pairs/km^2 in pine compared to 4 to 12 in bottomland hardwood.

Timing of breeding was similar between habitat types, with earliest egg laying dates occurring within the same 4-day period (27-30 April) all three years, with two exceptions: in 2002, 2 nests in bottomland hardwood were exceptionally early; one clutch started (first egg laid) on ~19 April and another on ~22 April (Figure 5). We found evidence of active nests in late July in pine, while in bottomland hardwood we recorded nests fledging as late as the first week of August (Figure 6). Incubation and nestling periods were consistent with previous records [31], lasting from 13 to 15 days and 10 to 12 days, respectively.

	1999-2000	2001		2002		2003		2001-2003	
	HARD	PINE	HARD	PINE	HARD	PINE	HARD	PINE	HARD
Total number of eggs	37	28	40	27	78	50	109	105	227
Total number of nestlings	23	16	28	20	57	26	71	62	156
Hatching success (%)	0.62	0.57	0.70	0.74	0.73	0.52	0.65	0.59	0.69
Nests with known clutch size	14	9	14	5	18	16	38	30	70
Nests with known fate	14	11	20	12	29	21	45	44	94
Nests fledged	7	5	7	7	12	5	16	17	35
Fledging success (%)	0.50	0.45	0.35	0.58	0.41	0.24	0.36	0.39	0.37

Hatching estimates do not include nests that were predated before egg laying was completed. No significant differences ($p<0.05$) were found.

Table 1. Hatching and fledging success of SWWA in bottomland hardwood (HARD) compared to pine (PINE) habitat types in southeast Louisiana, 1999-2003 [25].

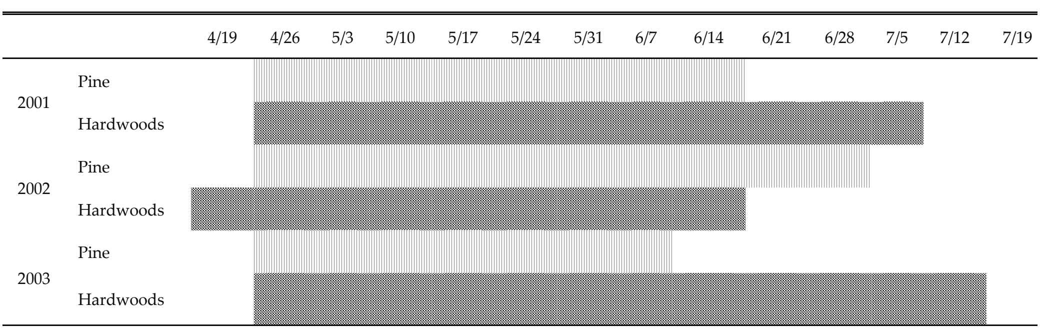

Figure 5. Comparison of the duration of the observed laying period for SWWA in pine versus hardwood habitat types [25].

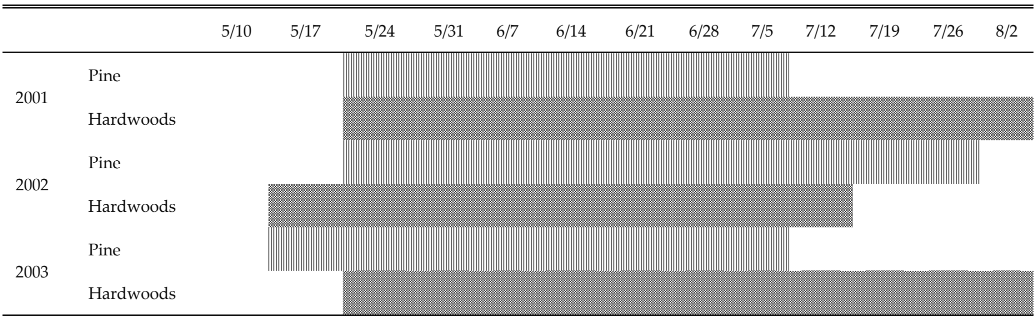

Figure 6. Comparison of the duration of the observed fledging period for SWWA in pine versus hardwood habitat types [25].

Average clutch size for all nests (n = 84) was 3.3 ± 0.55 (range 2-4 eggs; Table 2). Clutch size did not differ significantly between habitat types ($F_{1,76} = 1.70$, p = 0.20) or years ($F_{2,76} = 1.21$, p = 0.30). The interaction of habitat x year was also not significant ($F_{2,76} = 2.33$, p = 0.10). In 2002, females in bottomland hardwood more frequently produced clutches of 4 than clutches of 2-3 eggs ($x^2 = 6.14$, p = 0.01; Table 3). We did not find any conclusive evidence of double brooding, but females were not color-banded in this study, which made it difficult to confirm double brooding.

	HARDWOOD		PINE			
	Mean ± SD	**n**	**Mean ± SD**	**n**	**t-value**	**p**
Clutch size	3.35 ± 0.59	52	3.23 ± 0.49	32	0.49	0.62
Brood size	3 ± 0.71	45	2.75 ± 0.79	24	0.77	0.44
No. Fledglings	3.04 ± 0.69	28	3 ± 0.65	15	0.13	0.89

Table 2. Mean ± 1SD of clutch size, number of nestlings per nest, and number of fledglings per nest for SWWA nests found in bottomland hardwood and pine habitat types in southeast Louisiana, 2001-2003 [25].

	2001		2002*		2003	
	HARDWOOD	**PINE**	**HARDWOOD**	**PINE**	**HARDWOOD**	**PINE**
2 eggs	0	0	1	0	2	1
3 eggs	7	8	4	7	17	8
4 eggs	3	1	10	1	8	6

An * indicates that a chi-squared test comparing clutches of 2&3 vs. 4 eggs yielded a p-value < 0.05.

Table 3. Clutch sizes for SWWA nests found during the building/laying/ or incubation stages in bottomland hardwood compared to pine in southeast Louisiana, 2001-2003 [25].

Hatch rate did not differ significantly between habitat types ($p \geq 0.05$). Overall average brood size (n = 70) was 2.9 ± 0.75 nestlings, and did not differ between pine (2.75 ± 0.79, n = 24) and bottomland hardwood (3 ± 0.71, n = 45; Table 1). Average number of fledglings per nest also did not differ between pine (3 ± 0.65, n = 15) and bottomland hardwood (3.04 ± 0.7, n = 28). Overall nesting success rate ranged from 24 to 58% (direct estimates) and 13 to 44% (Mayfield estimates; Tables 4 and 5). We found no significant difference ($p > 0.2$) in number of nestlings fledged or successful nests between sites in all years, or in years pooled (Table 6). However, a comparison of survival probability for incubation and nestling stages, and overall reproductive success, as determined by Mayfield estimates, does reveal significant trends (Table 7). In 2001, nest survival was higher in pine, while in 2003 it was higher in bottomland hardwood. In 2002, incubation and nest survival were higher in bottomland hardwood, while probability of a nestling surviving was higher in pine. Despite this annual variation, survival across all years combined did not differ between habitat types ($p > 0.1$; Table 7). Due to difficulty of finding nests in pine, sample sizes were relatively small in 2001 and 2002, and we found few nests during the incubation stage in 2002. Thus, we argue that results for years pooled probably provide the most accurate estimate of reproductive performance in pine.

	2001	2002	2003	2001-2003
Total number of eggs	68	105	159	332
Total number of nestlings	44	77	97	218
Hatching success (%)	0.65	0.73	0.60	0.66
Nests with known clutch size	23	23	54	100
Nests with known fate	31	41	66	138
Nests fledged	12	19	21	52
Fledging success (%)	0.39	0.46	0.32	0.38

Table 4. Summary for comparison by year of breeding data from bottomland hardwood and pine habitat types combined [25].

	2001	2002	2003	2001-2003
Eggs hatched	1.192 (0.27)	0.000 (0.99)	2.486 (0.12)	3.175 (0.074)
Nestlings fledged	1.407 (0.23)	1.667 (0.20)	0.354 (0.55)	0.726 (0.39)
Nest success	0.327 (0.57)	0.981 (0.32)	0.911 (0.34)	0.025 (0.87)

Values indicate the x^2 value with the p-value in parentheses. Df = 1. No significant differences were found between habitat types.

Table 5. Results of chi-squared tests comparing reproductive metrics for SWWA between pine and bottomland hardwood habitat types in southeastern Louisiana, 2001-2003.

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	2001	2002	2003	2001-2003
Incubation	11.69 (<.001)*	40.54 (<.001)	2.88 (0.09)	2.43 (0.12)
Nestling	3.48 (0.06)	53.17 (<.001)*	9.15 (0.003)	0.081 (0.78)
Nest	9.9 (0.002)*	5.05(0.02)	8.56 (0.003)	0.60 (0.44)

Values indicate the x^2 value with the p-value in parentheses. Df = 1, p<0.05. Results with an "*" indicate that he survival probability was higher in pine. Results with a "" that the survival probability was higher in hard woods.

Table 6. Results of chi-squared tests comparing Mayfield estimates of pine and bottomland hardwood habitat types for specific reproductive variables.

	2001			**2002**			**2003**			**All years**		
	PINE	**HARD**	**Total**	**PINE**	**HARD**	**Total**	**PINE**	**HARD**	**Total**	**PINE**	**HARD**	**Total**
Incubation stage												
Days	74	88	162	33	166	199	126	231	357	233	485	718
Losses	2	5	7	3	4	7	7	9	16	12	18	30
Mortality	0.027	0.057	0.043	0.090	0.024	0.035	0.056	0.039	.045	0.052	0.037	0.042
Daily survival probability	0.973	0.943	0.957	0.91	0.976	0.965	0.944	0.961	0.955	0.948	0.963	0.958
Probability of surviving incubation stage	0.68*	0.44*	0.54	0.26*	0.71*	0.61	0.45	0.57	0.52	0.48	0.59	0.55
Nestling stage												
Days	52	69	121	38	123	161	48	154	202	138	346	484
Losses	2	4	6	0	6	6	5	9	14	7	19	26
Mortality	0.038	0.058	0.049	0	0.49	0.037	0.104	0.058	0.069	0.051	0.055	0.054
Daily survival probability	0.962	0.94	0.951	1	0.951	0.963	0.896	0.942	0.931	0.949	0.945	0.946
Probability of surviving nestling stage	0.65	0.52	0.57	1*	0.58*	0.66	0.30*	0.51*	0.45	0.56	0.54	0.54
Probability of fledging	0.44*	0.23*	.36	0.26*	0.41*	0.40	0.134*	0.30*	0.23	0.27	0.32	0.30

Table 7. Mayfield estimates of the reproductive success of SWWA in pinecompared to bottomland hardwood habitat types in southeast Louisiana, 2001-2003. Results with an "*" indicate that there was a significant difference (p < 0.05) between habitats.

We used 98 nests, monitored for 1,114 exposure days during April 26–August 7 (a 104-day breeding period) to estimate nest survival probabilities. Results were similar to those obtained for egg and nestling survival probabilities with the Mayfield method, with no difference in daily survival probability in pine (0.9604), bottomland hardwood (0.9599), and both habitat types combined (0.9601).

We attributed nest failure to predators in 77% of failed nests (n = 26) in pine and 83% of failed nests (n = 59) in bottomland hardwood. We also found evidence of one adult killed on a nest in bottomland hardwood. We only observed four cases involving nest parasitism by brown-headed cowbirds (*Molothrus ater*), specifically in pine sites in St. Helena Parish in 2001 and in Livingston Parish in 2003; and in bottomland hardwood once each in 2002 and 2003. Only one cowbird egg or chick was discovered per nest. Thus, only two nests in each habitat type were parasitized by brown-headed cowbirds (8% in pine and 3% in bottomland hardwoods). In 10% of failed nests, abandonment was the cause in pine and 8% in hardwood; weather (overexposure to cold, wet conditions during a tropical storm or loss of nests to flooding) caused 8% of nest failures in pine stands and 5% in hardwood.

