Lutz Fehrmann, Christoph Kleinn (Eds.)

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Forests in Climate Change Research and Policy: The Role of Forest Management and Conservation in a Complex International Setting

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Edited by

Lutz Fehrmann and Christoph Kleinn

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This volume contains the proceedings of the 2nd DAAD funded international workshop on "Forests in Climate Change Research and Policy: The Role of Forest Management and Conservation in a Complex International Setting" that was organized by the Chair of Forest Inventory and Remote Sensing at the Georg-August Universität Göttingen (Prof. Dr. Christoph Kleinn and Dr. Lutz Fehrmann) in collaboration with the Department of Forest and Wood Science at the University of Stellenbosch, South Africa (Prof. Dr. Thomas Seifert, Cori Ham and Dr. Ben du Toit).

A preparatory seminar with guest lectures given by Dr. Timm Tennigkeit (Unique Forestry Consultants), Prof. Dr. Markku Kanninen (University of Helsinki, Finland) and Fabian Schmitz (GIZ, Eschborn) was held in November 2011 at the University of Göttingen. The workshop took place along the COP17 and Forest Day 5 (organized by the Collaborative Partnership on Forests and CIFOR) from 1st to 7th December at the Ascot Conference Center in Pietermaritzburg and Durban, South Africa.

Adress of the Editor:

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Preface

Forests and any other trees outside the forest play a relevant role all three great UN conventions (on Climate Change, on Biodiversity, and on Combatting Desertification). The policy processes to implement the measures in these conventions on sub-national, national, regional and international level are extremely complex. And that complexity comes, among other factors, from a blend of different sectoral and national interests, from a large number of scientifically not yet entirely resolved issues and a wide range of different biophysical, social, cultural and political conditions all over the world.

It is a challenge for academia to educate the future decision makers (who are our students today) in a way that they are enthusiastic about the overall relevance of these processes – but also about the many details that are to be worked on. And it is a challenge to integrate this education into regular curricula because various dimensions need to be covered in a field that is rapidly further developing. On the other hand, these processes offer a unique possibility to illustrate the important – and sometimes somewhat neglected – science-policy interface.

The Faculty of Forest Sciences and Forest Ecology started in 2010 to implement a new format of what we would call “long-term / sustainable national capacity building”: we organize a workshop on “Forest and Climate” for master-students and professors (alumni of German universities) and integrate into that that workshop a visit to the Forest Day, the huge conference along the COP to UN-FCCC. Our students were intensively prepared for the visit of this high level international congress and this year in Durban along COP17, the Forest Day attracted about 1100 participants, including more than 250 members of delegations to the COP; an excellent opportunity for our students to depend their knowledge on forest related climate issues, to grasp the complexity of the processes – and, not least, not actively practice networking.

This year, thanks to the support from DAAD, we were able to invite 45 attendees from 21 countries to our workshop near Durban, from Ecuador to China; but mainly from Africa. We believe that this workshop and the visit to Forest Day 5 was an equally rewarding and instructive experience for all participants, both in scientific-technical terms and also in terms of international networking.

Organization of this workshop was only possible through the active and comprehensive support by many. Our greatest thanks are due DAAD, in particular to Mrs. Birgitt Skailes and Mrs. Anke Stahl for their unrestricted support to this innovative measure.

The perfect local implementation of the workshop was mainly due to Mr Cori Ham from Stellenbosch University, South Africa, who managed all upcoming issues with an extraordinary professionalism; a key person for our success. We are grateful to BSc Alina Kleinn for a thorough language review and editorial support when finalizing this proceedings volume. And great thanks to the participants of this workshop who all supported the implementation excellently.

We are again very grateful to the CIFOR organizing team of Forest Day 5, in particular to Dr. John Colmey and Mr. James Maiden for making it possible that our international students could again serve as congress assistants at Forest Day 5!

We hope that this volume does equally serve as a memory to the workshop and also as a useful reference for a variety of topic in the field of "forests and climate".

Dr. Lutz Fehrmann

Senior Research Associate
Chair of Forest Inventory and Remote Sensing

Prof. Dr. Christoph Kleinn

Head, Chair of Forest Inventory and Remote Sensing
Dean, Faculty of Forest Sciences and Forest Ecology

Workshop organizers (left to right):
Lutz Fehrmann, Thomas Seifert,
Cori Ham and Christoph Kleinn.

On this volume

This proceedings volume contains the seminar papers as presented at the DAAD funded international workshop on "Forests in Climate Change Research and Policy: The Role of Forest Management and Conservation in a Complex International Setting".

Contributions from 1st semester Master students are mixed with those of more experienced Scientists. As student contributions are considered as assessed assignment with credit points they have to comply with the examination regulations of the Faculty of Forest Sciences and Forest Ecology at the Georg-August Universität Göttingen. We motivated the participating early semester Master students to review scientific literature on their respective topics and to make use of actual scientific findings. In context of this coursework we therefore accept that some contributions make use of figures from published sources if they are cited and referenced correctly. The manuscripts are formatted and language-edited, but they did not undergo a scientific review. The editor took the academic freedom to adapt and harmonize some of the provided figures and tables during final review and formatting.

We hope that this volume does serve as a memory for all participants and is a contribution to strengthen the established scientific networks among students and scientists from 21 different countries. Great thanks to all who provided their contributions in compliance with the very tight deadline and who made it possible that this proceedings volume could be produced only a few weeks after our workshop.

By all accounts this was one of our most successful Forest Days to date, as much as I enjoyed the past ones, and a large part of our success was due to your team of students this year. We could not have had a more challenging venue and you could not have brought a nicer, more professional team of young men and women to guide everyone through the day.

On behalf of CIFOR and the Collaborative Partnership on Forests (CPF) thank you so much for your participation and please pass on our appreciation to the students.

John Colmey
Director of Communications
Center for International Forestry Research (CIFOR), Bogor, Indonesia

Workshop participants discussing with international scientists and stakeholders at the Issues Marketplace at Forest Day 5, Durban, South Africa, December 4, 2011 (Photo by Neil Palmer/ CIAT. Center for International Forestry Research).

Contents

Chapter one

Forest Management under Climate Change

Forestry and Forestry Research in South Africa

by Thomas Seifert, Cori Ham and Ben du Toit

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Abstract

Forestry in South Africa is an important part of the economy and contributes to many livelihoods, particularly in the poor rural areas. However, the sector faces many challenges. One prominent challenge is definitely global change which will impact on both growth conditions and on the socio-economic boundary conditions. The following text should serve as a brief introduction to growth conditions, challenges and the institutionalised forest research in South Africa. It is not meant to be exhaustive and can only provide a snapshot in a highly dynamic sector which has shown its ability to change and adapt with a surprising speed worldwide to keep up with the changes in technology and society in order to provide a sustainable resource to the people.

1. Forest ecosystems and Forestry in South Africa

1.1 Natural conditions for forest growth in South Africa

South Africa's land area is with 1.22 million km^2 about 3.4 times the land area of Germany. South Africa stretches in latitude from south 22° to 34° (This would encompass a region from central Libya to southern Italy mirrored to the northern hemisphere at a comparable longitude. To exemplify the countries' longitudinal extension: crossing South Africa from Cape Town to the Kruger National Park is about 1850 km or the distance from Freiburg im Breisgau (Germany) to Minsk (Belarus).

The population density of South Africa is low with 41 / km^2 (e.g. Germany 229 / km^2) and concentrates along the eastern seaboard and in a few cities in South Africa's interior. The South African landscape, climate and vegetation are strongly influenced by relief: the country has a flat, narrow coastal seaboard, pronounced escarpment zones and a very large interior plateau area at altitudes greater than 1000m above sea level. Situated between Atlantic and Indian Ocean the country receives a cold influence from the Antarctic Benguela stream along the Westcoast and a warm influence from the Indian Ocean, causing a complex interaction of weather influencing phenomena. The El Niño/La Niña-Southern Oscillation (ENSO) has an substantial influence on the country's climate with El Niño-related drought risks in the summer season from October to March (Richard et al. 2000, 2001).

The diverse morphology and complex climatic conditions shaped a wide spectrum of edaphic and climatic sub-regions with a wide variety of growing conditions for plants. Large parts of the country falls into warm temperate and subtropical climate classifications. Vast areas of the country's northwest are dominated by arid conditions that do not permit tree growth without irrigation. The north-eastern regions receive the bulk of their precipitation in the summer growing period, while the south-western Cape regions have a Mediterranean climate with peak precipitation in winter. The coastal areas in the Southern Cape around Knysna show a small seasonality in precipitation and receive rainfall all over the year. Not only the precipitation seasonality varies across the country but also the total amount of precipitation (Figure 1) leaving only a small proportion of the land area suitable for agriculture and forestry.

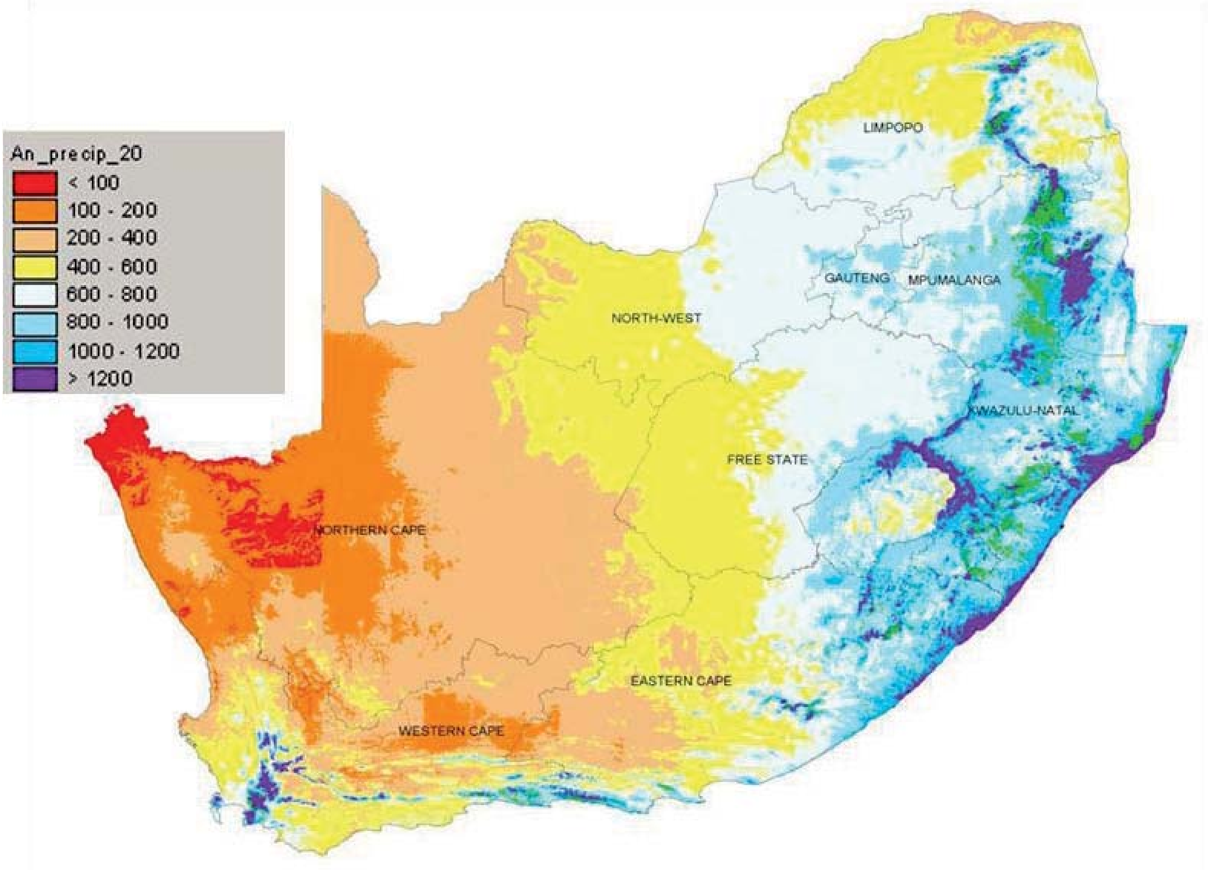

Figure 1. *Map showing the mean annual precipitation of South Africa (Schulze et al. 2008).*

1.2 Forests and tree dominated ecosystems

South Africa's main biomes are the savannas and woodlands in the northern and North-eastern part of the country, extended grasslands in the central plateau (Highveld), the Succulent Karoo and Nama Karoo are large semi desert areas in the North-western part, with the Fynbos, a Protea-dominated shrubland biome, occupying the South-western part of South Africa. Smaller areas along the coast line and at mountain slopes are occupied by thicket and Afrotemperate forests (Figures 2 to 5).

Figure 2. Border between a pine plantation and Fynbos (© B du Toit).

Figure 3. Afrotemperate forest adjacent to Fynbos in the Southern Cape (© B du Toit).

Figure 4. Themeda grass land and a eucalypt plantation in Kwa-Zulu-Natal (© B du Toit).

Figure 5. Savannah, northern Kwa-Zulu Natal (© B du Toit).

South Africa's forest resources encompass woodlands/savannahs which cover about one third of the country's land area (Willis et al. 2002), indigenous forests cover 0.5 % (estimated 504 803 ha, acc. Berliner & Benn 2004 ex. DWAF 2005) of the land surface and commercial plantations 1.1 % (1.2 million hectares).

1.3 Commercial forestry in South Africa

Natural forests are rather limited in area and productivity and most of them are protected. In the Southern Cape, where the biggest closed Afrotemperate forests are found, only a small area is used for timber production. The applied production system is a senility harvesting, where only trees are felled which have a high probability to die by natural circumstances in the next 10 years (Seydack et al. 1995). Though indigenous forests, if managed as multipurpose forests, could contribute more to the livelihood of local communities (Obiri et al. 2002). South Africa's main timber resource comes from commercial plantations with selected genotypes and hybrids and intensive silviculture to maximise the production on the limited plantation area in order to meet the objective of a balanced import-export situation in timber and wood based products.

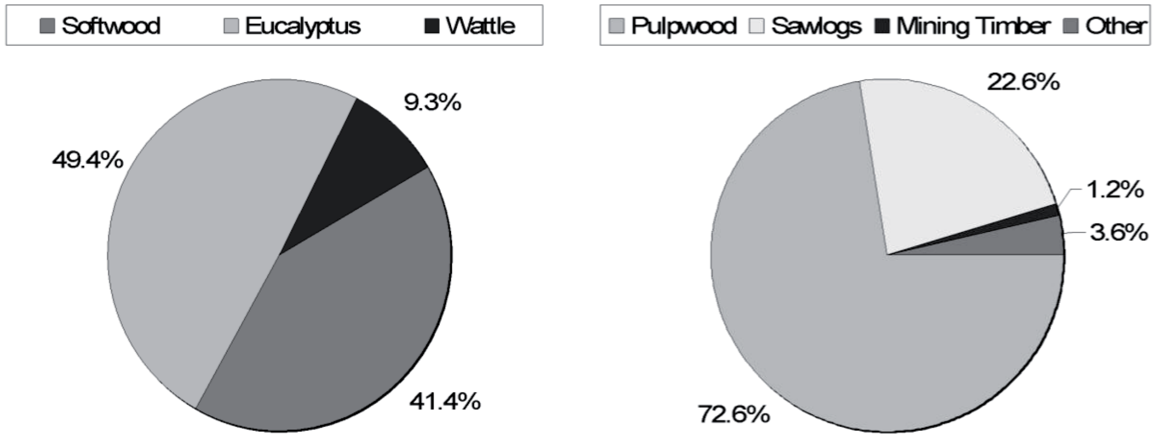

Figure 7. *Roundwood sales 2010 in South Afrika by species (left) and product (right) (Godsmark 2010).*

Commercial plantations in South Africa are mainly based on exotic eucalypt, pine and wattle (Australian *Acacia*) species (Figures 7 and 8).

The dominating production stream is pulp and paper amounting to 11 of 15 million total production. A good share of the pulp and paper production targets the Asian market. Table 1 illustrates the importance of pulpwood, sawlogs, poles, wood chips and mining timber. "In terms of changes in annual sales per product, sawlog sales showed the biggest gain - 536 000 t (18.4%) followed by pulpwood sales – 527 000 t (5.0%). Sales of other products dropped 52 000 t (-6.5%), the main reason being a 27.1% fall in mining timber sales" (Godsmark 2010).

Table 1. *Wood production from commercial plantations in South Africa in 2010 (Godsmark 2010).*

Products	Production (tons)
Pulpwood: Softwood	2 866 937
Pulpwood: Hardwood	8 219 532
Pulpwood total	11 086 469
Sawlogs: Softwood	3 154 673
Sawlogs: Hardwood	292 152
Sawlogs total	3 446 825
Poles: Softwood	105 584
Poles: Hardwood	222 522
Poles	328 106
Woodchips: Softwood	191 061
Mining: Timber:	190 383
Other: Hardwood	30 643
Grand Total	15 273 487

About 82.5 % of the sales are made by big corporates, 15.9 % by cooperatives and only 1.9 % by independent growers (Godsmark 2010).

Production cycles are comparatively short, ranging from an average of 9.7 in eucalypt pulpwood plantations to 10.2 years in wattle pulpwood plantations and 28.2 years in pine sawlog production circles with mean annual volume increments per hectare and year of of 21 (eucalypts), 13.4 (wattles) and 14.3 (pines).

1.4 Challenges for commercial forestry and forest research in South Africa[1]

South Africa's forestry and wood industry has made significant contributions to the sustainable supply of timber and fibre resources, employment and job creation, rural development and the provision of eco-system services over time, among many others. Notwithstanding this, the South African forest industry currently faces several additional major challenges, as follows: (1) international competitiveness in wood and fibre (cost and quality) delivery and an increasing demand for wood and fibre from a decreasing resource base both in South Africa and internationally; (2) socio-economic pressures; and one of the largest challenges (3) global change.

(1) International competitiveness

Commercial plantation forestry, as part of a global industry, is the cornerstone of sustainable timber and fibre production in South Africa. However, South Africa's role as a key player in international plantation forestry has been reduced in favour of international competitors such as Brazil, Chile, China, Australia and New Zealand. These countries have made significant investments in the research and development of their forestry and wood sectors. International developments and successes in tree breeding and site specific silviculture, and the inevitable mechanisation of harvesting operations have far outstripped national initiatives. Land suitable for forestry is also limited and this further constrains potential growth of the sector. Innovations must be made to create smart solutions adapted to South Africa. The Sawlog Strategy and Implementation Plan for South Africa (Ham et al. 2010) pointed out the need for (i) inventions to increase the productivity of the current resource, (ii) inventions to develop new and alternative resources and (iii) business inventions in order to optimise processes and develop new options.

(2) Socio-economic challenges in South Africa

Imminent changes to South African society include broad based black economic empowerment, land restitution and poverty reduction, particularly in rural areas. South Africa's forested land ownership is changing rapidly and will involve the redistribution of land to small owners, growers and communities who will require forestry expertise if they are to be empowered to use the land and resource to their and the countries benefit. This will change forestry

[1] Excerpt from Seifert et al. 2011: Position paper of forest and wood research

practice considerably and the full extent of its effect on productivity is unknown. In order to benefit the rural population, innovation is needed to transform the potentially detrimental fragmentation of forested land into a strong and integral part of South African forestry. A recent review of decision support systems (DSS) in South Africa (Seifert et al. in press) showed that current DSS systems are not geared towards the new challenges such as delineation, land restitution, theft and holistic land-management. While the existing DSS are productive and reliable in typical wood and fibre production oriented industry domains, they lack the capability to address land-use management holistically. This holistic viewpoint is essential to facilitate a regional optimisation of the land-use portfolio with regards to a full spectrum of ecosystem services, which are a precondition for sustainable regional planning.

(3) Global change

The key point of the most actual climate predictions are: (i) The temperature will increase, (ii) the mean annual precipitation will decrease in the West Cape and increase in the rest of the country. But the variability of precipitation is likely to increase across the country. The analysis on vulnerabilities of the forestry and wood sector to climatic change compiled for the Second National Report to the IPCC (Seifert et al. in press b) revealed a clear lack of knowledge with respect to the potential changes in growth and wood properties of commercial species. These changes include species adaptation to increased fire, hail, wind and snow risks as well as pathogens and the related expected damages/losses. Due to the uncertainty of current climate predictions, an "if-then" planning process based on scenario simulation is a first choice to facilitate a rapid response to actual climate change effects. Dynamic climate sensitive simulation tools for scenario planning are therefore required. Tree breeding for pathogen and drought resistant genotypes will be key factors for future success but these must also follow a holistic approach and take into account the resulting wood properties, product qualities and product marketability. The largely unused potential of climate change mitigation through optimised forestry operations and carbon sequestration can open up additional funding streams such as the REDD+ process. New inventory standards to determine forest area, growth and carbon sequestration should be established together with the neighbouring SADC countries.

2. Forest and tree related research in South Africa

2.1 Research institutions

Forest research in South Africa is conducted by academic institutions (universities), by industry financed research institutions and state owned research councils. Additionally, the bigger forest companies have established in-house research capacities with a focus on tree breeding and tree improvement.

Table 2. *Academic forest related research institutions and their research fields, sorted according to IUFRO divisions. Points indicate the capacity of the research group: ● 1 scientist, ●● 1-2 lead scientists plus MSc/PhD students, ●●● larger research group.*

	IUFRO Divisions							
	Silviculture	Eciophysiology & Genetics	Forest operations	Forest Assess ment modelling & management	Forest Products	Social, Policy, Economics & Information	Forest Health	Forest Environment
Stellen-bosch	●●	●●	●●	●●	●●●	●●	●	●
Pretoria						●●	●●●[1]	
KZN	●●●[2]	●●[2]			●●	●		
NMMU	●		●		●		●	●
UniVen	●	●						
Cape Town								●
Wits		●						

Units with large capacity associated with specific universities: [1] Forest and Agricultural Biotechnology Institute (FABI); [2] Institute for Commercial Forestry Research.

The academic institutions are Stellenbosch University, University of Pretoria, University of Kwa-Zulu-Natal, Nelson Mandela Metropolitan University (Saasveld), University of Venda, University of Cape Town and University of Witwatersrand. Their research focus in forestry is illustrated in Table 2. Only Stellenbosch University covers the full spectrum of forest related research.

The most important non academic institutions financed by industry are: The Institute for Commercial Forestry Research (ICFR), Pietermaritzburg with a focus on silviculture and genetic tree improvement, the TPCP tree pathology co-operative programme and the Forestry molecular biology co-operative programme (FMBC), both at the Forest and Agricultural Biotechnology Institute (FABI), linked with Pretoria University; the Division of Water, Environment and Forestry Technology (Environmentek) of the CSIR with a focus on tree improvement, hydrology, eco-physiology and forest products. Forestry related research on the biological control of invasive plants is conducted also at the Plant Protection Research Institute (PPRI) of the Agricultural Research Council (ARC).

2.2 The "Green Landscapes" project – extending the forestry perspective to an holistic landscape management[2]

Forestry has to recognise its role as an important land-use form in a context of a land-use portfolio. Tree based African landscapes share or compete with several other land-uses. These land-uses range from agriculture, in terms of food production; society, in terms of potentially impoverished rural and urban communities dependant on timber, non-timber products from natural forests and woodlands and arable land for their daily livelihood; and conservation and biodiversity needs. These land-uses not only mutually influence each other according to their spatial composition, but are subject to the influences of climatic change. Forests of the world have also been identified as major players in the mitigation of climate change and are found to strongly affect and contribute to the global climate. Yet in most cases sustainable management of this valuable resource, as mentioned above, is inadequate to entirely absent.

The objective of the "Green Landscapes" research programme is to contribute to the needs of society in developing spatial landscape based decision support tools and thus extend forestry management to a holistic land-use management. "Green Landscape Design" is a new concept of evidence based planning. The approach spatially integrates different land-use strategies, economic and social demands within the same region, including subsistence agriculture, biodiversity requirements and natural and commercial forestry in a trans-disciplinary approach based on systems thinking. Integrated land-use challenges will be met with an adapted landscape management approach that fulfils the following main criteria:

(1) Integrative and trans-disciplinary approach: The integration of the relevant variables requires significant collaboration between natural, engineering and social scientists since the problems of the respective disciplines interact strongly.
(2) Spatially explicit and regionally applicable: The position, extent and spatial arrangement of land-use forms create a specific pattern which affects the expected outcomes (products, eco-system services, etc.); thus, a rigorous and comprehensive spatial approach is imperative.
(3) Sensitive to climate change: Climatic change will play a major role in future land management because environmental and social conditions for land-use, production and work and many other landscape variables will change substantially. Long-term climatic trends as well as natural hazard prediction will have to be included in this scenario analysis.
(4) Adaptive planning: Planning must be flexible enough to choose the best land-use option in every situation every time. Compared to traditional long term static plans, a scenario supported by the Multiple Path approach offers a more suitable option. The idea is to determine the current situation, predict possible developments in the short

[2] "Green Landscapes" is a transdisciplinary project based at Stellenbosch University, financed by NRF/DST in the Global Change context.

and medium term and then update the planning effort in iterative steps. With this system, land-use in a region is constantly and continuously updated and optimised, ensuring a state where the most benefit for society without endangering environmental and economic sustainability, is derived.

(5) Data and policy driven: The use of reliable data and the constant alignment of management to relevant policies are important to prioritize different aspects of land-use and the possibility to react readily to change.

(6) Aggregation and suitability for technology transfer: The DSS and other models developed must be transferable to government/local authorities, practitioners, policy makers, land owners and other stakeholders for implementation at ground level in order to produce the desired outcomes of the research. The multitude of input variables with their complex interactions must be aggregated to a set of variables relevant for decision making.

A combination of GIS/RS integrated spatial eco-system models with decision support systems (DSS) are currently being practiced at the frontiers of scientific research worldwide (Denzer 2005, Fürst et al. 2010). However, no applicable or similar system is yet available for specific sub-Saharan African conditions. The scientific challenge is not so much the multi-criteria decision making model (MCDA) itself, which can be based on well-founded research, but rather the models necessary to produce the input for decision making and seamless integration into dynamic planning tools. These models must establish the ecologic, production oriented and socio-economic variables, which are used to feed the decision making process; and which in-turn rely heavily on the spatial arrangement of land-use forms in interaction with the natural landscape.

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Are there lessons to be learned from forestry in Germany?

by Hanns H. Höfle

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Abstract

Forests in Germany had been degraded and deforested in the past leading to shortages of timber and environmental problems. A general awareness of these problems and the discovery of sustainability initiated a restoration of forests starting with pioneer and later on with more demanding species. A long period of development allowed forestry in Germany to attain all those elements that must be in place for forestry to become a successful and respected sector of the economy such as good forest laws, strong forest administrations, security of forest area, clarity of tenure, sustainable forest management, reduced impact logging, establishment of training institutions and accumulation of knowledge. The situation of Germany has been unique and certainly differs from the situation in many developing countries. Nevertheless, some ideas and achievements of German forestry could be transferred – adjusted to the specific situations and aiming at building capacities and strengthening institutions.

Keywords: Forestry in Germany, forest history, sustainable forest management, transfer of knowledge, political process

1. Introduction

Flying over Germany, one discovers a pattern of well managed forests distributed between agricultural, residential and industrial areas and composed of different age classes and a wide variety of stand types. The forests cover about 11 million hectares or 30 % of the total area of Germany. The total standing timber volume is the highest in Europe outside Russia. Only the forests of Switzerland and Austria surpass the German average of 320 m^3/ha (BMVEL 2006). The annual growth is in the range of 100 million m^3 while yearly removals vary from 50 to 70 million m^3 depending on the status of the economy. 47 % of the forests are privately owned; 20 % of them belong to communities; the remaining 33 % are state forests. The infrastructure inside forests is practically complete due to road networks with an average road density of 35 m/ha. Likewise, forestry enjoys a good road and railway system outside forests.

2. Forest history

Without human interference, Germany would be almost totally covered by forests. The conversion of forests to other uses was in the beginning not the result of conscious land-use planning exercises but of a process of trial and error. Farmers abandoned agricultural land where the terrain was too steep or soils were too infertile. Another factor was power as owners of large estates kept forests as valuable resource or areas for hunting of wildlife. Nowadays, forests cover those areas where they are indispensable for soil protection, watershed management, biodiversity or other ecosystem services. The process of deforestation happened over a long period where all construction, energy, vehicles or furniture relied on timber. It was a "wooden era". As a consequence, more timber was harvested than could possibly grow in the same period and forests were degraded. Both degradation and deforestation led to a shortage of timber and to environmental problems in the same way as now happens in many developing countries. Fortunately, the German forester Hans Carl von Carlowitz discovered the idea of sustainability in 1713, though at that time restricted to timber production when he stipulated that not more timber should be cut than grows.

This idea, in combination with a general awareness of the problems, initiated a restoration of forests in Germany, often with pioneer species because degraded soils did not allow otherwise. Over a long period, German forest management followed the ideal of the "normal forest" with age class structures and fixed rotation periods. At present, there has been a paradigm shift: practically all public forest owners apply the ideas of near-natural (or close to nature or continuous cover) forestry emphasizing mixed stands, natural regeneration, harvesting of individual trees, important aspects of biodiversity and nature conservation as well as understanding sustainability in a broader sense encompassing economic, ecological and social elements as agreed at the conference in Rio in 1992.

The long time horizon allowed the accumulation of knowledge about forests and forestry and their economic, social and ecological role in society, to establish training and research institutions, to formulate forests laws, to organise forest administrations, to build a network of forest roads and to develop forest professions with a specific, high work ethic. Education in forestry started with sporadic initiatives in the 17th and 18th century. The first faculty of forestry was founded in Tharandt in 1811. Not much later, the first institutions for the training of foresters started. Finally, the vocational training of forest workers took off in the 1930s. Thus, a well trained workforce is now available at all levels. In addition, a consensus about the role of forests and forestry evolved over time resulting in a positive attitude towards forests and forestry. The general public at present values forest protection and recreation more than timber production.

The history of forestry in Germany can be looked at as a success story. Presently, however, forestry here meets the same challenges as forestry elsewhere: the struggle for economic viability in the light of rising costs, stagnating timber prices and the influence of globalisation; the effects of air pollution and climate change; the volatility of timber markets; the problems originating from small forest owners and urban societies or the necessity of compromises with other sectors of the economy which are often much more powerful than forestry.

The forest area in Germany is increasing due to natural regeneration of idle land and afforestation of marginal farm land. The forest law stipulates that the forest area has to be maintained or even enlarged. Thus, one is entitled to afforestation if there are no truly prohibiting factors such as biodiversity hot spots. On the other hand, the law makes it extremely difficult to convert forests to other uses. It may only happen if no other solution is available, e.g. for the construction of a high-speed railway track.

The standing timber volume is increasing since removals are smaller than growth. Parallel to this, the carbon stock of forests is also increasing. It is additionally supported through careful harvesting operations, limited removal of tops and branches, and protection of soils.

3. Prerequisites for well managed forests – the German example

Forestry in Germany is now well established, acknowledged and functions well. This needs commitment by the general public, politicians and decision-makers at large. In addition, many elements inside and outside forestry have to be in place to enable forestry to operate successfully. If one of these elements is missing, the system of forestry fails. Examples are manifold: forest laws are not enforced because of weak forest administrations; land use plans are not respected; the knowledge gained in training is not used in the field; management plans are not implemented.

Forestry cannot work sustainably if the forest area is not secured. Each forest area in Germany is fixed as the result of a public, transparent land-use planning process the results of which are respected by everybody. The tenure is cleared through a nationwide, definite register of land ownership. Both systems guarantee that there is no insecurity about tenure nor encroachment on forest areas, illegal logging or other illegal activities.

Well managed forests cannot be realised without a good forest law. The first forest laws in Germany were formulated in the first half of the 19th century and have been amended ever since. It must be kept in mind that a large range of other laws, e.g. about land-use planning, nature conservation or traffic regulations, is also relevant for forestry. It is important to assure that the laws are not contradictory and that the regulations that outline them are kept to a minimum.

Law enforcement requires a strong and effective administration following the principles of good governance. Such administration exists in German forestry as the outcome of capacity building over time, of sufficient resources made available by adequate budgets, of well trained and motivated personnel, of establishing a corporate identity and a modern style of management, and of being innovative in the sense of “learning enterprises”.

Forest administrations have realised that their members, the “human factor”, are their most valuable asset. Foresters in Germany are carefully selected and enjoy career opportunities. Notwithstanding the level of education, they prefer to work in the field and to put silvicultural and other strategies into practice. Thus, they optimise field level management. The professional ethic has a high standard: foresters follow the principles of carefulness and sustainability, put the general well being above personal privileges and are interested in life-long learning.

Administrations at various levels cooperate horizontally and vertically within the forest sector but also with agencies of other sectors such as agriculture, environment or infrastructure. Close cooperation with the research society, i.e. universities and research stations, is an important source for new ideas as well as a means to cope with problems arising in the forest sector. These may be finding optimal reactions to climate change or dealing with new pests and diseases. Beyond the checks and balances inherent in the political system, government administrations are tightly and constantly monitored by the general public, environmental and other NGOs, a critical press or by private persons with an interest in forestry.

Following the federal structure of Germany, the authority over forestry is conferred to the states. But there are mechanisms that lead to a uniform approach of forestry throughout Germany. At the same time there is enough leeway to take care of differences of sites and socio-economic settings.

The concept of sustainability or - more specific – of sustainable forest management (SFM) has a long tradition in German forestry starting with the focus on timber production and now incorporating the three - ecological, economic and social - aspects of sustainability. SFM is the guiding principle of forestry in Germany laid down in a definition agreed by all states about what “ordinary forestry” comprises. Consequently, the major part of forests in Germany is now certified either by FSC or PEFC.

SFM relies on a stable forest area and the absence of illegal activities. It is supported by a range of instruments like soil maps, silvicultural systems or inventories that bring the concept of SFM into practice. In addition, the necessary investments, e.g. into road construction, enrichment planting or protection of stands, have been and are still being made even if the economic viability of forest enterprises is constantly at risk.

SFM also presupposes that forest ecosystems maintain their resilience and stability. Limits to the amount of timber cut during each intervention and careful harvesting operations following the principles of reduced impact logging are means to take care of complex forest ecosystems. Both requirements have been in place in German forestry over a long time.

The concept of multiple use forestry, where more than one function of the forest has to be fulfilled in the same area, guarantees that the needs of society are taken care of. The high population density and the limited forest area do not allow segregation of the forest areas, i.e. to set aside large forests for just one function. These concepts have been supported by a vast amount of knowledge that has been accumulated over time, is spread through training institutions and is applied in the field.

A complete network of forest roads facilitates access and control and provides the basis for environmentally friendly harvesting operations. Reduced impact logging has been the standard practice in German forestry since a long time without being formulated in a concise manner as a "code of practice" but being applied on the basis of training, skills, knowledge and the principle of cautiousness. Protection of soils, these being the most important assets of productivity, is seriously considered in the selection of species, harvesting operations, removal of biomass or through compensation liming, the latter to limit the negative effects of harmful air pollutants.

Forest fires are not a major threat to forests in Germany. Nevertheless, control of forest fires as well as of pests and diseases has been and is a major issue. The expertise of universities and forest research stations provides substantial support in the fight against pests and diseases and serves as a good example for the close cooperation between research and practice.

Medium-term forest management plans play a crucial role in forestry due to the long production periods in non-tropical regions. They integrate the demands on and the possibilities of forests and have a long and successful history in Germany. They are well designed, realistic and based on actual, accurate data which are collected at the level of the management unit through a systematic grid of permanent sample plots as well as at the stand level. They are implemented, monitored and updated – the latter either at preplanned points in time or if need arises as in the case of severe disasters. To ascertain that management plans are implemented, foresters being later responsible for the implementation take part in the planning process which simultaneously opens the chance for local experiences to be incorporated into the plan, e.g. risks of windfall, relationships between growth rates of species, problems with regeneration or browsing pressure of wildlife. The implementation through short-term (yearly) plans is formalised, thoroughly controlled in natural and financial terms, and feedback is given to all relevant levels.

Long- and medium-term management plans also provide the instruments to apply modern silvicultural strategies. The shift to continuous cover forestry in Germany has not been a self-supporting process. Rather, this change of paradigm needed clear concepts, instruments to put policy into practice and a large set of training activities to make members of the administrations aware of and understand the new strategy. Since the variety of sites, tree species and stand types require individual treatments in the sense of differentiation, it was mandatory that a balance had to be reached between a uniform line of thought and the freedom required to cope with the specific aspects of a certain situation. To reach this, forest administrations could, once more, rely on the excellent training, knowledge and motivation of their members.

The forest law enforces private forest owners to follow the principles of sustainable forest management and requires medium-term forest management plans if the size of estates surpasses a certain size. All private forest owners are entitled to getting advice from the state forest administrations about how to manage their forests optimally. Thus, most of them are convinced that sustainable forest management with sound silvicultural strategies lies in their own interest.

The mix of ownership provides positive effects because private forest owners pursue somewhat other objectives than public owners. They are free to do so as long as they operate within the forest law. Public owners – states and communities – on the other hand are able to provide services which private owners are reluctant or unable to provide for economic reasons as long as the public is willing to pay for them. Thus, public forest enterprises are fully engaged in the provision of ecosystem services, recreation and environmental education.

Public and private forest enterprises compete with the industrial sector for employees. Consequently, they have to pay competitive wages and to apply the same standard of occupational health and safety. Forest firms, as part of the primary sector, have a hard time developing new products - contrary to the timber industry. Thus, they must find other ways for survival. They react with the substitution of labour by capital through mechanisation, less intensive activities (e.g. wider spacing in afforestations) and methods of lean management.

Additionally, forest enterprises deal with slow and long-lasting growth processes of trees and must simultaneously live up to the dynamics of a rapidly changing, globally oriented market economy. Therefore, without the commitment to sustainability forests would be lost since one might easily overcut forests not worrying about what happens in the long run. On the other hand, if a forest firm can draw on a wide variety of stable and mixed forests, it enjoys the advantage of a well assorted inventory of timber which allows supplying what is demanded by the market.

Forest enterprises rely on well established networks of forest roads the density of which is sufficient in most cases. Thus, new investment into roads is rarely required. On the contrary, many forest firms investigate now if and to what extent the existing system of forest roads could be changed to lower densities. Modern forest technology – cut to length systems or forwarding instead of skidding – allows doing this. The elements of reduced impact logging (RIL) are standard practice in harvesting operations. Soil protection is now stipulated by a specific law. However, forestry considered soil protection a top priority even before this law had been issued. Protection of soils creates a dilemma: modern harvesting technology requires the use of heavy machinery that compact soils with the first run already. As a compromise, the machines are restricted to a system of extraction racks (skidding trails) which they are not allowed to leave. This rule is part of all certification systems (FSC as well as PEFC) and it is strictly monitored through regular audits and as part of all planning processes.

The worldwide trend of substituting own workers by contractors is also adopted by forest enterprises. This requires a sufficient number of "good" and reliable contractors who must be fairly paid to be able to survive. They are mostly well equipped - often providing technological systems that forest firms do not entertain. Competition between contractors is high with certification as one key element: often, forest enterprises do not employ contractors who are not certified. Ideally, long-lasting relationships between forest firms and contractors evolve where both partners know and rely on each other.

A sufficient number of forest training institutions exists at the level of university, college or vocational education. They play a crucial rule in acquiring and disseminating knowledge through training and further education and in creating a pool of well informed, motivated and dedicated foresters and forest workers. The forest profession has been highly valued by the general public over a long time though at present problems arise because of evolving urban societies and the preference of conservation over utilisation of forests by many interest groups. The majority of foresters prefers to work in the field, to be in close contact with the public and to stay for a long time at the same place, thus, gaining deep insights into the local situations and the reaction of forests to silvicultural activities which allows them to practice silviculture as "adaptive management".