We suspected polygyny in one male's territory in bottomland hardwood, where two active nests were found during laying within 3.5 m of each other. Each female laid a clutch of three eggs; only one nest successfully fledged three young, while eggs in the other nest were destroyed by a bird (holes poked in the eggs) soon after laying. Although females were not banded, we suspect that it was the same female from the destroyed nest who renested within 6 m of her first nest and eventually fledged three young. We also observed four other instances in Honey Island Swamp and one in a pine site where we found active nests in close proximity to one another (within 10 m), but could not definitively determine if these were cases of polygyny or alternatively aggregated nest placement by pairs from adjacent territories.

4. Discussion

Our study is the first to monitor SWWA nesting in pine plantations, the first to compare SWWA nesting success in two different habitat types, and one of the few with sample sizes greater than 20 nests per habitat type (others include [40, 43]). Comparing density, breeding phenology, clutch size, nesting success measured multiple ways, impacts of predators and brood parasites, and comparing the two forest types for combined years did not reveal any significant differences. Thus, multiple lines of evidence support our hypothesis that SWWA reproductive success in pine plantations with suitable habitat is equal to that of bottomland hardwoods. Sample sizes were too small to confirm there were in fact no differences between habitat types (e.g., in frequencies of nest predation or brood parasitism), but based on consistency of these largely independent measures of nesting ecology, these two habitat types differ little for SWWA.

Breeding phenology did not differ by habitat with the exception of 2002, when breeding was documented one week earlier in bottomland hardwoods. In 2002, we found clutches of 4 eggs significantly more frequently in bottomland hardwoods than in pine stands, probably correlated with earlier nesting date, as larger clutches tended to occur earlier in the breeding season. Older, more-experienced, or more-fit pairs may preferentially select bottomland hardwoods, although SWWA males arrived on breeding territories at the same time in both pine and bottomland hardwood, demonstrating that bottomland hardwoods are not necessarily being preempted by experienced males. Instances of earlier clutch initiation date and larger clutch size, in addition to somewhat higher breeding density (although this was not tested), indicate that bottomland hardwoods may have provided slightly better habitat conditions than pine plantations. However, small sample sizes, difficulty of finding nests during laying, and the fact that these trends were not observed consistently every year precludes any such generalization without more data.

Additionally, annual adult survival was not examined in this study, so we do not know if populations in the two habitat types have identical population growth rate. Morphological data [25] suggest no ecotypic variation or population segregation by breeding habitat. We also did not account for differences between stands within each habitat type, which probably vary in quality, but rather combined all nests by habitat type due to limited sample sizes. Thus, we cannot be certain of no local variation within habitat type. Finally, because very few individuals were marked in our study we were unable to identify renesting attempts. Fates of all nests found were included in analyses. Therefore, estimates of nest success reported here may not accurately represent success of birds that may have reared young after second or third attempts [44].

SWWA appear able to move among habitat patches in an ideal free distribution pattern [45,46]. We found unoccupied stands of seemingly suitable dense canebrakes in Honey Island Swamp and areas newly colonized by SWWA where growth in thinned or cleared tracts that had previously been unoccupied reached higher breeding density during our study. Similarly, we witnessed SWWA moving out of a 14-year-old unthinned pine stand that had been actively used for breeding for at least 3 years, into an adjacent 21-year-old pine stand that had already been thinned for 6 years. Thus, although distribution and abundance of SWWA is not well known in any part of its range, it appears to be patchily distributed throughout suitable environments, suggesting low overall population density and unsaturated breeding habitat. As in our study, viable canebrakes were not saturated with birds and did not appear to limit populations of SWWA in southern Missouri [47] or correlate with greater nesting success in eastern Arkansas [43]. SWWA could be considered colonial breeders based on these patchy distributions [31], which may be attributed to social stimulation affecting habitat selection [48]. Coloniality, or dense populations occupying smaller territories, are reported to be indicative of higher quality habitat conditions and higher resource productivity [33,49], but see [28].

Because reproductive success of SWWA was comparable in two habitat types compared here, suggesting individuals freely select suitable breeding habitat [e.g., 26], we posit that pine plantations, where appropriate habitat conditions exist, do not constitute population sinks for this species. This finding is consistent with other recent studies documenting avian nesting success in general in pine plantations [20,50,51]. Secondly, pine plantations in our study differed considerably from bottomland hardwoods, both floristically and physiognomically, suggesting that SWWA does not select breeding habitat based just on structural characteristics like broad-leaved versus needle-leaved trees [25]. Although we did not measure landscape features that could influence presence of SWWA in pine stands, scarcity of suitable bottomland hardwoods in the study region (longleaf pine savannah historically being the primary forest type in the area) suggests that SWWA are not simply spilling over from adjacent habitat types.

4.1. Conservation implications

In addition to SWWA, other migratory species of conservation concern that are traditionally, if not exclusively, associated with hardwood forests have been frequently detected breeding in pine plantations, including (in our study) worm-eating warbler, hooded warbler (*Wilsonia citrina*), Kentucky warbler (*Oporornis formosus*), white-eyed vireo (*Vireo griseus*), wood thrush, and yellow-billed cuckoo (*Coccyzus americanus*). Use of pines by so many breeding forest interior, understory ground and shrub-nesting birds indicates that pine plantations provide suitable breeding habitat. SWWA typically experience low rates of nesting success as reported (in limited accounts, see [25,40]) across their range, and so are particularly sensitive to predators and other limiting factors on their breeding grounds. Thus, we suggest that they may serve as sensitive indicators of habitat quality. If so, then our results support the conclusion that pine plantations provide suitable breeding habitat not only for SWWA, but also for the larger community of understory breeding birds. More extensive, large-scale monitoring programs may reveal other "novel" landscapes for species of conservation concern.

A positive implication of this finding is that pine plantations in the United States is predicted to persist [9], which should help sustain abundant SWWA in Louisiana and other southeastern states [27]. However, the temporal windows of suitable habitat conditions (pole stage and mature pine) within pine forest patches is short, and forest products companies generally thin stands while closed canopy conditions still exist. Thinning can negatively affect avian reproductive success [52]. Nonetheless, it is important to recognize that short stand rotations mean that as many stands are becoming suitable for SWWA as are deteriorating throughout a landscape; this may mitigate against the short duration that particular stands are available for this species [27].

Because closed canopy pine stands with little herbaceous growth are generally considered to be of minimal biodiversity value, planting pines on wider rows and thinning as early as possible is generally recommended to improve herbaceous vegetation conditions and thus overall biodiversity within stands [18,53]. However, within the range of SWWA, consideration should be given to the value of closed canopy plantations to this species [this study, 24,25,27,37] when making management decisions. Additionally, management decisions during early rotation affect successional trajectories in intensively managed pine stands [15,53,54] and could affect habitat suitability for SWWA structurally and temporally.

Plantation forestry may become increasingly important for conserving biological diversity generally. For example, *Acer saccharum* forests in eastern Ontario managed for maple syrup provide suitable breeding habitat for cerulean warblers (*Dendroica cerulea*), another species of conservation concern [55]. Even-aged spruce plantations in Scotland support a higher density and diversity of native songbirds than the moorlands they replaced, without negatively impacting regional diversity [56]. Survival rate of wild turkey (*Meleagris gallopavo*) females in intensively managed pine landscapes in Mississippi was equivalent to traditional hardwood and mature pine habitat conditions associated with this species [57]. Young conifer plantations

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provided suitable foraging sites for the rare woodlark (*Lullula arborea*) in Britain [58], where 19 threatened fungal species were also recorded in conifer plantations, and species richness did not differ from natural forests [59]. Thus, silvicultural landscapes can increase geographic-scale (Beta) diversity. Such findings should encourage better understanding when commercial management is not incompatible with wildlife conservation.

Because SWWA is poorly detected and difficult to monitor with broad-based methods such as breeding bird surveys, no data exist on long-term population trends. Data are sparse on local distributions of SWWA rangewide, making it difficult to detect shifts in habitat use (e.g., [27], present study). Thus, more and better surveys of forest interior species are needed to assess current status and future viability. The opportunity to conserve species on private lands where the economic incentive exists to maintain forest cover should not be overlooked, particularly in regions where most forest land is privately held [9].

More research is needed on the breeding ecology of SWWA in novel habitat types to identify whether results found here are general. A comparison of reproductive success within pine in response to stand characteristics and management history would provide a better guide to management practices necessary for sustaining SWWA populations. More investigations *sensu* Graves [27] into landscape features associated with pine stands occupied by SWWA may also help to identify habitat conditions relative to reproductive success. Research is also needed on the temporal window of stand ages suitable for reproduction and population growth by SWWA, and how this window might conflict with commodity-production objectives.

In summary, our research has demonstrated that SWWA has expanded its local range in southeastern Louisiana into pine plantations, and is experiencing similar levels of reproductive success in this and in bottomland hardwoods, the historically most important habitat type. Our prediction that pole stage pine plantations are not an ecological trap for SWWA is supported, but more information is needed on how silvicultural regimes across the southeast United States may affect demographic parameters of forest interior bird species of present or future conservation concern [37]. Contributions of intensively managed forest landscapes for conservation have commonly been underrated, and must be recognized to develop and encourage management practices that integrate conservation of biological diversity with silviculture across broad landscapes. These forests should not be seen as surrogates for or threats to conservation of natural forests, but rather as potential contributors to maintenance of local and regional biodiversity.

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Chapter 11

Possibilities and Perspectives of Agroforestry in Chhattisgarh

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Additional information is available at the end of the chapter

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Abstract

Agroforestry (AF) is an ecofriendly and sustainable modern farming land use practice that maintains overall farm productivity by combining herbaceous food crops with woody perennial trees and livestock on the same piece of land, either alternately or at the same time, using scientific management practices that improve the socioeconomic condition of people. It is the new name for an ancient land use practice and just a compromise between agriculture and forestry. It plays a major role in enhancement of overall farm productivity, soil enrichment through litter fall, maintaining environmental services such as climate change mitigation (carbon sequestration), phytoremediation, watershed protection and biodiversity conservation. It is an effective and alternative management system to meet the target of increasing forest cover to 33 % as given by the national forest policy. Their scope and potential in any state including Chhattisgarh is tremendous. Farmers use generally N_2-fixing trees like some from the Leguminosae family including *Acacia spp*., *Dalbergia sissoo*, etc., on their farmland for enhancing their field crops and generating incomes and employment. Therefore, rural people should make some strategy for the implementation of agroforestry model with suitable combination of trees and field crops, and this combination does not only generate income for the upliftment of socioeconomic value but also concerns the ecological and environmental stability on the sustained basis, i.e. emphasis should be more on scientific management of these models.