The general public has developed a positive attitude towards forests and forestry over time because the needs of society for forest products, recreation and other ecosystem services have been taken care of. However, general knowledge about forests and forestry is declining more and more due to the urbanisation of society and the decreasing importance of the forestry sector. Many people value recreation and ecosystems services such as protection of water and soils higher than timber production. They also like to use timber but they do not like foresters to cut trees.

Finally, forestry in Germany enjoys the advantages of a strong, highly diversified timber industry. This allows forestry to practically sell all relevant species and all parts of trees at acceptable prices even though the economic viability of forest enterprises is always in danger because of rising costs and missing payments for ecosystem services. In addition, demand for wood for energy is rising and initiated the debate of whether timber should be primarily used for energy or as raw material for products.

4. Unique situation of forestry in Germany vs. differences elsewhere

Degradation and deforestation have not been unknown to forestry in Germany. But relevant decision makers became aware of the negative effects of deforestation and degradation before it was too late. They succeeded in stopping the ongoing processes and in initiating the restoration of forests to acceptable standards even if pioneer species had to be used in the first place. The corrective actions could take place over a long period where, simultaneously, knowledge was acquired, forest administrations were established, a motivated and well trained workforce evolved and instruments like medium-term forest management plans were developed and used. The forest area had been gazetted early; there were no encroachments on forests and only minor events of illegal activities happened.

The complexity of forest ecosystems was relatively limited and could be restored. Later on, the population pressure was reduced through the emigration of people to North and South America. The productivity in agriculture increased after the discovery of fertilisation, reducing the demand for additional agricultural areas. People having been displaced in the primary sector found jobs in the secondary sector due to the industrial revolution. Wood was substituted by coal as source of energy while the construction of railway systems allowed to bring the coal to the places of demand.

In summary, there have been extremely favorable conditions for forests and forestry in the past. They still prevail even if the economic situation of forest enterprises, being private or public, is far from satisfactory. Forestry benefited from long time horizons and timely development of other sectors which, at the same time, did not put outsized pressure on forestry. Thus, forestry in Germany now enjoys the advantages of being part of the economy of a developed country even if the economic viability of forest enterprises is constantly at risk and forestry in Germany has to deal with the same trends and problems that forestry meets elsewhere.

What a difference to the present situation in many developing countries! Often, the forest area is not secured and, even if this is the case, the results of land-use planning are not respected by other – more powerful – sectors of the economy. Problems of tenure are not clarified and the rights of people are neglected. Encroachment on forests and illegal activities from illegal logging to poaching are widespread. The population grows at alarming rates and shifting cultivation is often the only solution for survival – not considering the conversion of forests for large-scale agricultural activities like oil palm plantations. Jobs outside forestry are missing. The general public is well informed about living standards elsewhere and not willing to wait any longer for enjoying the same standard. Even if there are good forest (and other) laws, forest administrations are often so weak that law enforcement does not take place – not to mention corruption, neglect of good governance and the hesitation of well educated foresters to work in the field.

5. Is transfer of ideas and concepts possible?

If one presupposes that some of the features of forestry in Germany are really a prerequisite for success, one might ask if and how the transfer to other, in particular developing, countries might be adequate. At any rate, the situations between countries differ to such a great extent that a general recommendation cannot be given.

In many instances, it seems that the technical knowledge, e.g. how to establish stands, how to restore forests or to build forest roads, is available and the problem is not the transfer of knowledge but rather the appropriate application in the field. In other instances, where the technical knowledge might be insufficient or not available, the transfer of technical knowledge seems to be necessary. In both cases, an improvement of the situation might not be possible without changing established procedures, strengthening institutions and building capacities at various levels of administrations. Thus, the application as well as the transfer of technical knowledge must necessarily be accompanied by the development of ideas and concepts for better positioning forestry in the social and political arena. This is, without doubt, more complicated than the mere transfer of knowledge: one embarks on a long and tedious process and needs patience, perseverance and a distinct tolerance for frustration even if the time for solutions is short and running out. Again, some experiences of forestry in Germany might offer some support.

Raising awareness at the top, i.e. at the level of politicians and decision makers, and the bottom, i.e. at the grass root level, is a key issue and might constitute the starting point for all other efforts. Since it is extremely difficult to change the attitude of adults, raising awareness should start at school level in the context of environmental education (or "education for sustainable development" as it has recently been called).

Sometimes politicians are willing to support decisive solutions. This happened in Germany after the negative effects of the acid rain had been discovered: the parliament passed legislation that demanded rapid and effective actions towards reducing the emissions of air pollutants. More often, such grand solutions cannot be reached. Then, it is advisable to start with pilot projects that might lead to general solutions over time or with campaigns directed at specific problems or actors. Sustainable forest management, practiced and certified in one enterprise and later introduced in a large area, might provide one example. Greenpeace, another example, ran a very successful campaign in Europe to stop the bleaching of pulp with chlorides.

The "civil society", consisting of citizens who are engaged and demand transparency, is evolving in many countries as an increasingly stronger force that controls the actions of politicians and demands accountability. In this context, it should be clear that forestry, as a relative weak sector of the economy, needs partners to support the issues of forestry through networks and alliances.

Lastly, even if most people learn from their own mistakes more than from reports about mistakes of others, forestry in other countries might be willing to learn from the German experience and to avoid mistakes that German forestry made in the past (Klose 1985). Thus, forests should not be converted where they are urgently needed for the delivery of ecosystem services. Foresters must be aware that it is not sufficient to do a good job in the forest. How indispensable forests are and what forestry constitutes must be communicated to the general public. Thus, public relations are a must, in particular in democratic societies where every party fights for the attention and support of the people. Forestry as a relatively weak sector, considering its economic importance or political weight, should not operate in isolation but rather seek the cooperation with other sectors even if this sometimes requires compromises (e.g. with nature conservation or agriculture). To speak with one voice, in the case of different forest owners, is also essential.

The battle for forests and forestry is long, tedious and often frustrating. Nevertheless, foresters must not give up. Who else knows better about forests and is able to demonstrate the benefits that society gains from the products and ecosystem services of forests? If forests are lost, it is often not possible to restore the previous or even a merely satisfactory status.

6. Conclusion

The development of forestry in Germany over a long time horizon and under favourable conditions has certainly resulted in valid concepts, strong institutions and excellent stands. This, altogether, demonstrates what forestry needs to operate optimally and to fulfill the demands of society. The German example can certainly not be transferred directly to other countries, especially in the developing world. The basic concepts, however, might be used when the forest sector is going to be developed or strengthened. Then, working in the technical domain is not enough. Sufficient emphasis must also be given to the political and social process if the concepts and the field level management are expected to succeed.

7. References

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Gunung Walat Educational Forest: from bare land to forest stand

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Abstract

Gunung Walat Educational Forest (GWEF) was bare land in 1951 and dominantly covered by *Imperata cylindrica* and shrub. A plantation was established in 1959 by the forestry district, followed by the Faculty of Forestry of Bogor Agricultural University (IPB). Recently, enrichment planting was also conducted under the management of the forest administrator. The total forest area is 359 ha, which is mostly covered by agathis (*Agathis loranthifolia*) and pine (*Pinus merkusii*) stands. Enrichment planting is being done to recover damaged areas, in collaboration with companies with carbon sink schemes. The forest is surrounded by villages in which villagers collaborate with the forest administrator for agro forestry activities and resin extraction of agathis and pine trees. Agro forestry activity is characterized by the planting of rice, cassava, banana, coffee, and medicinal plant under the stands. Some faunas are also found in the area as wild faunas. All expenses of GWEF can be covered from self income generating activities, especially resin production and public services, which provides a unique example of how a small scale forest management can survive without cutting the trees. In addition, GWEF has been providing other services for people such as educational, recreation and support for local people's needed of fire wood.

1. Introduction - background

In 1951 Gunung Walat was bare land and mostly covered by *Imperata cylindrica,* grass and shrubs. The activity of reforestation was started in 1959 with an agathis plantation by the West Jawa Forestry Division. The total area is 359 ha, located in Sukabumi, 56 km from Bogor city Indonesia, between 6°53'35"-6°55'10" S and 106°47'50"-106°51'30" E, with mountainous topography ranging from steep (15-25%) to very steep slopes (>40%).

Gunung Walat Education Forest (GWEF) was established in 1969 and the management of GWEF has been conducted by the Faculty of Forestry Bogor Agricultural University (IPB) since 14 October 1969, based on a Decision Letter from the Forestry Head of West Jawa Province. The location of GWEF is shown in Figure 1.

Since IPB got the mandate, reforestation has started with schemes including sylviculture practices by students, planting many tree species, and recently rattan, bamboo, and also some medicinal herbs were found. The forest stand is predicted to be about 10,855 m^3 agathis, 9,471 m^3 pine, 464 m^3 puspa, 132 m^3 sengon, and 88 m^3 mahogany. Agathis and pine trees produce resin and it is sold as the main income generating activity.

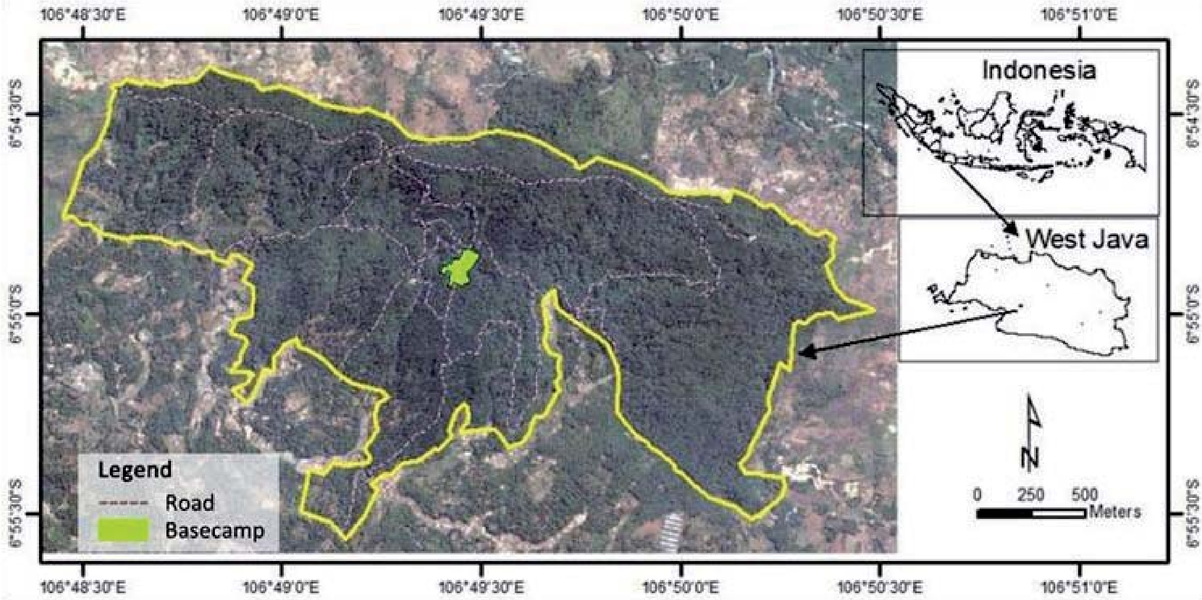

Figure 1. *GWEF in Sukabumi District, West Java, Indonesia.*

2. Reforestation

In the year 1951 existing soils in the area were categorized as red soils (Podsolic and Latosol) and Lithosol. Lithosol is soil which is very shallow (less than 20 cm) and is dominated by rock or stone (high degree of stoniness). High degrees of Lithosol were found especially in the north-eastern part, and such condition posed some problems for tree planting efforts. At that time, according to interviews with elderly locals around the GWEF, the environmental condition for agriculture bad with frequent flooding during rainy season and frequent drought during dry season due to lack or absence of forest in the area. Such conditions created problems for local people who wanted to cultivate wetland rice. Therefore, the Local Forestry Service Office and University of Indonesia (University of Indonesia, Faculty of Agriculture, Forestry Department, which in 1963 became IPB) took the initiative to develop forest in the 359 ha area, with initial planting of agathis. Planting activities were conducted by local people around the Gunung Walat area and IPB, and every year each batch of new forestry students was assigned to plant 4 hectares of forest. The Faculty of Forestry IPB students became the main tree planters in the GWEF area, and the tradition of tree planting by forestry students in the area continued until the year 1979 (HPGW 2010).

The tree species being planted for the first time (in the year 1951) was agathis because basically this species requires shade in the initial stage of its growth, and the small seedling of this species could utilize the natural side shade created by the existing shrub and alang-alang. For utilizing the side shade, agathis was planted by clearing (slashing and eliminating the alang-alang and shrub) in only very small patches (70 cm x 70 cm) for each seedling or planting hole of agathis. Shrub and alang-alang outside the whole patches were not slashed, to serve as side shade for the small seedlings of agathis. After the planted agathis reached height of 200 cm, the cleared area was increased because the agathis did not need shade anymore.

A problem encountered during the initial planting activity was the high degree of stoniness of the soils in the area, especially at the north-eastern side. An attempt to alleviate this problem was the generous use of organic matter (addition of compost) in the form of composted goat or sheep manure in the planting hole during the initial planting. Goat manure at that time could be easily obtained from traditional goat or sheep husbandry practiced by local people. The agathis stand has been growing well around the base camp and reached a diameter of 60-80 cm and a height of 30-40 m, as shown in Figure 2.

Figure 2. *Agathis stand around base camp.*

In 1973 about 53% of the GWEF area was covered by some tree species, and in 1980 almost all area was covered by forest stands consisting of agathis (*Agathis lorantifolia*), pine (*Pinus merkusii*), puspa (*Schima wallichii*), africa wood (*Maesopsis eminii*), mahogany (*Swietenia macrophylla*), rasamala (*Altingia excelsa*), rose wood (*Dalbergia latifolia*), *Gliricidae* sp, sengon (*Paraserianthes falcataria*), meranti (*Shorea* sp), and mangium (*Acacia mangium*), the forest stand is shown in Figure 3 (HPGW 2010).

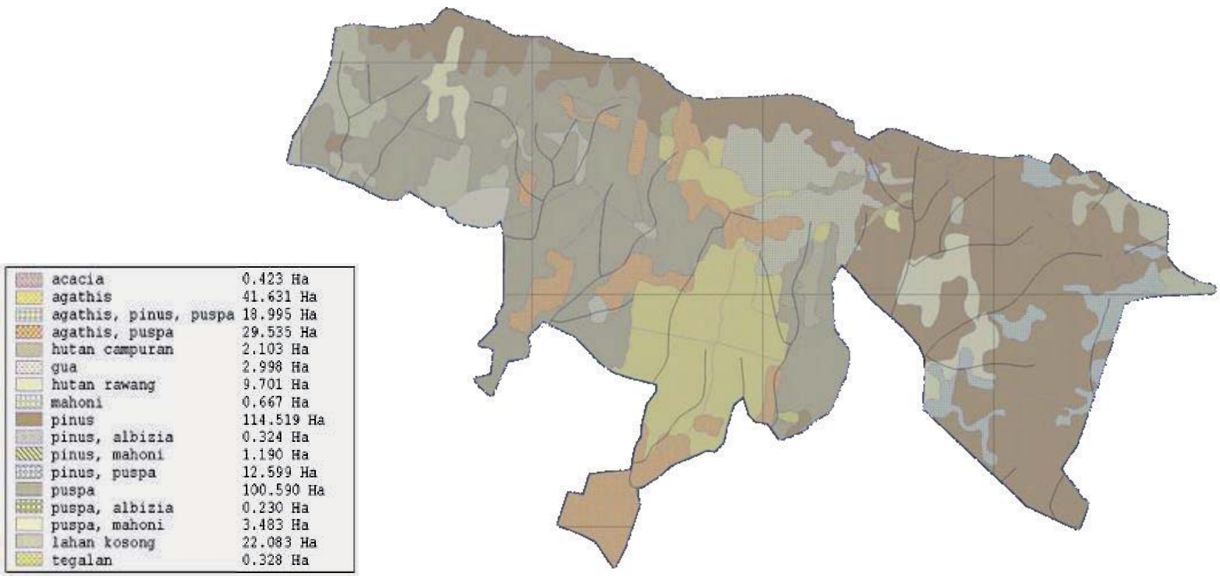

Figure 3. *Forest stands and tree species in GWEF.*

In 2011 the GWEF has 95% of forest cover, and within 191 ha that correspond to the present forest management plant, there are different forest types such as pure pine, agathis, and puspa. There are also mixed stands of the species above and other species like mahogany, sengon, africa wood, rasamala, rose wood, meranti, mangium, american kapok (*Ceiba pentandra*), *Gliricidae sepium*, and other species. The total number of tree species is about 44 including 2 rattan species and 13 bamboo species. The forest stand information is shown at Table 1.

The table describes forest stand structure and size of research area regarding age, number of plots and the amount in which harvesting activities have been applied. The definitions of the five stands are based on the inventory data and stand description. Enrichment planting is still carried out to replace extracted trees or disturbed areas. Furthermore in some forest area 68 species of medicinal shrub have been found, e.g. cardamom (*Curcuma xanthorriza*), and ginger (*Zingiber officinale*), and also agro-forestry e.g. banana (*Musa* sp), coffee (*Coffea robusta*), cassava (*Manihot utilissima*), and pineapple, all vegetations are growing under an open canopy of few trees such as *Swietenia macrophylla*, *Agathis loranthifolia*, *Schima wallichii*, *Maesopsis eminii* and durian (*Durio zibethinus*).

Table 1. *Quantitative stand information.*

Stand	Age (Year)	Area (ha)	Area (%)	Har. Area (Ha)	No.of Plots
Pinus merkusii	40	97.02	50.9	20.23	11
Agathis lorantifolia	60	15.96	8.4	15.96	3
Schima wallichii	40	19.27	10.1	-	6
Mix Plantation	40	42.08	22.1	-	6
Secondary forest	-	16.46	8.6	-	5
Total	-	190.79	100	36.19	31

Source : Georg-August-Universität Goettingen (2010)

Fauna found in the GWEF inlcudes long-tailed macaque (*Macaca fuscicularis*), wild boar (*Sus scrofa*), wild rabbit (*Nesolagus* sp), leopard cat (*Prionailurus bengalenensis*), squirrel (*Callociurus* sp), trenggiling (*Manis javanica*), and civet (*Paradoxurus hermaphroditic*). Some species of reptiles, insects, and birds are also living in this area, and based on survey the total number of bird species is about 52 from 22 familes. .

3. Carbon Sink Activity

One of the management objectives of the GWEF is to maintain and enhance environmental benefits. To achieve this objective, the GWEF managers have been conducting forest rehabilitations on some degraded areas since 2009, implementing carbon sink projects through collaboration with some companies. Such carbon sink projects are voluntary-based schemes in which a company may invest funds in the GWEF for planting and maintaining a number of trees during a certain contract period. Currently, there are five carbon sink projects implemented in the GWEF: The Tanabe Foundation, Toso, Conoco-Phillips, and NYK projects as shown in Table 2 (Executive board of HPGW 2010).

Table 2. *Carbon shink activity.*

Company	Year	Area	Tree species	Total Tree
Tanabe Foundation	2004	10 Ha	Agathis, Puspa, Rasamala, Manglid	-
TOSO Co. Indonesia	2009-2014	10 Ha	Agathis	4,000
TOSO Co. Japan	2010-2014	10 Ha	Pine	6,000
Conoco Philips	2009; 2010	5 Ha	Agathis, Pine, Rasamala	5,000
NYK Logistics	2009	-	-	1,500

Toso's carbon sink project is a 30-year project funded by Toso Company Limited, which is a Japanese company that develops and manufactures various interior products. During the first period of collaboration (2009–2015), the company provided funding to the GWEF for planting and maintaining 4000 *Agathis loranthifolia* trees to increase the forest's carbon stocks. Tree plantings were conducted in 2009 and 2010 with total area of 10 ha (HPGW 2011). For the next 24 years of collaboration, the GWEF has to maintain the planted trees with annual funding provided by the company.

The second carbon sink project was initiated by Conoco-Phillips, an American multinational energy corporation. In 2009 and 2010, this company provided funding to the GWEF for planting 5000 trees (consisting of *Agathis loranthifolia*, *Pinus merkusii*, *Altingia excelsa*, *Arenga pinnata*, and *Coffea robusta*) on a total area of 5 ha. The third carbon sink project was funded by NYK, a Japanese shipping company. In 2009, the company provided funding to the GWEF for planting 1500 trees. This project was not only aimed at increasing carbon stocks of the GWEF, but it also aimed to improve monkey habitats. Therefore, the degraded forest areas of this project were mostly planted with fruit trees that can be used to feed wild monkeys and increase carbon stocks.

All of the carbon sink projects, especially during the planting, were conducted by the GWEF through collaborations with local peoples, students (i.e. university students or junior and senior high school students), or guests who visit the GWEF. Such collaborations provide mutual benefits among parties who are interested in improving social and environmental conditions of the GWEF. For example, tree planting activities would provide additional incomes for local peoples and enhance student's skills.

4. Other activities

The other function of the GWEF includes Field Practice for students to improve their applied knowledge. It is also well situated for pupils from the area to come for educational games and recreations. It can potentially support integrated research by students. Owing to its many natural resources, it is also a centre for research activities, integrated collaborative research has been conducted there to reveal comprehensive information on the location. Another important function for the local community is the provision of energy since most locals depend on fire wood directly from the GWEF – showing the interdependence of people and forests. Last but not least, is has attractive functions as sport and recreation area owing to its proximity to the community. The interaction of people to environment being a sensitive issue, the GWEF has as goal to be the solution.

5. Financial Arrangement

Although the GWEF is a state-owned university forest, the government of Indonesia has not provided fully financial supports for managing the GWEF. Since 2000, the GWEF has been struggling to generate its own incomes to cover all management costs (e.g., production cost, employee salary, workers meal, and facility maintenance cost). The main income of the GWEF comes from resin productions, public services, and carbon sink projects.

Production of pine and agathis resins is the main source of the GWEF's income. In 2010, the GWEF produced resins up to 13.7 ± 4.7 tons/month, consisting of 7.8 ± 2.6 tons/month of pine resins and 5.9 ± 1.9 tons/month of agathis resins. The resin production fluctuated over months due to weather conditions, in which dry seasons (May to August) produced higher resins than rainy seasons as shown at Figure 4. In total, during 2010 the GWEF has produced resins about 165 tons, consisting of 93 tons pine resin and 72 tons agathis resin. The large resin production generated income of about 49% of the total of the GWEF's income in 2010. The resin production does not only provide economic benefits for the GWEF administrators, but it also provides economic benefits to local people who work as resin tappers. Such relatively high incomes from resin productions indicate that the GWEF could survive without cutting the trees.

The unique forest condition of the GWEF has motivated the administrators to develop public service programs. Ecotourism is a promising program implemented in the GWEF, where visitors can enjoy various activities, such as camping, mountain bike tracking, exploring caves, enjoying water springs, and watching wild faunas (e.g., birds and monkeys). In addition, the GWEF with its excellent facilities provides a comfortable place for various training activities conducted by other institutions.

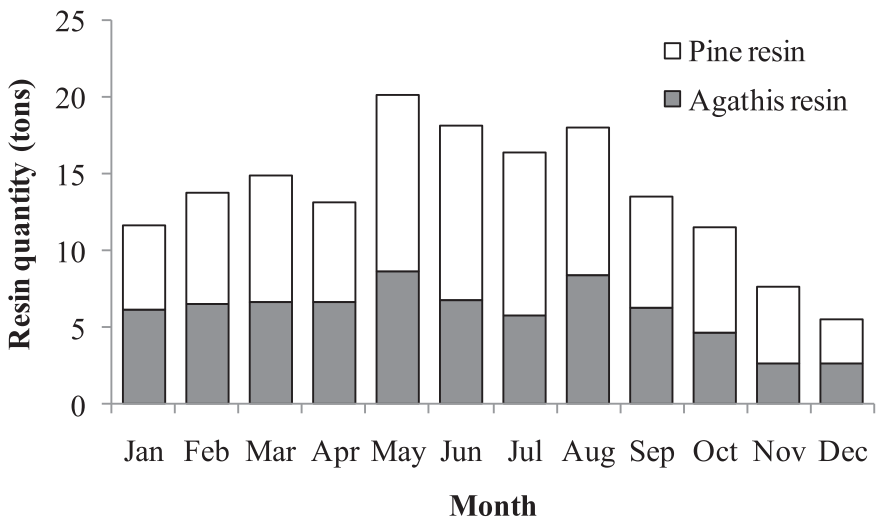

Figure 4. *Resin production of GWEF in 2010.*

6. Remarks

The transformation of bare lands into the close to nature forest of GWEF could indicate a success story of a small scale forest management in Indonesia. The forest is not for wood production but getting income from resin, eco-tourism, carbon-sink, and other activity without destroying the forest. All expenses can be covered with these activities without extracting the tree or wood, and this method can be applied to a similar forest stand.

7. Aknowledgement

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The Role of Deforestation and Afforestation for the Global Carbon Sequestration

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Abstract

Forests play a major role in carbon binding to reduce anthropogenic green house gases particularly in contemplation of global warming. But currently the forest area is declining enormously in most areas worldwide because of land use changes and an increasing demand for wood, even though the newest global forest assessment on the base of a remote sensing survey showed a much higher afforestation and reforestation rate than previously estimated. There are big differences in the forest land change balance in the different regions of the world; particularly in the tropics the loss of forests remains dramatic. Additionally, the frequencies of forest fires and pest outbreaks have increased. In consequence, these forests changed from carbon sink to carbon sources and emit extra greenhouse gases. Hence, it is an important challenge for forestry to develop efficient adaptation strategies for climate change to prevent ongoing decline of forest ecosystems. In summary, there are two main prospects of forestal activities reducing the greenhouse effects: (1) Reduction of land use change, mainly no deforestation and degradation (source aspect), (2) New sequestration potential by afforestation and reforestation (sink aspect). High hopes are placed in the second major solution strategy, using forest or silvicultural instruments: carbon sequestration through afforestation activities. But to achieve an even carbon balance it will be necessary to bind some 4-5 billion tons of carbon and therefore about 4 billion hectares have to be afforestated. This is an area that roughly corresponds to the current forest area of the earth, showing how unrealistic the implementation of such a claim is.

1. The global carbon problem

The so-called greenhouse effect is caused by greenhouse gases. Carbon dioxide, which is one of them, however, accounts for the highest share of the global warming by far. Therefore it is important to consider the global carbon cycle: There are three major carbon storages: the atmosphere at about 750 Gt C, the terrestrial carbon pool consisting of about 600 Gt in the biosphere (especially forests) and 1500 Gt in the pedosphere (soils) and finally the oceans with more than 39 000 Gt. From this huge amount of carbon stored in the water only a very small part is located in the superficial layers and thus has the possibility to exchange gas with the adjacent atmosphere.

These three major carbon reservoirs are in a giant circle with each other: Plants absorb carbon in the form of CO_2 and thereby produce biomass, but they also respire CO_2. In a later life phase of forests, when the respiration of living plants and the decay of dead biomass are increasing, the balance of carbon uptake and release can become lost. However, during the decay phase woods can even act as carbon sources. Worldwide, the exchange of carbon between the atmosphere on the one hand and the biosphere and pedosphere on the other hand is about 100 Gt of carbon per year in both directions.

The amount of carbon that circulates in the second large loop between the atmosphere and surface water of the oceans is of a similar magnitude. All these exchanges with huge amounts of carbon circulating between the three main carbon pools don't play a major role in the current climate change issue since these processes are balanced and are therefore in a state of equilibrium. The main problems, in relation with the mentioned large flows, are comparatively small disturbances of the carbon cycle, at a magnitude of at least 9 Gt/year. Such forwarded disorders, leading to a unilateral increase of CO_2 in the atmosphere, can derive of natural origins like volcanic eruptions for instance. In recent decades, however, it are overwhelmingly anthropogenic causes, which can be held responsible for the increase of CO_2 in the atmosphere. Even in the early decades of the 20th century, when the amount of additional CO_2 emitted into the atmosphere was less than 2 Gt, both the combustion of fossil fuels and land use change (deforestation) were to blame in roughly equal parts. From the middle of the last century, there is a dramatic increase in the share of emissions, which are caused by burning fossil fuels.

Today, the proportion of the total anthropogenic carbon emissions is more than 80%. Overall, the global carbon cycle, which naturally was in equilibrium, is additionally burdened by an annual amount, currently between 9 and 10 Gt. This amount must first be absorbed by the atmosphere, which finally results in an increasing CO_2 concentration measured at around 1 ppm / year. In consequence the greenhouse effect, i.e. the increased reflection of long-wave terrestrial radiation, is growing constantly.

2. Conceivable solutions for the problem

Which global solutions are possible for this problem? Considering first the possibilities that aim to turn the screw on carbon sources (discharge side), the most effective measure by far would be the reduction of emission from the combustion of fossil fuels. This without a doubt is a major political challenge. Although partial success has been achieved and there is hope for more, too much optimism here is not realistic. The other option on the causer side is a reduction of carbon emissions derived from land use change which constitutes a direct result of deforestation and degradation. At this point it is necessary to analyze the role of forestry in the context of the global carbon cycle.

Possible solutions are also conceivable on the receiving side (carbon sink). A sizeable amount of carbon from the atmosphere can be absorbed by the oceans, even if the absorption capacity decreases with the increasing temperature. In cybernetics such a reinforcing effect is referred as "positive feedback".

The second possible solution on the receiving side (sink) is the increased carbon sequestration through biomass production. And above all, forestry measures to solve this problem are quite possible and are requested from many sides. In this context, mainly the role of afforestations and reforestations are in discussion.

There are two main prospects of forestal activities to reduce the greenhouse effects:

1. Reduction of land use change, mainly meaning no deforestation and degradation (source aspect). "Deforestation" can be defined as the removal of forest cover to an extent that allows for alternative land use such as pasture, urban use, logging purposes. Deforestation is the biggest single cause of land degradation, followed by agricultural activities and overexploitation of vegetation (UNEP). Besides shifting cultivation, national settlement programs, forest exploitation for firewood, timber, mining and energy production, deforestation is also caused by ranching activities. This conversion of forested areas to non-forested land can result in arid land and wastelands. Deforestation is the most important factor for increasing soil erosion the worldwide extension of which is estimated to be two billion hectares (Oldemann et al. 1991). The definition of "degradation" commonly refers to reductions in the productive capacity of the forest (from closed to open forest), which negatively affect the stand or soil and, in particular, lower the biological productivity capacity and diversity (changes in species composition).
2. New sequestration potential by afforestation and reforestation and increase of timber stock in existing forests (sink aspect). "Afforestation" is defined as the establishment of forest plantations in areas not previously forested: "Reforestation" (or reafforestion) is the establishment of forests (through planting, seeding or other means) after a temporary loss of the forest cover. In addition, natural expansion of forests and wooded land is another possible way for new carbon sequestration. This form refers to the expansion of forest through natural succession on previously non-forested land, usually abandoned farmland.

3. Forest land change on a global level

The forest cover of the earth was about 6 billion hectares before human impact. According to the forest inventory of the UN Food and Agriculture Organization (FAO) in 2000, the current forest area is about 4 billion hectares; this is 30% of the ice free land surface of the earth. 95% of this area are natural forests, 5% are forest plantations. Almost 70% of all forest land is concentrated in ten countries. 47% of the global forests are tropical forests, 9% belong to the subtropical zone, 11% are temperate and 33% boreal forests.

In the second half of the 20^{th} century, from 1960 to 1990, about 450 million hectares of tropical forests disappeared. During this thirty year period, tropical forests in Asia were reduced by 30% and in Africa and Latin America by 18% each. In the 1990s, the world wide net loss of the forest area was dramatic with more than 8.3 Million hectares per year (Tab. 1).

In the following period from 2000 to 2005, the annual loss with less than 5 Million hectares gave hope for a changing trend. But from 2006 to 2010 the annual losses were increasing again to more than 5.6 Million hectares. During the last two decades the forests of the world have changed their area from more than 4.168 billion to 4.033 billion hectares. The total loss of 135 Million hectares corresponds nearby to the forest land of the Australian continent.

Table 1. *Forest land change since 1990, by continents and subcontinents (FAO 2010, modified).*

Region	N of countries		Forest land change (x 10^3 ha yr^{-1})			Forest land change (% yr^{-1})			remaining forest area 2010 (x10^3 ha)
	total	with neg. trend	1990 - 2000	2000 - 2005	2005 - 2010	1990 - 2000	2000 - 2005	2005 - 2010	
Africa	**58**	**42**	**-4067**	**-3419**	**-3410**	**-0.56**	**-0.49**	**-0.50**	**674419**
E + S	25	19	-1841	-1845	-1832	-0.62	-0.65	-0.67	267517
N	8	3	-590	-41	-41	-0.72	-0.05	-0.05	78814
W+ Central	25	20	-1637	-1533	-1536	-0.46	-0.45	-0.46	328088
Asia	**48**	**19**	**-595**	**2777**	**1693**	**-0,10**	**+0.48**	**+0.29**	**592512**
E	5	3	1762	3005	2557	+0.89	+1.29	+1.04	254626
S+SE	18	11	-2428	-363	-991	-0.77	-0.12	-0.33	294373
W+Central	25	5	72	135	127	+0.17	+0.32	+0.29	43513
Austr.+Oceania	**24**	**7**	**-36**	**-327**	**-1072**	**-0.02**	**-0.13**	**-0.55**	**191384**
N-America	4	1	32	148	228	0	+0.02	+0.03	678961
Central America	7	6	-374	-247	-249	-1.56	-1.15	-1.23	19499
Caribbean	26	7	53	59	41	+0.87	+0.90	+0.60	6933
S-America	13	9	-4213	-4413	-3581	-0.45	-0.49	-0,41	864351
Europe	**49**	**2**	**877**	**582**	**770**	**+0.09**	**+0.06**	**+0.08**	**1005001**
World			**-8323**	**-4841**	**-5581**	**-0.20**	**-0.12**	**-0.14**	**4033060**

There are big differences in the different parts of the world (Tab. 1). All parts of Africa – except North-Africa with a relative low forest cover - show no significant trend of improvement during the observed period. From a total number of 58 African countries 42 show a negative trend that means there was a significant loss of forest land during the last years. The relative forest land change remains very high at nearly 0.5% per year. A similar situation can be observed in South and Central America. Particularly the seven countries of Central America (except Costa Rica) show extremely high relative losses of forest land: The result of an annual decrease between 1 and 2% is that the forest area has been diminished by nearby 25% during only 20 years! Against the general worldwide trend that the intensity of deforestation and degradation is improving, Australia shows an alarming development in the opposite direction: During the 1990s an average net loss of 36000 ha per year was recorded, between 2000 und 2005 the speed of destruction was 9 times higher and experienced a 25-fold increase during the following five-year period!

Table 2. *List of the countries with the largest loss of forest area during the last 20 years (ranked by absolute forest area).*

Country		Forest area 2010	Forest land change 1990-2010		
		(x 10^3 ha)	(x 10^3 ha)	(x10^3 ha/yr)	(%)
1	Brazil	519522	**-55317**	**-2766**	-10
2	Indonesia	94432	**-24113**	**-1206**	-20
3	Nigeria	9041	**-8193**	**-410**	-48
4	Tanzania	33428	**-8067**	**-403**	-19
5	Myanmar	31773	**-7445**	**-372**	-19

In spite of the general trend of a slight improvement of deforestation and degradation, there are countries in almost all parts of the world where the losses of forests are dramatic. Table 2 lists the top five in terms of absolute deforestation area. Since 1990, only Brazil and Indonesia have already lost forest land of nearby 80 Million hectares together, which corresponds to the total land area of Sweden, Norway and Denmark combined. Together, all top five countries have lost a forest area of more than 100 Million ha within this 20 year period.

A view on the worst deforestation rate, the relative loss of forests for single countries, leads to another ranking and shows the dramatic development for some countries (Tab. 3). In Honduras, Nicaragua, Zimbabwe and Ecuador the forests have been reduced by about a third of their area twenty years ago. Nigeria on the first position of the negative ranking list has lost half of its forests during the last two decades.

Table 3. *List of the countries with the highest deforestation rate during the last 20 years (ranked by relative losses of the forest area).*

Country		Forest area 2010	Forest land change 1990-2010		
		(x 10^3 ha)	(x 10^3 ha)	(x 10^3 ha/yr)	(%)
1	Nigeria	9041	-8193	-410	**-48**
2	Honduras	5192	-2944	-147	**-36**
3	Nicaragua	3114	-1400	-70	**-31**
4	Zimbabwe	15624	-6540	-327	**-30**
5	Ecuador	9866	-3951	-198	**-29**

As a result of these tremendous deforestation processes, often followed by degradation, the global carbon stocks stored in wood biomass decreased by 10.4 Gt to an amount of 289 Gt in the past twenty years from 1990 to 2010 (Fig. 1).This trend is particularly dramatic in South and Central America, Africa and Asia. In Europe and North America a slight upward trend of carbon stock in forest biomass can be observed

All these demonstrated developments are based on the assessment data from the UN Food and Agriculture Organization (FAO), on the basis of a compilation of country reports that used a wide variety of sources (FAO 2010). In November 2011 the FAO has provided a new view of changes in the world's forests between 1990 and 2005 which are based on high-resolution satellite data. This remote sensing survey was based on a single source of data for all three points in time — 1990, 2000 and 2005 — and used the same input data and methodology for all countries.

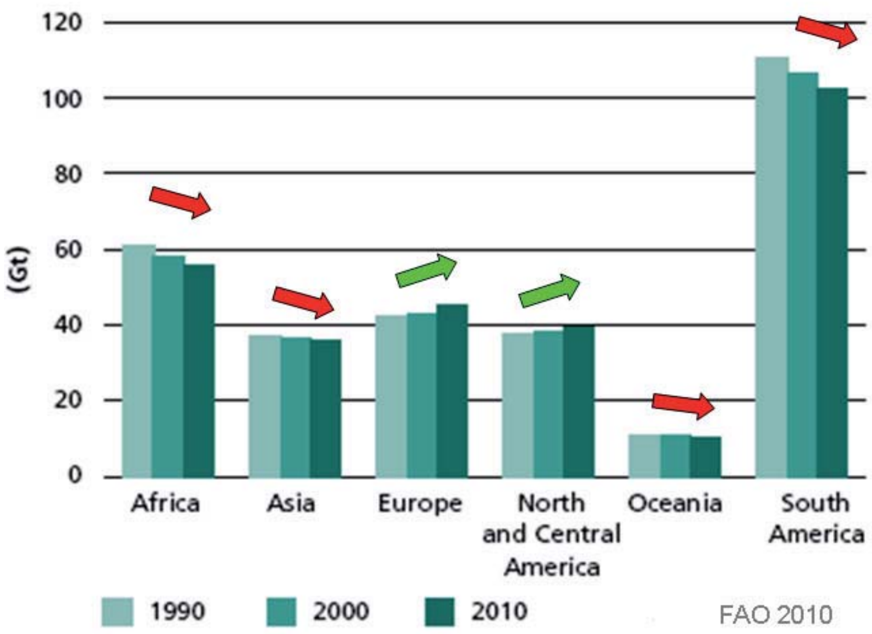

Figure 1. *Trends in carbon stocks in forest living biomass by region 1990 – 2010 (from FAO).*

In comparison to the traditional data from the Global Forest Resources Assessment 2010, the results differ in some aspects: consistent with previous estimates is only the rate of world deforestation averaged 14.5 million hectares per year between 1990 and 2005. The net loss of forest area, however, was not as great as previously believed, since gains in forest areas are larger than previously estimated. Afforestation, reforestation or natural expansion amount to 9.6 million hectares per year. Hence, there is an average forest net loss of 4.9 million hectares of forest per year over the 15-year period, or nearly 10 hectares per minute.

4. Arguments for plantations

50% of the world‘s natural forest is not available for use (Fenning and Gershenzon 2002). In the face of the dramatically increasing world population there is a strongly increasing demand for wood, even if the anticipated requirement per person will not change or decrease. In fact, the increase of wood demand seems to happen at a higher rate than the population inrease. Actually, Division of United Nations says that world population has increased by 1.3 % per year. The global demand for wood, however, is increasing by 1.7% yr^{-1} (FAO 2000). In the developing countries where wood is the most important energy source, plantations shall provide firewood. Over 50 % of world’s wood is used as fuel (fire wood and charcoal fuel), and more than 80 % of it is used in developing countries which tends to increase. For about 3 billion people wood is the most important energy source for cooking and heating. 80% of the world population does not dispose of the amount of paper that is regarded as necessary in order to the basic needs in reading and communication. This lack of paper is a serious threat to the efficiency of educational programs in developing countries (Gardner-Outlaw 1999).

In the developed countries planting activities are mainly done in order to provide timber and wood pulp. According to the FAO inventory, in 2000, 35% of the industrial roundwood was from plantation forest and is expected to be increased by 44% in 2020 (FAO 2000). In countries where the pressure on more or less natural forest by overexploitation is particularly high, plantations can play an important role to reduce this form of ecological mismanagement (Brown 2000, Evans and Turnbull 2004, Savill et al. 1997).

More and more environmental arguments are of particular relevance for afforestation activities: to prevent soil erosion and reduce flooding, to stabilize slopes, to act as windbreak, to prevent land degradation and desertification, to increase biodiversity of the bare land and to improve the global problem of climate change by carbon sequestration.

5. Afforestation "hot spots"

The global trend of forest plantation is increasing rapidly. By 2000, the forest plantation area was estimated to be 187 million hectares worldwide which is about 5% of the total forest area. A view on the balance of forest land change on a large scale (Tab. 1) shows that only four regions worldwide have a positive trend: Europe, North-America, Central- and West-Asia and most of all East-Asia. This impressive development in East-Asia is mainly the result of afforestations and reforestations in North-China. Here, during the last twenty years, the forest area has increased by nearly 50 million hectares which is an annual net change of about 2.5 Million hectares. The strongest activities could be observed between 2000 und 2005 (Tab. 5).

Table 5. *List of the countries with the strongest afforestation activities during the last 20 years (ranked by absolute afforested area).*

Country		Forest area 2010	Forest land change 1990-2010		
		($x\ 10^3$ ha)	($x\ 10^3$ ha)	($x\ 10^3$ ha/yr)	(%)
1	China	206861	**49720**	**2486**	132
2	USA	304022	**7687**	**384**	103
3	India	68434	**4495**	**225**	107
4	Viet Nam	13797	**4434**	**222**	147
5	Spain	18173	**4355**	**218**	132

The look on the countries with the strongest relative increase of forest land is not very helpful because countries with an extremely small forest area in the beginning can change the portion extraordinary. Number one of all about 200 countries is Island which started in 1990 with only 9000 ha of forest land (mainly birch) and increased the forest area by afforestations of about 1000 ha per year to 333% (Tab. 6). This is without doubt an impressive development for the naturally unforested country, but it remains unimportant for the global perspective.

Table 6. *List of the countries with the strongest afforestation activities during the last 20 years (ranked by relative increase of the forest area).*

Country		Forest area 2010 (x 10^3 ha)	Forest land change 1990-2010 (x 10^3 ha)	(x 10^3 ha/yr)	(%)
1	Iceland	30	21	1	**333**
2	Uruguay	1744	824	41	**190**
3	Egypt	70	26	1	**159**
4	China	206861	49720	2486	**132**
5	Spain	18173	4355	218	**132**

6. Can forestry measures compensate the man-made carbon input at the global level?

In order to achieve this ambitious goal it would be necessary to bind about 9 billion tons of carbon each year. At the best, half of the carbon emissions can be stored in the oceans so that at the least 4 billion tons remain in the atmosphere. A newly established forest can achieve an average growth potential of 4 m³ per year per hectare. This corresponds to an overall tree species average specific weight of 500 kg dry mass /m³ and an average carbon content of 50 % of each ton of carbon. If we assume this - and of course, under favorable site conditions plantation may have significantly higher growth rates - a carbon sequestration of up to 8 tons per ha (Schlamadinger and Karjalainen 2000) can be achieved. As an average however, these expectations are not realistic.

7. Conclusions

How can forestry help to achieve an effective impact on the reduction of greenhouse gases by storing carbon in biomass? The promotion and application of sustainable management concepts is a necessary prerequisite. This is less a problem of silvicultural techniques, but of political, socio-economic challenges. The increasingly observed problematic adaptation of forests to changing environmental conditions makes clear how important the conservation of existing forest ecosystems is. In this context, the efforts for effective forest protection will be intensified. The expectations addressed at forestry in general and in particular to silviculture, to make a significant contribution to the solution of the problem, must be viewed with caution. Although in recent years considerable efforts have been made regionally, the forestry sector cannot afford a global solution on its own.

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Technical Framework of Plantation Management towards Increasing Carbon stocks and Multi-functional Forest Service in China[3]

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Abstract

Forest as the main carbon sink plays an important role in carbon sequestration and climate-change mitigation. With the emphasis in forestry strategy shifting from timber production to ecological rehabilitation in China, plantation management is facing the challenge of refinement and adjustment. It is widely recognized that forest should be managed to serve economic, social and ecological functions. Meeting these multi-functional demands includes carbon sequestration and climate-change mitigation. Multi-functional forest management means to manage plantations in a sustainable way without separating their products and service functions. Based on our recent study and experiments in China, a summary and introduction is given in this paper to a technical framework of plantation management in a multi-functional way which is ecologically affordable. The framework is then expanded with three general principles as consideration guidelines, four evaluation dimensions with quantitative technical indicators for understanding forest situation, and five operation types for designing and implementing a silvicultural plan aimed at sustainable management of stand levels.

Keywords: Carbon sequestration, climate change mitigation, multi-function forest management, close-to-natural silviculture, stand operation plan, plantation transformation.

1. Introduction

REDD+ is the specific expression which describes that the target of forestry of the world is in the process of transformation from being dominated by timber utilization to focussing mainly on the sustainable management of environmental services. Similarly, Chinese forestry has also experienced the process from only focusing on timber production to protecting the environment and giving consideration to a balance between economic and ecological benefits (Lu and Gan 2002).

China signed the *Kyoto Protocol* in 1998 and it came into power in 2005 (Yang 2002) China has promised that, in reference to the base of 2005, its forest area will increase by 40 million hectares till 2020, and the forest stock will be increased in volume by 1.3 billion cubic meters. This promise has been expressed in the twelfth five-year's plan of the Chinese national

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development program (Liu 2011) In the United Nations Framework Convention on Climate Change in Copenhagen 2010, Chinese State Council Premier Wen Jiabao stated that China would continue to make positive contributions to carbon mitigation and the combating of climate change (Liu 2011) Furthermore, in his speech at the First APEC Meeting of Ministers Responsible for Forestry this year, the Chinese president Hu Jintao expressed that as forest is the biggest carbon sink in the world, increasing forest resource and decreasing deforestation as well as degradation is an effective way to fight against climate change. He proposed that multi-functional forest management (MFFM) should be considered as an international strategy. Multi-functional forest management aims at achieving a harmonious compromise between different forest functions. On the one hand forest should provide economic goods for society, on the other hand forest should also be able play its ecological service functions such as biodiversity conservation, carbon sequestration and combating desertification, to maintain regional and global ecological security. All of these points shown that Chinese forestry is changing towards multi-functional forest management, and studies on the field will contribute to both Chinese and global sustainable development.

2. Impact analysis of multi-functional management forest on carbon sequestration

Forest is the main carbon sink for climate change mitigation. Besides the amount of forest resource, there are other variables which influence the attributes of a forest's potential for carbon sequestration, such as tree species, growth rate, horizontal and vertical structure, proportion of heartwood/sapwood of trees, tree and stand age, sprout ability etc. (Gorte 2009, Zhang and Peng 2008, Xie and Wang 2011). By arranging and regulating those forest factors above reasonably, multi-functional forest management will increase carbon sequestration and thereby contribute to climate change mitigation. Multi-functional forest management is supposed to be an effective approach to maximize forest carbon sequestration (Sedjo 2011).

It is obvious that the increasing afforestation area can affect the ability of forest carbon absorption and sequestration, but forest area in most regions is limited to a certain scale. Alternatively, by prolonging cutting rotation with 2-3 thinning operations in between, or constructing uneven-aged stands with higher harvest diameters and longer cutting circles, will clearly increase the forest stock and then contribute to carbon sequestration. This is a positive effect on carbon absorption and sequestration that can be obtained by way of multi-functional forest management.

The traditional single species plantation use usually introduced fast growing tree species, but these often belong to lower C-density biomass tree species in comparison with hardwood or most native tree species which are generally used, at least partly, in multi-functional silviculture design. Furthermore, multi-functional forest management often requires a multi-species composition (Spiecker 2006), sometimes a conifer-broadleaf mixed stand structure, and application of large amounts of native species with high C-density biomass to construct a sound forest structure. Such uneven-aged forests are structurally more steady and sustainable, and the soil will be enriched due to the increased leaf-fall humus. Its water conservation ability will be also improved. It is obvious that by following a multi-functional forest management regime, forest quality and functions will be enhanced at the whole ecosystem level and result in a high resiliency to all disturbances, rather than only improving the ability of carbon sequestration.

As in other regions in the world, there are many cases of forest degradation in China. The degraded forest has many specific features amongst which low growth rate is the basic one. Multi-functional forest management regulates the species composition by increasing site condition suitable for self-fertilizing trees species, by forming a harmonious interaction mechanisms between the species and finally by realizing a productive and stable forest ecosystem. As a result, site/biotope based condition will be greatly improved and hence lead to a higher growth rate which consequently contributes to decreasing carbon emission (Knock and Plusczyk 2001, Shao 1994, Felton, Felton and Wood 2006).

One of the emphases of multi-function forest management design and execution is to facilitate the natural regeneration in order to realize continual forest coverage. In comparison with the new afforestation activities in a rotation management system, this is an effective way to regenerate the forest and emission reductions contribute to mitigate climate change.

The forests with a higher proportion of heartwood part due to a longer growing period can absorb more carbon than the forest with the same tree species composition but short cutting circle, due to a longer growing period bbecause of which the heartwood has a higher carbon density than the sapwood part (Wang and Feng 2001). Therefore, multi-functional forest management with the target of cultivating large diameter timber of larger diameter can consequently increase carbon absorption and sequestration.

In conclusion, the comprehensive effect of carbon sequestration and climate change mitigation tends to be higher in the multi-functional forest management regime. Experiences and methods should be summarized to support an enlarged implementation, especially to transform the widely existing single-species plantations into multi-structural close-to natural forests, to produce service-functions for regional and global sustainable economic and environmental development.

3. Technical Framework of Plantation Management towards Multi-functional Service Development

Multi-functional forest management and close-to-nature forest management are more or less an expression of the same thing from different angles and can be categorized into the same forest management regime (Lu, Zhang, Lei and Sturm 2006) Multi-functional forest management is focused on the management targets whereas close-to-nature forest management is concerned with technical aspects. The technical framework of plantation close-to-nature forest management under the targets of multi-functional forest utilization has been implemented and explored in China for more than 10 years. The framework consists of three general principles as consideration guidelines, four evaluation dimensions with quantitative technical indicators for understanding forest situation, and five operation types for designing and implementing a silvicultural plan (Lu 2006, Shao 2003) and is aimed at sustainable forest management on stand level (Ammon 1937, Assmann 1950).

3.1 The three principles of the technical framework

(1) Principle of bio-rationalization

Through the question "what is a forest?" and the corresponding answer, the first principle of bio-rationalization is proposed. The principle contains the consideration of biodiversity presented by tree species diversity, soil development processes and the selection of indigenous tree species as limitation in a forest management plan.

(2) Principle of hiring the force of natural automation

Through the question "what need not be done?" and the corresponding answer, the second principle is expressed. The features of a forest as a self-organized ecosystem with self-fertilizing ability could be used in forest management to create forests more stable to biological, physical and human disturbance.

(3) Principle of nature response promotion

Through the question "why do we do it in such a way?" and the corresponding answer, the third principle of nature response promotion is proposed. This principle emphasizes that each management operation we conducted in forests should aim at a certain improvement and get a positive response from nature; else it is not worth doing.

3.2 Four evaluation dimensions with quantitative technical indicators

Based on the three management principles, we summarize the main factors which influence our understanding of the forest situation into four orderly-dimensions with quantitative technical indicators.

(1) The first dimension: succession process of forest development

Five stages of forest natural succession are clarified according to the natural and scientific characteristics of forest in combination with the operation feasibility of close-to-nature forest management, which are:

1) Forest establishment stage: it ranges from the establishment of a plantation to the closing of the canopy, usually to form a single layer canopy with pioneer tree species. *2) Competition and differentiation stage:* it refers to the stage in which the height growth of all individuals begins and causes a rapid development of the dominant horizon. *3) Dominant selection stage:* the relationship among individuals has changed from positive competition to repulsion and the differentiation amongst individuals begins to manifest itself by the death of some weak trees. The height variation is obvious and individuals with high vitality dominate the main canopy horizon. Dominant and suppressed individuals can be easily distinguished and the shade-tolerant (climax) individuals have a large degree of natural regeneration. *4) Close-to-nature (pre-mature) stage:* the variation of individual height tends to stop and the shade-tolerant species start to appear by nature regeneration in the dominant horizon of the stands. The stand shows the characteristic of mixture of pioneer and climax species. This stage is considered to the beginning status of close-to-nature forest. *5) Natural permanent forest stage (mature forest):* This stage starts when the dominant trees meet maturity standards featured with the attainment of the target diameter by some individuals.

(2) The second dimension: character of forest canopy structure

The current canopy structure of the stand can be divided into the following four types: 1) pure or mixed forest composed of indigenous broadleaf tree species; 2) mixed conifer-broadleaf tree species; 3) pure coniferous species; 4) forests with degraded canopy due to loss of growing ability of most individuals. No matter at which succession stage the current forest is, the canopy structure and tree species are the most important factors determining forest management activities. For example, for canopy structure type 1 till stage 3, target tree management systems can be directly applied. For canopy structure type 4, the main management activity is to promote the regeneration.

(3) The third dimension: species attributes of light competition and silvicultural grouping

According to the biological and ecological characteristics, the dominant or target tree species in a region can be sequentially classified into 5 types: typical pioneer tree species, long-life pioneer tree species, opportunist tree species, sub-climax tree species, and climax tree species. The meaning of this classification is that tree species in the later sequence can be planted and survive under the former ones but the opposite sequence is not possible.

The competition for light of a tree species varies with forest community types, therefore the division of this sequence may be relative corresponding to the area and community. Tree species in the canopy horizon and for replanting should be studied and their characteristics of light should be clear in order to guarantee the scientific forest management design and the long-term management results.

(4) The fourth dimension: identifying the individual differentiation and competition

Variation among individuals always exists regardless of succession stages, stand structure and dominant tree species. We can make use of this variation so as to achieve the best management effects. The rationality of target tree management systems is that it takes the variation of individuals into consideration and then advances the corresponding management operation systems. According to the variation and competition of individuals, individual trees can be classified as four different types:

(1) *Target tree:* the dominant individuals, or in the dominant horizon which have a very good living status. The pole is straight and long without any disease and insect infection. Especially, there should be no damage at the base of the tree.

(2) *Competition tree:* the individual which affects the growth of the target trees and should be harvested and used. As the target of harvesting, it should also be the tree with good growth, contributing to timber production during the management.
(3) *Special target tree:* in order to enhance the mixture of tree species, keep stand structure and biodiversity, some tree species should be protected as special target trees.
(4) *Ordinary tree:* in special condition during the tending operations, an ordinary tree can be harvest in a proper amount to meet the timber demand.

3.3 The five operation types in a multi-functional silvicultural plan

Aiming at the specific stand needing to be transformed, investigation would be conducted to get necessary information for the evaluation of the stand situation according to the 4 orderly-dimensions with quantitative technical indicators. After estimating the concrete situation of the forest such as the development stage, structure type, species composition and possible option, stand quality and individual relationship, the specific silvicultural operation plan can be designed. Generally, there are five operation types or contents that should be included in the plan.

(1) *The design of targeted forest development type (FDT):* According to the forest characteristics and stand site condition etc., the targeted forest form is designed to describe possible success progress, sustainable stocking level and tree species composition, way of harvest and regeneration, target diameter of each species, target timber class and service functions. However, the forest development type is a summary about the stand future, and till now there is no standard method to do this. However, estimation and description of such stand parameters mentioned above are the main part of a FDT (Lu 2006, Larsen and Nielsen 2007).
(2) *Individual classification and stand tending or harvest operation:* According to the current succession stage, determine if the harvest operation or thinning operation should be conducted, and identify/mark all target trees in the stand, then cutting its competition-trees. Measures to accelerate the target trees are also included in the operation.
(3) *Protection and accelerating the natural regeneration:* This design contains the work of identification and marking the potential high quality seedlings in the regeneration layer. All possible measures to protect and improve its continual growth are welcomed in the design, these can be for example cutting the bush around the regeneration seedlings, thinning and fixing one vital seedling, and digging a pit on its rooting position to cumulate water and fertilizer for seedlings, etc.
(4) *Enrichment planting under-canopy:* When the plantation does not get enough natural regeneration, both in quality and quantity, enrichment planting should be designed. If the forest has already clustered regeneration, only a clustered replanting where natural regeneration is absent would be done.
(5) *Life-cycle management plan (LCMP):* This is a series of operations designed to tell the subsequent people how to follow the plan to successfully achieve the original design

of forest development type. Characteristics of the LCMP are to classify the stand growing period and design related activities, not according to the stand age or time, but according to the stand vertical structure, which is given by the dominant tree height, to avoid possible failure of operations due to site condition not reflecting to the stand age.

The three principles, four evaluation dimensions and five operation types mentioned above constitute the systemic framework of a close-to-natural plantation management towards a multi-functional service development, and they are the main contents of the design of silvicultural operating planning in a manner of structured order. The former one decides the allowable operating scale of the next one.

4. Conclusions

The Technical Framework of Plantation Management towards Multi-functional Service Development has been implemented in Guangxi, Hainan ,Shanxi and other provinces in China since 10 years, and achieved some success that clearly improving the quality of the forest as well as service the forest providesd have been clearly improved. Rather than a normal forest model,We realized that multi-functional forests is an abandon of Normal Forest Model, and no more strive for an similar ideal model that does not exist and may never have existed, we favor a more practical restoration target of achieving a healthy forest ecosystem that is a reasonable changed facsimile of a potential or possible natural forest. Furthermore, we do not announce an abolition of plantations, the overall ecosystem health will be changedrather, it means by improving something aspects such aslike the prolongation cutting circle with thinning and enrichment planting of native trees, etc., the overall ecosystem health will changed and may makinges then many existing plantations viable. In 2009 the *Science* did an investigation and said, tThe science behind this multi-functional approach is not novel, but its impact on the restoration of China's forests could be revolutionary (Stoner 2009).

Looking into the future and at the practical economic aspect, we see that in its early implementation stage, multi-functional forest management tends to be losing money and should be partly compensated. Currently, there are some compensation policies and regulations are given to support the public environmental forest on its way to multi-functional forest management in China. We believe that carbon market mechanisms will be a great support and accelerate the development of multi-functional forest management worldwide.

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Assisted migration – epoch making idea or human haughtiness

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Abstract

In this review assisted migration is discussed as a conservation tool. Climate change has a heavy impact on plants. In a restricted range they can react physiologically on changing conditions but many have to evolve or migrate or they will become extinct. Investigations showed that we cannot expect high rates neither in evolution nor in migration. Evolutionary processes can take place in short terms by exception but take thousands of years in general. Migration rates of 100 to 150 km per century have been predicted but 300 to 500 km per century would be necessary. To preserve species that are not able to evolve or migrate fast enough assisted migration is considered as new conservation tool. The debate about assisted migration is mostly based on ecological reasoning. On the one hand assisted migration might prevent biodiversity loss, enhance population fitness, ensure ecosystem services and advance conservation studies. On the other hand assisted migration could lead to invasive species, have negative genetic impacts, move resources to wrong priorities and deal only with species we deem important. Also cultural impacts would be expected. Decision frameworks have been developed that integrate assisted migration in present conservation strategies. These allow decision makers to evaluate every isolated case and manage biodiversity flexibly.

Keywords: assisted migration, biodiversity, climate change, conservation, invasive species

1. Introduction

The climate is doubtlessly changing and the change pushes into everyone's reality. To bring some examples: The blooming season of *Prunus jamasakura* in Japan significantly changed in the early 1900s and steadily advances since 1952 (Menzel and Dose 2005). From 65 investigated bird species between 1971 and 1995 in the United Kingdom 20 species had advanced their date of first clutch by an average of 8.8 days (Crick et al. 1997). *Picea mariana* has increased in height at the tree line in the northern forest-tundra since 1970 (Gamache and Payette 2004). Because of climate change species distribution and composition is also likely to change at a great scale (Parmesan 2006). Species must adapt or migrate or they might become extinct (Aitken et al. 2008). The idea to make more species survive climate change by translocating them to areas where they are probably viable suggests itself. While scientists are still discussing "assisted migration" people already took action (http://torreyaguardians.org/). The Torreya Guardians formed to protect *Torreya taxifolia* from extirpation. The group transported *Torreya taxifolia* from its narrow range in Florida to North Carolina where it has not been prevalent since the Cretaceous.

Loss et al. (2011) define "assisted migration" as "physical relocation of a species to a location outside its existing or historical range that is predicted to be favorable for persistence under future climate projections". Terms like "assisted colonization", "assisted translocation" and "managed relocation" have been used but all mean the same action (Loss et al. 2011).

In Forestry translocation of populations within the species range have also been termed "assisted migration" as it outranges the present practice to use seeds from local proveniences. This kind of "assisted migration" would mainly come into consideration with common and wide-spread species in order to obtain ecosystem health and productivity (Gray et al. 2011).

In this review I present the current state of discussion including a summary about the state of knowledge and the main arguments.

2. Need for assisted migration

Plants react to changing environmental factors. They can for example adapt to different temperatures by lipid positioning in the cell membrane. But physiological mechanisms are restricted by the genetic settings: In species that cannot adapt physiologically evolution has to take place or they have to migrate. Otherwise they will become extinct (Aitken et al. 2008).

Research on genetic changes by evolutionary processes refers to a determined time scale. Evolution in reaction to recent climate change takes place in short terms (<100 years). But the evolutionary mechanisms that are well investigated and the historic record of climate changes are of medium or long term (<10,000 years or <2,000,000 years). We cannot keep track of ongoing evolution in reaction to climate change but there are remarkable observations that could be used for estimations (Bradshaw and McNeilly 1991). Snaydon and Davis (1976), for example, found major evolutionary changes in the grass *Anthoxanthum odoratum* after different environmental conditions for about 110 years (Figure 1).

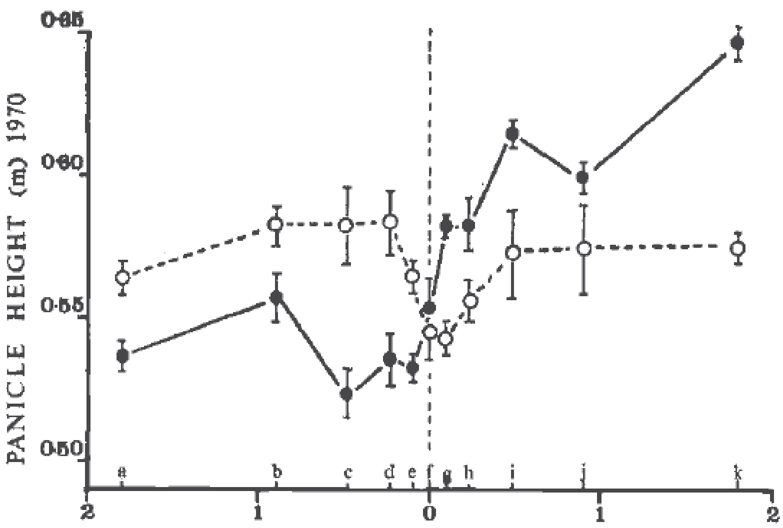

Figure 1. *Panicle height in different distances from the boundary of the two plots. The white dots show height of plants raised from seeds and the black dots raised from tillers. The letters give the mean distance from the boundary in m. a/k: 1.80, b/j: 0.9, c/i: 0.45, d/h: 0.23, e/g: 0.1, f: 0. Figure taken from Snaydon and Davis (1976).*

In the park grass experiment at Rothamsted one part of the area got fertilized with potassium sulfate and ammonium sulfate which decreased the pH on this part of the area. The other part was not fertilized with those two chemicals but received the same treatment in other points. Collecting seeds which were raised in uniform conditions showed that only about 110 years after beginning of the experiment panicle height and yield per plant in close distance to the border (e and g, both <10 cm mean distance) differed significantly. These differences could be found in tillers as well.

However, this example probably remains an exception as species do not generally evolve that fast. Otherwise we would more often be able to find such processes. Most species seem to lack an appropriate variability to the selection factor (Bradshaw and McNeilly 1991). Adaptation rates of forest trees are however promoted by high levels of genetic diversity and gene flow and slowed by long generation times and low mortality of established trees (Kuparinen et al. 2010). Kuparinen et al. (2010) found an evolutionary lag in quantitative genetic individual-based simulations. After 100 years of climate change the genotypic growth period length of *Pinus sylvestris* and *Betula pendula* might lie about 30-40% behind the climatically determined optimum. The gap becomes smaller if a higher mortality of established trees is assumed. Therefore the local demography has to be taken into account. Higher pollen and seed dispersal distances also accelerated genetic adaptation (Kuparinen et al. 2010).

During Quaternary climate change tree species migrated in latitude or elevation as we can reconstruct by pollen records or DNA (Aitken et al. 2008). Changes in distribution are usual so that migration is seen as expected reaction of plants to climate change. In the past migration rates of 20 to 40 km per century were observed. During present climate change, however, migration rates between 300 and 500 km per century are projected to be necessary. (reviewed by Davis and Shaw 2001) Malcolm et al. (2002) estimated possible migration rates required under CO_2-doubled climate using General Circulation Models and Global Vegetation Models. In their results migration rates of ≥ 1,000 m per year were common. For high latitude biomes (excluding tundra) an average of 27- 44% of grid cells had migration rates of ≥1,000 m per year. In tropical biomes high migration rates with ≥1,000 m per year were still calculated for 9-13 % of grid cells (Malcolm et al. 2002). These high migration rates are probably not reachable considering the exceptionally "fast" examples with 100 to 150 km per century (Davis and Shaw 2001). As possible reasons for the slow movement lack of seed sources, barriers to seed dispersal and poor soil conditions are taken into account (Aitken 2008).

High migration rates are considered to be related to founder populations established by long-distance seed dispersal. Pollen flow from neighboring populations might increase the genetic variation and thus, by hard selection, a well adapted new population could arise. Wind pollination, high fecundity and high gene flow conditions for this type of migration and therefore for adapting to rapid environment change (Mimura and Aitken 2007). Differences in flowering phenology between source and recipient population might limit pollen dispersal efficiency (Chmura et al. 2011).

Research on present range shifts in response to climate change has been done but clear results were hardly gained (Aitken 2008). Remarkable results were presented by Walther et al. (2005). They found that the distribution of *Ilex aquifolium* expanded north, parallel to the 0°C-January-isoline. Maybe, planted garden individuals provided opportunities to speed the migration of *Ilex aquifolium* up and enabled the specie to keep pace with climate change (Walther et al. 2005).

3. Practical experience

In garden experiments first insights in the possibilities of assisted migration in forestry could be attained. Gray et al. (2011) used reciprocal transplantations of *Populus tremuloides* to investigate local adaption of tree populations and their performance at different sites. A movement to the most northern region generally implied the same or increased performance relative to local sources. For example the local sources of the Taiga plains were outperformed by the Northern Boreal provenances by a 30% increase in height. In contrast, the translocation from northern to southern sites generally led to lower performance.

Recommendations for reforestation strategies are also gained from ecosystem-based modeling (Gray and Hamann 2011). These models use climate conditions and habitat requirements of individual species' populations. For the boreal forest in Canada, Alberta, genotypes of populations adapted to drier climate than the local are generally proposed for reforestation. However, the translocation of species out of their natural range does not seem to be an important element of Alberta´s forestry sector. Only few habitats for populations of montane regions of the USA are projected to arise in Alberta by climate change. In a modeling effort with 50 western North American tree species, Gray and Hamann (2011) recommend no species for reforestation outside its natural range.

Mueller and Hellmann (2008) investigated the invasive potential of translocated species. For plants, they found a low risk of invasion if species were translocated within one continent. Given the distribution of many plants, intercontinental assisted migration would be possible. Nevertheless, exceptions might appear. For example *Robinia pseudoacacia* got invasive in North America although it is native to the Appalachian uplands (Mueller and Hellmann 2008).

4. Debate

Hewitt et al. (2011) present arguments for and against assisted migration that have been announced in 50 articles about assisted migration in recent years. They found 60% of the articles generally supportive while 20% of the authors were undetermined and another 20% had major concerns or were opposing.

About half of the articles referred to data based on empirical field research, field experiments, simulation modeling, case studies or paleo-reconstruction. The other half used literature review/commentary and interviews.

Regarding the basis for formulated arguments (Figure 2) even more than 70% of the arguments for or against assisted migration were devised from ecological reasoning and literature review.

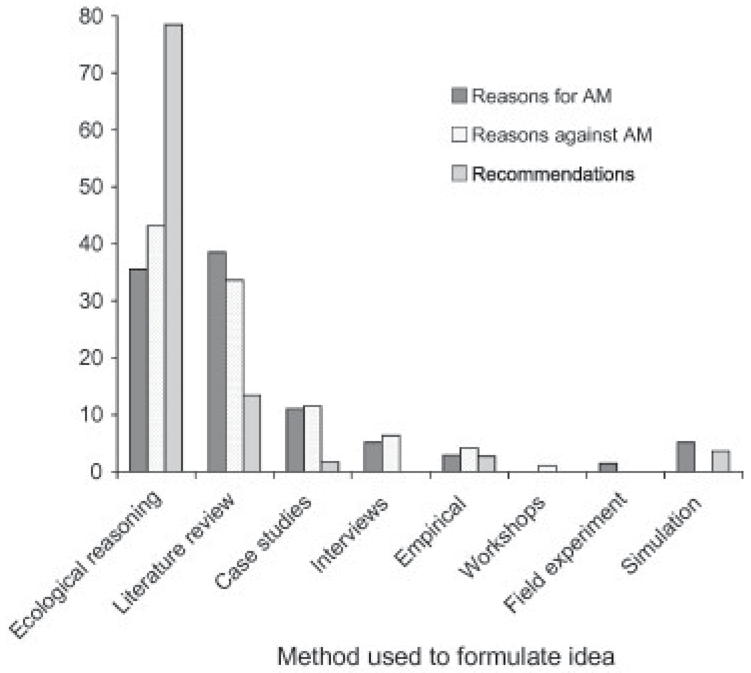

Figure 2. *Methods used to formulate ideas about assisted migration (AM). The numbers are percentages. Figure taken from Hewitt et al. (2011).*

The arguments could be grouped into arguments that support, or reject assisted migration directly because of an impact on species, ecosystems and society. Other arguments were grouped as indirect because they raise further points such as implementation, decision-making tools or logistics (Hewitt et al. 2011).

The main argument for assisted migration is simultaneously the strongest argument against it: protecting biodiversity. The opportunity to save biodiversity by translocating endangered species to probably more sufficient environments is attached to the idea of assisted migration (Table 1).

Table 1. *Arguments for and against assisted migration with direct connection. See also Hewitt et al. (2011).*

Pro	Con
Prevent biodiversity loss	Invasion risks, Irreversibility
Fitness benefits	Genetic impacts
Ecosystem services	Bias to species we deem important
Advance of conservation science	Wrong priority (moving resources)
Culture	Culture

Despite the recipient ecosystem would be affected. The translocated species might become invasive or carry diseases and thus cause the extinction of native species and interrupt native ecosystems (Davidson and Simkanin 2008). Those invasions are irreversible and thus the invasive risk of a species needs to be calculated well. Species that are endangered are often uncommon and might be understudied. This makes it even harder to assess whether a species could be translocated without severe concern (Huang 2008).

Further, more assisted migration might have genetic impacts on closely related species in the recipient community (Loss et al. 2011). Mechanisms like hybridization could be possible. The populations of the recipient region might as well benefit from gene flow however. Long distance dispersal is often limited and populations are highly adapted to local environments. Higher genetic variation might enable populations to cope with climate change (Savolainen et al. 2007).

Ecosystem services could also be ensured by assisted migration if appropriate species are translocated. This includes provisioning services like timber, food and water, but also regulating services like disturbance regulation or remediation (Chapin et al. 2007). The main focus of assisted migration would lie on species we deem important. If the selection would be consistent with natural demands is in question (Hewitt et al. 2011).

Another problem of assisted migration is that resources would probably be moved from present projects. The priorities would change and promising conservation strategies like protected areas or ecosystem restoration would suffer loss of money, support and expertise. Innovative management strategies of productive landscapes could also be weakened if resources were diverted (Fazey and Fischer 2009). Assisted migration could however promote advances in conservation science. A variety of research is possible, for example on impacts of bottleneck events, population modeling or founder effects (Parker 2008).

Arguments for and against assisted migration can also be raised from cultural considerations. Cultural services such as aesthetic and spiritual benefits or opportunities for recreation are provided by forests (Chapin et al. 2007). Arguments of indirect influences and reasons for and against assisted migration can also be found. One point is that there is no other solution for some stakeholders and species. Risk assessment provides an opportunity to manage risks, especially the risk of invasion. There is, however, social and political resistance against the translocation of species. Some of them are referring to financial and logistical constraints. Others are concerned about regulations and the possibility that assisted translocation might legitimize unauthorized translocation (reviewed by Hewitt et al. 2011). However, translocation is already occurring, for example for private gardens (Van der Veken et al. 2008).

5. Conclusions

In science we usually find more questions by investigations than answers. The impacts of assisted migration are not clear and research will take years. Nevertheless, time is running out and we have to decide now if we want assisted migration or not. There are some proposals of integrating conservation strategies that are, in my opinion, a good opportunity to use every management possibility that we have. Nature is very diverse and so should the management be.

Hoegh-Guldberg et al. (2011) developed a decision framework (Figure 3). In face of a specific management situation they offer three questions to arrive at a solution. Those questions refer to the risk of extinction, to the technical possibility of translocation and to the relation of benefits and costs. Dependent on the answers, they recommend different conservation strategies that include landscape connectivity as well as ex situ conservation and assisted migration. From my point of view, deciding newly from situation to situation is the only possibility to mitigate climate change impacts at all.

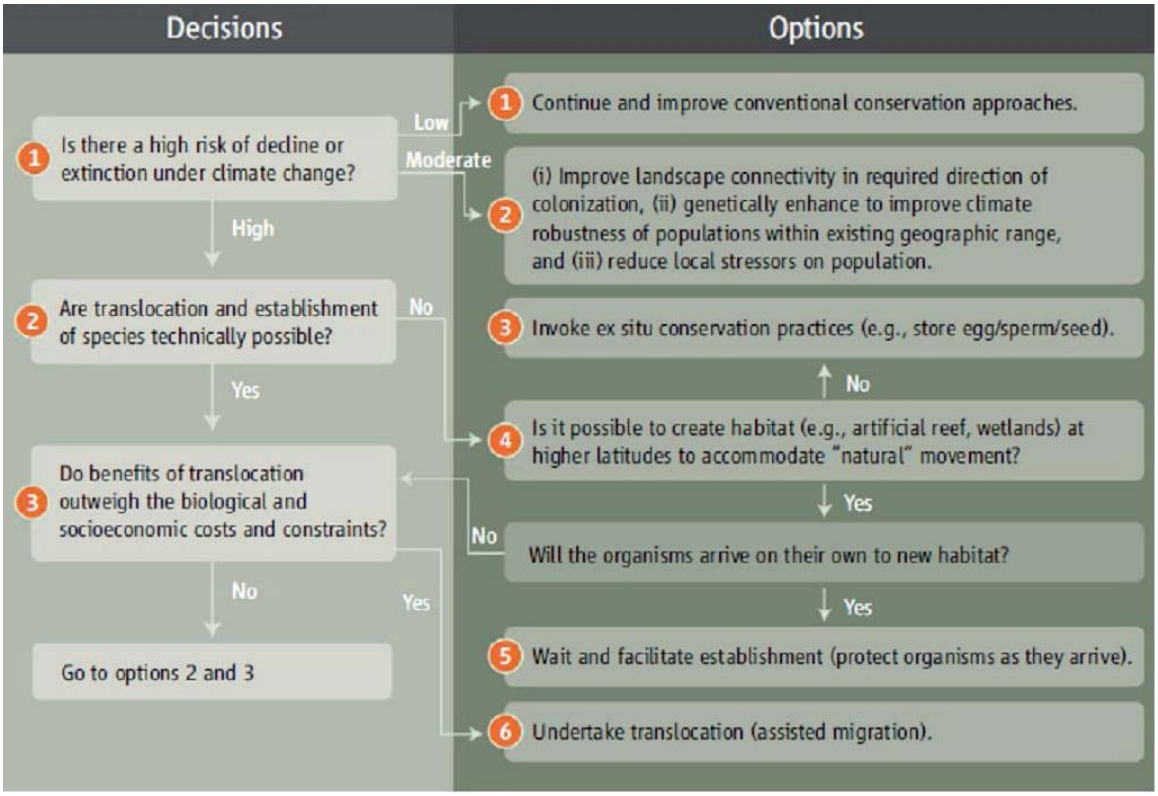

Figure 3. *Decision framework for evaluating different conservation strategies. Figure by Hoegh-Guldberg et al. (2011).*

Assisted migration should not be excluded from possible decisions from the beginning but be part of a variety of opportunities. We could also test assisted migration impacts step by step. For example, founder populations might be sufficient to conserve many species. After establishment, gene flow via pollen dispersal could form a new population that is likely to be well adapted (Aiken et al. 2008).

Assisted migration is applicable for most species characterized by small populations, restricted dispersal ability and adaptive potential and inhibiting low-connectivity landscapes. However, species with such characteristics also have a very low ability to become invasive (Loss et al. 2011), which is the main concern of the opponents of assisted migration. Restricting assisted migration to those species would reduce risks (and potentially costs).

Besides the ecological impacts of assisted migration there are also political concerns. Policy conflicts between proponents and recipient region may arise (Davidson and Simkanin 2008). Translocation of species would of course take place internationally as national borders are not given by nature. From my point of view, working on assisted migration is not an unbearable challenge but an opportunity. As Tennigkeit (2011) argues in his guest lecture in this workshop, there is consensus about conservation of biodiversity between politicians all over the world. So translocation over borders could not only help nature but international collaboration as well.

Nevertheless, risks and costs of assisted migration have to be remembered and decisions should be made in every isolated case. In any case a proactive strategy is to favour instead of only reacting to biodiversity loss or loss of resilience of our forests.

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Chapter two

Policy Issues of Climate Change

Forests and climate change: research and policy issues in India

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Abstract

Forest and climate change research in India is important for providing valuable inputs in order to combat the problem of climate change. Research on technical as well as policy issues focussed on various aspects of forests and climate change has been initiated in various organizations and regions of India. It has the aim of generating data which helps to understand the complexities of the problem and provides possible solutions for different scenarios created by or likely to be created by climate change. However, research and development in this field needs to be strengthened and complex issues needing urgent attention require to be taken up at a multi-institutional level.

1. Introduction - Background

With a geographical area of 328.7 million hectares, India is the seventh largest country in the world in terms of land area and the second most populous nation with a population of over 1.2 billion human beings. The forest and tree cover of India (India SFR 2009) is 78.37 million hectares which accounts for about 23.84 percent of the total geographical area.