Keywords: Agroforestry, Carbon sequestration, Ecological, Phytoremediation

1. Introduction

Agroforestry system is land management practice to cultivate woody perennial and agricultural crops on the same piece of land in temporal and spatial arrangement with sustainable production of crops and ecological and socioeconomic conditions. It is an ecologically sustainable land use option alternative to the prevalent subsistence farming patterns for conservation and development. According to Dhyani et al. [1], in India, the current area under agroforestry is estimated at 25.32 Mha, or 8.2 % of the total geographical area of the country. This includes 20.0 Mha in cultivated lands (7.0 Mha in irrigated and 13.0 Mha in rainfed areas) and 5.32 Mha in other areas such as shifting cultivation (2.28 Mha), home gardens and rehabilitation of problem soils (2.93 Mha). The science of agroforestry system centres around four factors – competition, complexity, sustainability and profitability – and there should be a balance among all these factors to get fruitful returns. Density of trees/shrubs varied from one agroforestry system to another, depending upon the availability of the resources [2]. Agroforestry has much potential, such as the overall (biomass) productivity enhancement, soil fertility improvement, soil conservation, nutrient cycling, microclimate improvement, carbon sequestration, bio-drainage, bioenergy and biofuel [3]. Agroforestry also has the potential to enhance ecosystems through carbon storage, prevention of deforestation, greater biodiversity, cleaner water and less land erosion. Agroforestry provides great opportunities to link water conservation with soil conservation; hence, the major focus has to be on this aspect [4]. It is also noted that sustainable agroforestry can upsurge resilience against environmental change, to enhance carbon sequestration and also to generate income, which will result in improved livelihood of small and subsistence farmers [5].

Traditional agroforestry practices involve planting trees in rows sparsely in crop field and/or along the allies (bunds). These trees provide food, timber, fuel, fodder, construction materials, raw materials for forest-based small-scale enterprises and other cottage industries and in some cases, enrich soil with essential nutrients [6-8]. Management practices for agroforestry are more complex because multiple species having varied phonological, physiological and agronomic requirements are involved [9]. The most important factor for the compatibility of agroforestry [10-11] is the selection of suitable tree and agricultural crop combination; usually trees that have multipurpose benefits like nitrogen fixing and are fast growing and adaptable to harsh conditions and economically important are preferred [12]. Agroforestry systems can be expedient over conservative agricultural and forest production methods [13]. Since agroforests are stereotypically less diverse than native forest, they support a substantial number of plant and animal species. Therefore, agroforestry, if properly developed, has the potential to improve socioeconomically a more sustainable and better landscape [14]. In order to promote agroforestry, it will require appropriate research intervention, adequate investment and suitable extension strategies; providing incentives to agroforestry, removing legal barriers in felling, transporting and marketing of agroforestry produce and developing harvest process technology of new products and market infrastructure; and above all, a forward-looking agroforestry policy to address these issues [15].

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2. Historical status of agroforestry in India

Agroforestry is as old as the origin of agriculture. But the scientific approach to this system has been realized recently. In India, research work on agroforestry (AF) was initiated during the late 1960s and 1970s by the Indian Grassland and Fodder Research Institute, Jhansi; Central Soil and Water Conservation Research and Training Institute, Dehradun; Central Arid Zone Research Institute, Jodhpur; and ICAR Research Complex for the North-Eastern Hill Region. The National Commission on Agriculture emphasized agroforestry education in the seventh five-year plan period, and all state agricultural universities have introduced it into the agriculture syllabus in accordance with the recommendation of the task force constituted during the first agroforestry seminar organized at Imphal, India, in May 1979. Indian Society of Tree Scientists (ISTS) organized a national seminar on 'Agroforestry for Rural Needs' in 1987. ICAR had already launched the All India Coordinated Research Project on Agroforestry which spread over 22 centres in the country in 1983. This programme was subsequently extended to 11 more centres covering all the 23 state agricultural universities, and it was decided that a National Research Centre for Agroforestry would be established during the seventh five-year plan of India (1985–1990). The Greening India mission under the National Climate Change Action Plan targets 1.5 Mha of degraded agricultural lands and fallows to be brought under agroforestry; about 0.8 Mha are under improved agroforestry practices on existing lands and 0.7 Mha of additional lands under agroforestry [16]. Also, there are a number of schemes and programmes being discussed and likely to be initiated in the near future. As per the Government of India initiative to encourage crop diversification in the earlier 'green revolution' states, Punjab wants to bring an additional area of 2 lakh ha under agroforestry to its present 1.3 lakh ha has crop diversification strategy [17]. Simultaneously, the post of Assistant Director General (Agroforestry) was also created at the ICAR headquarters in Delhi to coordinate the total research on agroforestry in India.

3. Scope of agroforestry in India

Agroforestry is an ideal land use option as it optimizes trade-offs between increased food production, poverty alleviation and environmental conservation [18]. This system is adopted in a large hectare of boundaries, bunds and wasteland area and permits the growing of suitable tree species in the field where most annual crops are growing well. Agroforestry assures permanent sources of higher income even in extreme adverse conditions. The role and scope of agroforestry are also studied in way of biodiversity conservation, yield of goods and services to society, augmentation of the carbon storages in agroecosystems, enhancing the fertility of the soil and providing social and economic well-being to people [19]. Realizing such scope, the All India Coordinated Research Project on Agroforestry was initiated in 1983 to initially operate at eight Research Institutes of the Indian Council of Agricultural Research (ICAR) and twelve agricultural universities, and now it is being extended to a large number of universities and institutes. Since agroforestry is a land use management system without deterioration of its fertility that results in more output, this adds to the national economy. Thus, a bright future of agroforestry in India is inevitable.

4. Practices of agroforestry in India

The practices of growing agricultural crops under scattered trees on farm land are old practices, for example, *Prosopis cineraria* in north-western India and poplars in north India, *Prosopis cineraria* and *Zizyphus* in arid area, *Acacia nilotica* in Indo-Gangetic plains, *Grewia optiva* and other tree species in the hills of Uttarakhand and Himachal Pradesh, *Eucalyptus globules* in the southern hill of Tamilnadu and *Borassus flabellifer* in the peninsular coastal region.

Farmers retain tree of *Acacia nilotica, Acacia catechu, Dalbergia sissoo, Mangifera indica, Zizyphus mauritiana* and *Gmelina arborea* and are preferred in Gujarat with crops. In Bihar, *Dalbergia sissoo, Litchi chinensis* and mango are frequently grown on field, but for boundary plantation, *Sissoo* and *Wendlandia exserta* are most commonly used. Farmers of Sikkim, grow bamboo (*Dendrocalamus*, Bambus) all along the irrigation channels. In Andaman, farmers grow *Gliricidia sepium, Jatropha* spp., *Ficus, Ceiba pentandra, Vitex trifolia* and *Erythrina variegata* as live hedges. In Chhattisgarh, *Acacia nilotica, Gmelina arborea* and *Albizia*-based agroforestry system are used. Under protein bank (silvopasture system), protein-rich fodder trees including *Acacia nilotica, Albizia lebbeck, Azadirachta indica, Leucaena leucocephala, Gliricidia sepium* and *Sesbania grandiflora* are planted.

In south India (Kerala), home garden (agrisilvipastoral system) is used which is the combination of trees, shrubs, vegetables and other herbaceous plants with livestock animals. Farmers retain the suitable species like *Anacardium occidentale*, *Artocarpus heterophyllus*, *Citrus* spp., *Psidium guajava*, *Mangifera indica*, *Azadirachta indica*, *Cocos nucifera*, etc. [20].

5. Potential of agroforestry in Chhattisgarh

Chhattisgarh is a predominantly tribal region in the eastern part of India, comprising a total geographical area of 137.90 lakh ha. The geographical location of Chhattisgarh is from 17° 46' north to 24° 5' north latitude and from 80° 15' east to 84° 20' east longitude. The total area of agro-climatic zone (eastern plateau and hill region) in Chhattisgarh is 23.29 lakh ha, which is 24.90 % of the total geographical area of the state. The loamy and clayey soil of this plain area is very fertile, and climate generally varies from moist subhumid to dry subhumid. Chhattisgarh state is rich in forest and has a vast variety of minor forest products to favourable agro-climatic conditions resulting in good forest area, i.e. 43.6 % of the total. Rice is the main crop cultivated in Durg District of Chhattisgarh state, India [21-22]. Agroforestry model in Chhattisgarh state is very prominent and applied. Certain MPTs like *Acacia nilotica*, *Butea monosperma*, *Terminalia arjuna*, *Albizia procera* and *Zizyphus mauritiana* are an integral part of the rural agroforestry practices of the region and have tremendous importance in poverty alleviation and income generation in the predominantly rainfed agrarian economy of the region. While

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traditional models with *Acacia nilotica* and *Butea monosperma* and homestead cultivation of horticultural crops have to be encouraged, extensive research inputs have to focus on increasing crop yields through better management of the tree crops and on minimizing competition for resources in the tree-crop interface [23]. Agroforestry system affects the carbon storage capacity and biomass production other than sole crop and tree plantation. A comparative study was done at Forestry Research Farm of Indira Gandhi Agricultural University, Raipur, Chhattisgarh; the total stand biomass is substantially higher in plantations (35 %) than agrisilviculture system, and agrisilviculture system had also the least net C storage (soil + tree) as compared to *Gmelina arborea* monoculture stands [24].

In Chhattisgarh, trees most commonly found in fields are *Acacia nilotica, Butea monosperma, Terminalia arjuna, Azadirachta indica, Pongamia pinnata*, etc. Fruit trees like *Carica papaya, Citrus* spp., *Mangifera indica* and *Psidium guajava* are very common and popular in Chhattisgarh. MPTs in the region include *Terminalia arjuna, T. tomentosa, Albizia procera, Mangifera indica, Butea monosperma, Zizyphus mauritiana, Azadirachta indica* (neem) and *Gmelina arborea* grown on paddy field bunds. Neem has a lot of importance in social forestry, agroforestry, reforestation and rehabilitation of the wasteland and degraded industrial lands. Thus, large-scale plantation of neem trees helps to combat desertification, deforestation and soil erosion and to reduce excessive global temperature [25]. *Bamboo* which was another highly preferred species could be encouraged for planting on field bunds, farm boundaries and homesteads. *Jatropha spp.* are also raised in the farm bund as a live fence, and it also generates the source of rural employment [26]. The prevalent agroforestry models/practices are *Acacia nilotica*, paddy model (most popular and widely accepted); *Butea monosperma*, paddy model (second most popular system and nearly 48 % of the farmers maintained them); and MPTs like *Albizia procera, Terminalia arjuna* and *Gmelina arborea* on field bunds as windbreaks or live hedges on boundaries. *Zizyphus mauritiana*-based homestead gardens are also used. In traditional agroforestry, crop density, aboveground biomass, belowground biomass and their productivity are affected by tree canopy size, age and distance from the tree trunk. Generally, as a distance increases, the grain yield also increases [27]. Also with increase in age, crown diameter and DBH of *Acacia nilotica* tree, the productivity of gram reduced from 37.73 % (6 year-old tree) to 68.49 % (20 year-old tree) [28]. For reducing tree-crop competition, tending operation including pruning is an effective tool which enhances the crop productivity; otherwise, there is reduction in yield (41 to 61 % reduction in wheat yield in unpruned *Eucalyptus* tree; [29]. Farmers often practice severe branch pruning every season before the planting of crops, to reduce tree-crop competition as well as to improve tree form [30].

6. Tree-crop interaction

Various interactions take place between the tree and herbaceous plants (crops and pasture), which are referred to as the tree-crop interface. Interaction is defined as the effect of one component of a system on the performance of another component and/or the overall system [31]. Regarding this, ICRAF researchers have developed an equation for quantifying tree-crop interaction (I), considering positive effects of tree and crop yield through soil fertility enrichment (F) and negative effects through crop competition (C) for growth resources between tree and crop I = F-C. If F> C, the interaction is positive; if F< C, the interaction is negative; and if F = C, interaction is neutral. Studying tree-crop interaction in agroforestry would help to devise appropriate ways to increase overall productivity of land. Increased productivity, improved soil fertility, nutrient cycling and soil conservation are the major positive effects of interactions, and competition is the main negative effect of interaction, which substantially reduces the crop yield. It may be for space, light, nutrients and moisture. Ecological sustainability and success of any agroforestry system depend on the interplay and complementarily between negative and positive interactions. It can yield positive results only if positive interactions outweigh the negative interactions [32].