Out of the above, about 9.2 million hectares is the tree cover in the form of trees outside forests, mainly agro-forestry plantations. Together the forest and tree cover play an important role in the mitigation of the effects of climate change. It has been estimated (SFR 2009) that the CO_2 removals by India's forest and tree cover is enough to neutralise 11.25% of India's total GHG emissions (CO_2 equivalent) at 1994 levels. Conservation and sustainable forest management have reversed deforestation in India.

According to Champion and Seth (1968) and Negi (1969), India has 16 major forest type groups which range from dry tropical forests to rain forests; evergreen and semi-evergreen forests, temperate forests, sub-alpine and alpine vegetation. This makes India a mega-biodiversity country, with the bio-diversity being influenced by Indo-Chinese, Malayan and other elements. There are over 40,000 species of plants and 75,000 species of animals in India.

Forests in India play a major role in mitigating climate change, particularly with sustainable forest management being a major initiative. Nevertheless, research in forests and climate change has been taken up a few years back and it needs to be strengthened in the years to come by adopting inter-disciplinary and multi-institutional approach. There is a need to focus and strengthen research in these fields.

2. Forest degradation

Various factors are contributing to forest degradation in India, even though massive efforts have been taken to ameliorate the problem so that forests help in mitigating the effects of climate change.

a. Forest fires affect a large forest area in the country during the summer season, usually from April to June. SFR (2009) has estimated that almost 50% of the forests are prone to fires though all such areas may not be affected every year.

b. Human impacts on forests include lopping and loss of forest lands. There is also a severe pressure by domestic and grazing animals on the forests. According to NFC (2006) more than 17 million tons of fuel wood are extracted from India's forests annually. With a livestock population of 529 million, forests meet about a fourth of the fodder requirements.

c. Forest invasive species like *Lantana camara* and even insect invasive species are resulting in forest degradation.

3. National action plan on climate change

India's National Action Plan on Climate Change (NAPCC 2008) outlines the ambitious plan at the national level for combating the problem of climate change. It comprises the following eight missions of which the Green India Mission is an integral part. A number of other missions under NAPCC have direct and indirect linkages to forestry research:

I. Solar mission

II. Mission for enhanced energy efficiency

III. Mission for sustainable habitat

IV. Water mission

V. Mission for sustaining the Himalayan ecosystem

VI. Green India mission

VII. Mission for sustainable agriculture

VIII. Mission on strategic knowledge for climate change

3.1 Green India Mission

The Green India Mission which is a part of the NAPCC 2008 was launched in 2010 and consists of the following elements:

a. Increase in forest cover and density

Under the Greening India programme 6 million hectares of degraded forest land would be afforested with the participation of the Joint Forest Management Committees. The elements of this programme include the following:

a. Training on silvicultural practices for fast growing and climate hardy tree species.
b. Reducing forest fragmentation by providing corridors for migration of floral and faunal species.
c. Enhancing public and private investment for raising plantations to increase the forest cover and forest density.
d. Enhancing community based initiatives.
e. Implementation of the Green India plan.
f. Formulation of strategies for forest fire management.

b. Biodiversity conservation

The NAPCC has stressed the conservation of India's rich biodiversity. The specific actions would include:

a. In situ and ex situ conservation of genetic resources.
b. Documenting genetic diversity by creating bio-diversity registers.
c. Effective implementation of the Wildlife Protection Act.
d. Effective implementation of the Biological Diversity Act, 2002.

Forestry research and policy research support will play a vital role in the success of the green India mission. Various packages of practices need to be developed for forest densification and for plantations on barren lands. Massive investments in the form of financial and technical inputs have been started for supporting the elements of the Green India Mission.

4. Forest soil organic carbon

There are two basic sources of organic matter in soil. The primary source is of plant origin that includes crop residue, green manure, peat and organic fertilizers whereas the secondary source is comprised of excreta and body casts of macro-and micro-organisms. The organic matter received through these sources undergoes mineralization to convert into soil organic carbon (SOC). The organic material like leaves, twigs, branches, etc. is decomposed biochemically into simpler compounds. The simpler compounds, formed as a consequence of decomposition, undergo are-synthesis through a biochemical process, forming high molecular weight compounds basically made up of poly-phenols and proteins, known as humus. The soil organic carbon is thus stored for a long time in the form of humic-substances (Negi and Gupta 2011).

Based on different approaches and estimates, the total forest soil organic carbon stocks in India are in the range of 23.4-47.5 Pg C (Ravindranath et al. 1997, Dadhwal et al. 1998, Velayutham et al. 2000). Enhanced sequestration of atmospheric CO_2 in the soil, ultimately as stable soil organic matter, provides a more lasting solution than sequestering CO_2 in standing biomass. Comparison of soil organic carbon storing capacity of major soils of India revealed that carbon stored per hectare in brown forest and laterite soil was the highest. Research and inventory of different forest soils for soil organic carbon and soil microbiology is being conducted.

5. Research initiatives and issues

Forestry research in India is largely being conducted by the eight institutes of the Indian Council of Forestry Research and Education located in different regions of the country though many universities and some non-governmental organizations are also engaged in forestry research. ICFRE and other organizations have initiated several programmes for conducting research on forests and climate change. These include vegetation shift; vulnerability analysis; canopy modelling; soil organic carbon and other studies. The ICFRE is also an observer under the UNFCCC and gives inputs at the national and international levels.

The research issues which are being addressed or need to be addressed at the national and regional levels are listed below:

- Impact of climate change on various forest ecosystems; dynamic models for specific forest types. This will involve detailed studies in all the 202 forest types, particularly in the transition zones between them so as to clearly bring out the changes, if any in these ecosystems due to changes in climatic conditions.
- Impact of climate change on the role of forests as carbon sinks. The function of forest vegetation and soil as carbon store may vary as the climate changes and systems will be developed to study these for evolving suitable mitigation measures. Assessment of the mitigation potential of different forest ecosystems will be done on a short term basis.
- Development of biomass expansion factors for different tree species is being done in the Himalayan region and these studies will ultimately cover the entire country.
- Identification of potential forest invasive species and their status due to the effect of climate change; both plant and animal species.
- Generating baseline data on present biodiversity composition of different forest types to monitor changes in species composition; migration of species; both plant and animal species. This information will form an important baseline for long term monitoring with respect to impact of climate change.
- Identification and monitoring indicator plant and animal species in different ecosystems and monitoring their status with respect to changing climatic conditions.

- Selection of species suited for changing climatic conditions requires to be done urgently as an adaptation measure so that the forest plantation programme remains unaffected and species/varieties suited for changed climatic conditions can be planted. This will also lead to the development of a package of silvicultural practices for different scenarios likely to emerge under changed climatic conditions.
- Predicting physiological and anatomical changes in plant and animal species in response to climate change under different ecosystems. Studies on three species of *Rhododendron* occurring in the Himalayan region have already been initiated in the Forest Research Institute Dehradun and initial results indicate that there could be changes in tree phenology due to changing climate.
- Identify effects of climate change on plant-animal interaction; tree canopy insect interaction; dispersal and pollination.
- Assessment of changes in wood properties in response to changing climatic conditions; different species and ecosystems and evolving adaptation measures.
- Identification of species showing higher carbon sequestration potential and use of genetic tools to enhance the carbon sequestration potential of forest species.
- Improved use of wood for locking carbon for longer periods of time. This is a mitigation measure that will lock carbon and delay its release into the atmosphere.
- CO_2 flux studies in plants are needed to understand the process of exchange of gases with respect to climatic conditions, age, size and other factors. A number of towers have been set up in different ecosystems to generate data on this aspect.
- Use of keystone species to monitor the impacts of climate change on forests in the long term.

6. Forest and climate change policy research issues

Policy research issues in the field of forests and climate change in India are also vital for providing valuable inputs to planners and policy makers. These include:

- Analysis of existing forest and climate change policies and strategies (e.g. national REDD+ strategy, forest adaptation and mitigation strategy);
- Analyze their coherence with other national climate change strategies e.g. national action plan on climate change (NAPCC), green India mission (GIM), nationally appropriate mitigation actions (NAMAS);
- Analysis of climate change mitigation and adaptation actions relevant for the forestry sector, using research results and other sources of information;
- Identifying conflicts and synergies of other sector policies within NAPCC (agriculture, energy, mining, rural/urban development, transport, poverty reduction, etc.) with climate change strategies or actions in the forestry sector;

- Legal and policy framework for the forestry sector for the implementation of climate change related policies and actions;
- Information and data generation, exchange and dissemination of information on forests and climate change, including e.g. climate change impact and vulnerability assessments;
- Research on policy aspects of forests and climate change;
- Traditional knowledge; systems for reporting data and information to UNFCCC and other international bodies; communications and outreach to stakeholder groups and the public.

7. Conclusions

Forestry research has a major role to play in understanding forests and climate change in India and to come up with solutions which will help in combating climate change. An interdisciplinary and multi-institutional approach is being advocated so that a multiple effort can be made with participation of all stakeholders. Efforts at the national and regional levels have started for providing the necessary research support for the role of forests in mitigating the effects of climate change. Forestry research organizations would also be providing answers to solutions for successful implementation of the Green India Mission under the National Action Plan on Climate Change.

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A Review of South African Forest Policy: Gearing Up for Climate Change

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Abstract

This paper glances over the definition of policies and pauses on the development of and current South African policies relating to climate change. A brief discussion of the most prominent policies and legislation governing climate change and related issues in South Africa is provided. The practical impact and implications of these policies are discussed. The potential effects of climate change and the degree of vulnerability of plantation forestry and natural forests are highlighted. Sensitivity analysis and scenario studies conducted showed that hybrid species are more robust than currently planted pure species and that South Africa's tree breeding resources are capable of accommodating such a change. In conclusion recommendations are made on how South Africa can improve its position with regards to the integration of climate change regulation into current policy and legislation.

Keywords: Climate change, policies, sensitivity analysis South Africa

1. Introduction

South Africa is a country in transition where legislation and policies are aimed at providing an effective approach to poverty alleviation, the sustainable use of forests, stimulating economic growth and the conservation of forest resources. The inclusion of local communities is a major focus under the Participatory Forest Management (PFM) approach as they were excluded from utilizing forest resources for many decades. South Africa has excellent legislation e.g. The National Forests Act, (Act 84 of 1998) but limited human and financial resources to enforce and monitor many of its guiding principles. Climate change is a reality, it needs to be integrated into current policy and the formulation of mitigation and adaptation strategies prioritized amongst the objectives mentioned above.

2. Definition of Policies

Policy, in its broadest sense, can be defined as "the system of ideas and standards that specify the goals, the kind of instruments that can be used to obtain them and the very nature of the problems they are meant to address" (Tyler 2009). It can therefore be said that a policy encompasses two main elements: a set of goals and objectives, and an outline of the course of action to achieve them. The main function of a policy is to provide guidance and a sense of direction over a period of time. It is intended to guide and determine present and future decisions (FAO 2010). Policies should not be static, but they should rather evolve continuously. They should be modified and adapted in order to address current matters of importance (Tyler

2009). Policies, and in this case, specifically forestry policies, should be negotiated agreements between government and stakeholders. They are not meant to be unilaterally imposed by government. A forestry policy is a policy for the society, not merely for the forestry administration (FAO 2010).

3. Vulnerability of the Forestry sector to Climate change

3.1. Effect on plantations and natural forests

Climate change is an issue that needs to be addressed. Increases in atmospheric CO_2 levels are likely to increase photosynthetic rates (Fairbanks and Scholes 1999) but could also be countered by increases in plant respiration rates (Moore et al. 2008) and changes to carbon allocation patterns, with possibly a greater proportion being allocated to below ground biomass as trees come under stress (Fairbanks and Scholes 1999). Any increases in photosynthetic efficiency could be limited by soil fertility and nutrient supply as plant nutrient uptake is governed by soil water availability. Along with increases in CO_2 levels, significant increases in O_3 levels are also predicted which have been found to be detrimental to the growth of coniferous trees (Wipfler et al. 2005). These increases will have a large impact on the industry as more than half (51%) of the planted area in South Africa is planted with *Pinus* spp (FSA 2009). There have been a number of previous studies focusing on the effects of climate change on the South African forestry industry (Schulze and Kunz, 1995, Fairbanks and Scholes 1999). These studies basically use rainfall and temperature data to map out optimal growing areas for a species under current and future climate scenarios. These sensitivity analysis studies have shown that changes in rainfall and temperature are likely to have a marked impact on the areas suitable for the growth of a particular species.

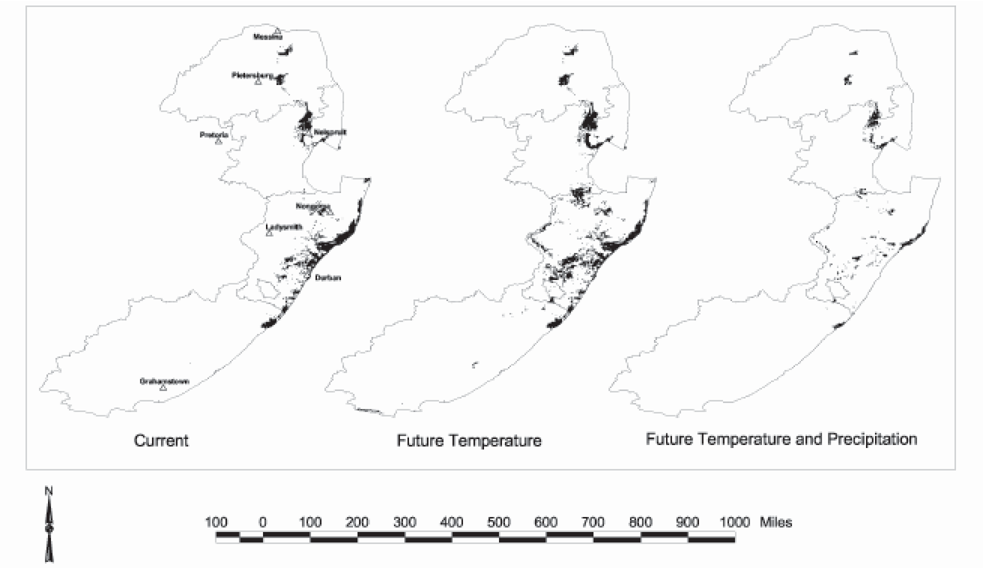

Figure 1. *Example of a sensitivity analysis map for E.grandis under current and future scenarios (taken from Fairbanks and Scholes, 1999).*

The map shown in figure 1 only incorporates temperature and precipitation changes and does not include potential changes in the ranges of biotic and abiotic risk factors as was proposed by Smith et al. (2005) for a complete site species matching criteria. The study done by Warburton and Schulze (2008) provides a more complete picture of what the industry can expect. They used temperature and precipitation as their main deciding factors but did not neglect to include changes in the suitable geographic areas of for e.g. *Cryphonectria canker* or *Sparopsis fungal* disease after damage caused by hail (van Staden et al. 2004). Based on the results of the sensitivity analysis for an array of future climate scenarios, maps were developed for the major plantation species of pines and eucalyptus. Each species was mapped according to areas that will become optimal, hold a moderate risk or pose a high risk to afforestation efforts. An example of such a map can be seen in figure 2.

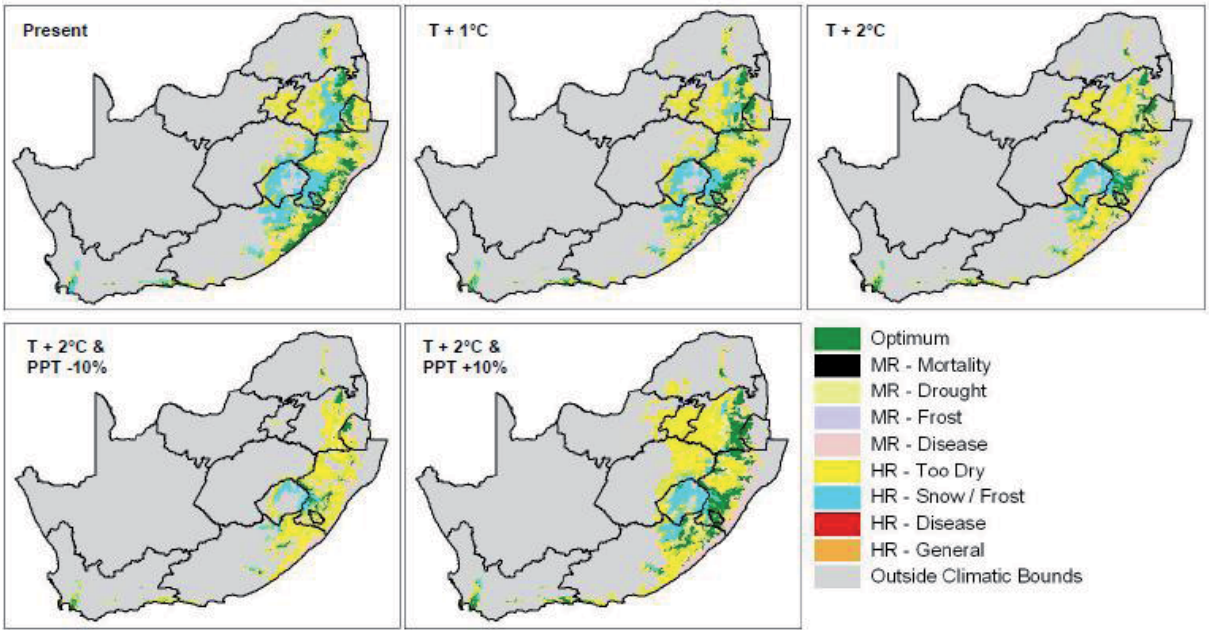

Figure 2. *Results of a sensitivity analysis for E.grandis under 4 different climate change scenarios (taken from Warburton and Schulze, 2008).*

Even with scenario analysis and sensitivity studies as the aforementioned, there still remains a fair degree of uncertainty with regards to climate change (Pearson *et al*., 2006). The possibility remains that new, more robust, genotypes, species or hybrids that are resistant to higher temperatures, drought risks and diseases may need to be planted. The South African forestry industry is fortunate in having a very broad diversity in species and hybrids available and a highly sophisticated tree breeding infrastructure (Evans, 1999), which would aid significantly in the adaptation of planted species.

3.2 Effect on Wood properties

The effect of a changing climate on the growth of trees is intensively investigated but little is known, especially in South Africa, on how the wood properties might change. A small fluctuation in recovery rates and pulp yields has huge financial implications for the mills. Therefore, a better understanding of what the wood processing sector can expect in terms of changes in wood quality within the next 50 years is imperative for future growth. From studies abroad and a few selected local investigations it can be expected that the industry will experience changes in bark thickness (van Laar, 2007), wood density (Beets *et al*., 1999), modulus of elasticity, resin pocket formations (Cown, 1973), micro fibril angle (Jordan et al., 2007) and juvenile fibre lengths (Watt et al., 2008).

4. National Forestry Programme

Policies cannot function in isolation. As discussed above, policies set the goals and the course of action to achieve the goal. It does not, however specify in detail the instruments and practices for implementation. Forest policies are integrated under an umbrella framework, together with forestry legislation and institutional frameworks. These three elements together form a National Forestry Programme (NFP) (FAO 2011). A NFP does not only focus on the planning element but considerable emphasis is placed on implementation. Legislation and institutional frameworks form the key factors in the implementation process (DWAF 2005).

Legislation sets out the rights, responsibilities and rules through which the policy will be implemented. It is legally binding and non-compliance is punishable by judicial powers. Forest policy and forest legislation are, therefore, complementary tools (FAO 2010).

Institutional frameworks refer to those organizations responsible for the development and implementation of forestry rules, policies, strategies and legislation. These organizations include national, community-based, public and private bodies (FAO 2011).

5. Policies and Climate Change

Countries need to act against the effects of climate change. Existing forest and forest-related policies should be reviewed and amended to address climate change and related issues. The revision and amendment process need to be consistent with other objectives of the forestry sector, national development policies, land use plans, as well as policies of other key sectors, such as agriculture, energy and environment.

Governments have to ensure that policies are put in place to adhere to international commitments and obligations. Legislation must be developed to effectively enable and support these international commitments. If necessary, institutional organizations should be modified, and/or new bodies established to implement the policies and legislation addressing climate change. These organizations have to support coordination and collaboration of different bodies over an array of sectors related to climate change (FAO 2011).

South Africa has developed a complex framework of policies answering to its commitments to international protocols and declarations relating to the climate change challenge. The country has enthusiastically signed and ratified several international and regional protocols and agreements. Unfortunately, no legislation directly tackling climate change has been adopted (Richards 2008).

6. South African Climate Change Related Policies

6.1 Pre- and Post 1994

The traditional view on forestry in South Africa was that forestry is a science of managing forested land. The main focus of forest management was on the production of timber. Forest policy formulation was considered a technical task only to be undertaken by national government, hence there was limited community participation in management of forests (FAO 2011).

In 1994 South Africa became a constitutional democracy. This transition of the political landscape opened a policy window. Today forestry is about the relationship between people and forest products. Management objectives encompass a broader scope of forest products and ecosystems. The formulation of forestry policies is considered a process involving a range of forestry stakeholders, representatives from other sectors as well as the community (FAO 2010).

Forest policies are still concerned with the conservation of natural forests and the management of commercial forestry. In terms of the modern view on forestry, policies now also address community forestry and aim to improve the living conditions of all people. Forestry is mainly rurally based in South Africa and there is a natural link between it and the rural population. Forestry can provide several opportunities to these people, who are mostly previously disadvantaged, in the form of building material, material for crafts, fuel and employment. The policy making-process needs to address all three spheres of modern forestry (White Paper 1997).

6.2 Current Policies and Legislation

South Africa has made considerable progress on putting in place the necessary policies to address the challenges of climate change. A spectrum of policies and legislation has been formulated on climate change related issues. South Africa has furthermore signed several international protocols and agreements pertaining to climate change issues. South Africa's comparatively advanced policy making architecture and a range of active environmental pressure groups account for this achievement (Richards 2008). A brief discussion on the key policies and legislation follows.

6.2.1 Policies

United Nations Framework Convention on Climate Change (UNFCCC): South Africa ratified the UNFCCC in 1997 and subsequently committed itself to support climate change mitigation and adaptation (Richards, 2008).

Kyoto Protocol: South Africa entered into acceptance of the Kyoto Protocol on 31 July 2002. This Protocol, which came into effect in 2005, commits member countries to stabilizing the concentrations of greenhouse gasses (GHG) in the atmosphere in order to prevent damage to the climate system. As a developing country, South Africa is however not obliged to reduce its GHG (Warburton, 2006).

Southern African Development Community (SADC) Forestry Protocol: This protocol was signed by Heads of State, including South Africa in 2002. In the Preamble of the document it clearly states that the member countries recognize “the value of forests to humanity, including their role in maintaining the earth’s climate”. The objectives of the protocol include promoting the development, conservation and sustainable management of all types of forest, as well as to promote trade in forest products to alleviate poverty and to achieve effective protection of the environment and safeguard the interests of both present and future generations (Protocol, 2002).

National Climate Change Response White Paper: The White Paper was approved by the South African Parliament on 12 October 2011. It has two main objectives, namely to manage climate change impacts and to make a contribution to the global effort to stabilize GHG. It distinguishes between adaptation and mitigation as methods to achieve its goals.

In terms of adaptation, the White Paper includes a risk-based process to identify short- and medium-term adaptation interventions to be addressed. This process will identify the adaptation response which requires coordination between private sectors and governmental departments. According to the White Paper, this process will be reviewable every five years.

The White Paper sets out South Africa’s approach to mitigation. According to the White Paper a carbon budget approach will be adopted. The carbon budgets will be translated into emission reduction outcomes on company level. Companies will be required to draft mitigation plans and desired emission reduction outcomes will be defined for each significant economic sector.

Furthermore, the White Paper requires that all government departments have to review their policies, strategies and legislation within two years of implementation, to ensure alignment with the White Paper. It also requires that the departments communicate with citizens about climate change to inform and educate them and to influence their behavioural choices with regards to climate change and related issues.

Ultimately, the success of the response to climate change has to be monitored. The strategies that work have to be replicated and the lesser successful strategies have to be addressed. Success will be measured with regards to costs, outcome and impact. For these purposes a Climate Change Response Monitoring and Evaluation System will be put in place. This system will initially be based on South African scientific measurement standards, but it is expected that the system will evolve with international measuring, reporting and verification requirements (White Paper, 2011).

6.2.2 Legislation

Constitution of Republic of South Africa (Act 108 of 1996): The Constitution is the supreme law of South Africa. All legislation, law and policies must be in line with it. Furthermore, obligations imposed by it must be fulfilled and adhere to.

Section 24 of the Constitution deals with environmental rights and stipulates that "Everyone has the right- (a) to an environment that is not harmful to their health and well-being; and (b) to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that – (i) prevent pollution and ecological degradation; (ii) promote conservation; and (iii) secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development.".

National Forestry Act 84 of 1998: This Act aims to balance the use and protection of South Africa's forests through sustainable forest management. This includes sustainable use, cooperative governance and stakeholder participation. The Act requires the conservation of natural forests, biological diversity ecosystems and habitats.

National Veld and Forest Fire Act 101 of 1998: Veld and forest fires contribute to climate change as they release stored-up carbon, and other GHG, and destroy vegetation. The Forest Fire Act aims to prevent and combat veld, forest and mountain fires throughout South Africa.

National Environmental Management Act 107 of 1998: The Act aims to promote conservation, secure ecological sustainable development and use of natural resources, while promoting economic and social development. It is a direct answer to the constitutional law that everyone has the right to an environment that is not harmful to his/her health or well-being.

7. Key challenges

In order for continued progress to be made, the following key challenges need to be met.

Awareness – There is limited awareness of and experience with climate change issues, not only in the forestry sector but amongst the general public as well. Climate change is not directly dealt with in schools at primary or secondary level and students only get serious exposure to the issue once they reach a tertiary institution.

Resources – South Africa has a relatively small pool of financial and technical resources available to implement mitigation/adaptation strategies. Industry cannot solely rely on Government funding, which is limited to begin with, but need to consider alternative sources such as the Global Environmental Fund or lobby with the private sector to secure consistent funding for research and development.

Natural forests and woodlands – There is a clear lack of knowledge when it comes to climate change effects on natural forests and woodlands in South Africa. Although no negative impacts have been reported in the natural forests of the Southern Cape (Midgely and Seydack, 2006), there is still cause for concern. It is expected that the proportions of species will shift in response to increasing disturbances in the forest (Adie and Lawes *et al*., 2009). With drought and fire patterns becoming increasingly unpredictable, as the future precipitation patterns are not well understood, the "hands-off" approach currently employed when dealing with natural forests will need to be reconsidered.

Base line information – There is no long term base of scientific information available that researchers and policy makers can use to aid them in setting the direction for future research and policies.

Water legislation - South Africa is a dry country (Meadows, 2006) and the available water resources are in high demand. Plantation forestry is classified as a stream flow reduction activity under the National Water Act of 1998 (no. 36 of 1998), which means that forestry activities have to pay for the water that the trees use. This act is a major barrier to afforestation activities.

Research and development – The forestry sector cannot operate in isolation from other sectors. There is a need for information and resource sharing and the establishment of cross boundary research and development programmes.

8. Considerations for the future

Forests and woodlands play an important role in the livelihoods of many South African citizens and if this is to continue on a sustainable basis in the future, the following key aspects need to be considered and possibly incorporated into current South African legislation.

The issue of securing consistent funding for climate change research, technology development and the implementation of strategic plans for mitigation and adaptation remains at the forefront of the discussion. As mentioned before, governmental funding is limited and alternative sources should be investigated. The establishment of mechanisms such as carbon credit markets under REDD+ or payment for ecosystem services (PES) are viable options that could provide a form of stable revenue. The problem however lies with local communities. A large proportion of afforested land has been awarded back to the communities following the passing of the Land Restitution Act of 1994, while a significant area still has its land claim decisions pending. This land then belongs to communities and participatory forest management practices have to be adopted by the forestry companies in order to avoid a land use change. These communities rely on the large lump sums of income that they receive periodically to build houses, purchase vehicles and fund small business ventures (Howard *et al*, 2005).

Policies should be aimed at getting more stakeholders involved with a focus point placed on the development of collaborative research and development programmes. The sharing of knowledge, skills and resources needs to be encouraged across the various sectors. It is not necessary to develop new legislation and policy from scratch, but rather integrate climate change into the existing policies and strategies such as the National Forest Programmes (NFP). South Africa, as a member of the Southern African Development Community (SADC), cannot operate alone in its attempts to combat climate change. Regional policies for SADC should be developed with the guiding principles of promoting the use of wood-based products, the alleviation of poverty, the reduction of greenhouse gas emissions from forest operations and the conservation of natural forests and woodlands.

Principles, criteria, indicators and standards need to be established in order to monitor and evaluate the implementation of regional and national action plans. Capacity building within the sector should be aimed at, addressing areas where a shortage of resources and skills has been identified. These include the discipline of forest monitoring, and the formation of a dedicated task team to initiate and drive climate change processes like public awareness raising, research coordination and stakeholder consultation.

9. Conclusion

Climate change is not a problem that can be ignored. It must urgently be addressed. South Africa's effort to address this problem has to be acknowledged. The decision described in the National Climate Change Response White Paper to institute sectorial desired emission reduction outcomes is a great step in the right direction. It indicates a concrete and practical commitment by South Africa. Also, a mandatory emissions reporting, monitoring and evaluation system is welcomed (White Paper 2011).

However, the political will to act does not guarantee action. South Africa still struggles to transform policy ideals into effective mechanisms of implementation. South Africa needs to mobilize financial, human and knowledge resources to be in a position to tackle the climate change dilemma more effectively (Richard 2008).

It has been suggested that an overreaching policy institute with sufficient capacity is a necessity. Government will have to develop the required capacity on all levels, national and sub-national, to implement and monitor climate change strategies (Tyler 2009).

In order to address the challenges of climate change, all spheres of the government, private sector and civil society will have to cooperate and adhere to obligations. Ultimately, the success will depend on decisions by individual citizens to embrace climate change friendly lifestyles and habits. Everyone is a stakeholder (White Paper 2011).

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Financing forestry in Uganda: the potential of REDD+ to increase forest conservation area

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Abstract

Inadequate finance is one of the major problems tropical countries are facing in their endeavour to conserve forests. As part of the solution to this problem, REDD+, a large international forest financing scheme, is currently being designed to gather and distribute finance for forest conservation with a particular focus on tropical countries. This source of funding is extremely important to Uganda: the majority of forests in the country comprised of private and community forestlands do not have access to any significant finance. The remaining forests, managed by the government, are financed (albeit insufficiently) either through direct budget allocations or independent of such allocations by semi-autonomous government agencies. This paper explores whether the flow of REDD+ finance could increase the area of forest conservation – considering the REDD+ 'attractiveness' of different forest types, and the categories of forests that are already being targeted for REDD+ projects in the country.

Keywords: Finance, forest conservation, REDD+, Uganda.

1. Introduction

Forest conservation in most tropical countries is severely constrained partly by the shortage of finance. In Uganda, where nearly 200,000 ha of forests are lost annually (Obua et al. 2010), financial constraint adds to a long list of other problems facing the forestry sector. These include: intense human and economic pressure on forestlands due to a rapidly growing population; weak institutional capacity, linkages and policy synchrony; limited public awareness of forest tenure; and sparse data on the forest resources. A forest is defined in Uganda as an area of at least 1 ha of land with minimum tree cover of 30 percent and potential minimum tree height of 5 m (National Forestry Authority 2008). Figure 1 shows mapped forestlands in the country.

Out of the estimated 4.9 million ha of forests and woodlands (Table 1) only about 30 percent are managed by the government. Thus, a large part of Ugandan forests is under private/communal ownership and management. These estimates are, however, based on forest inventories carried out in the 1990s.

There are three government agencies responsible for managing forests on government land: the National Forestry Authority (NFA), the District Forest Services (DFS), and the Uganda Wildlife Authority (UWA).

Table 1. Areas (ha) of forests and woodlands in Uganda under different ownership and management.

Land cover	Government land		Private land	Total
	Forest reserves	National parks /wildlife reserves	Private and customary land	
Tropical high forest	306,000	267,000	351,000	924,000
Woodlands	411,000	462,000	3,102,000	3,975,000
Plantations	20,000	2,000	11,000	33,000
Total forest	737,000	731,000	3,464,000	4,932,000
Other cover types	414,000	1,167,000	13,901,000	15,482,000
Total land	1,151,000	1,898,000	17,365,000	20,414,000

Source: Ministry of Water, Lands and Environment (2001).

The NFA manages forests gazetted by the national parliament as Central Forest Reserves (CFRs), while the DFS manages Local Forest Reserves (LFRs). The UWA manages all forests found inside national parks and wildlife reserves. The DFS and NFA are also responsible for providing technical support to private/community forests. The CFRs, LFRs, national parks, and wildlife reserves (including forests inside them) form a network of protected areas (Figure 1).

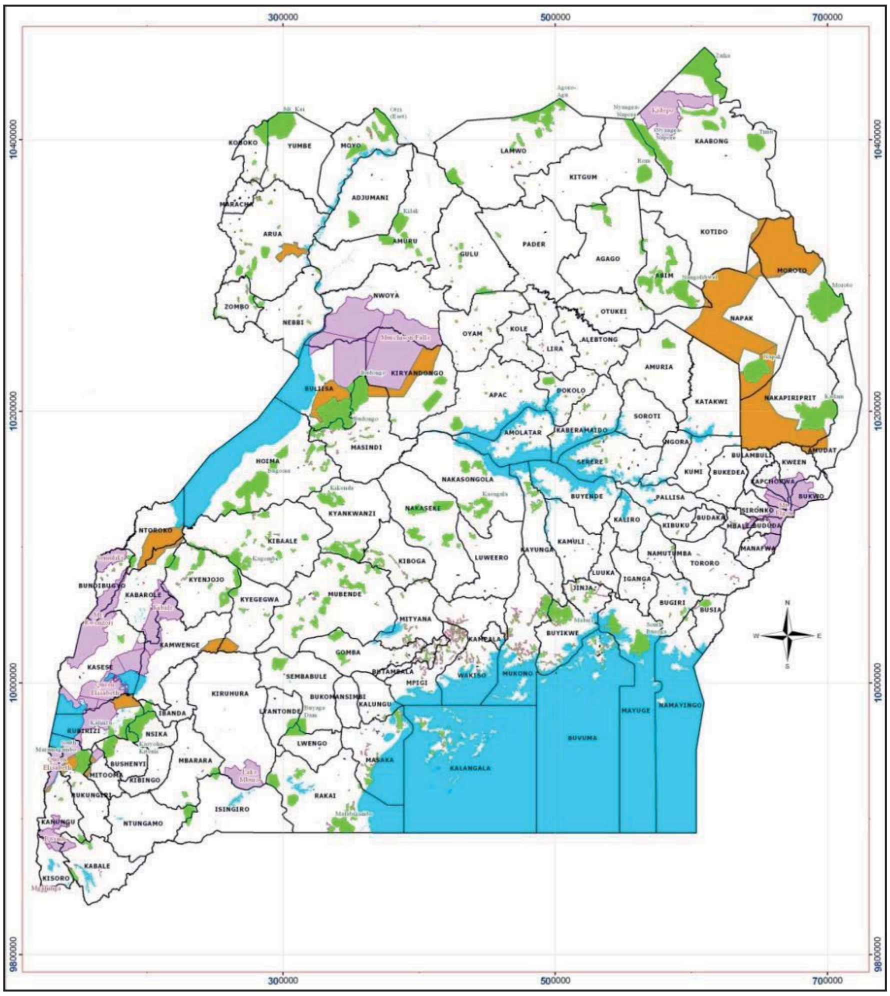

Figure 1. Forests and wildlife areas in Uganda. Note the absence of private/community forests from the map (Source: NFA 2008).

2. Financing forest conservation – historical perspective

Traditionally, all forestry activities carried out by the government have been financed using money allocated in the national budget. The Forest Department – later replaced by the NFA – obtained its entire funding from the budget allocations in the line ministry (National Forestry Authority 2011). It is worth noting that up till now, about 29 percent of the national budget is funded by development partners (Ministry of Finance, Planning and Economic Development 2011). For the development partners to fund the forestry sector, the government has to demonstrate prioritisation of the sector in national development goals (Kamugisha-Ruhombe 2009).

The financing of government-managed forests significantly changed in 2004 when the NFA was established. The NFA is semi-autonomous: it raises and uses its own finances in accordance with the provisions of the National Forestry and Tree Planting Act, 2003, which created it (National Forestry Authority 2011, Government of Uganda 2003). The UWA, established in 1996, finances its activities including the protection of forests under its jurisdiction in the same way. Unlike the latter two agencies, the DFS still obtains funds through budget allocations in the respective districts. Revenues that accrue from LFRs within a district are fully retained in that district (Banana et al. 2000). This revenue is, however, nearly insignificant as there are only about 5,000 ha of poorly-managed LFRs in the whole country. The districts receive fiscal transfers from the central government for budget support, which they can allocate to forestry activities. Nonetheless, the transfers and budget allocations to the forestry sector both at the national and district levels are very small. Masindi district, for example – although being one of the most forest-essential districts – allocated less than 3 percent of its annual budget to the entire natural resource sector between 2006 and 2010 (Kamugisha-Ruhombe 2009). The financial resources of the NFA are also very limited. Consequently, both the NFA and DFS are unable to support private/community forests. To date no detailed mapping (inventory) of private and community forests – a large share of Ugandan forests – has been done.

For a long time, private sector investment in forestry was non-existent as forest management was regarded as the work of the government. Environmental Non-Governmental Organisations (NGOs) and a recent government project[4] are still the only major sources of financial and technical support for private/community forests that are less commercially-oriented. Since 2004, the European Union, later joined by the Norwegian government, has been supporting commercial tree-planting through a grant scheme known as the Sawlog Production Grant Scheme (SPGS). This is where private sector investment in forestry is now directed, with the primary aim of creating timber plantations. By 2009, the scheme had already supported the establishment of over 10,000 ha of timber plantations. The interest of the private sector is to grow more of these timber plantations (Jacovelli 2009). This has been driven

[4] The Farm Income Enhancement and Forest Conservation (FIEFOC) Project is funded by both grants and loans from the African Development Bank and the Nordic Development Fund.

by the fact that part of the cost (in some cases nearly half the cost) of establishing a hectare of the timber plantation could be paid for by the SPGS grant if the investor sought it and met the requirements set out by the SPGS. In addition, the NFA leased out certain parts of CFRs to private investors for the purpose of establishing timber plantations; this is currently on-halt due to alleged misdeeds in the lease processes and the misuse of the leased forestlands.

3. The national REDD+ strategy

Uganda has just begun the development of a national architecture for REDD+ (reducing emissions from deforestation and forest degradation, and enhancing forest conservation, carbon stocks and sustainable forest management). The country submitted a Readiness Preparation Proposal (R-PP) to the Forest Carbon Partnership Fund managed by the World Bank in May 2011. The R-PP sets a broad framework of what is needed to prepare the country for implementing a national REDD+ strategy. This includes: policy and institutional arrangements; setting up a national forest monitoring system for measuring, reporting and verifying greenhouse gas (GHG) emissions, and creating a system for providing information on social and environmental risks and impacts of implementing REDD+ (Ministry of Water and Environment, 2011).

As a national strategy, the R-PP encompasses all forest resources in the country. Furthermore, it envisages the roles of private/community forest owners as implementers of pilot projects and sustainable forest management (SFM), with technical assistance from the NFA, the DFS, and the UWA (Ministry of Water and Environment, 2011). From the Readiness Proposal alone, it is not feasible to gauge where REDD+ finance could flow, and whether it would result into an increase of the area under improved forest management. It is, therefore, necessary to look at forest resources that are the actual and potential targets of REDD+ schemes together with the circumstances surrounding the protection of all other forest resources.

4. Where REDD+ finance could go

From a practical point of view, the 'attractiveness' of a forest for REDD+ can be judged based on the following criteria:

- The extent of threat – drivers of deforestation and forest degradation – the forest is facing, which provides the overall justification for taking actions to deal with the threats. If a forest is not facing any threats of deforestation and degradation now or potentially in the future, there is no justification to act through a REDD+ course of action.
- The potential to enhance carbon stocks. A forest with a reduced carbon stock has a higher potential for carbon stock enhancement and could thus achieve more of the plus (+) in the REDD+.