7. Agroforestry contribution

Agroforestry contributes a vital role in Indian economy and has potential to satisfy three objectives, viz. to protect and ameliorate the environment, enhance sustainable production of economic goods on a long-term basis and improve socioeconomic condition of rural people. It has many contributions like rehabilitation of degraded land, increased farm productivity and capability of conserving natural resource and it is an option to increase the forest cover to 33 % in the country. Besides meeting the subsistence need of food, fruits, fibre and medicines, this farming practice meets almost half of the demand of the fuel wood, two-thirds of the small timber, 70–80 % wood for plywood, 60 % raw material for paper pulp and 9–11 % of green fodder requirement of livestock. Also, agroforestry practices have enhanced overall biomass productivity from 2 to 10 t $ha^{-1}y^{-1}$ in rainfed areas in general and the arid and semiarid regions in particular [1]. Agroforestry is also providing livelihood opportunities through lac, apiculture and sericulture cultivation, and suitable trees for gum and resin have been identified for development under agroforestry [33]. Under agroforestry system, tree cultivation on agricultural land improves biomass productivity per unit area and also uses nutrients from different soil layers. Further, land such as bund and avenues that are hitherto not cultivated would increase the tree cover of the landscape [34].

8. Carbon sequestration

Active absorption of atmospheric carbon dioxide (CO_2) from the atmosphere through photosynthesis and its subsequent storage in the biomass of the growing trees or plants is referred to as carbon sequestration [35]. The carbon sequestration capacity depends upon tree species and their growing condition and management practices under agroforestry system. Further, allocation of sequestered carbon in different tree components may also vary. As per Rajendra Prasad et al. [36], carbon content in different tree species was in the order of *Eucalyptus tereticornis* = *Azadirachta indica* = *Acacia nilotica* = *Butea monosperma* > *Albizia procera* = *Dalbergia sissoo* > *Emblica officinalis* = *Anogeissus pendula*. The order of carbon content in tree components was branch = stem > root > foliage > stem bark = branch bark. Among all the studied tree species, *Albizia procera* was found to be the most efficient in capturing C (127.74 kg C/tree) and removing

CO_2 from the atmosphere (46.83 kg/tree/year), while *Anogeissus pendula* was the least with corresponding values of carbon (8.22 kg C/tree) and CO_2 (3.01 kg/tree/year), respectively.

Agroforestry is also an attractive option for climate change mitigation as it sequesters carbon in vegetation and soil, produces wood, serves as substitute for similar products that are unsustainably harvested from natural forests and also contributes to farmer's income [37]. As per Alavalapati and Nair [38], agroforestry is widely considered as a potential way and low-cost method to sequester atmospheric carbon and recognized as one of the strategies for climate change mitigation. In agroforestry system, tree components are managed and pruned for reducing competition, and these pruned materials are generally non-timber products. Such materials are returned to soil to increase carbon biomass. By including trees in agricultural production systems, agroforestry can, arguably, increase the amount of C stored in lands devoted to agriculture while still allowing for the growing of food crops [39]. The total C content of forests has been estimated at 638 Gt for 2005, which is more than the amount of carbon in the entire atmosphere [40-41]. It was estimated that over 2 billion ha of degraded land exists globally [42], of which 1.5 billion ha is located within tropical lands. Restoration of these afforestation and agroforestry practices to sequester 8.7×109 Mg C year^{-1} in the tropical and 4.9 × 109 Mg C year^{-1} in the temperate above-ground C pools [43] is the major benefit to the ecosystem. Hence, the combining information on above-ground, time-averaged C stocks and the soil C values for the estimation of C-sequestration potentials in agroforestry systems is an obligation [44-45].

Agroforestry model	Carbon storage capacity	Region	Author
Silvopastoral system (5 years)	9.5–19.7 tC/ha	Semiarid	[47]
Silvopastoral system (aged 6 years)	1.5–18.5 tC/ha	Northwestern India	[48]
Block plantation (aged 6 years)	24.1–31.1 tC/ha	Central India	[49]
Agrisilviculture system (aged 8 years)	4.7–13.0 tC/ha	Arid region	[50]
Agrisilviculture system (aged 11 years)	26.0 tC/ha	Semiarid region	[51]
Eucalyptus bund plantation	59,361 t	Punjab (Rupnagar district)	[52]
Poplar block plantation	330,510 t		
Populus deltoides 'G-48' + wheat	18.53 tC/ha	Tarai region of central Himalaya	[53]
P. deltoides + wheat boundary plantation	4.66 tC/ha		
Silvopasture	31.71 tC/ha	Himachal Pradesh	[54]
Natural grassland	19.2 tC/ha		
Agrihorti silviculture	18.81 tC/ha		
Hortipastoral	17.16 tC/ha		
Agrisilviculture	13.37 tC/ha		
Agri-horticulture	12.28 tC/ha		

Table 1. Carbon storage capacity as per agroforestry model in different regions of India

There are various literatures (Table 1) on carbon storage capacity which varies from region to region and also depends upon the nature and performance of tree crop under different agroforestry models. Also, Nair et al. [46] summarized that the potential of agroforestry system in term of carbon storage varied from 0.3 to 15.2 Mg C/ha/yr; the highest being in the humid tropics receiving high rainfall. Thus, the importance of agroforestry as a land use system is receiving wider recognition not only in terms of agricultural sustainability but also in issues related to C-sequestration or climate change.

9. Agroforestry for biodiversity conservation

Agroforestry is not something new but a new set of old farming practices that integrate crops and/or livestock with trees and shrubs under which one set of practices provides multiple benefits either in a tangible or an intangible way including diversified income sources, increased biological production, better water quality and improved habitat for both humans and wildlife. Young [55] described it as a collective name for land use systems in which trees are grown in association with agricultural crops and/or pasture either in a spatial arrangement or a time sequence with economic and ecological interaction between the tree and non-tree components of the system. It is a multiple land use system in which perennials are grown in conjunction with agronomic crops and/or livestock either simultaneously or in sequence with an ecological and economic interaction between the tree components of the system [55-56]. This land use farming system has integration of variety of tree species with herbaceous crops increase the biodiversity and increase the overall productivity consumed by households, reduce soil loss and improve the physical and chemical properties of soil. Similarly as per Singh et al. [57], agroforestry system has many diverse contributions comprised of biodiversity conservation, yield of goods and services to society, augmentation of the carbon storage in agroecosystems enhancing the fertility of the soils and provision of social and economic well-being to people. Tree plays a diverse function under the different agroforestry models/systems. As per Muthappa [58], under the coffee agroforests, trees are mainly retained in the farm for shade and fuel wood (100 %), support for pepper and timber (98 %), religious value (96 %), food (76 %) and others (69 %), resulting in reduction in pressure on the natural forest. Agroforestry practices such as home garden (agrohortisiviculture) systems, live fences around farmlands, agrisilviculture system, agroforestry species for green manure, silvofishery system, trees in and around the agricultural fields and silvopasture system were found most promising for biodiversity and meeting the diverse needs to uplift the socioeconomic status of farmers. As per Murthy et al. [59], agroforestry practices may use only 5 % of the farming land area yet account for over 50 % of the biodiversity, improving wildlife habitat and harbouring birds and beneficial insects which feed on crop pests. Therefore, under the agroforestry systems, trees can contribute nesting sites, protective cover against predators, access to breeding territory and access to food sources in all seasons and encourage beneficial species such as pollinators.

10. Utilizing wasteland

Wastelands are degraded lands that lack their life-sustaining potential as a result of inherent or imposed disabilities such as by location, environment, chemical and physical properties of the soil or financial or management constraints [60]. It includes area affected by water logging, ravine, sheet and gully erosion, riverine lands, shifting cultivation, salinity, wind erosion, extreme moisture deficiency, etc. Due to complete loss of top soil, these degraded lands are ecologically unstable and are unsuitable for cultivation. The main causes responsible for development of wasteland include deforestation, shifting cultivation, overgrazing, unskilled irrigation, industrialization activities, etc. Deforestation on a vast scale has increased soil erosion, disturbed water regimes and resulted in scarce supply of fuelwood, fodder and small timber on which the vast majority of India's rural population has been dependent for centuries. The degradation of wasteland can be overcome by participatory approach like social forestry, joint forest management, community forestry, etc., with the help of local people in the planning and management of lands [61] through afforestation of suitable species like *Jatropha*, neem [25-26], *Acacias* species, etc. Further, these degraded, and wasteland are reclaimed and restored through a scientific plantation technique, either sole tree plantation under afforestation scheme or practices of different agroforestry models based on specific location. Agroforestry models for fodder production, viz. silvopasture, hortipasture, hortisilvipasture and agrisilviculture system, are usually established in degraded cultivable lands. The wastelands could be effectively utilized for fodder production parallel to livestock production through agroforestry system, which is also an environmentally safe system of land use. Silvopastoral system increases the dry fodder biomass yield from 1.25–4.50 tons (natural pasture) to 4.50–8.70 tons per hectare per year and could hold 8–15 sheep per hectare. The average dry fodder production potential of the hortipasture, horti-silvipasture and horti-silvi system is normally 3.855, 4.410 and 1.282 tons per hectare per year, respectively, under rainfed condition. Agrisilviculture system of fodder production (Napier-Bajra hybrid grass + *Sesbania grandiflora*) yields more dry fodder biomass and protein under irrigated condition. Among the agroforestry models, Napier-Bajra hybrid grass + *Leucaena leucocephala*/*Sesbania grandiflora* as agrisilviculture system of fodder production is more successful for irrigated lands. Silvopasture with *Leucaena leucocephala* + *Gliricidia sepium* + *Albizia lebbeck* as tree components and *Cenchrus ciliaris* + *Stylosanthes scabra* as pasture components was recommended for greening of wastelands in rainfed condition [62]. In addition, government organizations can lease 'wasteland' from the state government for *Jatropha* cultivation. This land has been initially allocated to government organizations for a period of 20 years, and this may be extended for a further 10 years [63].

As per latest agricultural statistics, about 173.6 million ha of land in India is degraded, and these lands may be utilized for some kind of tree plantations and agroforestry system to meet the requirement of forage, fuel, food and other forest products. In afforestation programme, forest plantation constitutes 5 % of the world's total forest area or around 187 million ha [64]. The average rate of successful plantation establishment over the last decades was 3.1 million ha per year, of which 1.9 million ha was in the tropical area. Of the estimated 187 million ha of plantations worldwide, Asia has by far the largest area of forest plantation, accounting for 62 % of the world total [65]. In India, silviculturally, ANR (assisted natural regeneration) is used as an approach of afforestation. ANR forms the major strategy of treating degraded forest through joint forest management approach under the national afforestation plan (NAP) and externally aided forestry projects (EAP). It is the dominant plantation model of forest treatment in India. ANR in India is treated as a tool for afforestation. It forms the dominant component of the national afforestation plan (NAP), Government of India's flagship afforestation program. NAP aims to support and accelerate the ongoing process of devolving forest protection, management and development functions to decentralized institutes of joint forest management committee (JFMC) at the village level. It has covered a total area of about 1.69 million ha during 2000-2010 and spread over 42535 JFMCs in 800 Forest Development Agencies (FDAs) at a cost of Rs. 2237.36 crores [66]. ANR also forms the major strategy for rehabilitation of forest land under externally aided forestry projects being operated in 11 states of India at an investment of Rs. 5718 crores [67]. So, for making a good and clean environment, a huge-scale plantation should be done on the plain and hilly areas. Degraded lands, i.e. unfertile land, barren land and wasteland, are also reclaiming by with the help of large-scale suitable plantation of suitable tree species. Moreover, wasteland can be reclaimed through afforestation activities like agroforestry, silviculture and social forestry; these should be adopted to protect agricultural lands from further deterioration arising out of degradational processes.