- The security of land and tree resource tenure and associated rights, which provides a safeguard against owners' commitment to implement REDD+, and creates justice in forest resource governance by ensuring that it is those who have acted to avoid deforestation and forest degradation who get duly rewarded.
- Existence of institutional and policy arrangements that can be relied on to implement REDD+ activities.
- Evidence of incapability to implement a REDD+ project without REDD+ finance – *additionality* – the argument that if avoided deforestation, SFM, and enhancement of forest carbon stocks could have been achieved without REDD+ finance, then rewarding people for doing so is not justified – even illogical.
- The potential for furthering sustainable development including poverty reduction, and setting national development on a path that has low GHG emissions.

In Uganda, private/communal forestlands are reported to generally have higher rates of deforestation – about 2.9 percent against 0.3 percent in some of the well-protected CFRs (Kaggwa et al. 2009). They also have a reduced carbon stock density; face increasing threat of conversion to other land uses; and are owned and surrounded by very poor subsisting communities. The combination of these factors makes these forests very attractive for REDD+. Their major problems are that they exist as small patches – implying an increased cost of REDD+ implementation; and they lack well-defined tenure including boundary demarcations. On the other hand, forests on government land have clear tenure, which are defined by national legislations (although these are not well-known or appreciated by the majority of surrounding subsisting communities). They are also larger in size and managed by established institutional structures: the DFS, the UWA, and the NFA, and in some cases under Collaborative Forest/Resource Management (CFM/CRM) arrangements with surrounding communities. As a result, most of the well-stocked government-managed forests face a reduced threat of deforestation and forest degradation. In addition, the potential to enhance the carbon stocks of well-stocked forests is low.

A ranking of forest resources for their REDD+ 'attractiveness' by Namirembe and Mugyenyi (2010) based on the criteria listed above is presented in Table 2. Although government-managed forests rank first and might dominate REDD+ schemes in terms of area, private/community forests feature prominently (second position) with strong positive arguments in terms of the need and advantage of directing REDD+ finance to them.

Table 2. *Ranking of Ugandan forests and woodlands for REDD+ attractiveness.*

Ranking	Example forests/woodlands	Main criteria/reasons
1st	Government forestland: Low-stocked tropical high forests managed by NFA with Collaborative Forest Management arrangement e.g. South Busoga, Sango Bay, Budongo, Mabira, Kasyoha-Kitomi CFRs	High carbon stock enhancement potential (emissions reductions per hectare); and existence of institution comprising government-local community collaboration
2nd	Private forestland: Low-stocked tropical high forests e.g. private forestlands in northern, western and central regions	High additionality; high carbon stock enhancement potential (emissions reductions per hectare); and sustainable development/poverty reduction
3rd	Government land: Low-stocked tropical high forests managed by UWA with Community Resource Management (CRM) arrangement e.g. Pakanyi near Murchison national park, and CRM sites around Mt. Elgon, Semliki and Queen Elizabeth national parks	High carbon stock enhancement potential (emissions reductions per hectare); and presence of institutional arrangement, but issue of focus on wildlife (animals) and sharing of revenue from REDD+
4th	Private/community owned woodlands and government-managed woodlands e.g. woodlands in northern, north-eastern, and eastern regions; and CRM areas and Community Wildlife Areas such as Karuma, Toro-Semliki, Kabwoya, Kaiso-Tonya, and around Lake Mburo national park	Low carbon stock enhancement potential (emissions reductions per hectare); and very high opportunity costs as these are the major sources of wood fuels and fodder for livestock

Source: Namirembe and Mugyenyi, 2010. 1st is most attractive, 4th is least attractive.

The first few REDD+ initiatives in Uganda are already targeting forests outside government-managed lands. They include: a feasibility study for a REDD+ project in the Murchison-Semliki landscape, western Uganda, involving about 122,876 ha of private and community forest mosaics in Masindi, Buliisa, Hoima, Kibaale, and Kyenjojo districts (Leal et al. 2011). Another is the Budongo-Bugoma REDD+ project feasibility assessment targeting about 210,000 ha of private and community forest and woodland mosaics in Hoima, Kibaale, and Kyenjojo districts (Ebeling and Namirembe 2010). The third is the Abalinda Ebihangwa REDD+ Forestry Project being developed on a 1,687-acre privately owned natural forest in Hoima district (Elliot 2010). These initial projects illustrate that REDD+ would extend finance to cover forests that used to be financially neglected. If this indeed happens, the overall area under forest conservation could increase.

5. Conclusion

Ugandan forests, the majority of which are outside government-managed lands, have long suffered from neglect and lack of financial investment. REDD+ finance offers the opportunity to change this trend by directing finance to private/community forests, and increasing it for government forestlands. Actual pilot REDD+ projects will most likely commence on private/communal forestlands and on forestlands managed by the government with some form of community participation. Lessons learnt from these could potentially guide future decisions. Part of the indispensable private sector investment in REDD+, and NGOs-related REDD+ finance will also most likely go to areas outside government-managed forests. Thus, overall, a fractional increase in areas under effective forest conservation could be expected as a result of the flow of REDD+ finance. For this to succeed, however, financial reward for REDD+ must favourably compete against returns from alternative land uses. At the national and project level, a fair and clear system of sharing responsibilities and benefits must be established. And at the resource level, extensive mapping (inventory) of private/community forests must be done – as where there is no forest or trees (mapped) there cannot be deforestation and forest degradation, thus, no REDD+.

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Climate Change Response in the Forestry Sector-Kenya's Experience

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Abstract

The world is concerned about the anticipated impacts of climate change which predict that developing countries such as Kenya will be adversely affected due to their vulnerability and limited adaptive capacity. Forest conservation, sustainable management of forests, reforestation and afforestation have been identified to play a key role in climate change mitigation and adaptation. At the same time, they contribute to food security and poverty alleviation, and are thus a strategy implemented in some developing countries to support international efforts. This paper presents the core programmes that are implemented in the forestry sector in Kenya and their contributions towards climate change mitigation and adaptation as well as the progress on REDD+ implementation in the country.

Key words: mitigation, adaptation, sustainable forest management

1. Introduction

Kenya has a landmass of about 582,350 km^2 of which only 20% is arable while 80% consists of Arid and Semi-Arid Land (ASAL). Over 70% of the population depends on rain-fed agriculture for subsistence and wood fuel for energy. Due to climate change and other consequences of anthropogenic activities, desertification is advancing and the extent of arid and semi-arid land is increasing. Kenya is classified as a low forest cover country (KEFRI 2006) with 5.9% of land area under forests and woodlands (Figure 1).

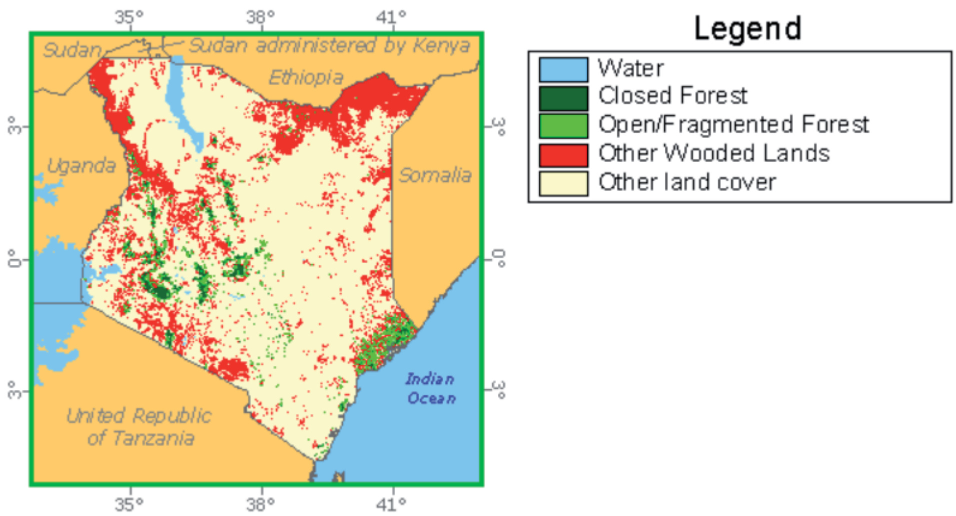

Figure 1. *Forest cover map for Kenya from FAO Forest Resources Assessment (FRA, 2000) from http://www.fao.org/forestry/country/18314/en/ken/ visited on 29th November 2011.*

About 2.6% of the Kenyan national area (3.456 million ha) is covered by indigenous closed canopy forest, mangroves and plantations in both public and private lands. Woodlands, which are mainly found in ASALs, cover the remaining 3.3 %. In addition, the country has over 10 million ha of farmland with trees and 24.5 million ha, bush lands cover. As shown in Figure 2, farmlands, bush lands and woodlands are the major source of wood biomass in Kenya (FAO 2010).

Despite the low forest cover, the forest sector contributes significantly to the country's economic as well as socio-cultural development since forest ecosystems provide multiple products and services critical to the economy. Beside wood and non-wood products, these include biodiversity conservation, water catchment areas, wildlife habitat and soil conservation. Forests also play a crucial role in adaptation to and mitigation of the impacts of climate change.

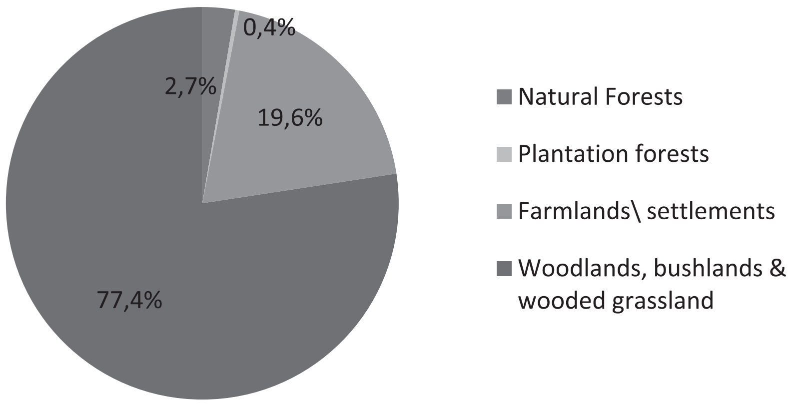

Figure 2. *Percentage of forest and trees outside forests in Kenya (FRA 2010).*

2. Core forestry programmes and their contributions to climate change mitigation and adaptation

Kenya loses about 12,000 ha of forest each year through deforestation; primarily conversion of forests to agriculture for public or private development projects (FAO 2005). The remaining forests are often degraded due to, among other causes, unsustainable utilization, illegal logging, uncontrolled grazing and exploitation for charcoal. Deforestation and degradation is evident in both the high elevation water catchment forest areas (popularly referred to as water towers), and in bush land in the ASALs. Charcoal making is rampant because the majority of Kenyans, especially those living in peri-urban and urban areas heavily depend on it as a source of energy for cooking and heating.

However, deliberate efforts are being made by the government, the private sector, development partners, local communities and civil society to conserve forests and restore degraded forest areas throughout the country. Kenya has a long-term development plan (Vision 2030) that emphasizes the need to conserve forest resources. Forestry flagship projects in this plan include conservation and management of the five major water catchments and an increase of forest cover to 10% (KFS 2010). Several programmes are being implemented to provide both ecosystem goods and services in the forestry sector as well as to contribute to climate change mitigation, adaptation and poverty reduction in Kenya.

a) Natural forest conservation, management and protection programme

The natural forest conservation, management and protection programme aims at sustainably managing natural forests for economic, social and environmental benefits.

Sustainably managed forests play an important role in climate change mitigation and adaptation while contributing to food security and poverty alleviation (FAO 2010). The forests conserve carbon stocks, biodiversity, water catchments and numerous ecosystem services therein. Rehabilitation of degraded areas in natural forests increases the carbon stocks in these areas thus mitigating climate change. To address climate change adaptation under this programme, the forest service has been promoting nature based enterprises and alternative livelihood activities (bee-keeping, poultry farming, fish farming, butterfly farming, ecotourism and other non timber forest products) to build the resilience of forest adjacent communities (figure 3). This aims at providing alternative income sources to these rural poor communities to reduce pressure on the forest as a result of illegal logging and encroachment.

Figure 3. *Alternative livelihood community projects in Mt Kenya to provide additional income and reduce pressure on dependence on the natural forest. Photo by Rose.Akombo 2010.*

This programme also promotes the use of improved firewood stoves to the rural poor who depend on wood energy as their major source of energy. These stoves are more efficient and reduce the amount of firewood use per household hence reducing the quantity of deadwood and litter collected from natural forests.

b) Industrial forest plantations establishment and management

Natural forests and woodlands provide goods and services that support many households. However, no timber is legally extracted from this ecosystem in Kenya. Therefore, plantation forests are important in meeting the country's demand for timber and other wood products which has increased over the years. The objective of this programme is to maintain and enhance productivity of industrial forest plantations and increase efficiency in wood utilization for wealth and employment creation. Currently, there are approximately 125,000 hectares of industrial forest plantations, composed mainly of Cypress, Pine and Eucalyptus. Increasing industrial forest plantations and improving the plantation health will boost the revenues generated which support the government expenditures including natural forest conservation and infrastructure development in the sector.

In addition to production of wood and fibers, forest plantations provide several environmental services, including carbon sequestration and storage, regulation of the hydrological cycle, soil stabilization/conservation and improvement in the connectivity of landscape mosaics for biodiversity conservation and the reduction of desertification (Kanninen, 2010).

c) Dryland and farm forestry

This programme aims to promote farm forestry and sustainable management of dryland forests. Kenya's drylands are home to more than 30% of the country's population, 70% of the national livestock population and the bulk of the world-famous wildlife that supports the vibrant tourism sector. Dryland forests are important due to biodiversity conservation and harboring unique and endemic species that are particularly adapted to extreme ecological conditions. They provide essential ecosystem goods and services for people, livelihoods and well-being. They have the potential, if well valued and sustainably managed, to contribute to climate change adaptation and mitigation, prevent soil erosion and desertification, and contribute to economic development, food security and poverty reduction. Investing in forestry will provide income in case of crop failure or livestock loss hence cushioning farmers from climate change induced stress. Drylands also offer the greatest potential for intensified afforestation towards achieving the national objective of 10% tree cover due to low population density in these areas.

The new Forest Policy emphasizes the development of farm forestry as another strategy of increasing the low forest cover, diversifying subsistence products and incomes while providing ecosystem services such as soil and water conservation, microclimate regulation and windbreaks. Therefore, trees planted through afforestation, reforestation and agroforestry in rural landscape and cities, reduce pressure on the natural forests in highly populated areas, sequester carbon as well as buffer against biophysical changes induced by floods, droughts and temperature increase.

Following a logging ban in gazetted forests in Kenya in 2000, trees outside forests on farms and drylands have supported the countries local wood demand for over 10 years plus. This testifies the significant role this programme has played.

3. Progress on REDD+ Readiness

In response to the challenges and opportunities posed by climate change, Kenya has developed a National Climate Change Response Strategy (GoK 2010). The NCCRS seeks to strengthen and focus nationwide actions towards climate change adaptation and GHG emission mitigation. This will be achieved by ensuring commitment and engagement of all stakeholders while taking into account the vulnerable nature of Kenya's natural resources and society (GoK 2010). The NCCRS identifies forestry as a key sector for delivering climate change benefits; mainly through the REDD mechanism. They provide opportunities for both mitigation and adaptation to climate change as they provide local ecosystem services relevant for adaptation as well as the global ecosystem service of carbon sequestration, relevant for mitigation (Bruno et al. 2010).

Kenya Forest Service (KFS) as the focal point for REDD+ in the country, has embarked on reforming the forestry sector in line with the new Kenyan constitution, Vision 2030, Forest Act 2005, National Climate Change Response Strategy, Kenya Forest Service Strategic Plan 2009/10-2013/14 and the Readiness Proposal Plan (R-PP). The new forest legislation (Forests Act 2005) and the land policy are strongly supportive of long-term investments including climate change mitigation/adaptation activities (KFS 2010).

Kenya's R-PP was approved by the Forest Carbon Partnership Facility (FCPF) in October 2010. The R-PP presents a 3-year roadmap for the elaboration of a National REDD+ strategy and implementation framework that includes activities that mitigate emissions which are eligible for international finance and in-line with national economic, social and environmental priorities. Currently there are joint efforts by key stakeholders engaged in REDD+ to develop national REDD strategy options that address the drivers/causes of DD and the institutional and legal implementation framework necessary to realize these options. In addition, modalities to establish a historical reference emission scenario for (GHG) emissions from deforestation and forest degradation and the development of monitoring system to measure, report and verify (MRV) the effect of the REDD+ activity on GHG emissions, livelihoods and biodiversity are underway with key challenges highlighted in the last paragraph of this sub-topic.

Box 1. *Some opportunities for climate change mitigation under REDD+ in Kenya.*

- Conservation and management of existing forest areas. About 3.4 million ha of forests need to be secured and protected to provide environmental functions.
- Rehabilitation of degraded forest areas. About 120,000 ha of degraded forest areas require rehabilitation.
- Renewable energy from biomass. Plantation forestry development. Kenya currently has about 24,000 ha of establishment backlogs.
- Rehabilitation of degraded sites in ASALs that have been negatively impacted by overgrazing and charcoal burning.
- Agroforestry within farmlands. Kenya has about 10.4 million ha of farmlands that can support investments.

As a Party to the United Nations Framework on Climate Change Convention (UNFCCC), Kenya has an obligation to conserve and sustainably manage its forests as carbon storehouses. REDD+ is potentially an important mechanism which will help developing countries like

Kenya meet its forest-related goals, including the constitutional obligation to increase the forest cover to a least 10 percent of land area while eradicating poverty.

Kenya undertook a rigorous participatory process to develop its REDD+ Readiness Preparation Proposal, drawing on expertise from the government, civil society organizations and the private sector. It is therefore ready to implement its REDD+ readiness plan, building on the groundwork developed in numerous forestry initiatives. However, a number of early actions that require international support such as capacity building for Measuring, Reporting and Monitoring emissions and sinks in the forestry sector, rehabilitation of degraded forests and addressing the drivers of deforestation and forest degradation, have been identified to enable the effective implementation of REDD+.

4. Challenges facing the forestry sector in Kenya

The key issues and challenges facing the forestry sector in Kenya include:

i. *Low and decreasing forest and tree cover.* The country's forest cover is estimated at 5.9 % and is declining due to the increased pressure on forest land. This is considered critically low for a country dependent on agriculture and should be at least 10%, which is considered the internationally recommended minimum forest cover. The country is therefore classified as "forest poor".

ii. *Unsustainable utilization of forest resources, especially biomass energy.* Over 70% of the Kenyans rely on wood biomass for their energy requirements which exerts considerable pressure on the tree and forest resources. In addition, the wood conversion technologies for timber manufacturing and charcoal production are obsolete and wasteful of wood leading to overharvesting of trees to meet the demand.

iii. *Climate change.* The changing climate has a direct impact on forest resources and ecosystems and on people and their livelihoods. Disasters such as flooding, landslides, and drought have become more frequent and severe. Forests play an important role in both mitigation and adaptation to climate change through carbon sequestration, flood control and landscape stabilization.

iv. *Resource mobilization to support forest sector development.* Forest goods and services are largely public in nature and therefore depend to a large extent on public funding. However, prioritization of public investment and incentives to the private sector for forestry development has been low, partly as a result of low valuation of forestry goods and services, leading to the very slow growth of the sector. Further, there is low investment in forest industries which impacts on the level of technology and value addition.

v. *Information on forests.* The sustainable development of forest resources depends to a large extent on the generation, development and transfer of technologies. Accurate scientific information is critical for informed decision-making by all stakeholders. Investment in forestry research, training and education needs to be given a higher priority, and linkages between research institutions, universities and other higher education centers, forest institutions, civil society and the private sector need to be strengthened.

vi. *Forest sector governance:* sustainable development of the forest sector requires effective regulation and forest law enforcement. To achieve sectoral goals, it is imperative that governance challenges are addressed in policy, legal and institutional reform processes.

5. Conclusion

Even if international mechanisms to provide carbon finance for emissions management activities in forests do not reach the magnitude many are expecting, the Government of Kenya remains committed to the design of policies and measures to protect its remaining forest resources in ways that help improve local livelihoods, conserve biodiversity and mitigate climate change. Kenya prioritizes the implementation of environmentally and socially sustainable land-use and forest policies that will meet the demands of the current and future generations.

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A review on opportunities and constraints of A/R-CDM projects in developing countries

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Abstract

The Clean Development Mechanism (CDM) is the only flexible mechanism in which developing countries (Non-Annex I parties) can participate and can be incorporated between Annex I and Non-Annex I parties. Among the 15 sectors that can be implemented under the Kyoto Protocol-CDM, forestry-based carbon sequestration projects could demonstrate a win-win situation from a climate change combating and sustainable development perspective, if properly designed and successfully implemented. Therefore, it is now generally accepted that Afforestation and Reforestation CDM (A/R – CDM) can play an important role in mitigating climate change as well as providing a landscape approach under REDD+ activities. At the same time, it can support poverty alleviation, create green development and improve international collaboration in developing countries. A/R-CDM projects being implemented to date are mostly in countries of Latin America and Asia, some projects exist in Africa and Europe. However, up till 18 November 2011, only 32 A/R – CDM projects, out of 4195 in all sectors, have been UNFCCC approved. Many remain in the registration pipeline. It is apparent that there are considerable constraints to the development of A/R-CDM projects, and the likelihood of their utilization depends on a range of social and economic challenges including financial constraints, longer time frames, competition of timber production and carbon sequestration, ownership conflicts, methodological constraints and political constraints. This paper describes potential opportunities and constraints of A/R – CDM projects in developing countries based on literature reviews.

Keywords: A/R-CDM, developing countries, Kyoto Protocol, landscape approach

1. Introduction - Background

Climate change, resulting in global warming, has emerged as one of the most crucial environmental challenges of the 21st century (Bizikova et al. 2008). It could adversely affect living things on earth and has become a threat to their ecosystems. It has received increasing attention in international negotiations (Min Zaw Oo 2010). Currently the deep and multiple links between development and climate change are acknowledged, emphasizing the need to move climate policy into the broader context of development, equity, poverty reduction and sustainable development (Bizikova et al. 2008). The United Nations Framework Convention on Climate Change (UNFCCC) is an international environmental treaty produced at the United Nations Conference on Environment and Development (UNCED), held in Rio de Janeiro in 1992. With 194 Parties, UNFCCC is the parent of the 1997 Kyoto Protocol. The Kyoto Protocol is an international agreement linked to UNFCCC and has been ratified by 191 of the UNFCCC Parties. The detailed rules for the implementation of the Protocol were adopted at COP 7 in Marrakesh in 2001, and are called the "Marrakesh Accords". Under the Protocol, 37 states, consisting of highly industrialized countries and countries undergoing the process of transition to a market economy, have legally binding emission limitation and reduction commitments. Those amount to an average of five percent against 1990 levels over the five-year period 2008-2012. (www.cdm.unfccc.int). The targets committed to under the Kyoto Protocol cover six main greenhouse gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF_6). The Kyoto Protocol establishes three cooperative mechanisms designed to help Annex I Parties reduce the costs of meeting their emission targets by achieving emission reductions at lower costs in other countries than they could domestically. These are the following:

- *International Emissions Trading* (ET) permits countries to transfer parts of their 'allowed emissions' (assigned amount units) - only Annex I Parties can participate in this mechanism.
- *Joint Implementation* (JI) allows countries to claim credit for emission reductions that arise from investment in other industrialized countries but can only be implemented between developed countries and EIT (Economies in transition) countries.
- *Clean Development Mechanism* (CDM) allows emission reduction projects that assist developing countries in achieving sustainable development and that generate 'certified emission reductions' for use by the investing countries or companies (Moej 2011).

Developing countries are most vulnerable to climate change impacts due to fewer resources for adaptation (UNFCCC 2007). Among 15 sectors that can be implemented under the Kyoto Protocol-CDM, carbon sequestration projects through land-use, land-use change and forestry (LULUCF) could demonstrate a win-win situation from the perspective of climate change combating and sustainable development, if properly designed and successfully implemented. Thus, the purpose of this paper aims to assess the opportunities and constraints encountered in implementing A/R-CDM projects currently in developing countries.

2. Overview of the A/R-CDM Project

The CDM is a market-based instrument under the Kyoto-Protocol consisting of the implementation of projects that either reduce emissions of greenhouse gases (for example, renewable energy) or enhance removals of CO_2 (specifically afforestation and reforestation projects) (Forner 2005). It has the double objective of assisting developing countries to achieve sustainable development and to help developed countries with meeting their emission reduction obligations under the protocol (Forner 2005). The figure below shows the CDM project cycle approved by UNFCCC.

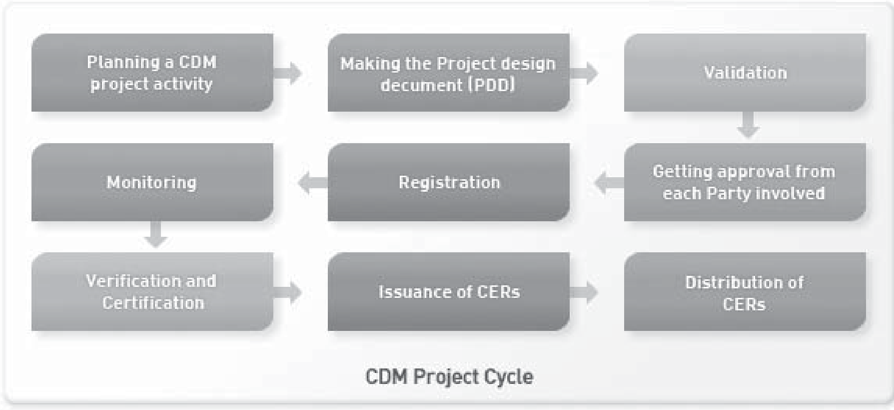

Figure 1. *Project cycle for the CDM (Source: http://www.kgpa.or.kr/eng/03_overseas/03_overseas_sub03_03.html (23-11-2011)).*

According to the decisions made by the Executive Board of UNFCCC, there are 15 sectors where CDM projects can be implemented.

Table 1. *Lists of registered CDM projects under UNFCCC by each sector.*

No	Sectoral Scope*	Registered Projects
1	Energy industries (renewable - / non-renewable sources)	2835
2	Energy distribution	0
3	Energy demand	43
4	Manufacturing industries	208
5	Chemical industries	72
6	Construction	0
7	Transport	10
8	Mining/mineral production	51
9	Metal production	9
10	Fugitive emissions from fuels (solid, oil and gas)	169
11	Fugitive emissions from production and consumption of halocarbons and sulphur hexafluoride	29
12	Solvent use	0
13	Waste handling and disposal	589
14	Afforestation and reforestation	32
15	Agriculture	148
Total		4195

Source: http://cdm.unfccc.int/Statistics/Registration (accessed on 18-11-2011).

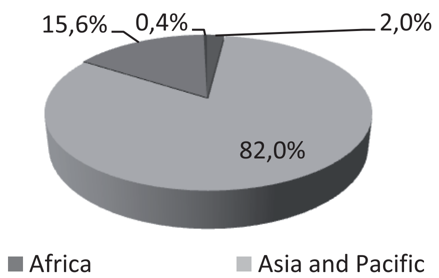

Figure 2. *Regional distribution of CDM projects (Source: http://cdm.unfccc.int (accessed on 18-11-2011).*

Rules and procedures regarding A/R CDM project activities are similar to those of GHG emission reduction CDM project activity. The most significant difference of A/R CDM is non-permanence. In A/R CDM, CO_2 once sequestered in trees could be release back into the atmosphere in an occasion such as a forest fire or a die back due to pests. The issue of non-permanence is addressed by creating different type of CERs (Certified Emission Reduction), namely temporary CERs (tCERs) and long-term CERs (lCERs) (Moej, 2011). A non-Annex I Party may host an A/R CDM project, if it has selected and reported to the EB (Executive Board) through its DNA (Designated National Authority): (a) A single minimum tree crown cover value between 10 and 30%; and (b) A single minimum land area value between 0.05 and 1 hectare; and (c) A single minimum tree height value between 2 and 5 meters (Moej, 2011).

Nowadays, the introduction of afforestation and reforestation activities under REDD+ projects as part of the landscape approaches is being considered. Introducing A/R activities under REDD+, can definitely support the reduction of emissions from the forestry sector and at the same time increase carbon stocks of forests that are targeted by REDD+ projects.

In addition to large-scale A/R projects under the Kyoto-protocol, rules and modalities for *small-scale projects* have been generated in order to enable the participation of low income communities and individuals. To make these activities viable, simplified modalities and procedures were designed, which are expected to reduce the high transaction costs usually associated with A/R-CDM (Haupt & Lüpke 2007).

To qualify as small-scale, projects have to comply with the following conditions:

- Projects may be carried out only by low income individuals or communities, as defined by the host country.
- If carbon removals exceed an annual limit of 8,000 tons of CO_2, these are not eligible as certified emissions reductions.
- Projects must not be a de-bundled large scale activity. To register a set of small-scale A/R-CDM project activities, these have to be at least one kilometer apart. (Haupt & Lüpke 2007).

3. A/R-CDM Projects in developing countries

Currently (18 November 2011), only 32 A/R–CDM projects, out of 4195 in all sectors, have been UNFCCC approved (UNFCCC 2011). It is apparent that there are considerable constraints to the development of A/R-CDM projects, and the likelihood of their utilization depends on a range of social and economic challenges. Most of the A/R-CDM projects implemented to date are in countries of Latin America, amounting to 13 registered projects, followed by Asia with 11, Africa with 6 and Europe with 2, as shown in figure 3.

A/R-CDM projects registered in Latin America are mostly implemented in Brazil and Mexico. Most of the A/R-CDM projects implemented in Asia are in India and China. In terms of other Asian countries, these projects are mostly within the pipeline and some are still requesting registration. Currently 3 A/R-CDM projects are being implemented in China, 7 projects in India and 1 project in Vietnam.

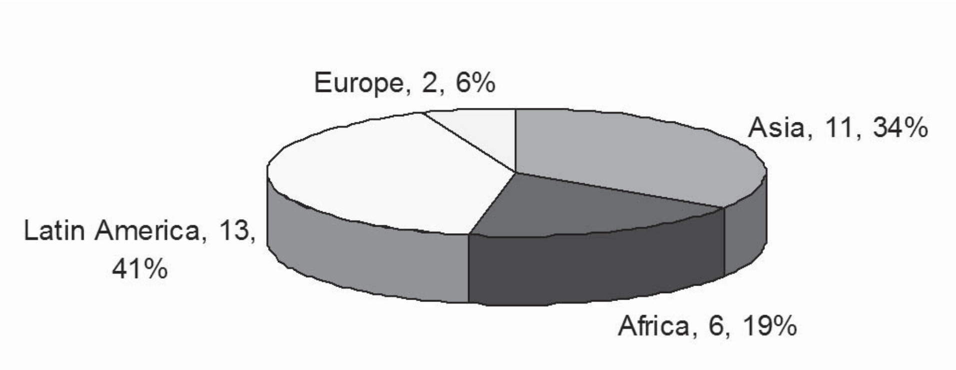

Figure 3. *A/R-CDM projects in Developing countries (Source : www.forestcarbonasia.org (18-11-2011)).*

Africa has a lower number of registered A/R–CDM projects compared to countries in Latin America and Asia. According to the World Bank (2011), complex rules for designing CDM projects such as land eligibility and non-permanence are among the obstacles hindering development and registration of projects. Non-permanence, for example the risk that trees burn down and thus lose their carbon stock, is currently addressed through temporary crediting, which can limit the demand for forest carbon assets. Some of the registered AR–CDM projects in Africa include the Humbo reforestation project in Ethiopia, the Uganda Nile basin reforestation project and the *Ibi Batéké* Project in the Democratic Republic of Congo (World Bank 2011). The DRC project is expected to absorb an estimated 2.4 million tons of CO_2 over the next 30 years and provide work for around 400 people.

4. Opportunities of A/R-CDM Projects

4.1 Income generation and employment opportunities

A/R–CDM projects can contribute to community cash income as well as access to non timber forest products such as fruits, fuelwood and medicinal plants among others. For example through the Nhambita community carbon project in Mozambique local household receive a cash payment of US$ 242.60 per hectare over 7 years for carbon sequestered on their farms (Jindal 2008). In Tanzania, local farmers with TIST (The International Small Group Tree Planting Programme) contract receive 20 Tanzanian Shillings (US$ 0.02) per tree per ha in 20 years (Scurrah-Ehrhart 2006). This income is important for community livelihood, paying school fees and other household services. Forest plantations also have the potential of offering significant employment to marginalized local communities. Morrison and Bass (1992) documented that one ha of plantation can offer 70 days of labor in grassland/flat land and up 400 days in mountainous regions. It is also anticipated that CDM plantations are likely to follow rotation harvesting thus maintaining demand of laborers (Smith 2002).

4.2 International collaboration

A/R-CDM projects enhance international collaboration while combating global climate change. This is because it involves negotiation and signing contracts between two parties (developed and developing countries) on payment for carbon dioxide offset. Issues related to global climate change and carbon sequestration have been at stake in various international panels on climate change as well as conferences of parties thus fostering international cooperation among countries.

4.3 Biodiversity conservation

Forest plantations under A/R–CDM projects might have high timber productivity and may thus reduce pressure on natural forests (Smith 2002). Forest plantations can play an important role in the regeneration of secondary forests, especially in severely degraded ecosystem, and act as corridor linking two or more fragmented ecosystems (Smith 2002). This will enable migration of a wider variety of fauna as well as provide habitats for small mammals, birds, amphibians, reptiles and macro and microbes mixed species plantations are created that will later approach the structure of a natural forest. For example, the World Bank Biocarbon Fund Andasibe – Mantandia Biodiversity corridor project has been playing an important role in the protection of several endemic species through linking fragments of the Malagasy rainforest in Madagascar (Jindal et al. 2008). In Uganda, the rehabilitation of 24,000 ha in Mt. Elgon and Kibale National Park has been helping with the conservation of endangered local biodiversity such as the Chimpanzee.

4.4 Green Economy

A green economy is one whose growth of income and jobs is driven by investments that reduce carbon emissions and pollution, increase energy and materials efficiency and enhance natural capital (Radka 2011). The potential of A/R-CDM projects is even more important in facing and mitigating climate change related events such as droughts, heat waves and floods, all of which can effect national development. In this context, the development dividend and carbon finance are especially appropriate where poverty alleviation and environmental protection suggest themselves as priorities of the forestry sector. As a project-based mechanism the CDM can specifically target local circumstances and needs that can encourage green development of the projected areas. Therefore, it is apparent that A/R-CDM projects play an important role in providing countries with solutions for limiting greenhouse gas concentration in the atmosphere while enhancing their natural capital.

5. Constraints for A/R-CDM Projects

5.1 Political constraint

The inclusion of forest sinks in mitigation activities has been one of the most controversial issues in climate change negotiations. Several parties stressed the potential risks of forestry projects: Carbon removals by forests are considered to be only temporary (Zhuping Mo

2007). These risks and related scepticism have, to a certain degree, impaired the political process as well as the potential of forestry related carbon sequestration projects (Zhuping Mo 2007). Due to the resulting methodological and technical uncertainties, negotiators had great difficulty in agreeing on a scheme to account for carbon sequestration by forests (Streck & Scholz 2006).

At a national level, in all the participating countries the national policy seems inclusive but a lot more needs to be done at lower levels (provincial, district). Many policy measures need "surgery" for the sake of harmony and synergy. The capacity at local level is relatively poor and a special effort is needed to address this issue. It is due to this that participation of forestry sector activities in Southeast Asia is low: lack of capacity at different levels of government, lack of capacity to implement, lack of awareness of the national or local implication of the international agreement/law and lack of available expertise (Murdiyarso 2005).

5.2 Financial constraint

This is one of the major challenges impeding development of AR/CDM projects in developing countries. Thomas et al. (2010) mentioned important financial considerations associated with A/R-CDM projects, including: cash flow and the immediacy of returns; restrictions on the inclusion of CERs from CDM projects in regulated carbon markets; securing finance to enable project development; transaction costs; and issues associated with project profitability. A/R-CDM projects also compete for finance with other CDM projects, which are attractive to investors because of their earlier return on investment (Thomas et al. 2010). Thus, finance for A/R-CDM projects remains difficult to secure amongst CDM financiers. In short, the ability of proponents to secure finance is an important constraint to the development of more A/R-CDM projects (Thomas et al. 2010).

5.3 Time Constraint

Aforestation and reforestation projects involving planting new trees take a number of years to yield net carbon sequestration benefits. During this waiting period, project management costs related to weeding and other silvicultural practices continues to be incurred. Therefore despite of the annual return from carbon sequestration, the delay in returns serves as a disincentive for landholders considering engaging in CDM A/R projects (Thomas et al. 2010).

5.4 Timber versus Carbon

The profitability of forest-based C sequestration projects will depend on the international carbon price, additional income from agroforestry products, and the ongoing costs of monitoring (Nair et al. 2009). Therefore, if the price of carbon is lower than timbers, optimal management will involve intensive forest harvesting for timbers with more immediate revenue and profit.

5.5 Methodological Constraint

A/R-CDM projects has been technically challenging to the formulation of methodologies acceptable to the Executive Board (Haupt & Lüpke 2007).A/R projects are involved in features unique to forest or land management: e.g., biodiversity, hydrology or land ownership which require data on background (e.g., proof of land eligibility) that might be costly to obtain under some circumstances (Haupt and Lupke 2007). In developing countries there is often a general lack of the knowledge and technology capacity required to meet the demands of the CDM registration process (Shin et al. 2007). To establish additionality (demonstrating that the emission removal or reduction benefits of the project would not have occurred without that project) a baseline (the scenario describing the development in absence of the proposed project) must be set and future scenarios must be evaluated. This requires local historical knowledge and scientific expertise (Palm et al. 2009). It has been argued that in many developing countries additionality should be easily demonstrated by the fact that without the assistance of external NGOs forest plantations would never have been established (Shin et al. 2007). The UNFCCC describes a number of methodologies (nine for large-scale projects, five for small-scale projects, and two for consolidated projects) that may be used in A/R-CDM activities (cdm.unfccc.int). These methodologies (procedures for the measurement of carbon sequestration) are complex and difficult, and a variety of estimates of carbon sequestration and carbon losses in different land use systems exist. Measurement of terrestrial carbon sequestration is imprecise and difficult compared to measurement of fossil fuel direct emissions (Hohne et al. 2007).

5.6 Ownership conflicts

In developing countries where a great deal of land is held in common, the issues of land tenure and property rights are potential constraints. In Mexico, for instance, 80% of rural land (usually forest and pasture) is held in common by communities (Corbera and Brown 2008). There can be a severe disparity between customary and statutory land rights (Jindal et al. 2008). Forestry projects also require the involvement of diverse stakeholders and occupy large areas of land. Stakeholder groups may have conflicting interests, and there is often the likelihood of competition for land use with the agricultural sector or urban development (Shin et al. 2007). These factors can seriously compromise the viability of projects. In this context, tenureship has to be clear and structured for the implementation of a CDM project. The strong legal background is a crucial element to ensure equitable benefit sharing and to avoid social conflicts, which could impair the permanence of carbon sequestration projects (Haupt & Lüpke 2007).

6. Conclusion

Tropical forest ecosystems are now believed to be the most important potential carbon sinks because of their multispecies composition and their high productivity. Most of the world's tropical forests can be found in Asia, Africa and Latin America in which mostly developing countries are situated and rural people are very much dependent on forest resources for their subsistence needs and rural livelihoods. A/R-CDM projects form important incentives for income generation and employment opportunities in addition to being important for carbon sequestration, biodiversity conservation and soil water conservation in developing countries. Despite these incentives, there are few A/R-CDM projects as compared to other sectors. Yet most UNFCCC approved projects are concentrated to Asia and Latin America very few are in Africa. Most carbon sequestration projects in developing countries are based on voluntary carbon sequestration, thus non Kyoto-compliant. Factors hindering compliance with A/R-CDM projects include financial constraints, long time frames, competition of timber and carbon, ownership conflicts, methodologies and monitoring schemes, and governance and accountability among others. In order to speed up AR–CDM projects, it is important to support training and local capacity for implementing climate mitigation projects in LULUCF and A/R sectors and develop simplified methodologies and monitoring schemes for A/R projects. Moreover, clear landownership mechanisms are also important to curb local people's interest. Formulating tenure land use policy is quite important in least developed countries in order for them to be able to secure benefits from A/R-CDM projects. In this case, it is also important to understand local land tenure systems before introducing A/R–CDM projects in order to avoid land use conflicts.

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Chapter three

Monitoring, Reporting and Verification

Forest monitoring issues in climate change research and policy

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Abstract

Mitigating the effects of climate change is one of the major current challenges for humankind. One intensively discussed approach is the enhancement of carbon stocks in forests, thus reducing atmospheric CO_2 concentrations. The UNFCCC is the convention that deals with internationally concerted measures to reduce CO_2 emissions and to increase carbon sequestering through human interventions including forest management. However, forestry has been recognized as an activity where a quantitative monitoring of human induced C emission to the atmosphere and C removals from the atmosphere are extremely difficult to establish. At first, in the Marrakesh Accords 2001, only re- and afforestation were included as eligible actions in context of the Clean Development Mechanism (CDM). It took several years until a general inclusion of a broad range of forestry activities was devised, the REDD process: Financial compensation is awarded for successful national measures that reduce deforestation and forest degradation. This is calling for efficient and reliable monitoring systems. Measurement – Reporting – Verification (MRV) has been established and accepted as a standard framework for such monitoring processes; and that involves forest inventory as a key component. In this paper, we address and analyze forest inventory challenges in the context of forestry related projects and MRV.

1. Introduction - background

With the beginning of the industrialization, human activities have caused atmospheric CO_2 concentrations to increase from about 280 ppm to more than 390 ppm, resulting in an additional greenhouse effect by changing the earth's energy balance (Solomon et al. 2007). Current and future changes in the greenhouse effect are expected to increase average earth surface temperature by 2-4°C by the end of the century, with regional changes in precipitation pattern and weather extremes. Some regions are expected to experience dryer summers and wetter winter, while other regions may face changes in monsoonal climatic conditions. As CO_2 is the main anthropogenic greenhouse gas it is important to have a basic understanding of the global CO_2 cycle when dealing with approaches to reducing atmospheric CO_2 concentrations.

Figure 1 shows a graphic depiction of the major carbon stores and processes, where the unit is Petagram (Pg) (1 Pg $=10^{15}$ g=1 billion metric tons), which is a unit common to quantifying global C pools. We see that the largest portion of C is by far fixed in the earth crust, not available for exchange.

The largest portion which is in principle available for exchange is in the oceans; but there, most C is in the deep sea where there needs to be a movement to the superficial layers with an estimated 750 Pg of C, before an exchange with the atmosphere takes place. Approximately another 750 Pg are in the atmosphere and slightly less in plants, mainly in trees. The carbon pool in soils is altogether nearly three times the plant C pool. Another important pool, in particular in the context of human induced changes in atmospheric C, are the fossil fuels that include coal, oil and gas.

The arrows in Figure 1 illustrate the many exchange processes between the four major C reservoirs (the atmosphere, the oceans, land and fossil fuels) and make clear that the global C cycle is a complex system, which might be well buffered against small interventions but where the effect of larger interventions is difficult to predict. It appears that the human interventions over the past 150 years are a larger intervention.

2. The role of forests in global C dynamics

Over earth history a balance of carbon fluxes through the individual carbon pools developed, resulting is fairly large but well balanced C fluxes in and out of the oceans and in and out of land ecosystems. Terrestrial ecosystem and particularly forests play an important role by absorbing CO_2 through photosynthesis and by releasing CO_2 through plant and microbial respiration.

Currently, humans emit more than 8 Pg C yr^{-1} by burning fossil fuels, thus altering the natural carbon cycle. Ocean and land have reacted to this perturbation and about half of these emissions are sequestered in the oceans and in land ecosystems with the other half resulting in the observed increase of CO_2 in the atmosphere. While the uptake in the oceans is fairly constant at about 2 Pg C yr^{-1} and well understood, the uptake by land ecosystems exhibits fairly large year-to-year variations that are not yet fully explainable and thus not predictable (Le Quéré et al., 2009). Land carbon fluxes are additionally complicated as about 1.5 Pg C are emitted every year as a result from land use change, mainly deforestation and forest degradation. It thus becomes evident that human activities in managing land ecosystems and particularly forests are a major determinant of the terrestrial carbon sink and offer an opportunity to cost-effectively reduce the ongoing increase in atmospheric CO_2 concentrations.

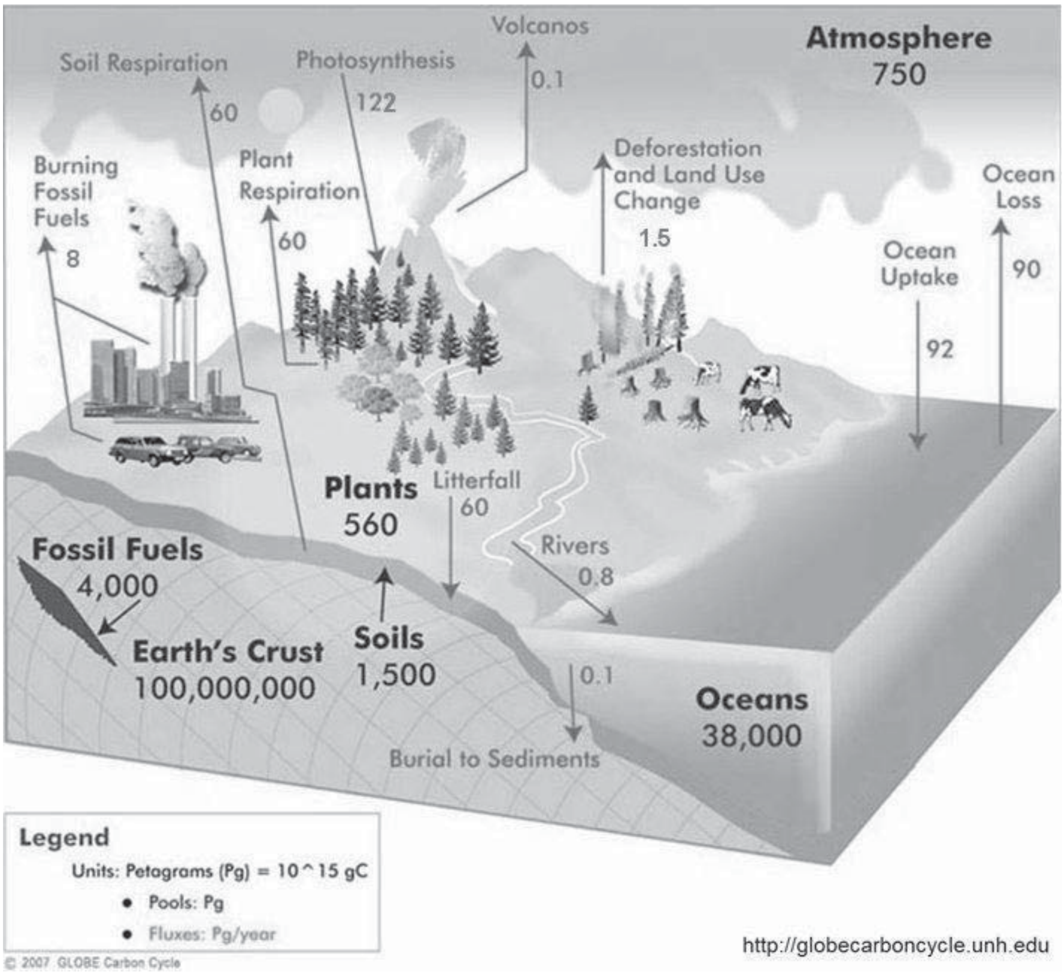

Figure 1. *Illustration of the global carbon cycle (from http://globalcarboncycle.unh.edu). Updated numbers from Le Quéré et al. 2009.*

The most relevant human induced processes of C exchange between forest and the atmosphere are illustrated in Figure 2, while natural processes are illustrated in Figure 1: forests store C while growing and set C free through natural decay processes; therefore, on the long run, forests without human interventions can be considered close to a C-balanced system. A considerable source, however, is land conversion, when forest is converted to other land uses. This reduces the above ground C pool considerably as it does the below ground C pool.

C is stored in trees for a long time. And when wood is used to produce long-term products, this period is even extended. Wood may also replace fossil fuels for energy, thus reducing the C emission from fossil fuels.

For a long-term and sustainable reduction of atmospheric C, it therefore makes sense to take measures to enhance C stocks in forests both by conserving and extending forest area and by increasing the C stock per unit area.

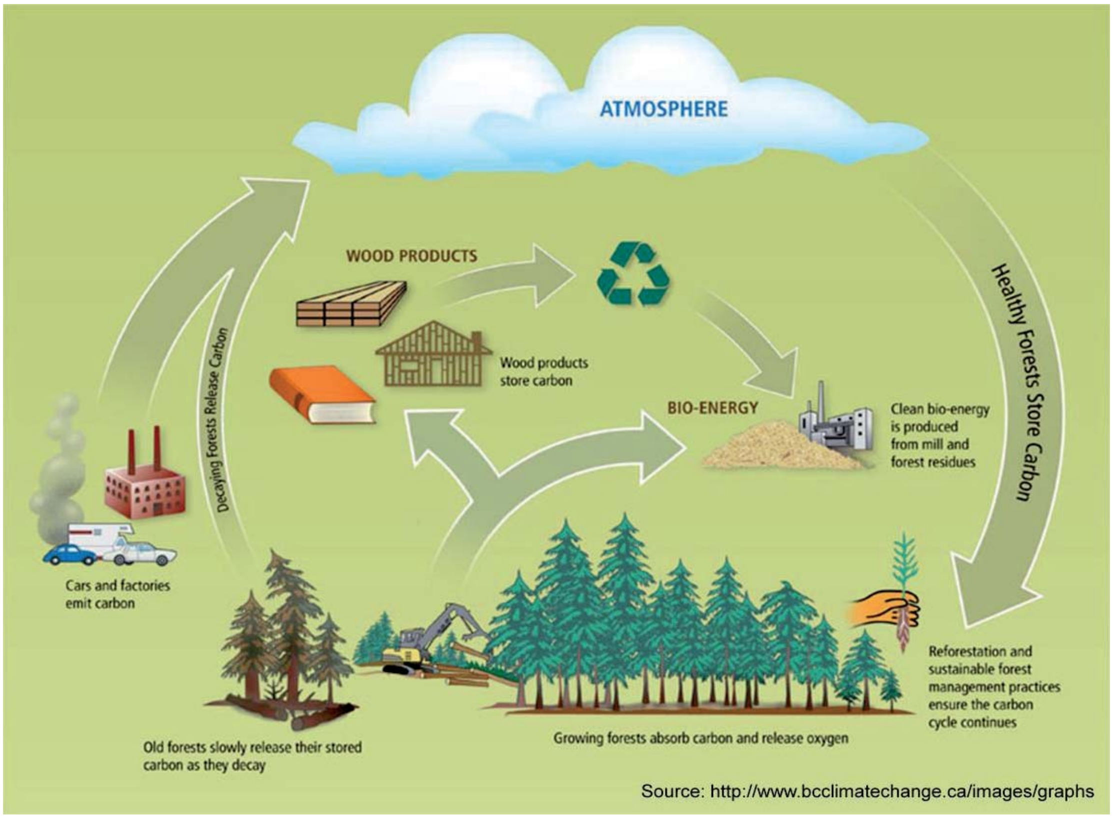

Figure 2. *Major components of the forest and wood related carbon cycle (from http://www.bcclimatechange.calimages/graphs).*

3. What does UNFCCC say about forest monitoring?

In the Marrakesh Accords of COP7 in 2001, forest related carbon projects were only admitted for reforestation and afforestation; at that time, a general agreement on forest carbon enhancement was not considered feasible also because a reliable and verifiable monitoring was not considered possible. Also " 'Avoided deforestation' projects were excluded from the 2008-2012 commitment period of the Kyoto Protocol because of concerns of diluting fossil fuel reductions, sovereignty and methods to measure emission reductions" (Gibbs et al. 2007, Gullison et al. 2007). Then, in COP13 in Bali, the discussion on fostering avoided deforestation was newly promoted and eventually the REDD process installed.

These political processes are long and difficult and many partially contradicting national interests needed to be taken into account, as in all UN-managed international processes. Then, in the Cancún Agreements (Decision 1/CP.16: Outcome of the work of the Ad Hoc Working Group on Long-term Cooperative Action under the Convention FCCC/CP/2010/7/Add.1) the first concrete steps were agreed towards a comprehensive implementation of REDD+, which also includes statements about information provision and monitoring; see Box 1.

Although formulated in a seemingly weak manner and leaving various "ways out", this is a clear message to countries that wish to participate and possibly benefit from the REDD+ process: "a robust and transparent national forest monitoring system for the monitoring and reporting …" needs to be installed. This is largely a forest inventory task, even though a number of "ifs" are integrated into §71(c), as for example "as an interim measure", "in accordance with national circumstances", "with the provisions contained in 4/CP15"; "with any further elaboration and those provisions agreed by the Conference of the Parties".

Box 1. *Some of the forest monitoring related statements in the Cancún Agreements from COP16 in Cancún 2010.*

…
70. Encourages developing country Parties to contribute to mitigation actions in the forest sector by undertaking the following activities, as deemed appropriate by each Party and in accordance with their respective capabilities and national circumstances:
(a) Reducing emissions from deforestation;
(b) Reducing emissions from forest degradation;
(c) Conservation of forest carbon stocks;
(d) Sustainable management of forests;
(e) Enhancement of forest carbon stocks;
….
71. Requests developing country Parties aiming to undertake the activities referred to in paragraph 70 above, in the context of the provision of adequate and predictable support, including financial resources and technical and technological support to developing country Parties, in accordance with national circumstances and respective capabilities, to develop the following elements:
(a) A national strategy or action plan;
(b) A national forest reference emission level and/or forest reference
….
(c) A robust and transparent national forest monitoring system for the monitoring and reporting of the activities referred to in paragraph 70 above, with, if appropriate, subnational monitoring and reporting as an interim measure, in accordance with national circumstances, and with the provisions contained in decision 4/CP.15, and with any further elaboration of those provisions agreed by the Conference of the Parties;
…

4. In more concrete terms: what is required?

In order to understand the carbon dynamics in forests and the role of forests in the global carbon cycle and to generate an information base that can be used for existing and upcoming carbon financing schemes, reliable data is required that describes carbon stocks and carbon dynamics with a certain degree of precision and spatial explicitness.

In more concrete terms, for all land use categories and for all carbon pools, data needs to be produced for national reporting on the respective processes, if relevant human induced changes in the carbon pools are to be expected. Pools should only be excluded if there is evidence that these pools do not exhibit relevant changes. A subdivision of reporting per land use category may be indicated, if sub-categories with distinct carbon features can be singled out; for example plantation forests and old growth natural forests, reporting can be done for these sub-categories.

Activity data and emission factors need to be determined and reported. "Activity data" refers to area and area changes of forest land or types of forest land and "emission factors" refer to the carbon density per unit area of forest. Both variables are typical forest inventory variables, although the terminology is slightly different. Changes in forest area are relevant for UCFCCC reporting when they are a result of human activities, and the same holds for emission factors. That is, for both variables, it is not only important to record status and changes but also to establish evidence of human intervention. Any human intervention in forests is named “forest management” in UNFCCC terminology; this is another terminological particularity which needs to be observed by professionals with a forestry background.

National forest inventories, as they are established in many countries, can provide large portions of the required information; even more: designed in a suitable manner, these inventories constitute at the same time valuable data sources, also informing on some elements of biodiversity, on the utilization of the forest resource, on the tree resource outside the forest and various other domains.

According to the Intergovernmental Panel on Climate Change (IPCC) guidelines for reporting to the UNFCCC, there are three levels of uncertainty that are standard for reporting, also called tier levels. The higher the tier, the more precise the carbon estimates and the more will the results be considered as reliable when it comes to financial compensation; however, higher precision unavoidably comes with higher cost and a higher need for specific forest monitoring expertise.

Tiers are „levels of detail/precision/accuracy“ and “correspond to a progression from the use of simple equations with default data to country-specific data in more complex national systems” (GOFC-GOLD 2009). Table 1 gives a more explicit description of these 3 tiers.

Table 1. *Data needs for meeting the requirements of the three IPCC Tiers (from: GOFC-GOLD 2009).*

Tier	Data needs / examples of appropiate biomass data
Tier 1 (basic)	Default MAI* (for degradation) and/or forest biomass stock (for deforestation) values for broad continental forest types – includes six classes for each continental area to encompass differences in elevation and general climatic zone; default values given for all vegetation-based pools
Tier 2 (intermediate)	MAI* and/or forest biomass values from existing forest inventories and/or ecological studies. Default values provided for all non-tree pools Newly collected forest biomass data.
Tier 3 (most demanding)	Repeated measurements of trees from permanent plots and/or calibrated process models. Can use default data for other pools stratified by in-country regions and forest type, or estimates from process models.

*MAI=Mean annual increment of tree growth

Countries (parties) who wish to participate in the REDD+ process need to adhere to defined standards of giving evidence that they have in fact achieved the carbon management goals that they wish to “sell”. This “giving evidence” requires transparency of methods and implementation. The standard is now MRV (Measurement – Reporting – Verification) which is an instrument that is being applied in numerous political processes. Adhering to MRV principles is essential for all countries participating in REDD+.

5. MRV

“*Measurement, Reporting and Verification*” (MRV) is included in the Cancún Agreements as one of the most critical elements necessary for the successful implementation of any REDD+ mechanism” (IISD 2011). The UN-REDD Programme provides a concise definition of MRV (GOFC-GOLD 2009) which is given in Box 2.

In Figure 3, the links are depicted between the overall goals of carbon reduction and the relevant MRV elements (essentially M = Measurement and Monitoring) to support the corresponding processes. It is clearly seen that national forest inventories and remote sensing play a crucial role. However, what is insinuated here, it is certainly not entirely correct: that activity data is exclusively covered by remote sensing and that NFIs are providers of emission factors only; there is much more interconnectedness and the provision of activity data can efficiently be supported by NFIs as well when designed accordingly.

Box 2. *Definition of MRV according to the UN-REDD Programme from GOFC-GOLD 2009).*

Measurement: The process of data collection over time, providing basic datasets, including associated accuracy and precision, for the range of relevant variables. Possible data sources are field measurements, field observations, detection through remote sensing and interviews.

Reporting: The process of formal reporting of assessment results to the UNFCCC, according to predetermined formats and according to established standards, especially the Intergovernmental Panel on Climate Change (IPCC) Guidelines and GPG [Good Practice Guidance].

Verification: The process of formal verification of reports, for example, the established approach to verify national communications and national inventory reports to the UNFCCC.

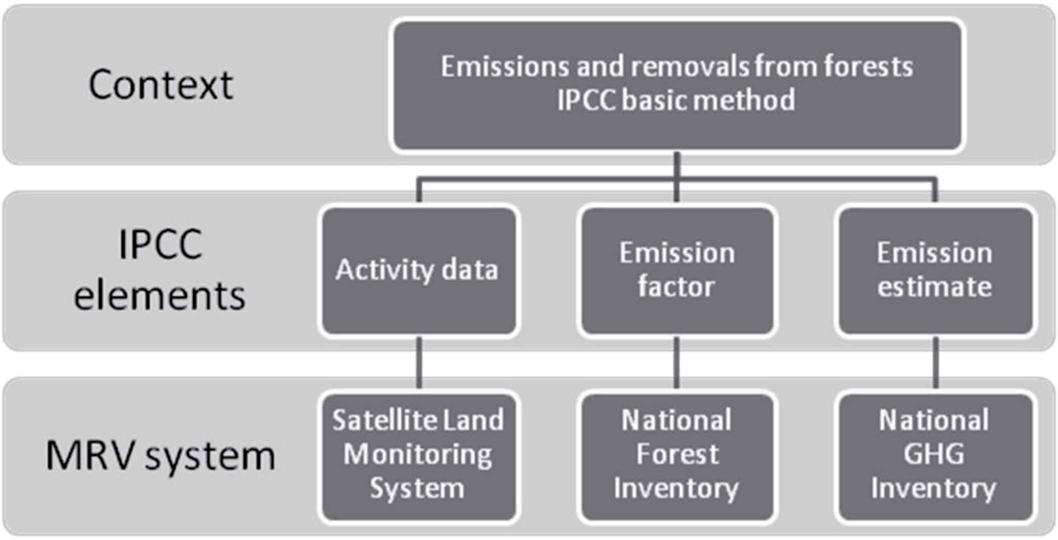

Figure 3. *The three basic carbon-related MRV components and their relation to the IPCC guidelines (from UN-REDD 2009).*

6. Challenges

It is important for forest monitoring experts to understand the principles and the role of MRV. In a Discussion Paper of IISD (International Institute for Sustainable Develpoment, 2011) a number of key issues are listed concerning making MRV operational for REDD. It is likely that some of these issues will be addressed before and at COP17 in Durban, 2011. Table 2 lists these key general questions and respective detail questions.

Table 2. *MRV challenges and issues to be specified (from IISD 2011).*

Key Questions	Building blocks to answer questions
What is a forest within the REDD context? What should be monitored?	Where do disparities lie in definitions between countries? What determines country decisions on what is called a forest and how are these decisions made? How can a common understanding be reached on moving forward? Can the whole landscape approach and accounting solve the issue?
How can Reference Emission Levels and Reference Levels be determined? Over what period and across what scale?	What is the evolution of thinking since 2008 on country positions regarding reference scale and time? Are there more experiences, best practices and lessons that can help inform the SBSTA process? Can they be replicated and adopted nationally? How does the baseline affect the country's ability to participate and benefit from REDD? How does the preferred baseline of one country affect participation by other countries? How can early action at the sub-national level be credited under a national approach? How can the nested approach be supported? How do countries make decisions that are realistic in their own context?
How to determine accuracy thresholds?	How can countries best design a step-wise MRV approach along the lines of Tiers 1, 2 and 3 to enable progress towards greater accuracy? What are the realistic choices? What are the trade-offs? What will be the impacts of excluding some carbon pools on leakage?
How to determine accuracy thresholds?	How can countries best design a step-wise MRV approach along the lines of Tiers 1, 2 and 3 to enable progress towards greater accuracy? What are the realistic choices? What are the trade-offs? What will be the impacts of excluding some carbon pools on leakage?
What are priority capacity building areas?	How do developing countries gain the right technical and institutional capacity to effectively implement REDD?
What are the implications for MRV looking beyond carbon?	Could regional approaches help address capacity issues? How can the development of roadmaps be supported? What are the existing experiences and lessons from countries?
What are the costs of MRV?	What are the significant upfront and long-term costs for MRV that countries face?
How can this be financed?	What trade-offs are countries making between cost and accuracy? How can funding to support countries match short term and long term needs? What financing arrangements will encourage the greatest flow of funds for countries?
What is the relationship between REDD and NAMAs[1]?	Will REDD be part of NAMAs? What is the position of the parties? Will REDD compete with other NAMAs for financing? What are the suggestions of countries of how this could happen?

[1]NAMA = **N**ationally **A**ppropriate **M**itigation **A**ctions

A number of technical issues address questions that are dealt with in forest inventory since decades, for example the issue of the forest definition and the trade-off between accuracy and cost when looking at the overall goals. Uncertainty and its quantification are relevant and crucial elements in all inventory and monitoring activities. Cost of MRV is, of course, the overarching issue: if an MRV system to monitor compliance is prohibitively expensive, the whole REDD+ process would become non-operational.

Essentially, the MRV challenges listed and described in Table 2 refer to questions that are at stake in all large area forest inventory projects: it is about technical questions of definitions and design optimization (key questions 1,2,3), about the users of the data and the policy goals (key questions 3,5,6,9), about cost (key questions 7, 8), about integration of other sectors (key questions 6, 1) and, of course, about building, enhancing and maintaining national expertise and capacity (key question 5), which includes establishing a long-term institution that deals with MRV.

FAO, in 2000, has installed the programme Support to National Forest Monitoring and Assessment NFMA, with the goal to help developing countries produce high quality information on the forest resource and to build respective capacity. That programme follows the approach of relatively modest-budgeted national forest monitoring systems, where such systems are combined with the assessment of information on the tree resource outside the forest (TOF) and on aspects of forest use. The pilot study for that programme that was done in Costa Rica is described in Kleinn at el. (2005). Similar exercises are detailed in Kleinn and Morales (2006) for a sub-national bamboo inventory in Colombia and in Fischer et al. (2011) for a national inventory of Burkina Faso in dry West-Africa.

There are specific challenges of these large area monitoring studies that are a function of the ecozones covered, the national expertise present, the funds available and the natural resource (forest, TOF, bamboo, all land uses, …) considered. However, the basic methodological challenges (and opportunities) are similar in all situations, among them:

- Biomass estimation on the ground ("emission factors") still offers plenty of room for improvement while much research is focused on remote sensing for estimation of "activity data". Improving biomass estimation is a long term project that requires comprehensive field work and excellent networking when building corresponding data bases. The number of research studies with the goal to improve tree biomass functions is probably far less than those that strive to improve remote sensing based area estimation. Some examples for biomass studies are Fehrmann and Kleinn (2006), Fehrmann et al. (2008) and Camargo and Kleinn (2008).
- The situation for the below ground carbon pools, where even less studies exist, is even more difficult. Most biomass models are for above ground biomass. Below ground biomass and soil organic carbon is lesser covered; the corresponding studies are extremely costly and tedious (Ribeiro et al. 2011). However, it is known that the soil carbon pools play a significant role and are affected by human interventions and land

use changes. There is hardly any large area forest inventory that seriously integrates the below ground carbon pools.

- Frequently it is emphasized that it is not enough to have an estimate of the carbon pools but it is also required to produce spatially explicit information on the biomass/carbon distribution = carbon maps. The only way to produce such maps is by integrating remote sensing as wall-to-wall carrier data with field observations on biomass/carbon. The field observations of biomass/carbon are used to establish a model that is applied to all pixels in the remotely sensed image (e.g. Fuchs et al. 2009), where frequently, however, the field biomass data is of doubtful quality because of the lack of an operational field methodology for accurate biomass estimation.
- Data quality and specification of uncertainty are major challenges and there are numerous sources of error and variability in the estimation of carbon stocks and changes, which includes measurement errors of the indicator variables, model errors and sampling errors. It is known, for example, that the total error is in many cases bigger than the changes that are to be observed, so that these changes – although present - cannot be identified as changes. Improving precision of estimation would increase cost dramatically.
- REDD+ is more than just carbon, but it is also about fostering other benefits from forests. Monitoring systems, therefore, should not have a carbon focus only but integrate other targets as well, for example data on biodiversity indicators and on indicators of forest use. Examples of the integration of biodiversity indicators are the estimation of forest edge lengths and fragmentation status (Kleinn and Kändler 2011) and the estimation of tree species richness (Lam and Kleinn 2008, Magnussen et al. 2009).

7. Conclusions

There is a long tradition in forest monitoring, and forest inventory activities date back several centuries. This is a big difference to other sectors that deal with natural resources as for example agriculture or conservation. However, when dealing with the REDD+ process, it becomes very clear that forest monitoring has more than just a scientific-technical dimension: it is highly political and in the context of REDD+ the information provided from forest inventories also gets an economic value; all of a sudden, uncertainty is a big issue (Kleinn et al. 2010).

Unfortunately, it is currently still the common attitude of forest inventory people to very much focus on the technical-scientific optimization of monitoring systems and to engage to a much lesser degree with the discourse with those groups who steer the political processes. On the other side, only very few decision makers and COP negotiators have a comprehensive technical knowledge of forest monitoring; very frequently, even the most basic issues do not appear to be well understood. It is a challenge in forest monitoring as in various other technical-scientific fields, to try to bridge the science-policy divide; and this also means that the political dimension of forest monitoring is more acknowledged in the forest monitoring community, which also include the development of respective academic curricula.

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Risk Mapping for Commercial Forestry in South Africa: The ICFR Perspective

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Abstract

Forest risk modeling and management are becoming increasingly important issues in the context of planted forests, and forestry land owners are feeling a growing need to develop tools and techniques to assess and manage risk. Important risks include biosecurity (pest and diseases), fire and extreme events such as snow, frost and drought, with climate and climate change being the main drivers. Hence the challenge to the South African forestry industry is to maintain and when possible improve productivity in a changing environment. Commercial forestry in South Africa consists of approximately 1.2 million hectares (1% of the country) of plantation forests subdivided into management units (compartments) of single species and even age. The main commercially grown species are *Pinus* (52.5%), *Eucalyptus* (39.1%) and *Acacia* (7.6%) genera, and are grown for pulp and paper and sawtimber (Forestry South Africa, 2009). Rotation length is 6-12 years for pulp stands and 20-30 years for sawtimber stands. Climate is one of the main drivers of productivity, affecting inherent site fertility as well as pest and pathogens outbreaks, frequency and intensity of fires, and competition from invasive plant species. The Institute for Commercial Forestry Research (ICFR) has been conducting research on behalf of the South African forestry industry for the past 65 years, and the purpose of this communication is to give an overview of the current research focus in the area of risk modeling. There are four main projects currently running in this area of research, climate change, site classification, site-species matching and pest and diseases. The outputs are very simple, spatially based models that can be easily interpreted and used for management and operational decision-making.

1. Climate change

The South African forestry industry has recognized a gap between climatologists and forestry planners; climate change predictions developed by the climatologists are not easily available to the forestry planners for management and decision making. Furthermore, the global focus on forests and climate change research has been on mitigation and on the development of forecasting models applied to natural forests, and research findings are generally not applicable to single species plantation forests. Therefore, there is a need to bridge this gap and develop spatial models that are applicable to the plantation forestry context and can be used for management purposes. The Climate System Analysis Group (CSAG, University of Cape Town) has applied nine global circulation models downscaled at the regional level to real daily rainfall and temperature data for 83 climate stations located across the country. The raw data is available to the public via a web interface (http://cip.csag.uct.ac.za). The average mean annual precipitation (MAP) and mean annual temperature (MAT) predictions obtained from the nine models were used to create medium term (2065-2085) MAP and MAT grids via spatial interpolation and according to the methodology described by Schulze (2007). The medium term MAP and MAT grids have been used in a variety of practical applications, such as future site-species suitability, frost and drought risk and pest and diseases distribution.

In relation to bridging the gap between climatologists and practicing foresters, an exploratory study was conducted for the province of KwaZulu-Natal, to evaluate and quantify the actual changes in rainfall and temperature over the past 50 years. Sixty-three rainfall stations and seven temperature stations were selected within the forestry areas of the province, and daily rainfall and temperature data from January 1950 to December 2007 were used to perform the analyses. Rainfall stations were grouped according to their geographic position into five climatically homogeneous areas, whilst due to the small sample size, temperature analyses were performed at the station's level. Changes in climate patterns were analyzed by comparing two data sub-sets; 1950-1970 and 1987-2007. An independent two-sample t-test was performed to detect significant differences between the two data sub-sets. Whilst significant differences (1950-1970: 1200 mm; 1987-2007: 1078 mm; $p < 0.05$) in mean annual precipitation were detected in only one of the five areas of the province, the high coefficient of variation indicated more erratic rainfall patterns in all five areas (Table 1).

Table 1. *Mean annual precipitation (MAP), Standard Deviation (Stdev) and Coefficient of Variation (CV %) for the two sub-datasets. (KZN – KwaZulu-Natal).*

Area	MAP: 1950 - 1970	STDV	CV%	MAP: 1987 - 2007	STDV	CV%
Midlands	893.7	81.31	9.1	921.3	176.72	19.2
Northern KZN	971.5	157.99	16.3	939.2	184.62	19.7
Southern KZN	886.3	101.67	11.5	912.0	192.35	21.1
Zululand	1014.0	168.66	16.6	1040.0	266.68	25.6
Zululand Inland	1200.0	150.58	12.5	1078.0	200.82	18.6

A significant decrease in the average number of rainfall events per year was detected in all five areas (Figure 1), coupled with a significant increase in the average number of rainfall events of 40 mm or more per year in three of the five areas (Figure 2).

Mean annual temperature increased significantly in three of the seven temperature stations ($p < 0.05$). Similarly, a significantly higher average number of days where the maximum temperature was equal or in excess of 30°C was observed in three of the seven temperature stations.

Overall, results confirm predicted global trends of more frequent extreme events, erratic rainfall patterns and temperature increases.

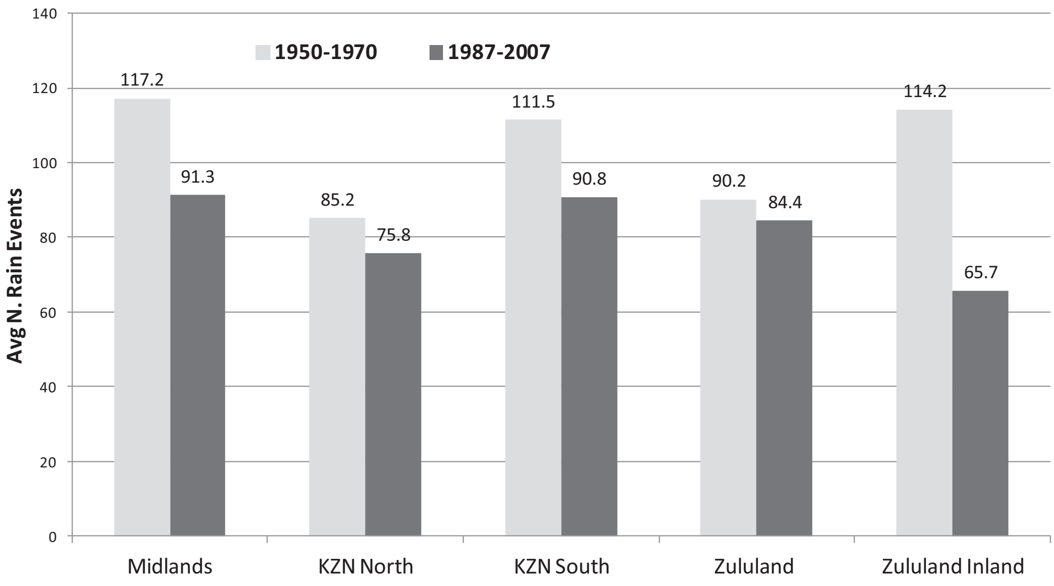

__Figure 1.__ Average number of rainfall events per year: 1950-1970, 1987-2007.

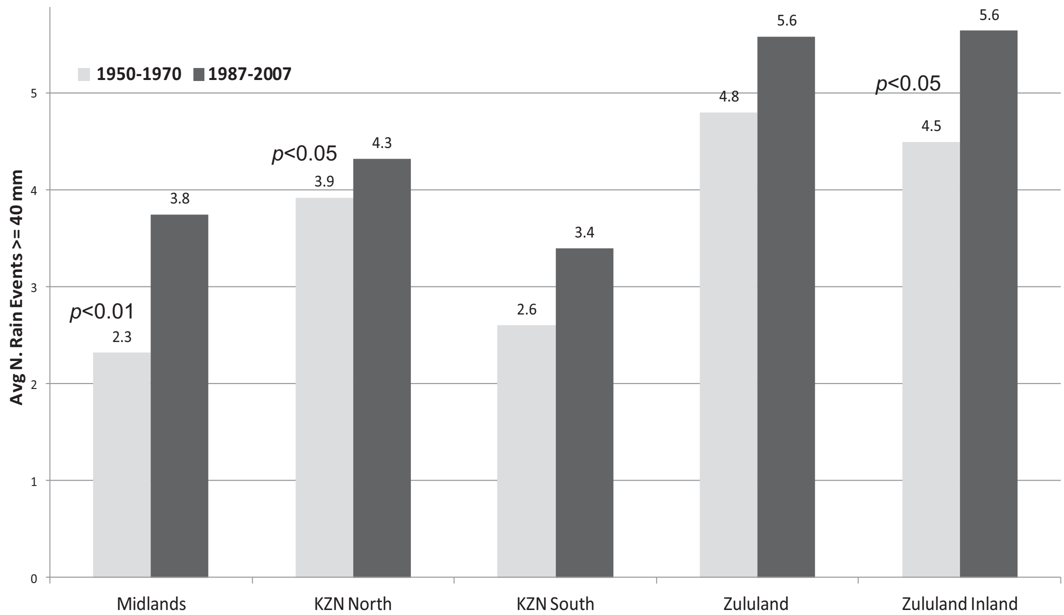

__Figure 2.__ Average number of rainfall events > 40 mm per year.

2. Site Classification: current vs future.

The ICFR forestry site classification system was developed by Smith et al. (2005) to provide a platform for silvicultural, tree breeding and wood quality research results, and to facilitate the uptake of research findings. The system is based on three levels of classification; MAT, MAP and geological grouping, and each site class is linked to information such as species suitability, pest and diseases risk and predicted productivity. The first level of classification is defined by three classes (cool temperate, warm temperate and sub-tropical), and further subdivided at the second and third level of classification to a total of 27 site classes. The system was developed for the summer rainfall region of South Africa, where most of the commercial forestry areas are located. Predicted MAP and MAT grids (see Climate Change section) were used to develop a future forestry site classification map, and to detect predicted changes in the occurrence of the site classes (Figure 3).

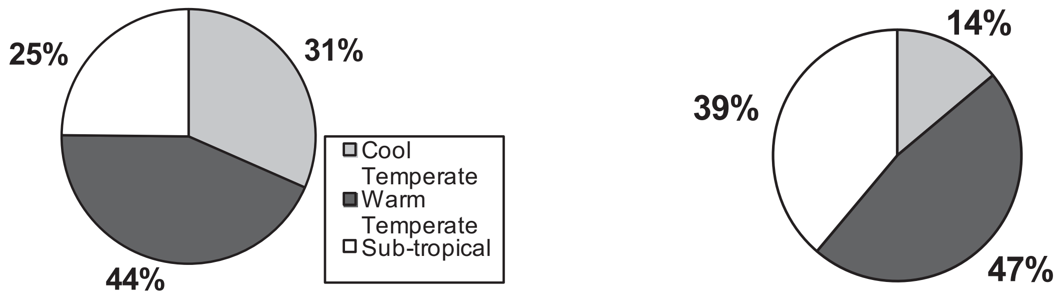

Figure 3. Current (left) and predicted (right) representation of forestry site classes in the summer rainfall region of South Africa.

The predicted site classification system has proved to be an efficient tool to analyse and illustrate future scenarios for site species matching, potential productivity and risk evaluation (frost, drought, pest and diseases; Figure 4).