11. Nutrient cycling in agroforestry

Forest ecosystems represent closed and efficient nutrient cycling systems, meaning that they have high rates of turnover and low rates of outputs or losses from (as well as inputs into) the system. Whereby nutrient cycling systems are open or leaky in agricultural systems and they have low rate of turnover within the system, inputs are comparatively high. Similarly, Nair [68] has reported that more nutrients in the system are reused by plants under the agroforestry before being lost from the system without affecting the overall productivity of the system. Trees can increase nutrient inputs to agroforestry systems by retrieval from lower soil horizons and weathering rock. The basis of this assumption is that, because of their deep roots, trees are able to absorb nutrients from soil depths that crop roots cannot reach.

Generally, agroforestry practices increase the soil organic matter through leaf litter addition. It increases the population of beneficial microorganism and improves biological nitrogen fixation in soil. All microbiological activity in soil contributes to cycling of nutrient and other ecosystem functions, and all soil functions contribute to ecosystem services. Recycling in natural system is one of the many ecosystem services that sustain and contribute to the well-being of human society [69]. Low soil fertility is one of the greatest biophysical constraints of production of agroforestry crops across the world [70]. Cow dung is a very good source for maintaining the production capacity of soil and enhances the microbial population. It is one of the renewable and sustainable energy resources through dung cakes or biogas which replaces the dependence upon charcoal, fuel wood, firewood and fossil fuel. Besides it, application of cow dung in a proper and sustainable way can enhance not only productivity of yield but also minimizing the chances of bacterial and fungal pathogenic disease [71].

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Therefore, added organic matter acts as a source of energy and enhances nutrient cycling in soil. In addition, it moderates soil microclimate and improves soil aggregate system [20].

12. Agroforestry systems increase inputs through nitrogen fixation

Nitrogen-fixing trees can substantially increase nitrogen inputs to agroforestry systems. Many of the tree and shrub species selected for agroforestry are legumes belonging to the so-called fast-growing nitrogen-fixing trees, notably species of *Leucaena, Calliandra, Erythrina, Gliricidia* and *Sesbania. Leucaena leucocephala* is the important tree grown everywhere in arid, semiarid and humid regions and fixes nitrogen up to 100–500 kg N_2 ha^{-1} yr^{-1} [72]. Similarly as per Dwivedi [73], several Leguminosae trees such as *Leucaena leucocephala*, *Acacia nilotica, Dalbergia sissoo, Gliricidia* spp., *Sesbania* spp., etc., and some nonlegumes, e.g. *Casuarina equisetifolia*, *Alnus* spp., etc., are important to fix about 50 to 500 kg of nitrogen per ha. Agamuthu and Broughton [74] showed that nutrient cycling in oil-palm plantation where leguminous cover crops (*Centrosema pubescens* and *Pueraria phaseoloides*) were used was more efficient than in plantation where there was no cover crop. In coffee and cacao plantation with shade trees (some of which are N_2-fixing), 100–300 kg N ha^{-1} yr^{-1} is returned from litter and prunings, which is much higher than the amount removed during harvest or derived from N_2-fixation. Other nitrogen-fixing legumes include *Albizia, Inga, Prosopis* and the numerous *Acacia* species, together with *Faidherbia albida.* The members of family Casuarinaceae and *Alnus nepalensis* are most widely used for plantations in tropics and temperate zones, respectively which are non leguminous.

13. Water stress in relation with growth and productivity in agroforestry

One of the growing global concerns is to increase the water productivity for meeting the water demand of the rising population. According to the estimates of the World Commission on Water, demand for water will increase by approximately 50 % over the next 30 years and about half of the world's population will live in conditions of severe water stress by 2025. Due to rapid degradation of water catchments and climate change, there is a major threat in decreasing water supplies in many parts of the world. Further, global warming, climate change and deforestation are majorly responsible for the fluctuation in spatial and temporal distribution of rainfall which finally leads to water deficit.

Water stress in plant is developed during periods of water deficiency because plants are unable to absorb adequate water to match the transpiration rate. A water deficiency exists when the amount of rainfall is less than potential evapotranspiration. Water stress may be either due to water shortage or due to excess of water. Water deficit is one of the key limiting factors for plant growth, productivity and survival and often adversely affects agroforestry practices in arid and semiarid areas [75]. However, plants can normally acclimate to water stress through physiological and morphological responses [76]. However, critical water stress leads to death of plants. Agroforestry has the potential to improve water productivity in two ways. Trees can increase the quantity of water used in farms for tree or crop transpiration and may also improve the productivity of the water that is used by increasing the biomass of trees or crops produced per unit of water used [77]. The rate of depletion of land and surface water in our country is indeed alarming. So the rational approach is required, like by developing the suitable agroforestry model and/or integrating with the rain water harvesting unit for overcoming the water crisis in the country [78]. So water stress in agroforestry can be minimized by developing the appropriate models in general and growing site-specific species in particular.

14. Socioeconomic upliftment through agroforestry

Agroforestry can improve the livelihoods of smallholder farmers as by providing various production services [79], viz. fruit and nuts, fuel wood, timber, medicine, fodder for livestock, green fertilizers, assets that can be sold in time of need and additional/diversified income. It generates high income and minimizes risks in cropping enterprises. It provides long-term investment opportunity, diversified land use and commercial tree cropping and can generate diversified on-farm employment, wood and non-timber forest product (NTFP) and ensure raw-material supply to forest-based industries. Agroforestry has potential for poverty alleviation and tribal development and generating employment and providing women's empowerment schemes. Farmers will be encouraged to take up farm/agroforestry for higher income generation by evolving technology, extension and credit support packages and removing constraints to development of agroforestry. Suitable species for commercial agroforestry may include *Acacia nilotica, Bamboo species, Casuarina equisetifolia, Eucalyptus species*, *Populus deltoides* and *Prosopis cineraria* for different climatic, edaphic and agricultural conditions.

Agroforestry models for different site conditions have to be developed and demonstrated under different agro-ecological regions in the country. Agroforestry system prevailed in Chhattisgarh which depended on their potential to generate high income of farmers which is measured through their economic analysis. In Chhattisgarh state, agri-horticulture model comprises combination of horticulture tree (aonla) and field crops (groundnut and gram) and their different parameters of economic analysis (input/output) including total expense (tree +crops) per ha (86,494 Rs.), total benefits per ha (93,903 Rs.), net benefit per ha (7,410 Rs.) and B:C ratio (1.09). Similarly, agrisilviculture system comprises combination of tree species (*Gmelina arborea*) and field crop (paddy and linseed), and their economic parameters are total expense (tree+crops) per ha (69,139 Rs.), total benefits per ha (1,19,997 Rs.), net benefit per ha (50,858 Rs.) and B:C ratio (1.74). These economic analyses are sufficient to measure socioeconomic potential of different agroforestry models and give idea about whether this model be accepted or not [80].

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15. Role of agroforestry in NTFP production

The trees in agroforestry practices generally fulfil multiple purposes, involving the protection of the soil or improvement of its fertility, as well as the production of one or more products [81]. As per Leakey [82], agroforestry is a dynamic, ecologically based, natural-resource management system that, through the integration of trees in farmland and rangeland, diversifies and sustains smallholder production for increased social, economic and environmental benefits. These socioeconomically viable and biologically diverse systems suggest that agroforestry can produce NTFPs commercially and in a sustainable way. Non-wood tree products are used by people every day of their lives for their own need (food, fodder, medicines, building materials, resins, dyes, flavourings, etc.). Multipurpose trees play an important role to fulfil all needs as tangible and intangible benefits. As per ICRAF [83], multipurpose trees and shrubs are those that can produce food, fodder, fuelwood, mulch, fruit, timber and other products. New initiatives in agroforestry are seeking to promote poverty alleviation and environmental rehabilitation in developing countries, through the integration of indigenous trees, whose products have traditionally been gathered from natural forests, into tropical farming systems [84].

Non-timber forest products (NTFPs) include a broad range of edible, medicinal, decorative and handicraft goods harvested from woodlands [85-87]. Seeds, flowers, fruits, leaves, roots, bark, latex, resins, gum and other non-wood plant parts are categorized under NTFPs. The domestication of trees for agroforestry approaches to poverty alleviation and environmental rehabilitation in the tropics depends on the expansion of the market demand for their non-timber forest products. As per Leakey [88], the nutritive values of the flesh, kernels and seed oils of the fruit tree species, viz. *Irvingia gabonensis*, *Dacryodes edulis*, *Ricinodendron heudelottii*, *Chrysophyllum albidum*, *Garcinia kola*, *Adansonia digitata*, *Vitellaria paradoxa*, *Parkia biglobosa*, *Tamarindus indica*, *Sclerocarya birrea*, *Uapaca kirkiana*, *Zizyphus mauritiana*, *Vangueria infausta*, *Azanza garckeana*, *Inga edulis* and *Bactris gasipaes*, have been identified, in four eco-regions of the tropics, by subsistence farmers as their top priorities for domestication under agroforestry practices. As per Ike [89], *Irvingia* species *(wombolu* and *gabonensis)* are common among the trees planted under agroforestry practices, and their major importance to the farmers is the seed which is of significant economic value. The major system (89 %) of exploiting *Irvingia gabonensis* and *Irvingia wombolu* is from the wild. Other exploitation systems were around homestead (85.7 %), agroforestry (83.5 %) and *Irvingia* plantations (39.6 %) [90]. The most important part of *I. gabonensis* to the rural people is its nutritious seeds which have also been found useful in the reduction of cholesterol and body weight in obese patients [91]. In agroforestry practices, rates of growth and reproduction of NTFP, enhancement forest plantings and home gardens may also differ significantly from those in unmanaged forest environments, due to differences in intraspecific competition [92], light [93] or a combination of factors [94].

16. Conclusion

Agroforestry has emerged as a robust land use which advocates crop diversification, soil and soil-water conservation, cycling of organic matter and sequestration of CO_2 in plant and soil. This tree-crop combination provides shade to the field crop with making land productive and increasing revenue. Studying tree-crop interaction in agroforestry would help to devise appropriate ways to increase overall productivity of land. Increased productivity, improved soil fertility, nutrient cycling and soil conservation are the major positive effects of interactions, and competition is the main negative effect of interaction, which substantially reduces the crop yield. There are many research reports indicating significantly higher yield of crops in different agroforestry systems compared to sole crop yields. In the present scenario of climate change, agroforestry practices, emerging as a viable option for combating negative impacts of climate change. Convincing people regarding adoption and promotion of agroforestry is a great challenge and can be overcome by capacity building, providing suitable incentives and utilizing public-private partnership. Also, the government incentives and policies are the main task for success of intensive agroforestry system. Nowadays, agroforestry has gained popularity among farmers, researchers, policymakers and others for its ability to contribute significantly in meeting deficits of tree products and socioeconomic and environmental benefits. Therefore, agroforestry system gives diversification, provides societal continuum, creates green cover for carbon sequestration, generates fresh water harvesting potential and ground water recharge and increases the nutrient uptake, and their utilization management practices that lead to improved organic matter status of the soil will lead inevitably to improved nutrient cycling and better soil productivity.