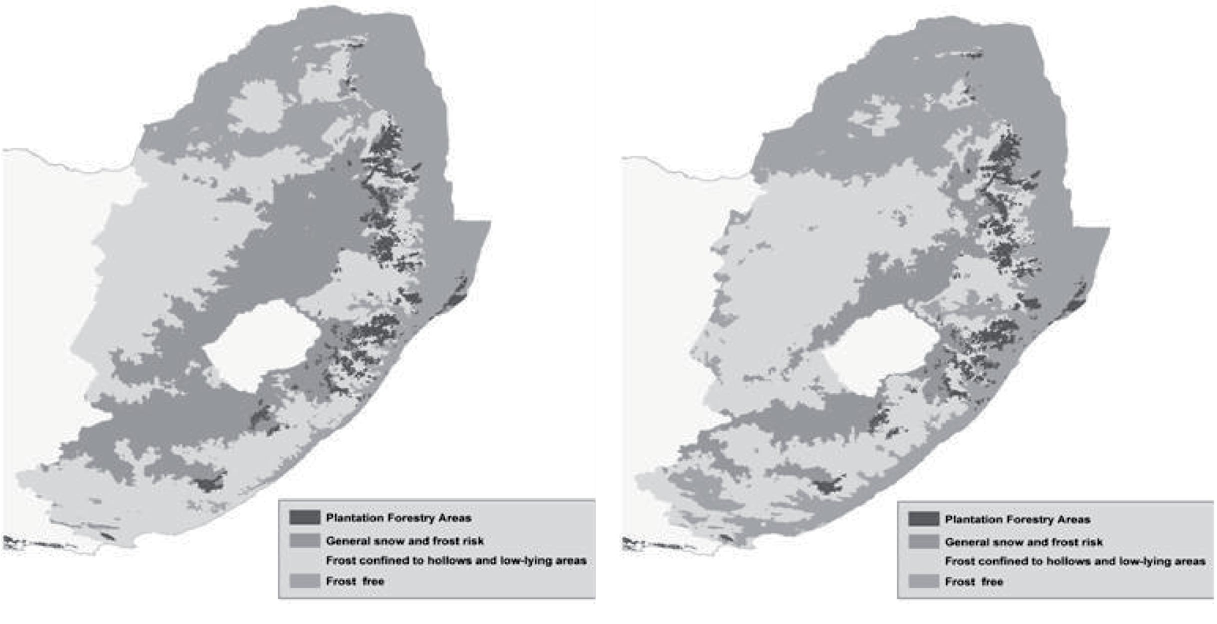

Figure 4. Current (left) and predicted (right) frost and snow risk in the forestry areas of the summer rainfall region of South Africa.

3. Monitoring water balance

Water availability is one of the main limiting factors for stand productivity in South Africa and yearly fluctuations in available water are often the cause of inaccuracy in stand yield projections, with strong management repercussions. A simple real-time Aridity Index, based on rainfall and potential evapotranspiration (Tsakiris and Vangelis 2005) was calculated for the province of KwaZulu-Natal. Monthly potential evapotranspiration (PET) from January 2006 to December 2010 was extracted for 63 rainfall stations located in the forestry areas of KwaZulu-Natal from the MODIS evapotranspiration dataset (MOD16, 2011).

The MOD16 PET dataset is 1-km2 land surface potential evapotranspiration (PET) for the global vegetated land area at 8-day, monthly and annual interval for the period 2000-2010.

The value of the index for a certain period of the year (k) is calculated by the following equation:

$$a_k = \frac{\sum_{j=1}^{j=k} P_j}{\sum_{j=1}^{j=k} PET_j}$$

where Pj and $PETj$ are the precipitation and potential evapotranspiration of the j-th month of the year. For the purpose of this analysis, the Aridity Index was calculated yearly from 2000 to 2007 for each of the five areas of KwaZulu-Natal and compared to the long term annual aridity index derived from historical data (Schulze 2007; Figure 5). The evaluation of this index as a parameter and to calibrate empirical growth models is process.

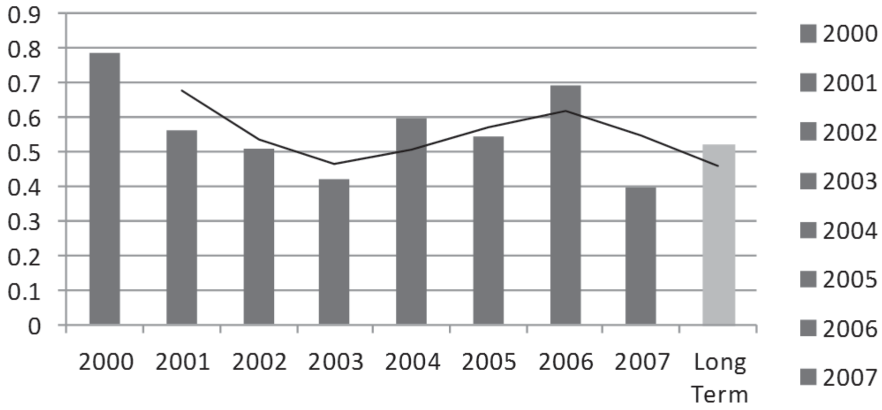

Figure 5. *Yearly Aridity Index for the Zululand inland area for the years 2000 – 2010 and long-term Aridity Index based on historical data.*

4. Pest and Diseases

Pest and diseases are a major risk for plantation forests in South Africa, and they are strongly climate driven. Much of the recent research has been focusing on *Sirex noctilio* (Hymenoptera: Siricidae), a woodwasp native to Eurasia and North Africa, first detected in the Western Cape area of South Africa in 1994 (Tribe & Cillié 2004). *Sirex* has since spread to all the pine plantations in the country, affecting most pine species commercially grown in South Africa. A bioclimatic model to assess the susceptibility of pine plantations to *Sirex* was developed in Random Forest (Breiman 2001) using the R interface (Williams 2009) and following the methodology developed by Ismail et al. (2010). Random Forest is a non parametric predictive model algorithm and uses a training-test dataset as well as explanatory variables to build the model and test its robustness (Table 2).

For the purpose of this study, the training-test dataset consisted of about 4000 points, where the presence/absence of *Sirex* (response variable) was verified in field. One-hundred and twelve 1’ x 1’ historical climatic variables obtained by the South African Climatology and Agrohydrology Atlas (Schulze 2009) were used as explanatory variables. The predictive model was built for the summer and winter rainfall regions of South Africa and run at the landscape level to highlight areas of high, medium and low risk of *Sirex* within the pine plantations. The model was also run at a finer scale (compartment/management unit), where, apart from the climatic variables, compartment-specific information such as species, age, damage/stress were included.

Table 2. *Predictive power and Estimated Error Rate of the Sirex predictive model for the summer and winter rainfall regions of South Africa.*

	Summer Rainfall Region	Winter Rainfall Region
Predictive Power (F)	0.924	0.848
Estimated Error Rate (%)	7.60	15.16

The models were imported into a GIS (Geographic Information System) environment and *Sirex* risk maps were compiled at the landscape and company/farm levels, and used for management and operational purposes within the South African *Sirex* Control Programme.

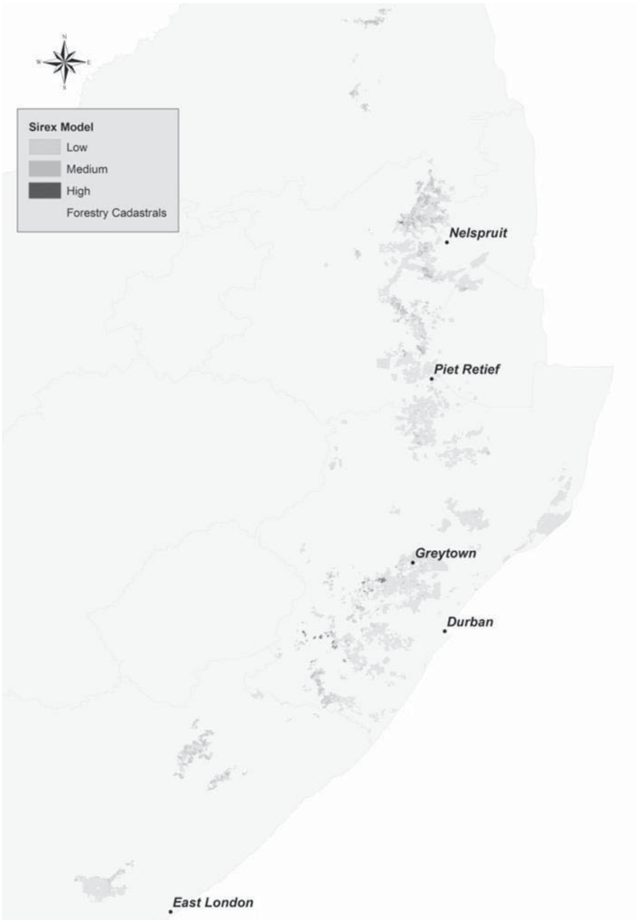

Figure 6. *Sirex risk map, Summer Rainfall Region.*

The purpose of this communication is to provide an overview of the current research at the ICFR in the area of risk mapping. Our focus has been mainly on site species suitability, pest and diseases and water balance, particularly in the context of climate change. We intend to expand the role that the ICFR is playing towards the implementation of the National Forest

Protection Strategy by growing the risk modeling area of research, particularly in the area of pest and diseases and drought, frost and fire risk.

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Forest monitoring for REDD+: challenges in mapping forest carbon

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Abstract

Forests play an important role in the global carbon cycle. In order to quantify the amount of carbon dioxide released by deforestation and forest degradation, reliable estimates of carbon stored in forest biomass are needed. Data from forest inventories can be used to to map forest carbon, either by providing estimates of carbon stocks per forest stratum, or by means of local estimates using spatial interpolation techniques. Remote sensing imagery can be used to estimate forest carbon directly, using optical high spatial resolution or LiDAR and radar data, or by combining field-based measurements with fine, medium, or coarse spatial resolution images. All methods are associated with uncertainty and error. Future research in mapping forest carbon may focus on integrating multi-source data.

1. Introduction - background

Forests store more carbon than any other terrestrial ecosystem and thus play an important role in the global carbon cycle (Bonan 2008). When forest land is degraded or cleared, a significant share of the stored carbon is released into the atmosphere as carbon dioxide (CO_2) (Gibbs et al. 2007). According to the Stern review (2007) about one fifth of the annual global CO_2 emissions comes from land-use changes, driven almost entirely by emissions from deforestation. The REDD concept aims at reducing emissions from land-use changes. At its core, REDD provides financial incentives for developing countries to encourage them to maintain their forest carbon stock and, thereby, lower emissions from deforestation and forest degradation.

Despite recent technological advances, it is still impossible to measure carbon stocks across landscapes directly (Andersson et al. 2009). In order to quantify the amount of CO_2 released by deforestation and forest degradation, reliable estimates of carbon stored in forest biomass are needed. Interest in such estimates, in particular in above-ground biomass (AGB), is not new. Since decades forest scientists develop and improve methods to estimate AGB of standing trees. In many forest types, most notably in tropical regions, AGB of living trees constitutes the largest pool of carbon and that most directly impacted by deforestation (Gibbs et al. 2007). However, other sources of carbon exist in a forest and pools other than AGB may constitute the greatest share of carbon stored, as for example in peat-swamp forests in South East Asia. Forest carbon, that is the total amount of carbon stored in forest land, can be split up into different carbon storage pools (Woodbury et al. 2007): trees (including roots, stems, branches, and foliage), understory vegetation (including e.g. herbs, shrubs), standing and down dead wood, the forest floor (e.g. litter, humus) and all organic material in the soil. The Intergovernmental Panel on Climate Change (IPCC 2006) groups these pools into three main types: above- and below-ground biomass, dead organic matter (dead wood and litter) and soil organic matter.

The focus in this paper is on AGB. A general introduction to forest monitoring issues in the climate change context is given by Kleinn et al. 2011 (see chapter 3 in this volume). Section 2 focuses on technical issues and describes basic approaches to estimate and map forest carbon. Key challenges regarding data collection and analysis are highlighted.

2. Methods to map forest carbon

One of the first steps in any survey is to precisely define the domain of interest. To estimate forest carbon, a clear forest definition is therefore inevitable. The United Nations Framework Convention on Climate Change (UNFCCC) "defines" forest land by a set of threshold values: an area of more than 0.5–1.0 ha, a minimum tree crown cover of 10–30% with trees that can grow at minimum 2–5 m tall (UNFCCC 2002). As it is possible to choose between different threshold values, forest definitions vary from place to place. If, for example, the same forest definition is applied in two countries, they may have the same forest area, but they may report different figures to the UNFCCC, if they use different threshold values. It is important that a country clearly states how "forest" is defined and that the definition remains consistent over time. Once forest land is properly defined, several methods are available to assess forest carbon.

2.1 Forest inventory data

In field-based forest inventories data are collected on either fixed area sample plots or plots of variable size. The spatial configuration of plot centres depends on the sample scheme applied. Systematic sampling, where the plot centres are located on a regularly spaced grid, is common for forest resource assessments. On each sample unit a set of variables is recorded (e.g. diameter at breast height [DBH], tree height) for each or a number of trees. Neither biomass nor carbon is measured directly. Allometric models are commonly used to estimate stem volume of trees. These models make use of the fact that volume is strongly correlated with trunk diameter and tree height (Brown and Lugo 1982). Allometric equations are developed by harvesting a number of trees, determine the stem volume and relate it to measured variables (i.e. DBH, height) of the harvested trees. To account for components such as branches, roots and leaves, expansion factors are used to estimate tree biomass. Complex allometric biomass functions can be used to relate tree parameters directly to biomass. Non-parametric methods, such as the K-nearest-neighbour (Knn) technique, have also been applied to estimate biomass of individual trees (Fehrmann 2006).

To convert tree biomass to carbon, biomass conversion factors are used (see Sandström et al. 2007). The development of allometric models for different tree species has been subject to research for decades in Europe and North America (Fehrmann and Kleinn 2006, Lindner and Karjalainen 2007). However, Gibbs et al. (2007) noted that for many tropical tree species no valid allometric equations are available. Fehrmann and Kleinn (2006) highlighted several issues that need to receive attention when allometric models are used. Chave et al. (2004) and Baker et al. (2004) identified several sources of error when using allometric models to estimate biomass over large areas. This includes error due to model choice.

To overcome some of the limitations of estimating biomass over large areas a valuable option might be to divide the total forest area into different parts, that is, to stratify the study area. By grouping forests into homogeneous sub-units, not only precision of estimates can be improved but also costs can be reduced. Gibbs et al. (2007) recommended developing a 'stratification matrix' using broad forest types (e.g. evergreen broadleaf, semi-deciduous dry forests) and conditions (e.g. drainage, slope, or age). Sampling can be carried out in each stratum individually.

When carbon estimates are available on the plot level they can be averaged and the total tree carbon can be calculated for each forest stratum separately or for the total forest area. In this way aggregated estimates are obtained. To map forest carbon using forest inventory (FI) data only, several methods are available. Maps of mean carbon densities for each stratum can be readily produced. These maps are not able to display small scale variability, however. To produce local estimates (i.e., continuous maps) different interpolation techniques, including splines (with tension), inverse distance weighting or geostatistical methods such as ordinary kriging or co-kriging are useful tools. Some of these methods require additional information, as for example data on soils or topographic data. The suitability of a particular method depends on the characteristics of the study area. There is no single best way of estimating forest carbon using FI data. It is good practice to provide measures of uncertainty when maps are made available to others.

2.2 Remote sensing techniques

Even though efficiency of data collection and analysis can be improved by stratification, large area forest inventories remain expensive and time consuming. The use of remotely sensed data as an additional source of information can help to reduce costs. Furthermore, remote sensing data provides 'wall-to-wall' mapping, i.e., data is available at any location in the image. Ancillary information can also help to improve precision of estimates.

Remote sensing instruments fall under two main categories: passive and active sensors. Passive, or optical, sensors record reflected solar radiation from the earth's surface. Active sensors transmit radiation to the surface and record the radiation that is reflected back to the sensor. Examples of active sensors include the Synthetic Aperture Radar (SAR) and Light Detection and Ranging (LiDAR) sensors. Landsat ETM+ is a popular passiv sensor. Active and passive sensors can either be space (i.e., satellite) or airborne (e.g., airplane).

Remote sensing devices differ in spatial, radiometric, spectral and temporal resolution. Spatial resolution describes the minimum size of an observation unit, often referred to as the pixel size. Spatial resolution ranges from fine to medium to coarse. The boundaries between these ranges are arbitrarily defined (i.e. there are differences of opinion within the research community). Airborne LiDAR usually have a spatial resolution of less than one meter, medium resolution Landsat ETM+ has a pixel size of 30 m and the Advanced Very High Resolution Radiometer (AVHRR) has a spatial resolution of about one kilometer. Radiometric resolution determines how finely a sensor can distinguish differences in radiometric intensity. Remote sensing devices record radiation at different wavelengths (or bands) and spectral resolution describes the ability of a sensor to resolve features in the electromagnetic spectrum. The spectral signature of a pixel is the combination of absorbed and reflected electromagnetic radiation (ER) in the different wavelengths. Temporal resolution refers to the frequency of pass over specific sites, that is, the time it takes until a sensor collects data from the same site. There is always a trade-off between the different kinds of resolution. A sensor with high spectral resolution usually has low spatial resolution, and if a sensor has a high spatial resolution, the temporal resolution is usually low.

As it is the case for FI field measurements, carbon cannot be measured directly by remote sensing devices, therefore, recordable variables from which biomass estimates can be derived must be observed. There are two basic approaches to estimate forest biomass using optical remote sensing data. Directly, using the spectral signature of pixels (sometimes combined with texture measures), or indirectly, where biomass is estimated from canopy parameters.

Fine resolution imagery is commonly used for indirect estimation, i.e., biophysical parameters are extracted from an image. These parameters can then be used as input for allometric models. The crown diameter, for example, can be used to model tree biomass. Culvenor (2003) summarises how fine resolution data can be used for the extraction of individual tree information. Since the late 1940s aerial photographs have been used frequently in this context (Lu 2006). Fine resolution (less than 5 m) space-borne sensors include IKONOS or QuickBird.

A drawback of fine resolution data is the low spectral resolution, especially for near infrared which is important for AGB estimation. Also, the need for large data storage and computing power for image processing prohibit the application of fine resolution data in large areas (Lu 2006). Finally, high spatial resolution imagery is much more expensive than medium or coarse spatial resolution images.

Products from the popular Landsat satellite (Thematic Mapper [TM] and Enhanced Thematic Mapper [ETM+]) and other medium spatial resolution sensors are used to estimate biomass on a per pixel basis using multiple linear and nonlinear regression, K-nearest-neighbour, or neural networks. These techniques combine both, ground information (e.g., FI data) and remote sensing data. When biomass estimates are available on the plot level and images are available for the area in which the plots are located, ground-based and remotely sensed information can be linked and statistically evaluated. Plots with high biomass values may have a typical spectral response and plots with low biomass values may have a different typical response. Based on this relationship biomass can be estimated at locations were ground data is not available. To improve precision of estimates, texture measures can be included in the model. These measures also use information from neighbouring pixels.

Coarse spatial resolution (> 100 m pixel size) imagery is used to estimate biomass over very large areas (e.g., at national, regional or global scales). The methods used are comparable to those used for medium spatial resolution data. Popular coarse spatial resolution satellites include AVHRR (Advanced Very High Resolution Radiometer), SPOT VEGETATION and MODIS (Moderate Resolution Imaging Spectroradiometer).

A problem regarding medium and in particular coarse spatial resolution imagery is that field-measurements often cover much smaller areas than the area covered by a single image pixel. It is, therefore, difficult to integrate plot data and variables derived from remote sensing. A closely related problem is the occurrence of so-called “mixed pixels”, i.e., different features in one single pixel. As the models that relate ground-based information and remote sensing imagery are never perfect, different degrees of success for AGB estimation have been reported in previous studies (Lu 2006). Another difficult task in optical remote sensing is atmospheric correction. The occurrence of clouds or haze in some areas can prohibit the acquisition of usable data, in particular in mountainous tropical regions.

As an alternative to passive sensors that are prone to atmospheric conditions LiDAR or radar data can be employed to estimate forest carbon. An advantage of active sensors is that data can be acquired irrespective of weather and light conditions. As with fine resolution data from optical sensors, radar and LiDAR data is used to extract biophysical parameters as input for allometric biomass models. Several studies have proven that active sensors are valuable for AGB estimation (Sader 1987, Kurvonen et al. 1999, Lu 2006). Since most radar and LiDAR data were captured through airborne sensors, research has focused on small area study sites only. Pre-processing, removal of noise and image processing require expert knowledge and skills. Moreover, acquiring such data is much more costly than optical remote sensing data.

As can be seen from the paragraphs above, different remote sensing instruments can accomplish very different tasks. Several authors presented integrated approaches using data at different spatial and spectral resolutions. Asner (2009), for example, combined field measurements with medium resolution satellite and LiDAR data. Plügge et al. (2010) used an integrated multi-scale approach to map forest biomass in Madagascar.

3. Discussion and Conclusions

The appropriate choice of data sources and methods for any forest carbon mapping project depends, among other things, on the area under study. No method is equally suitable for all types of forests. An approach to map forest carbon in a deciduous dry forest differs from an approach in a tropical moist forest. Furthermore, studies that look at an entire country with millions of hectare of forest differ from studies that concentrate on a few hectares only.

The design of a forest inventory program also include making trade-offs between costs and accuracy. Studies that deliver precise estimates of forest carbon may be unfeasible due of financial constraints. In this regard, it is often argued that remote sensing considerably lowers costs of data acquisition and reduces the need of extensive field-based sampling (see for example Patenaude et al. 2004, Lu 2006). Andersson et al. (2009), however, noted that "the potential for cost reductions depends ultimately on which set of remote-sensing instruments is selected".

Future research may focus on the integration of multi-source data including fine, medium and coarse resolution imagery, as well as modelling techniques that properly combine information from various spatial scales.

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Modelling global data of climate and vegetation to a local scale; the case of Costa Rica, Central America

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Abstract

Climatic and vegetation data are important elements to determine the degree of climate change in terms of the mitigation and adaptation approaches that should be taken. In this study we explored the variability of monthly precipitation per climatic region and the potential evapotranspiration against the Normalized Difference Vegetation Index (NDVI). We used the following global data sets: 1) rainfall and temperature for the period of 1973-1990 obtained from the New LocClim database, and 2) a time series of NDVI for the period of 2001-2010 from the Vito free SPOT-VEGETATION products. As an exploratory analysis we studied the relationship between the mean values of NDVI, precipitation and potential evapotranspiration as a method to evaluate the moisture availability in 6 climatic regions and 6 climatic sub-regions in Costa Rica in Central America. The highest variations in NDVI were in the North Pacific region, the Central Valley regions and their respective sub-regions. The correlation between NDVI and the climatic variables varies significantly between months. The highest correlations we found were between 0.6 and 0.73 for all sub-climatic regions in the North and Caribbean regions. These regions have a Monsoon and Atlantic rainy regime, with a decrease in precipitation from January to April. In general, when the rainfall decreases in December the NDVI is still increasing, this indicates that the soils provide the moisture needed by the plants, but, in the sub-regions with a Pacific influence, the water is used by the soil. This is a plausible explanation for the low or even negative correlations. The available global data sets free of charge provide a starting point. However, it is necessary to understand the information gaps and develop methods to identify relationships between climate and vegetation at a local scale.

Keywords: Normalized Difference Vegetation Index, NDVI, precipitation, potential evapotranspiration, Costa Rica.

1. Introduction

It is recognized that climate change will have a severe global impact, and it is one of the major current discussion themes in the world. As one way to address this challenge, the Reduction of Emissions from Deforestation and Forest Degradation (*REDD+*) takes an important role on issues like conservation and the enhancement of carbon stocks in tropical forests. *REDD+* also includes sustainable forest management as a general goal. An important component of the *REDD+* mechanism is Measurement, Reporting and Verification (MRV) to allow a transparent and comprehensive monitoring of the entire process. Monitoring is about collecting and assessing information over time, and for *REDD+* this monitoring is at national level. Information (data) and services which can provide the data and infrastructure are also defined according to nationally available capacities. In addition, a "history-based" reference emission level must be determined in order to compare it with the emission reduction effects of the newly implemented measures.

For national level forest cover estimation only remote sensing can provide a window to the past (given that imagery is available) and is the only data source that allows wall-to-wall mapping at acceptable cost; although accuracy and precision is always an issue. Today, most of the national forest maps have been produced with optical passive sensors.

Though seemingly straightforward, remote sensing based forest mapping is a complex undertaking and involves analysis and interpretation. Vegetation indices (VIs) as "indicators of vegetation characteristics" are widely used in this context (Glenn et al. 2008), and are calculated by different band transformations from optical sensors (Fuchs et al. 2009).

The calculation of VIs also depends on many factors that are not specific vegetation characteristics, e.g. solar zenith angle, view angle, soil background and climatic conditions such as atmosphere and moisture (Jackson and Huete 1991). Many authors have, therefore, established correlations between climate variables and VIs. For example, Shisanya et al. (2011) studied the rainfall variability and its impact on *NDVI* in Kenya, Ji and Peters (2003) evaluated the vegetation response (trough *NDVI*) to drought in the Northern Great Plains and Zaitchik et al. (2006) studied the inter-annual climatic variability to characterize the climatic sensitivities of vegetation in the Middle East.

Given that climatic variables have a significant impact on the determination of VIs, it becomes clear that VIs for one and the same area vary over time. Analysis of time-series of VI over different seasons will then be useful. In this study, we wish to identify how the *NDVI* mean monthly values vary as a function of climatic variables. As an example, we use study areas in Costa Rica. By this analysis we wish to contribute to improving approaches for remote sensing based forest cover estimations. Such information may also be useful for time and spatial planning and for designing applications of water resource development schemes, related to various land uses. (Tsakiris et al. 2007).

In our research we used climate variables like precipitation and potential evapotranspiration which is also comparable with the FAO's aridity index (Tsakiris et al. 2007). To correlate the *NDVI* data, we combine several techniques like interpolation and linear regressions in order to compute Costa Rica´s surface in pixels of mean monthly values.

In this paper, the objectives are to assess the inter-annual climate variability to identify the gaps in climate and vegetation analysis with global databases, then to explore the influence of climate on vegetation based on the *NDVI* in Costa Rica. A secondary objective is to explore a method to analyze the relationship between vegetation and climatic data in the context of monitoring, verification and reporting. With our results we will better understand how reliable it is to model the interaction between vegetation and climate at a local scale, and, if it is possible to apply the same methods for other countries in Central America.

2. Study area and data sources

Costa Rica lies between Nicaragua, Panama, the Caribbean Sea and the Pacific Ocean on the Central American isthmus. There are two mountain systems that run from the North Western region to the South Eastern one, dividing the country in three general areas: the so called Pacific influence, the Caribbean influence, and the Central Valley. The mountain system and the impact of the oceans define the climatic regions of Costa Rica.

We used the climatic regions and sub regions for Costa Rica defined by Solano and Villalobos (1997). This is a regionalization based on climate and geographic characteristics. We acquired historical records of monthly precipitation (1960-1990) for Costa Rica (Grieser et al. 2006) from the New LocClim 1.10 database. We used 244 stations for temperature and 249 for precipitation.

Additionally to the climatic regions, we randomly selected 6 climatic sub-regions (that is: one sub-region per region).

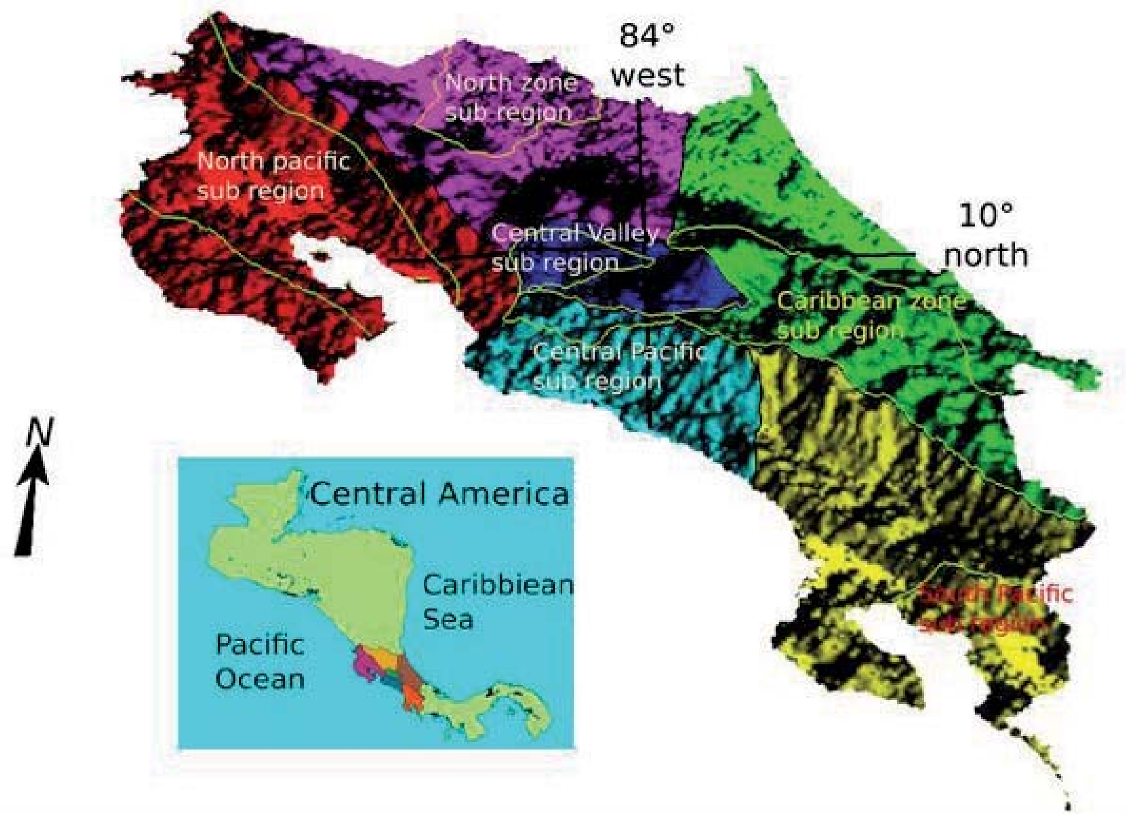

Figure 1. *Climatic regions and selected sub-regions on the Shuttle Radar Topography Mission (SRTM) digital elevation model.*

We used the Shuttle Radar Topography Mission (*SRTM*) elevation data from the U.S. Geological Survey Center for Earth Resource Observation and Science (EROS) with a spatial resolution of approximately 90 m (USGS 2006). The national border of Costa Rica was obtained from the World Bank and the Comisión Centroamerica de Ambiente y Desarrollo (CCAD) reports (World Bank and CCAD 2000).

For *NDVI* analysis, we used 10-day maximum *NDVI* data (the ‘‘VGT-D10’’ product) from VITO (Flemish Institute for Technological Research; VITO 2006), which is based on 10-day bidirectional composite syntheses of SPOT-VEGETATION imagery (Système Pour l’Observation de la Terre) with a spatial resolution of 1km^2.

3. Methods

3.1 Normalized Difference Vegetation Index

We extracted subsets of downloaded SPOT-VEGETATIOND10 *NDVI* tiles using VGTExtract 1.4.2. Three composites per month were used, on the first day of the month, the 11th and on the 21st day. Then we imported the imagery into R (R Development Core Team, 2009) with the “*Raster”* R package (Hijmans and van Etten, 2012).

High cloud cover occurs frequently in Central America leading to large regions with missing optical sensor observations even in the *NDVI* 10 days synthesis products. Therefore it was necessary to estimate the missing sensor observations using a spatio-temporal imputation method using the Expectation Maximization (EM) algorithm of the “*Amelia” R* package (Honaker et al. 2011). The average monthly values of *NDVI* for the period from 2001 to 2010 were calculated based on these filled data. Spatially irregularly distributed monthly means of meteorological stations were interpolated to a regular raster grid using the Regularized Spline with Tension (*RST*) interpolation method implemented as v.surf.rst in *GRASS* (GRASS Development Team 2008). We used a linear regression model to estimate the slope and intersect linear parameters, for each climatic region and for every month based on the variation of the temperature and elevation from the “New LocClim” data base. These parameters were then applied to the *SRTM* digital elevation model as the dependent variable to estimate the mean air temperature of Costa Rica.

We calculated the Potential Evapotranspiration (PET) based on Hamon (1963) and the formulae presented in Lu et al. (2005). This method uses several variables such as the daytime length, the saturated vapor density, the mean temperature and a calibration coefficient. We also calculated PET based on four other methods such as Holdridge (Holdridge 1962), Thornthwaithe (Lu et al. 2005) Lu-Hamon (Lu et al. 2005) and the FAO Penman-Monteith equation as in New LocClim (version.1.1) (Grieser et al. 2006), in order to compare the methods and to decide which method and which calibration coefficient to choose for our study.

4. Results

We present the results for the 5 different approaches to calculate potential evapotranspiration which are all based on mean monthly temperature (Figure 2). The overall standard deviations for these 5 methods are 14.0 mm and 12.2 mm in April and October, respectively {$\min_{April}$:

81.70 mm (Hamon), max_{April}: 117.14 mm (New LocClim); $min_{October}$: 76.64 mm (Hamon), $max_{October}$: 109.00 mm (Holdridge)}. The Hamon method calculated and presented in Figure 2 is without kPEC.

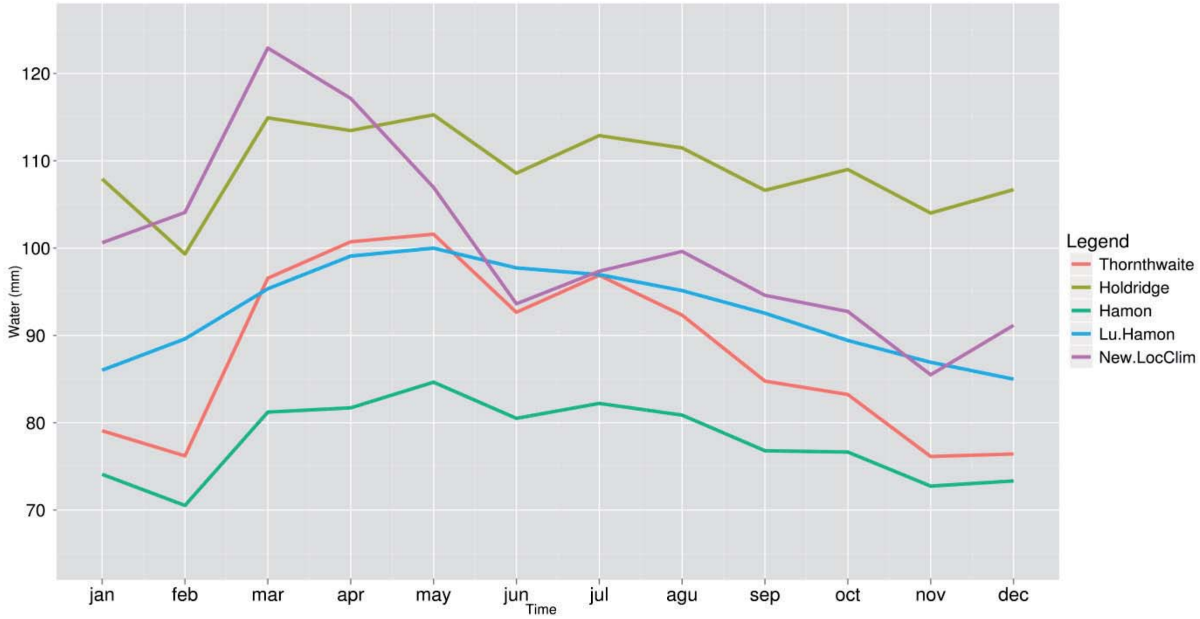

Figure 2. *Five different methods of potential evapotranspiration for typical temperature values in Costa Rica.*

Figure 4 shows the calculated *NDVI* for the months of April and October. The high variability of the time series D10 *NDVI* 2001 – 2010 is shown at: http://www.gwdg.de/~hfuchs/cr/cloudfree.

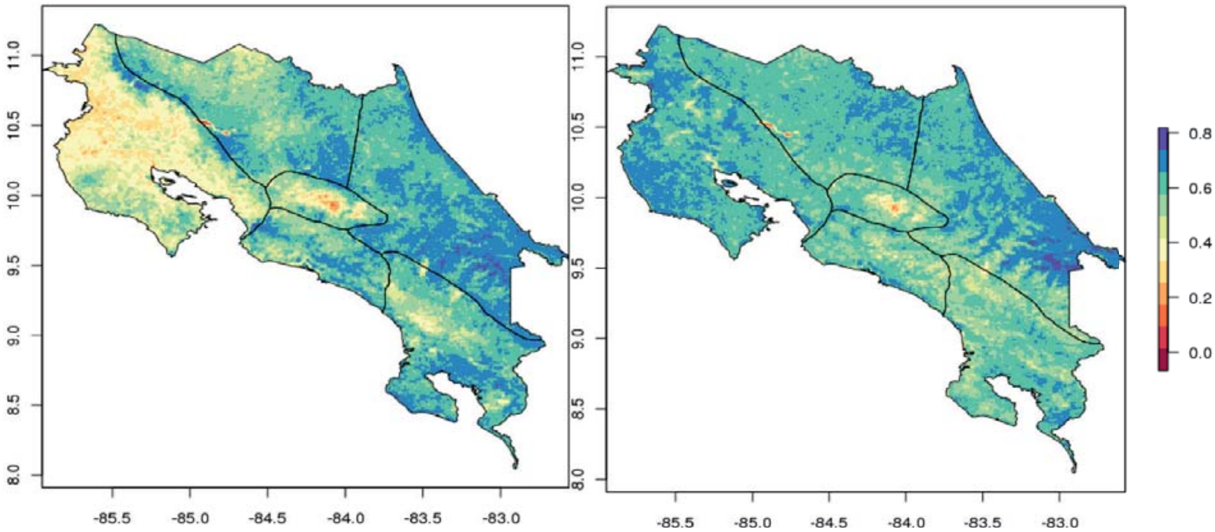

Figure 3. *Costa Rica's average NDVI maps for the months April (left) and October (right) in the period 2001-2010.*

Considerable differences between the *NDVI* values for April and October are observed in the North Pacific and in the Central Valley Region. The *NDVI* for April is 0.40 and 0.48 and for October 0.59 and 0.67 respectively.

A one-year time series of the standardized climatic variables and the *NDVI* (Figure 4), broken down to sub-regions. Compared to the regions the sub-regions gave the highest values of Pearson's correlation coefficient (Table 1).

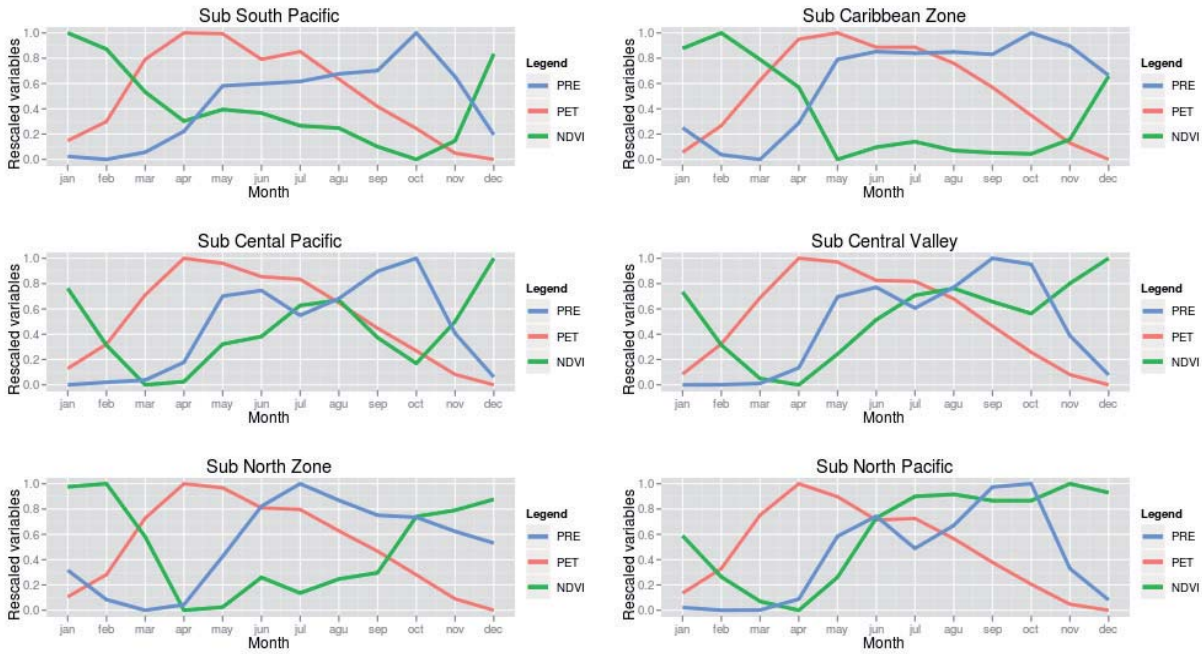

Figure 4. *Scaled climatic variables and NDVI by sub climatic regions in Costa Rica.*

Pearson's correlation coefficients for 6 randomly selected sub-regions and the 6 climatic regions (Table 1). As we made a pixel-based analysis, we emphasized the R squared, because it tells us how much of the variance of NDVI are explaining because PET and PRE.