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Chapter 12

An Approach for Assessing Changes of Forest Land Use, Their Drivers, and Their Impact to Society and Environment

Mats Sandewall and Mersha Gebrehiwot

Additional information is available at the end of the chapter

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Abstract

Globalization, urbanization, and new policies are changing land use, environment, and rural life. Policy makers need means to understand changes and their impacts for making wise decisions. This paper explores a methodological landscape-level approach for assessment and monitoring of changes in land use, forest cover and society, its drivers and impacts. It is based upon experience from case studies in Asia and Africa. The paper suggests that such approaches should address major issues of land use change including its drivers and impacts, generate policy relevant and accurate information, be cost-efficient and practical to implement, make appropriate use of modern knowledge, and engage stakeholders and decision makers. Technically, the approaches should cover all land types, objectively describe current land use and trends, enable verification, and be robust and flexible to address upcoming needs.

The approach combines participatory field point sampling for estimating land use trends with remote sensing and GIS, household and key informant interviews for obtaining socio-economic and other information, and meetings with farmers and decision makers for feed-back and discussing policy issues. It illustrates that land use assessments for policy purposes can be developed to meet proposed requirements by combining different techniques and involving local stakeholders in inventory processes.

Keywords: Landscape level, Participatory point sampling, Combining methods, Policy relevant, Asia, Africa

1. Introduction

1.1. A changing society and environment

Globalization, urbanization, and economic developments are changing land use, environment, climate, and rural life. Existing policies and strategies combined with demographic, economic, market, institutional, and technological issues are often identified as dominant underlying causes of tropical deforestation and land use change [1, 2]. Policy makers need means to understand changes and their impacts for making wise decisions.

Forest land use in tropical regions is mostly not about managing permanent forest estates for increased and sustained timber production, but multi-purpose, multi-stakeholder oriented and related to land management. Governments and rural stakeholders continuously try to adapt and understand changes but the consensus on driving forces, impacts, and how to address them is often missing [3]. While rural households do their best to manage land and other resources within given frames and to develop livelihood strategies that consider risks and opportunities, governments attempt to manage resources and promote a sustainable development through policies, legislation, and implementation of appropriate strategies. The role of the international community is to influence development and address the multi-functionality of the forests through multilaterally agreed principles and programs [4,5].

The development of sustainable policies and management strategies on forest and land use requires data and information that accurately describe the current situation and on-going changes. It requires systems for assessment and monitoring of changes. It also includes the impact of previous strategies that may need to be improved. Data is sometimes used in combination with modelling and scenario building for evaluating land use options [6,7]. The research area land change science includes the dynamics of human and biophysical land systems, its drivers and impacts, and how to address it through observation, monitoring, modelling, and evaluation [8, 9].

1.2. Acquiring data needed to understand and address land use and land cover change in forest policy

There is an increasing number of methods and approaches to assess, understand, and predict land use change with various degrees of sophistication [10,11]. Modern technology, such as remote sensing, Geographic Information Systems, and various forms of regression modelling enables the analysis of significant amounts of data and information. This situation provides new opportunities (e.g., in the context of monitoring climate change and in analyzing large-scale trends in forest cover). Various information including spatial land use data and socio-economic data are also being integrated in GIS systems.

However, dynamics that is not reflected in land cover change, but having socio-economic and environmental impacts, such as the intensification of agriculture, is still not very well captured by new technology [9]. Besides, in order to predict and meet future changes and policy it is critical to understand the driving forces of the changes [11, 12]. Those drivers are mostly related to the needs and expectations of the local stakeholders.

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Policies and strategies regarding land use and deforestation require data and information from different sectors and sources. Examples are population censuses, official agriculture and socio-economic statistics, macro-economic data, production and consumption statistics, maps, forest inventories, agricultural surveys, and research data. However, combining data from different sources and analyzing it for a policy-specific purpose is difficult, when data are not accurate enough, not aggregated in the same way, or not intended to be used for the purpose [13].

Involving stakeholders at local level in data collection and analysis can help establishing the broad policy base needed for a more sustainable use of natural resources than today. When the data providers are outsiders without a local perspective on the land use there is a risk that derived strategies fail to target important issues. Concepts such as "Integrated Natural Resource Management" call for active stakeholder involvement in problem formulation, data collection, and resource use planning and decision making [14].

In many western countries, development of policies and strategies in the forestry sector is supported by National Forest Inventories (NFIs) [15]. Those are often combining field sampling and remote sensing and producing objective, unbiased, and statistically precise data on timber volumes and forest cover changes. Being designed to produce data covering the entire land area on a regional, national, or sub-national scale, their purpose is to facilitate forest policy decisions based on evidence or factual knowledge [16]. They are increasingly evolving as continuous assessments enabling monitoring of changes. Their objectives are expressed by policy processes which assume that systematic and quality controlled information is required [17]. Acknowledging that forest sector data produced without consideration of local livelihoods have a narrow use, consultative and integrated methods including agriculture and institutional aspects are increasingly being introduced in the NFIs [3, 18].

The links between data capture and policy processes are still vague and ambiguous in many countries [19]. One reason is that inventory results are often politically sensitive and that governments could be more interested in forwarding a certain message than presenting a correct analysis [13]. Another is compartmentalization and lack of policy integration [20, 21]. Forest inventory data are usually handled by forestry or other technical departments with limited attention or capacity on socio-economic policy issues. Therefore they rarely provide answers to questions such as "why do local people do what they do?" and "what is the livelihoods impact of a particular policy?" There are also administrative and technical reasons. At broad (e.g. national) scales "the level of aggregation of data tends to obscure the variability of situations and relationships" [6]. The inventory design makes capture of, for example, timber data efficient but often makes it difficult to combine results with agriculture or socio-economic data in the analysis. The increased use of remote sensing and GIS have changed the conditions and time required but these technologies only address some of the information needs in resource management, and field inventories are still important [22].

When local management is in tune with and supported by national policies and strategies, it improves the potential for problem solving and development [23]. That perspective is also well reflected in the three pillars and six principles of "good forest governance" [24]. The degree of decentralization in decision making on resource management differs among countries and over time. Local level management based on bio-physical, cultural, and socio-economic and institutional considerations (e.g. [25]) is an equally important base for local development as national policies. The case of Tanzania where government policies back up community-based decision making in forestry is one positive example [26]. The Participatory Forest Management that was initiated in a number of projects by the Ethiopian government in the 1990s is another positive example that involved the local stakeholders in planning and decision making [27]. Other examples show that poorly harmonized policies and programs in agriculture and forest protection can have negative effects on local communities' life and environment [28].

One case illustrates the importance of combining resource assessment with social surveys and participation of stakeholders when developing land use policies and programs. In the 1980s the government of Ethiopia launched an ambitious program of community tree planting. It was known as "community forestry" and supported by donors and non-governmental organizations. The program never met its intended development goals and much of its efforts were wasted, largely because of its failure in assessing and estimating the resource and socio-economic needs of the rural households and communities, and other associated benefits [29, 30].

The described governance situation, whereby the role of the state in forestry is focused on policy issues and providing an enabling environment for local actors and stakeholders through various steering instruments, requires adequately supportive methods for assessment, monitoring, and interaction with local stakeholders. The situation to be considered (as described in this introduction) and the requirements to address those are summarized in Table 1.

Situation and aspects to be considered	Requirements on assessment approach
Land use forestand society are changing rapidly	Reflect current situation and trends
Land use isdynamic (e.g., decreased forest area means expansion of another land use)	Cover the entire landscape
Land use is multifunctional and involving multiple stakeholders	Reflect how stakeholders perceive changes
Policy makersneed to understand drivers and impacts of change to address it	Enable inclusion of different data sources.
Policy makers need adequate tools to obtain information for responding to upcoming needs	Generate information within reasonable time and cost. Be robust and flexible.
Stakeholders and policymakers need consensus on change for policy implementation	Involve actors and stakeholders
Source: original	

Table 1. Situation to be considered and corresponding requirements on approach that could assess land use change for the purpose of policy development.

2. The methodological approach

2.1. Background and purpose

This paper discusses the applicability of a participatory landscape-based sampling approach applying the requirements mentioned in the previous section. It was developed and tested for the purpose of assessing forest landscape changes, their drivers and their impacts to local societies and environments, and has been tested and applied in various countries and contexts in Asia and Africa. The term "approach" is defined herewith as set of methods combined for the purpose of addressing a specific issue.

The developed approach includes a core component for primarily quantitative assessment of land use and its trends named participatory field point sampling (pfps). It also contains various supportive components aimed to generate information that verifies the sampling data and further explains the trends, why and how land use has changed, for example, information on socio-economics, market conditions, policy, and farmer's perspectives on the impact of the changes (Figure 1). The idea is to improve our understanding of drivers and impacts of change by combining various sources of information [31].

To facilitate any response to results and findings, the approach also aimed to promote a policy dialogue among local actors (farmers), local government representatives, and decision makers. Therefore, the presentation and discussion with stakeholders of work plans and preliminary results, and discussion with decision makers on the final outcome, are important steps of the approach.

2.2. A landscape-based point sampling approach, design, and implementation

The general approach is to combine quantitative data and information of actual land use based on objective field observations and measurements with qualitative information on the land use and its changes, which is obtained from local actors and knowledgeable local informants.

The inventory design is based upon a systematic grid of sample points covering the area of study (Figures 2 and 3). The area would be a landscape, normally with administrative boundaries. It could be small (for example, a village) or bigger (such as a district) depending on situation and needs. In some cases, as illustrated in Figure 2, a two-step approach could be applied, whereby plots are initially allocated on commune level, and later on village level for detailed follow-up of specific issues. In the Ethiopian case, Figure 3, an initial assessment on a satellite image showed that most wood lots were situated nearby roads. Therefore separate strata, one for field sampling and one for image interpretation only, were defined.

Generally, the distance between the sample points is set to achieve a certain precision. In systematic sampling, the standard error cannot be correctly estimated [3]. Equations for simple random sampling may however be used for the purpose of defining how many points are needed to ensure that a certain required precision is achieved. In this case we adopt a conservative estimate of the variance by assuming that the true error may well be smaller than the error at simple random sampling, but will not exceed it [32]. In the various case studies we

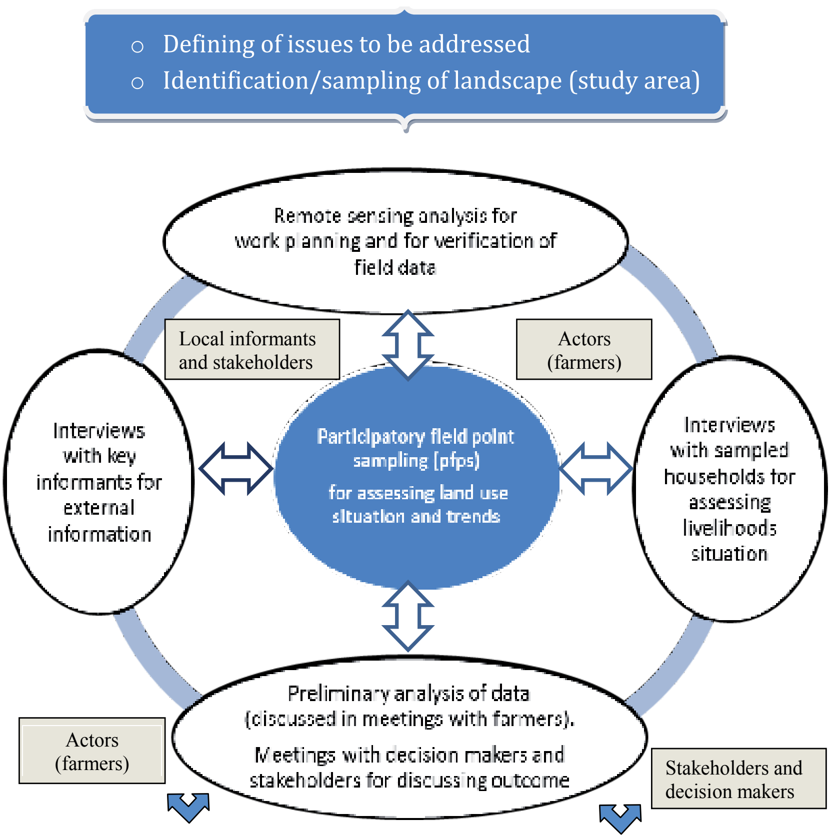

Figure 1. Main components of the approach (Source: original).

have used sample sizes between 50 and 75 sampling points, which have generated standard errors less than 10% for any class representing more than 25% of the total area.

Sampling points are defined and located on the ground using alternative techniques depending on local situation and available materials such as satellite images, aerial photos, topographic or other maps, compass, and GPS. Approaches similar to the one used in the Ethiopian study (Figure 3) have become more feasible lately as a result of improved access to satellite imagery and GPS. The advantage of using a GPS is that it reduces subjectivity and bias in the location of the sampling points in the field. It also provides the opportunity to identify the same point on images originating from different years.

Data collection: The recording is made when the surveyor and the key-informant, for example, an experienced and knowledgeable farmer or an extension worker, jointly visit the sampling point. While observing and recording the current land use the key informant provides further data on the present, past, and intended future land use (Figure 2). Data related with land use change, drivers of changes, and potential consequences are recorded on each point. Historical data are collected for certain years (e.g., every fifth year) including those years when remote

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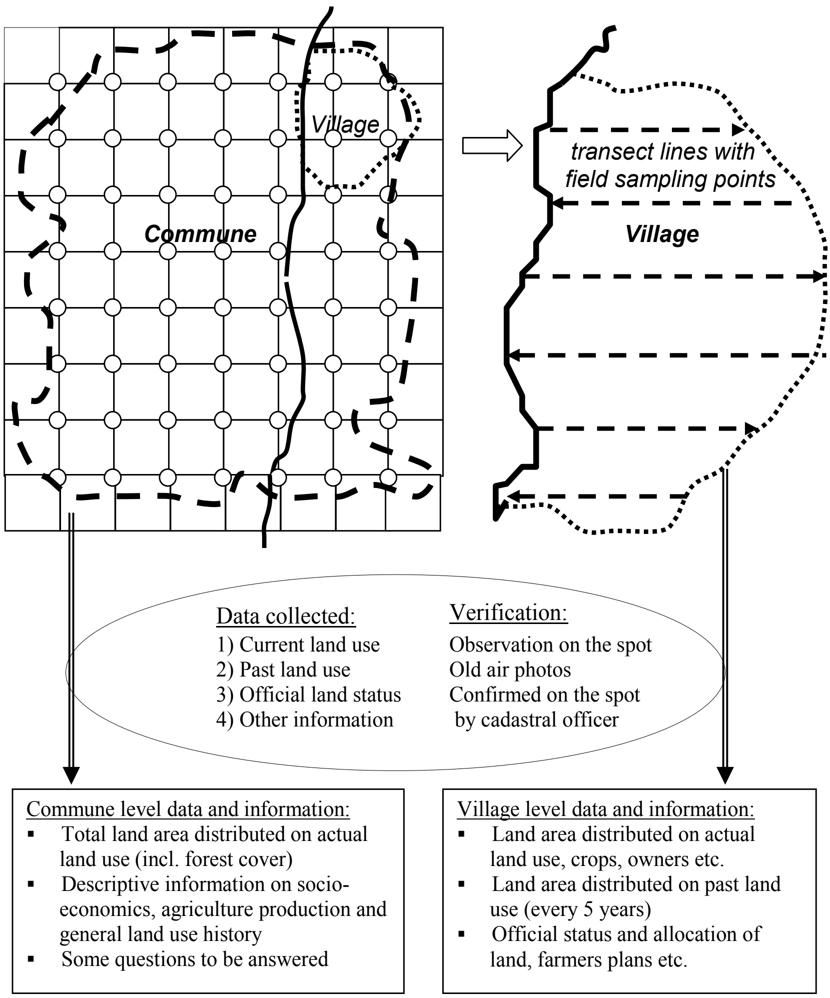

Figure 2. Participatory field point sampling in a Vietnamese commune (Ohlsson *et al.*, 2005).

sensing data sources are available. When the key informant does not know the details, local farmers are contacted (during the field visit or afterwards). Notes are taken on issues to be followed up during subsequent meetings with households and other stakeholders.

Output: The first output is a table or diagram based on data from all sampling points, which illustrates the changes in land use and forest cover over time (Figure 4). A map that shows the spatial and temporal land use change may also be produced later. The first output is prepared in connection with the field work and used in participatory meetings on the causes and implications of the trends. The outcome of discussions and meetings are recorded and used in the further analyses of trends and their drivers and impacts, during which also the information form interviews and other sources are included. When documented, the analyses are presented and discussed with centrally placed decision makers in a way that it reaches the policy level.

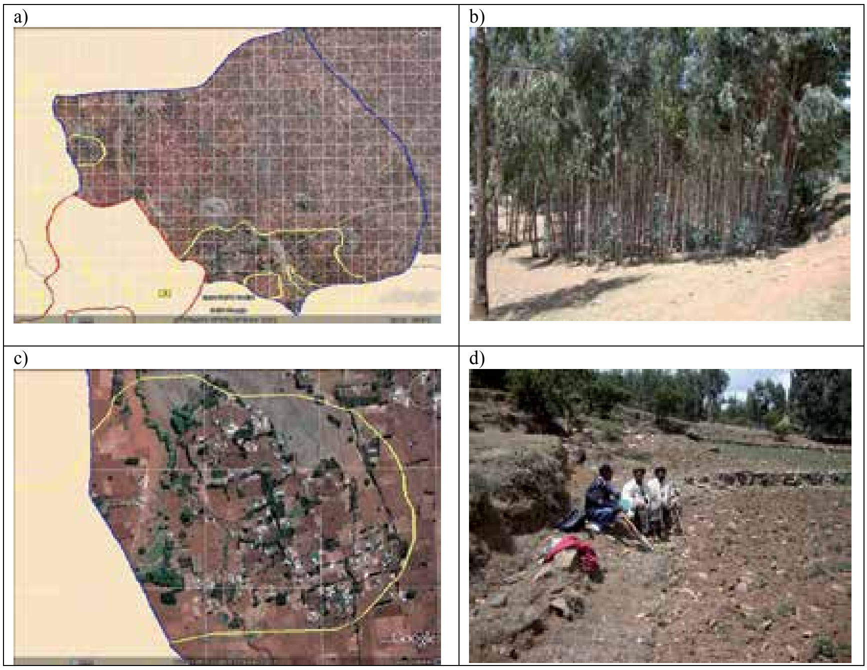

Figure 3. Pfps approach applied in Ethiopian study on household based plantation forestry a) Layout of strata and sampling grid on satellite image b) Wood lot plantation c) Stratum for field sampling d) Discussion of land use history with local key informants at a field sampling point (Source: original).

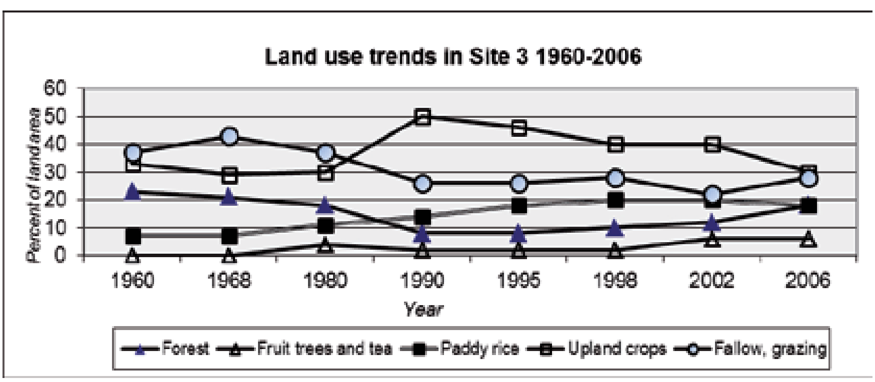

Figure 4. Output diagram based upon land use data from pfps points in Vietnamese study (Source: original).

2.2.1. Other system components

Verification of accuracy: Some data are verified by observations in the field. Other data, which cannot be verified during fieldwork (e.g., historical data) are verified by use of remote sensing

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data (when available) and secondary sources including triangulation of interview data. The pfps output may be supplemented by land use land cover classification using remote sensing data sources [33].

Analysis of data: An immediate analysis of land use data is made at the time of the survey, when the team is still in the area. Preliminary findings and trends are presented to villagers in stakeholder meetings for obtaining comments and feedback on possible causes of trends of change. Use of maps and remote sensing data often facilitate the communication in those meetings.

Complementary information: In order to obtain additional information about an area, for example, demographic and socio-economic issues and livelihoods situation of households, pfps is combined with other forms of data capture, such as image classification, structured interviews with households and key informants, formal and informal focus group discussions, or other forms of Participatory Rural Appraisal [34].

Participatory process for information and experience sharing: Stakeholders include farmers, experts, policy-makers, researchers and other individuals, groups and organizations that are directly affected by decisions and actions or have the power to influence the outcomes of these decisions [35]. The pfps as well as all other components of the approach (e.g., planning, household interviews, key informants interviews, meetings with stakeholders and decision makers) therefore include participatory elements (Figure 1).

3. Experience of case studies

3.1. Studies undertaken

The approach has been applied within the frames of various research studies in Laos, Vietnam, China, and Ethiopia during 1997–2012 [7, 12, 33, 36, 37]. The objective of the first two studies (1997–99) was to identify and develop a feasible method for estimating the actual land use and its changes as a base for various types of strategic land use planning including scenario modelling. The methodological requirements of the approach (Table 2) were defined based on needs referred in literature and/or experienced by the research team. More recently the applicability of the approach has been tested under other conditions in another region (Ethiopia). The review of the various studies in the following text serves to illustrate the range of various applications.

Laos (1997-99): The objective was to understand how land use changes had been affected by various events in shifting cultivation landscapes in Northern Laos. Data were also to be used for testing a land use scenario model. In a watershed with seven villages (10000 ha) some 75 sampling points were laid out on topographic maps and visited in the field with an extension officer. Five sets of aerial photos and satellite images 1953–1996 were used for verification of land use data and historical events. Interviews with sampled households and meetings involving farmers and decision makers were held at various stages of the process.

Consideration	Requirements
1. Area coverage and details	a) Cover the whole landscape and not only, e.g., forest land. b) Provide data with sufficient geographic resolution.
2. Accuracy and precision	a) Provide unbiased data with known precision. b) Enable cross checking of data to improve accuracy.
3. Time perspective	a) Reflect current land use (the actual use of the land at the time of the inventory). b) Describe historical trends and on-going and expected future changes. c) Enable continuous monitoring of changes in relation to current policies and strategies if desired.
4. Cost and robustness	a) Be based on adequate technology as regards cost and human resource. b) Be robust and simple to plan, undertake, process, and analyze and thereby provide data timely. c) Be acceptably independent of local security and terrain difficulty.
5. Flexibility	a) Make use of local knowledge and enable incorporation of additional spontaneous information from field observations. b) Be applicable in different situations (with respect to budget, available tools, physical conditions, and so on).
6. Data and information	Provide cross-sector data such as a) forest cover, b) stocking, c) current agriculture crops and production level, d) over-lapping land use, e) land suitability for agriculture, f) income-consumption-market, g) historical trends, h) people's perceptions and plans, i) land tenure, j) official land status, and k) demography.
7. Inventory output	Data and information should provide an understanding of current situation and trends, which is needed in strategic planning. It should also enable analysis of optional strategies, e.g., through modelling of scenarios on future developments.

Source: original

Table 2. Considerations made while developing the approach in Laos and Vietnam 1997–99.

The original idea was actually to interpret air photos as a base and verify data through field samples but the sampling provided so much external information that the reverse approach was adopted [36].

Vietnam (1997-99): The aim was to understand the impact of state planning by comparing government reporting, farmers' information, and observed changes. A commune of 21 villages (5400 ha) was first surveyed, trends were determined, and issues raised. One village was then surveyed in detail for better understanding of discrepancies between government plans and observed trends. Pfps points were laid out along transects and visited by a survey team and a senior villager (Figure 2). Interviews in sample households from three income strata were made. Key informants (market, government) were interviewed separately. Land use scenarios were elaborated based on survey data, and village meetings with local actors and decision makers were held for discussing outcomes in a land management context [7]. The study illustrated the difference between harmonized (agreed) official data prepared for management purposes and strategic data showing factual trends needed for strategic planning. Pfps turned out to be an appropriate method as farmer's awareness and memory of historical details was specific and mostly correct when verified by other sources.

Ethiopia (2005-2007): The issue was to understand drivers and impacts of land use and land cover changes in relation to political, demographic, and environmental trends in a semi-arid agriculture landscape and adapt previous research methodologies to an African context. Two adjacent villages were studied [33] and scenarios elaborated. Socio-economic studies for determining issues of food security were included. The study identified a need for remote sensing data to verify trends, as farmers' memory of historical details was linked to events, but not to years in the same way as in the Asian studies. An application involving GPS and satellite imagery was elaborated.

Vietnam (2006-2007): The issue was to analyze trends in farm households' tree plantation, its drivers and livelihoods impacts. The study took place in an area with increasing wood demand from new industries. Three villages at various distances from a pulp industry were studied through point sampling, interviews with households and key informants (business, science, and political representatives), and stakeholder meetings [12].

China and Ethiopia (2011-2012): This study analyzed trends in plantation forestry, its driving forces and impacts to environment, climate, economic growth, and livelihoods in China, Ethiopia, and Vietnam by combining regional, national, and local scale analyses (of which the pfps approach was applied in the local scale analyses). The purpose was linking the internationally and nationally reported trends with observed situations on the ground for identifying features, trends, and aspects that were not reflected by national data and/or required an integrated societal context [37].

3.2. Applicability of the approach in a new context

The approach was initially developed in Southeast Asia. When applied under other conditions in a new country and context, the flexibility of the approach is challenged. This section reviews experiences from application of the approach in Ethiopia.

The issue was trends of wood lot plantation in agriculture landscapes. The choice of study areas was based on an initial assessment using Google Earth satellite imagery in the Asian studies conducted 10 years earlier we had not had that opportunity). It revealed that wood lots were clustered nearby roads while the ambition was to select administrative villages for the purpose of connecting data from various sources. A major share of those villages had little forestry or other cultivation. To make work efficient, pfps points were laid out on satellite images in pre-defined strata, of which strata with many wood lots were subject to field work, while other strata were interpreted on image only (Figure 3). As a result, the degree of details and the historical trends were best described for the woodlot strata but this was also the purpose.

Pfps was combined with household and key informant interviews, focus group meetings, and discussions with concerned stake holders and decision makers at sub-national level. Official documents related with land use and related policies were compiled as a complement. The time for planning, arrangements of maps, and pfps field observations was about one week for a team to cover about 60 field plots. Household interviews and village meeting required additionally one week. All data collection, except the complementary interpretation of image plots, was undertaken in a sequence. The time required corresponds well to experiences from the Asian studies

The possibility to verify historical data given by the key informants depends on their age and experience, type of information and access to remote sensing data. In the studies in Laos and Vietnam people were often used to memorize their history connected to certain years, and many senior village representatives had a good memory of the land use history of each village member. In the Ethiopian study, it was necessary to systematically locate and consult the concerned farmer to obtain similar information and farmers' memory of land use was primarily linked to critical events (e.g., under what regime did it happen). Similar observations were made in another study [33]. The preparedness of farmers to forward information varied but did not provide any major difficulty when sufficient time had been given to introduce the purpose and when farmers were not too busy doing other work. Access to old air photos often vitalized people's memory. Concerning drivers and impacts, the initial pfps provided ideas, but structured interviews and other means were needed to provide a representative picture of, for example, livelihood issues.

4. Discussion

This paper highlights criteria and questions to be considered in the context of assessing and monitoring forest and land use change for the purpose of addressing forest policy issues. It suggests that the multi-functional type of forestry and land management present in many parts of Asia and Africa and the rapid changes of land use, society, and environment requires approaches for assessment and monitoring, which are supportive to policy and strategy development.

The presented cases were pilot studies by external research teams for studying policy-related issues. The authors do not have access to the policy level but may need to "speculate" on its potential appropriateness as policy tools. The approach scrutinized in this paper satisfied the requirements set-up in Asia also when it was used in an African context. The questions formulated and addressed in the following text serve to illustrate some crucial aspects of the approach.

What major issues in relation to forest and land use change could be addressed?

The approach is rather flexible and can basically address a broad number of issues related to land use and its change such as deforestation, afforestation, and change of forest cover over time including drivers and impacts of changes, ambitions, and expectation for the future (Table

3). The approach does not generate detailed information on changes in the structure and composition of the forest, soil conditions, or other strictly bio-physical aspects for which purpose controlled measurements are required.

Context and Questions	**Information source[1]**					
	1	**2**	**3**	**4**	**5**	**6**
Deforestation, reforestation: What are the land use and land cover fluctuations over a given period of time, e.g., the latest 30 years?	*x*	*x*	*x*			
Deforestation, reforestation: What type of land/forest management systems have been applied	*x*	*x*		*x*	*x*	*x*
Deforestation, reforestation, land use: What kind of change is it, e.g., what type of land has changed to what?		*x*	*x*			
Driving forces: What is the use or market of the products from a specific land use?		*x*		*x*	*x*	*x*
Driving forces: When farmers changed land use, what was their reason for doing so?		*x*		*x*		*x*
Driving forces: How do farmers perceive the change, its causes, and environmental impacts?				*x*		*x*
Impacts: Does the change refer to a certain category of farmers (e.g., wealth, gender)?				*x*	*x*	*x*
Impacts: How has the change influenced the poverty and livelihoods situation?				*x*		*x*
Policy: What can the government do to support farmers toward a more sustainable land use and livelihood?				*x*	*x*	*x*
Driving forces: How has the observed land use change been influenced by external and internal factors during the period?						*x*

Source: original

[1]Information sources: 1) pfps observation, 2) pfps informant, 3) remote sensing/GIS, 4) household interviews, 5) key informants, and 6) meetings with local farmers and decision makers

Table 3. Some questions that can be addressed through the approach, and the main corresponding method or source supplying the information.

Does the approach generate policy relevant information?

In the case studies the approach has covered small pilot areas, which have been chosen with the aim to address a certain issue. It cannot simply be extrapolated to represent, for example, provinces or the nation, for which purposive inventories, censuses, and other data sources are needed [37]. However, it enables study of the relation between various types of conditions and changes over time and it could be designed to address rather specific policy issues. In that context it should be seen as a tool that supports a process of generating policy input which may be combined with other methods and data for verification and up-scaling.

Does the approach provide accurate information?

It builds on information that can be verified to a certain extent but not entirely. Through the sampling approach the quantitative land use information of the pfps is basically unbiased and it is possible to (conservatively) estimate its precision. The qualitative information relies on the proper use of social science methods and requires persons trained with that background [34, 38]. One of its advantages is that it captures both quantitative and qualitative changes and assesses how those changes are perceived by the local actors and stakeholders.

Is the approach cost-efficient and practical?

It involves human expertise in the fieldwork, which may be considered expensive. On the other hand it is based on relatively small landscape samples and generates data and certain results almost instantly, which is an advantage for interaction among those performing the study and the local actors. It also provides opportunities to assemble decision makers from different sectors discussing cross-sector issues.

Does the approach make proper use of modern knowledge?

The approach builds on analysis of systematic observations in combination with local knowledge and experience. It is seen as a package of various techniques and methods that can be flexibly exchanged and integrate new components and knowledge. Remote sensing and aerial photos are used for planning, discussion with actors and stakeholders, and for verification while advanced applications in data base management, remote sensing analysis, and GIS will primarily be needed for up-scaling purposes and broader analyses. One aspect is that technological methods sometimes alienate scientists and decision makers from local level perspectives and driving forces, whereby emerging trends could easily be missed out.

Does the approach engage actors and stakeholders?

Most of the data collection activities including pfps, household interviews, and stakeholder meetings are participatory and integrate local knowledge and perspectives with collection of data and information. Meetings with decision makers for discussing findings and related policy issues, sometimes also including scenario modelling [7], aim to ensure that those findings and issues are disseminated and reach the intended target groups. A basic principle is to make use of existing knowledge and perspectives of local actors, in order to improve the information, broaden the understanding of the situation at hand among all actors and stakeholders, and to facilitate their ability to address findings and results in the future. By involving stakeholders, results will be potentially available as decision support in resource management [39].

What are the potential applications?

Previous case studies have shown that it can provide an effective tool for initial pilot and baseline studies in research studies, rural development projects, and various situations where the land use conditions at a proposed site are not sufficiently well known. The compact setting

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enables completion of studies in a relatively short time and makes it appropriate for pilot project purposes. With some modification it may also provide an option as a component in national monitoring and assessment of forest and land use. In some tropical countries, inventory systems have integrated participatory approaches in order to improve data quality and broaden knowledge of the systems [18].

5. Conclusions

This paper explores a methodological landscape-level approach for assessment and analysis of changes in land use, forest cover and society, its drivers and impacts. It is based upon experience from a number of case studies in Asia and Africa. It suggests that such approaches should a) address major issues regarding land use change including its drivers and impacts, b) generate policy relevant and accurate information, c) be cost-efficient and practical to implement, d) make appropriate use of modern knowledge, and e) engage actors, stakeholders, and decision makers. From a technical aspect, the methods of the approach should preferably cover all land (not only forest land), objectively describe current land use and trends, enable verification, and be robust although flexible enough to address upcoming needs.

The presented approach was flexible and feasible for addressing a range of policy issues related to forestry and land use change in tropical countries. It illustrates that by combining different techniques and involving local stakeholders in inventory processes, it is possible to meet a number of requirements on tropical land use and forest change assessment for purposes of policy and strategic planning. It could possibly be useful as a tool supportive in generating input to strategic planning for addressing forest policy issues. In what way this would be organized and how attractive it could be in a national context would ultimately depend on the governance situation and other conditions.

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Forests are the dominant terrestrial ecosystem of Earth. They are distributed across the globe. Forests account for 75% of the gross primary productivity of the Earth's biosphere, and contain 80% of the Earth's plant biomass. Human society and forests influence each other in both positive and negative ways. Forests provide ecosystem services to humans. Forests can also impose costs, affect people's health, and interfere with tourist enjoyment. This publication presents reviews and research results on negative and positive human interference on forests, as well as ecology, management, governance, policy and economic issues. The book consists of four sections with 12 chapters derived from around the world.

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