Table 1. *Pearson's correlation coefficients for 6 randomly selected sub-regions and the 6 climatic regions.*

Pearson correlation coefficient	Climatic variable	Region or Sub-region*	Month	Pearson correlation coefficient	Climatic variable	Region or Sub-region*	Month
0.735	*PET*	scz	oct	0.608	*PET*	scz	sep
0.724	*PRE*	snz	feb	0.610	*PET*	scp	jun
0.716	*PRE*	snz	mar	0.604	*PRE*	snz	jul
0.710	*PRE*	snz	may	0.603	*PET*	ssp	nov
0.688	*PRE*	snz	dec	0.600	*PET*	cz	oct
0.677	*PET*	scz	nov	0.599	*PET*	scz	dec
0.669	*PET*	scz	Aug	0.575	*PET*	ssp	jul
0.662	*PRE*	snz	apr	0.562	*PET*	scz	jun
0.653	*PRE*	snz	jun	0.555	*PET*	cz	nov
0.647	*PET*	ssp	dec	-0.599	*PET*	np	feb
0.642	*PET*	scz	jul	-0.646	*PET*	np	mar
0.635	*PRE*	snz	Jan	-0.652	*PET*	np	apr

We rescaled the PRE, NDVI and PET in order to present the results in the Figure 4. Note that only coefficients greater than 0.5 or lesser than -0.5 are listed. The highest correlation (0.735) between NDVI and PET can be found in October in the Caribbean sub-region; followed by 0.724 and 0.716 in February and March in the Sub North Zone for NDVI and bout for PRE. By contrast we found negative correlations in the North Pacific region (0.599, -0.646, -0.652) for NDVI and PET in the months February, March and April.

5. Discussion

The modeled variables such as precipitation and temperature are usually very complex. The division based on climatic regions only (6 for Costa Rica) was insufficient because of the high variability within all of these climatic regions. As expected, the sub-climatic regions, which are 27, are more accurate but the analysis is very time consuming. In our study we presented the results for 6 selected sub-climatic regions as shown in Figure 4.

The Penman-Monteith method requires large amounts of data because the calculation incorporates values for solar radiation, temperature, wind speed, and relative humidity. In the majority of the world's regions, these meteorological data are not available (Vicente-Serrano et al. 2009). Verbist et al. (2005) analyse such limitation due to the lack of data availability in more detail. There, Costa Rica, with just 11 complete stations, is ranked as a "country with partially complete or incomplete stations". On the other hand, Nicaragua has only 1 complete station and is ranked as a country which is insufficiently documented. Therefore, it is not possible to directly transfer and use the same methodology that we applied here for Costa Rica for the whole of Central America or any other larger region.

The amount of *PET* as a demand of the atmosphere (Tsakiris et al. 2007) represents water consuming activities, however, it is a hypothetical quantity which cannot be directly measured (Holdridge 1962). There are several methods to estimate *PET* in the literature which are based only on mean air temperature as we illustrated in Figure 2. Most of them are derived for temperate zones; hence a correction is needed for low latitudes like in the case of Costa Rica. Information regarding *PET* can be used as a baseline for climate change studies in which potential distributions of flora and fauna can be predicted under the impact of climate change. From such information, priority areas for biodiversity conservation can be identified. On the other hand, the *PET* value and the difference between the precipitation *PRE* and *PET* can be easily calculated on a monthly basis. This provides a simple measure of water surplus or deficit. One issue that makes *PET* important is that it can be used to calculate the actual evapotranspiration. With this quantity it is possible to derive a soil water balance measure which is the ultimate information needed to establish the relationship between ecosystems, the water balance and the service as water regulator.

In the case of precipitation, accuracy and bias may be affected by the high spatio-temporal variability of precipitation as showed in Shisanya et al. (2011), and the complex relationships between precipitation and climate.

During the interpolation process the key point was segmentation. Because the spatial arrangement of the meteorological stations is not well distributed, segmentation processing is needed. For example, the Central Valley region has only 5 % of the area of Costa Rica but it has 22 % of the meteorological stations. On the other hand the North region has 21 % of the area but only 11% of the stations. The stations are also not well distributed within this climatic region.

Gathering and exploitation of information delivered by airborne or satellite sensors can be performed in a variety of different ways depending on the users' intention and the field of research. One major issue is how to handle the data in an appropriate manner. As the atmospheric conditions are changing over time and location, the solar irradiance is never a constant. Therefore the calculation of special spectral indices derived from the remotely sensed data is a suitable way. Since we are focused on plant-sensitive data in this study, a vegetation index (VI) is useful. However, even then the results should be considered carefully, because such indices can either be obtained from sensor voltage output, digital numbers and radiance, or reflectance values producing different results (Jackson and Huete 1991). One very common and important VI is the *Normalized Difference Vegetation Index*, see eq. 1. Incorporating the reflection behavior of plants in the near infrared spectrum, the *NDVI* can be used as an indicator for healthy/non-healthy vegetation and its condition at a specific point of time.

Many studies show the (seasonal) relation between *NDVI* and rainfall. But in case of tropical countries like Costa Rica, there is only a small variation in the monthly mean temperature. For that reason it is also crucial that we have a look at precipitation and potential evapotranspiration in order to have a better understanding of the interactions and relationships of climate and vegetation.

Global data sets are a very good starting point in order to model climate and vegetation data to a local scale. A special consideration of which methods or parameters in one method can be applied or cannot be applied should be taken. If, as in the case of Costa Rica, the regions Caribbean Zone and North zone have a lack of climatic stations, this represents a challenge and only with the segmentation procedure were reasonable results possible.

Another issue worth mentioning is the subsequent reaction or growth of living vegetation after rainfall. This circumstance can be seen in Figure 5 and especially in the sub-regions of South Pacific and sub Caribbean Zone.

6. Conclusions

Global data sets available free of charge, provide a starting point to run models at a local scale. However, we need to understand and close the information gaps and develop methods to identify relationships between climate and vegetation at local scale. Regarding potential evapotranspiration, only temperature based methods are appropriate, because there is insufficient data and landscape label analysis.

In order to apply *NDVI* time series analysis we need data on a regular basis and only remote sensing is able to provide these data. On the long term vegetation modeled as *NDVI* will provide valuable information about climate change and these time-series data is necessary to build or adjust ecosystem maps. Although the VITO products are atmospherically corrected, those effects are still there because the methods used are model-based and the information used to archive this models are based on general conditions. Further considerations like soil moisture must be included in account related *NDVI*, especially in areas of irrigated crops, if comparisons should be made.

Soil water storage quantification is needed in order to calculate the effect of water movements on the *NDVI,* also the quantification of the actual evapotranspiration is need.

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Chapter four
Forest Fires

Management and research on Afromontane and Afrotemperate forests in South Africa

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Abstract

Natural forests of Southern Africa may be the smallest biome, but they are extremely species rich and serve as safety zones in times of surrounding fires. Two forest types are defined and they are mostly split by a slight geographical difference. They are also categorised by topography, geology and hydrology (von Beitenbach 1974). These forests are mostly formed by dominating winds and fire, and can thus be managed accordingly. Management is mostly based on conservation, but some timber harvesting is still conducted. In an ongoing research project, the effect of drought on these forests is tested with respect to diameter increment and mortality.

Keywords: Afromontane, Afrotemperate, drought, fire

1. Introduction

Afrotemperate and Afromontane forests spread throughout Africa (Figure 1) and they can usually be found near bodies of water or in valleys where runoff water is plentiful.

Figure 1. *Simplified vegetation map of Africa. Afromontane and Afrotemperate forests (White, F. 1983).*

In South-Africa itself, this forest biome is the smallest of the biomes and covers only a total land area of 683 780 ha or 0.56% of the total country area. Although small, this biome is also one of the most bio-diversity rich ecosystems and contains roughly 465 plant species. This species richness can most likely be attributed to the fact that the forest is a long corridor, linked from east to west. Because of this spread many altitudes, soils and climate types can be found.

The two forest systems (Afrotemperate and Afromontane) are very hard to distinguish from one another. It is generally accepted that Afromontane forests occur more to the east of the country, while Afrotemperate occurs more towards the south west. Afromontane forests are also known as either mixed mist-belt forests or *Podocarpus* mixed forests. The Afrotemperate forests on the other hand are also known as Coastal belt forests or Southern Cape forests.

Both of these forest types have been sub-categorised, by Von Breitenbach (1974) (Figure 2), according to hydrology and landscape position. Each of the eight categories was aptly named to describe their state of moisture. The categories ranged from a low and very dry scrub up to a very wet high forest.

Figure 2. *Forest types as Defined by Von Breitenbach, 1974.*

These forests have a very low resistance towards drought, which can be deduced by their growing patterns. The spread of the forests is dominated by air and fire patterns (Figure 3) as suggested by Geldenhuys (2004).

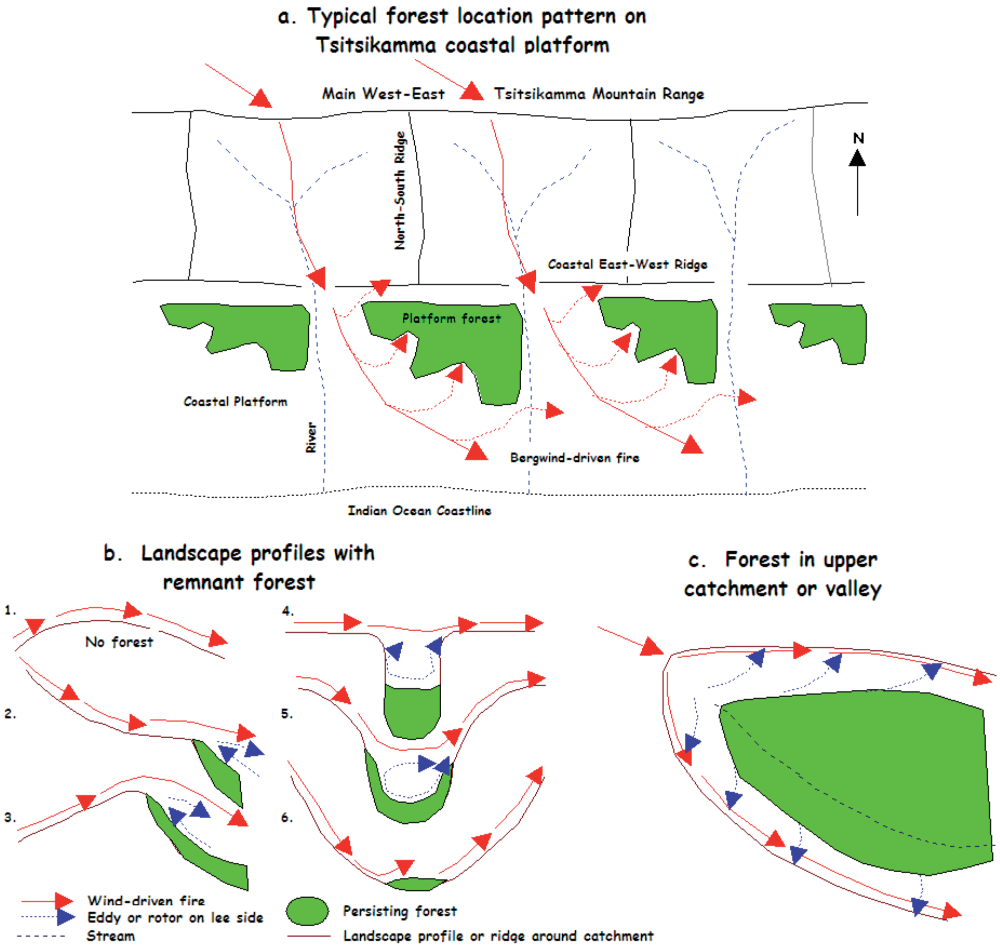

Figure 3. *Fire and wind patterns forming natural forests, adapted from Geldenhuys 2004.*

2. Management

Most of the indigenous forests are currently under the management of South-African National Parks (SANParks). They actively manage, monitor and promote these forests. SANParks has a total of 41 538 ha of land in the Southern Cape and Tsitsikamma areas. 35 765 ha of this is natural forest while the remaining 5 399 ha is under fynbos. As conservation is their core function, most of the area under their management is used for recreation and natural parks. One percent of the Tsitsikamma area is for instance used for research, although the whole area is constantly being monitored for change or disturbance.

Roughly 27% of the total forested area is utilized for timber harvesting based on a senility index developed by Seydack et al. (1995) that works similar to natural processes. Only senile (dead and dying) trees are removed in the system they have coined Senility Criteria Harvesting (SCH). Each species of harvested trees has a criterion, e.g. 40% crown dieback, which is used to see if the tree is close to dying of old age. Trees are topped, felled and removed by animal logging where they are sold on an auction to local furniture makers.

3. Research project

The main purpose of the research project is to determine the effects that drought has on these natural forests. As we all know, water is one of the most important driving factors in the growth of forests. Bates et al. (2008) suggested that climactic change may have a severe impact on the rates of precipitation and the occurrence of droughts. It will thus be important to understand the effect drought will have on individual trees, different species and different forest types.

Three main questions can be expected to be answered by this study, they are as follows:

1. Which diameter classes are affected (ontogenetic changes in drought sensitivity)?
2. Do species react differently to drought (species specific sensitivity)?
3. Is the sensitivity different in different forest types (dry/medium moist/moist high forest)?
   a. Is it possible that drought could affect very wet sites positively?
   b. Will dry sites be affected less in times of drought because of existing adaptation?

Ontogenetic changes in trees (Seydack et al. 2011) may also prove to be a factor since trees might react differently at stages of their development. Younger stems are expected to be less resistant toward drought since their root systems are less developed and they can only obtain both water and nutrients from upper soil levels. A different possibility is that they are less exposed to both wind and radiation, which are major causes of transpiration. In this instance they may benefit from the microclimate created by the larger trees.

Another aspect to investigate will be whether different species within the different forest types also have different reactions to drought. This could mean that a slight shift in genomes. The last possible adaptation would be to investigate whether dry forests have an intrinsic resistance towards drought or if very wet forests are getting additional benefits due to less water-logging stress.

Up to date, very little research has been done on the drought resistance of these forests. Geldenhuys et al. (1993) did a similar study to investigate whether there is a difference between evergreen- and deciduous tree species. This study will further build on the latter by utilizing only species present in all three forest types. We will also investigate the effect of drought, if any, which could be indicated by the presence of increased mortality/ decreased in growth.

If drought proves to be a driving factor in the formation of the forests, a shift in the categories which von Breitenbach (1974) suggested may occur. The forests will move to a more dry state, which in turn will open the forests up for fire, since the dry forests are sparser. This may not necessarily increase fire occurrence, since fire will still be spread by the dominating berg winds. A new problem with fires could be a higher frequency of lightning strikes, which would cause major running fires.

4. Conclusions

Research on natural forests systems is needed to better implement management practices. With climate change being an important topic, it is crucial to know how it will affect these systems and how they will need to be managed afterwards.

5. Acknowledgements

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Reconstructing past fire regimes: applications and relevance to fire management

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Abstract

Nowadays, forest fires have increased significantly around the world, in size, frequency, and intensity. Hence, anticipating future forest-fire regimes under a changing climate requires that scientists and natural resource managers understand the factors that control fire across space and time. Fire scars – proxy records of fires, formed in the growth rings of long-lived trees – provide an annually accurate window into past low-severity fire regimes. The Mexican forest experiences recurring forest fires, especially during El Niño years. However the government efforts for fire prevention are still insufficient to reduce both fire frequency and fire intensity. Nevertheless, Mexico needs to develop fire prevention strategies with high efficiency in order to avoid the loss of natural resources and to protect all the reforestation efforts. As any other natural disaster, fires have always provoked important biotic and abiotic changes. However, not all ecosystems are adapted to the increasing frequency and sizes of forest fire. The objective of this article is to illustrate the significance and, as far as possible, to ascertain the quantitative importance of forest fires and how they can threaten reforestation efforts of Mexican agencies in charge of the natural resources. These data also offer crucial reference information on fire as a dynamic landscape process for use in ecosystem management, especially when managing for forest structure and resilience to climate change.

1. Introduction: Towards an increasing awareness of fire as an ecological factor

Fire is a disturbance agent within the criteria of Pickett and White (1985). It is a relatively discrete event in time, although it may vary from seconds in a grass fire to weeks or months in a peat fire. Fires change ecosystems, community and population structure, either by selectively favoring certain species or creating conditions for new species to invade (Agee 1993).

Nowadays, scientific and natural resources managers are increasingly becoming aware of the ecological role of fire and the need to understand the past dynamics and the relation between the fire and management practices in order to preserve and to handle the present biodiversity and the function of the ecosystem (Bergeron et al. 2002, González et al. 2007). Nevertheless, human activities influence natural fire regimes by in some cases increasing fires in forests that would seldom burn under natural conditions and in other cases suppressing natural fire, which causes ecological impacts that lead to infrequent, catastrophic fires due to a build up of fuel (Goldammer et al. 2001).

In the last decade the number of investigations about historic reconstruction of fires has been increased with the purpose to understand the relation between climate, fire and vegetation, and historical and current anthropogenic interactions (Heyerdahl and Card 2000, Gonzalez 2005). These studies have been directed mainly at two aspects: the reconstruction of historic fire regimes and the analysis of climatic variability. The United States, Canada and Mexico have carried out scientific investigations that have highlighted the importance of the historical reconstruction of forest fires (Wouters 1993, Bergeron et al. 2003, Stephens and Ruth 2005, Gonzalez et al. 2008). The above mentioned investigations found that the generation of specific knowledge about disturbances and their ecological effects is essential for the development of fire management strategies and their integration into the management, restoration and protection of natural resources.

In this research line one of the most employed techniques to identify, date and describe the historic incident of fire have been the dendrochronological techniques, which include scars and growth ring sampling in burned trees (Mcbride 1983, Gonzalez 2005, Gonzalez et al. 2008). The aim of this work is to review the “dendrochronology” approach for reconstructing the long term fire history, fire ecology, and its applications to the natural resources management.

2. Reconstructing past fire regimes

2.1 Morphological evidence of fire

The first evidence needed to establish the fire history of a specific ecosystem is the fire occurrence, whether fire has been present in the area. This may be established from the fire scars on trees, from plants that appears to have germinated after a fire, or from charcoal (Agee 1993). Fire scars are an excellent source of fire frequency data, because they can be used to establish precise years of past fire events. Techniques for reconstruction of fire data include the application of dendrochronological methods.

A fire scar is formed when the fire is too intense and/or when it burns long enough to penetrate the bark and kill part of the cambium. If the tree survives, each following year, the adjacent live cambium is expanded slowly on the surface of the scar and later encloses it through the growth process. This way, the year in which the tree was affected will remain engraved in the rings, declaring the morphological evidence (Agee 1993), and remaining available for many years (Figure 1).

The fire scars can be identified easily since they are usually triangular and extend to the base of the tree, they can be found in adjacent trees of the same age, registering the same year of fire, and they associate with the presence of charcoal on exposed sapwood or bark (Agee 1993).

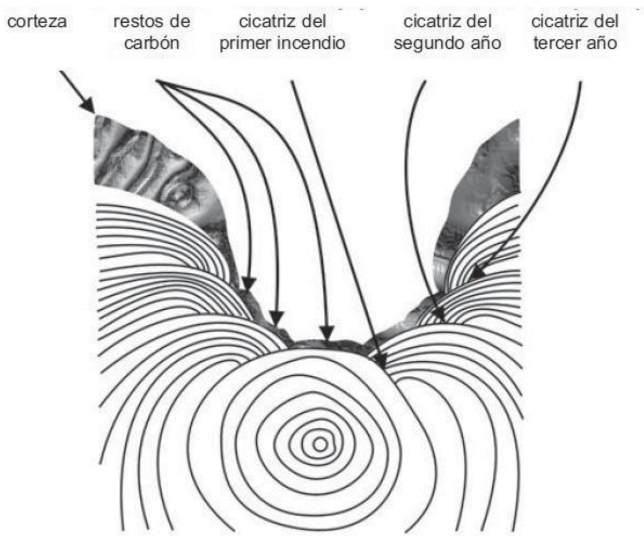

Figure 1. *Small fire scars along a common radius. These are often healed over and would not be visible from the exterior of a live tree (from González et al. 2007).*

A fire regime can be considered as a synthesis of the fire occurrence, of its behavior, and of its ecological effects inside a specific area throughout the years. The concept of a fire regime has now developed into a generalized and structured description of the role of fire in ecosystems and may therefore be defined as a sequence of fires that occur in a defined space-time window (Falk and Swetnam 2003). Describing fire regimes consists of defining a general collection of fire characteristics that may be organized, assembled and used according to the needs of the users (Agee 1993).

Fire regimes may thus refer to different times (past, present, future; single events, years, decades, centuries), different spatial units (a single ecosystem, single vegetation type, specific geographical areas), different origins of fire (natural, anthropogenic), and may consider not only the fire characteristics (fire intensity, fire type, fire behavior), but also conditions that determine fire occurrence (fuel type, fire weather, terrain) and post-fire impact (e.g. fire severity). Besides the fire-regime definition in the strict sense, describing which fire occurs when and where (frequency, size, seasonality, intensity and type), there are also a significant number of other attributes and derived variables that may be combined to build for this fire-regime definitions in the broad sense. Such a modular and flexible definition of fire regimes is needed to bring some structure to a very heterogeneous body of fire attributes and to reconcile the physical nature of fire with the biological context within which it occurs (Goldammer et al. 2001).

2.2 Dendrochronology

The use of dendrochronology for reconstruction past fire events depends on the capacity of tree species to develop year rings and to overgrow fire injuries (Swetnam et al. 1999). Where robust tree ring chronologies exist, fire scars of single trees can be dated with annual precision by means of cross-dating in order to synchronize their ring sequences with the reference chronology (Madany et al. 1982). If the position of the scar within the ring is visible, even the season and in certain cases the month of the event can be estimated (Baisan and Swetnam 1990). By compiling fire scar records from numerous specimens collected throughout forest stands, it is then possible to reconstruct fire events with extremely high time resolution over periods of several centuries and to synchronize these records across multiple spatial scales (Swetnam et al. 1999, Morgan et al. 2001).

Fire scars are usually best recognized on full cross-sections. According to Dieterich and Swetnam (1984), single cross-sections may fail to record all fire events because of the patchy behavior of forest fires. The most complete records of fire occurrence may be obtained by sampling several trees in close proximity to each other (Agee, 1993). Because of limitations of taking complete cross sections from living trees, there are alternative methods that provide accurate evidence of fire scars. They involve extracting partial cross-sections or sampling increment cores (Arno and Sneck 1977).

2.3 Considerations for reconstructing a fire chronology

The first action to consider for the reconstruction of a fire regime is the selection of the study area. In this area some aspects have to be considered like the quantity of exhibited fire scars in the woodland and a smaller degree of disturbance by silvicultural interventions. Nevertheless, in many cases areas submitted to timber harvesting present a great potential for sampling. This is because many of the individuals present fire scars. Being cut above the scar level, they leave an excellent fire chronology available in the stump area (Cerano et al. 2009).

2.4 Fire scars and fire seasonality

Fire scars are an excellent source of fire frequency data, because they can be used to established precise years of past fire events (Stokes and Smiley 1968). The samples can be obtained from cross sections, increment cores, standing dead trees and, alive trees (Arno and Sneck 1977). Once the samples are collected (cores or cross sections), they are prepared for the dendrochronological analysis. This preparation consists of drying the samples in the open air and in shadow conditions. Later the samples are submitted to a process of polishing to bring out the growth ring structures and to appreciate with greater clarity the location of the fire scar (Cerano et al. 2009).

According to Baisan and Swetnam (1990), the season of each fire can be inferred from the position of fire scars within annual growth rings. Scar positions are classified as (1) early (first third of earlywood); (2) middle (second third); (3) late (last third); (4) latewood (in latewood); or (5) dormant (at ring boundary). Once the position of the scar is identified, statistical analysis has to be carried out.

2.5 Fire frequency summary statistics and fire statistical software

The composite mean fire return interval (MFI) and the natural fire rotation (NFR) are the two summary statistics most widely reported in the literature to summarize the fire frequency/area distribution (Agee 1993). The composite MFI is described as the average number of years between fires of any size that occurred within a specified area (Romme 1980) and all detected fire years are included in the calculation of the composite MFI regardless of their size. This is because compositing was intended to be used in relatively small or homogenous areas where fire spread is assumed, and/or where any fire is determined to be of significance or interest (Dieterich 1980). It has become customary, therefore, to add a ''relative area burned'' component to the MFI to determine the mean interval between larger fire years. This is done by calculating mean intervals for fire years only that scar a minimum percentage of samples. This has the effect of filtering out intervals between presumably smaller and isolated fire years (Swetnam and Baisan 1996). Filtering at the 10% and 25% level is most common, meaning that only intervals of fire years recorded by 10% or 25% of recording samples, respectively, are used in the calculation. Therefore, the level of filtering can be denoted with a subscript (e.g., $MFI_{10\%}$, $MFI_{25\%}$, or MFI_{all} for ''all fire years''). The NFR is defined as the average number of years required for an area equivalent to the study area to burn (Romme 1980, Agee 1993). The value of the NFR is theoretically analogous to the Fire Cycle (Agee 1993), which is estimated from stand age distributions, and the population mean fire interval (Baker and Ehle 2001). The NFR is based on cumulative area burned for a specified time period rather than the frequency of fire years.

In order to analyze fire history statistics the *FHX2* software version 3.2 is one of the most used in the literature (Grissino-Mayer 2001). However, nowadays a variety of software are available, for instance, the package *dplR* for statistical and visual cross-dating is also widely used (Buun 2010).

3. Study case in the Sierra Madre Oriental

In Mexico, the El Niño Southern Oscillation (ENSO) is a climate-forcing mechanism that has been shown to affect precipitation and the occurrence of fires (Cochrane 2009). Linkages between ENSO and the occurrence of forest fires have been recognized at scales ranging from local to regional (Heyerdahl and Alvarado 2003, Fulé et al., 2005, Skinner et al. 2008). La Niña winters (ENSO cool phase) in northwestern Mexico are typically hot and dry, and fires are more likely to burn during these years (Swetnam and Betancourt 1990, Heyerdahl and Alvarado 2003, Fulé et al. 2005, Skinner et al. 2008). In southern Mexico, however, El Niño winters (ENSO warm phase) are dry and fire-prone (Magaña et al. 2003, Román- Cuesta et al. 2004, Seager et al. 2009).

The Sierra Madre Oriental, in eastern Mexico, is located on and near the dipole where ENSO events change effects; it is situated between areas where La Niña is associated with dry conditions (northwestern Mexico), and areas where El Niño is associated with dry conditions (southern Mexico) (Caso et al. 2007, Seager et al. 2009). Because of its geographical location on and near the ENSO dipole, it is unknown whether warm or cool phases of the oscillation are more likely to be associated with fire occurrence in this area. Severe fires burned in the Sierra Madre Oriental during the 1998 El Niño event, but the 1998 El Niño was extremely strong and therefore may have had atypical effects on fires in this region (Yocom et al. 2010).

A study by Yocom et al (2010) was conducted in Peña Nevada, at 3540 m elevation. This mountain is located in the Sierra Madre Oriental in the state of Nuevo León, Mexico. Here three sites of ~25 ha each were established at San Onofre (SO), El Diferencial (DI), and Mesa Acuña (MA) (Figure 2). The sites were spaced ~1 km apart and had comparable elevation and vegetation.

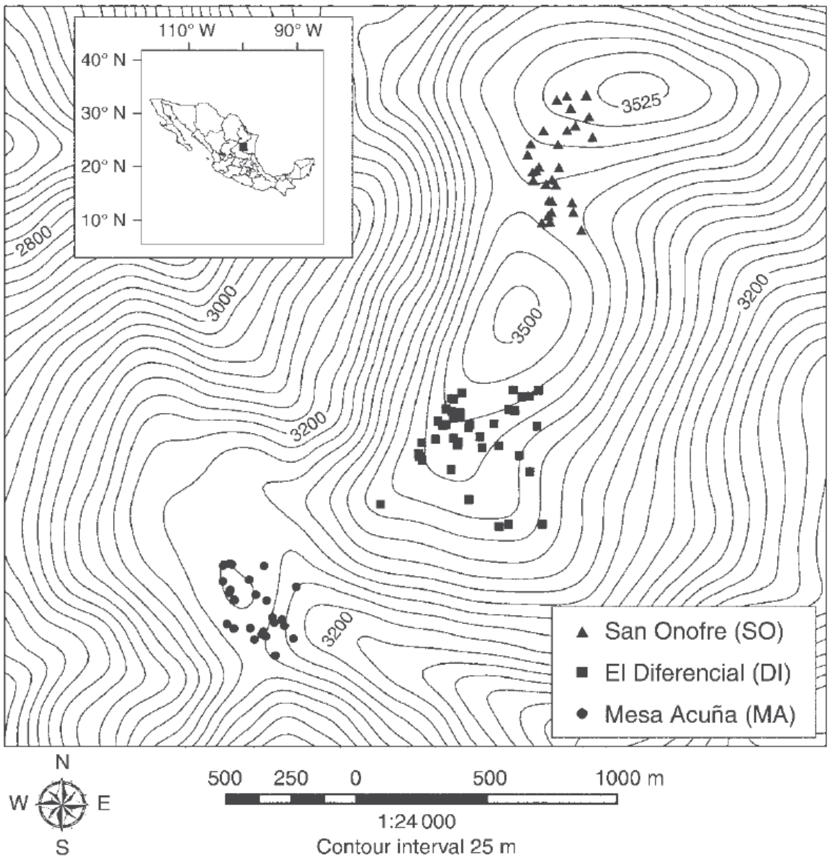

Figure 2. *Map of the three study sites arrayed along the northern ridge of Peña Nevada peak, Nuevo Leon, Mexico (taken from Yocom et al. 2010).*

Fire history statistics were calculated for periods in which there was an adequate tree-ring record. Each site was determined to have an adequate tree-ring record when at least 10% of total samples in that site were scarred. The same criterion was used by the authors when calculating statistics for the three sites combined. In the three sites combined, the period with an adequate tree-ring record was 1645–1929. Each site individually had an adequate tree-ring record from 1641 to 1920 (SO), 1645–1929 (DI), and 1774–1928 (MA).

In the overall study area a total of 112 samples were collected: 34 in SO, 48 in DI, and 30 in MA. The majority of samples were taken from stumps and all but one of the samples was from *P. hartwegii*; the exception came from a single *P. menziesii*. The authors were able to crossdate 100 of the samples (89%) and they identified 408 scars in total. They were unable to date 12 samples (11%) because of rotten wood, rings that were too tight, or an insufficient number of rings to permit reliable crossdating. Yocom et al (2010) found that the earliest fire scar identified in the three sites occurred in 1521, and the last fire scars were from 1998, the year that much of the forest in the region burned severely. According to Yocom et al. (2010), until the late 1920s, the fire regime at Peña Nevada showed relatively little variability across sites and through time (Figure 3). The MFI_{all} was within one year's difference between sites (SO, 9.3 years; DI, 8.6 years; MA, 9.6 years). The mean fire interval ($MFI_{25\%}$) for more widespread fires (those that burned ≥25% of the trees) was longer, and varied from 11.9 years in MA to 18.6 years in SO. The Weibull distribution, which has been used in describing fire regimes because it is flexible, able to fit skewed data sets, and provides a standard way to compare fire regimes across ecological gradients (Grissino-Mayer 1999), fits the author´s data well. Weibull median probability interval values were similar to mean fire interval values. The mean fire interval for individual trees was 17 years.

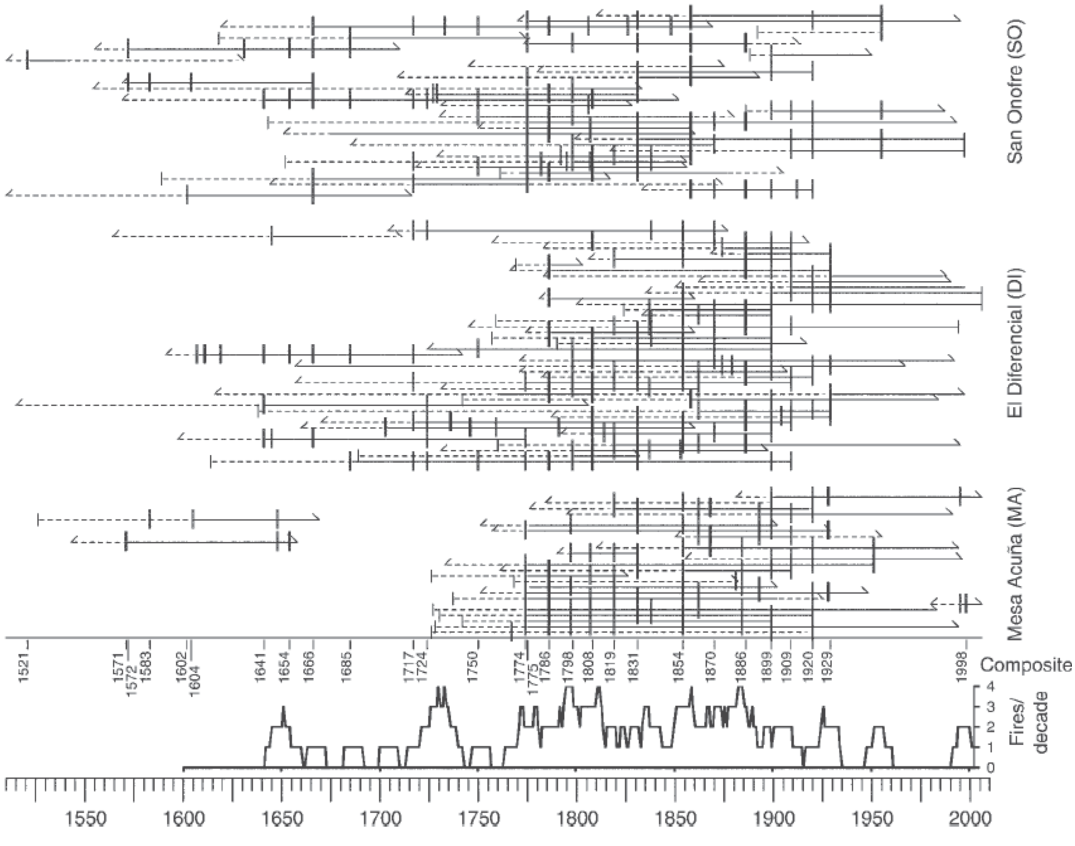

Figure 3. *Fire history chart of Peña Nevada for the years 1510–2006. Horizontal lines represent samples, and vertical lines represent fire scars. The composite record (filtered to include only those fires that scarred at least 25% of recording trees in all three sites) is shown with years below the chart. Software used was FHX2 version 3.2 (Grissino-Mayer 2001). Also shown is a running (10-year) average of the number of fires per decade (bottom panel) (taken from Yocom et al. 2010).*

The authors found that between 1774 and 1929, out of 38 years with fires, seven years (18%) had fires recorded at all three sites (SO, DI, and MA): 1786, 1819, 1831, 1838, 1899, 1909, and 1920. Twenty-two fire dates (58%) were unique to one site only and nine fire dates (24%) were recorded at two sites. Although the sites did not share many of the same fire years, all three sites recorded similar numbers of fires during the period 1774–1929 (21 fires in SO, 23 fires in DI, and 17 fires in MA). Employing dendrochronological techniques, the authors were also able to determine seasonality of 55% of the fire scars. Of those, 92% were found on the ring boundary, meaning that the majority of fires occurred in the dormant season. Another 5% were found in early earlywood, and 3% were found in middle earlywood.

One of the main findings from the authors (Yocom et al. 2010) was that a dramatic decline in fire frequency occurred after the 1920s (Figure 3). Site SO experienced one fire between 1920 and 1998 (1955), DI had no fires between 1929 and 1998, and MA had one fire between 1929 and 1995 (1951). Consequently, site SO had a 43-year fire-free interval, DI had a 69-year fire-free interval, and MA had a 44-year fire-free interval. Yocom et al. (2010) mentioned that the near cessation of fires after the 1920s is probably related to the formation of the Ejido La Encantada on Peña Nevada in 1937. Ejidos are communities that live on rural lands that are held in common and managed with some level of governmental control (Thoms and Betters 1998). Heyerdahl and Alvarado 2003 found that in the Sierra Madre Occidental, a decrease in the percentage of sites with fire around 1930 coincided with the granting of lands to ejidos. Heyerdahl and Alvarado (2003) speculated that granting land to ejidos may have changed the fire regimes through the introduction or intensification of cattle grazing, road building, logging, and changing the traditional role of fire. These same factors probably changed the fire regime at Peña Nevada when Ejido La Encantada was formed.

4. Conclusions

Creating effective land management approaches requires having a better understanding of past forest stand and landscape dynamics, and in particular a well-grounded knowledge of the natural range of variability in the disturbances and processes that have shaped such ecosystems before the appearance of the most recent disturbance. The review presented in this manuscript demonstrates how the extraction and analytical techniques, and the general knowledge related to fire proxies have improved in the last decades and how this development is likely to accelerate in the near future.

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The insulation capacity of tree bark against fire damage in the Western Cape Region, South Africa

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Abstract

Forests fires are on the increase worldwide due to increased human activity within forest ecosystems, global warming and climate change (Goldammer 2007). In South Africa there has been an increase in fuel accumulation due to drought conditions that have persisted in the past decade (Calvin and Wettlaufer 2000). As a result there has been an exponential increase in wildfire damage, particularly in the summer rainfall regions, destroying widespread areas of plantation forests (de Ronde 2008). This study aims to create an understanding of the natural fire resistance of commercial and indigenous trees by quantifying the resistance capacity of the bark of eight species relative to their bark thickness and moisture content. Fire damage on stem fresh discs was simulated using an electric heat gun. First results prove the importance of bark thickness on insulative capacity. Species-specific differences could be shown.

1. Introduction

Forests fires are on the increase worldwide due to increased human activity within forest ecosystems, the effects of global warming and climate change. These lead to a complex interaction of events resulting in increased fire weather within forest ecosystems. Land use pressures have forced human intervention in tropical and rainforests, leading to depletion of these forests and enhancing chances of fire (Goldammer 2007).

Apart from land use pressure, intensive fire management has in some instances contributed to severe wildfires in areas where long term fire exclusion practices have lead to accumulation of fuels. Prescribed burning has proven an effective method in controlling fuel load, but the wrong application (e.g. burning in too dry or windy conditions) can be disastrous and destructive to plantations if the fires are not controlled (Daniels et al. 2011).

Global warming and climate change promote weather conditions with a higher fire risk i.e. hot/dry conditions, warm temperatures and climatic water deficits. These conditions trigger drought stress and mortality, increasing the fuel levels in forest ecosystems and increasing chances of fire (van Mantgem et al. 2009). The warming effect can also trigger insect and pathogen attack (e.g. Berg et al. 2006) which causes tree deaths and increases fuel loads within forests, indirectly contributing to fires.

In many parts of the world, increased wildfires during the past few decades have been linked to global warming and climate change. For example western North America and South

Western British Columbia have experienced regional warming and water deficits that have directly affected trees in old forests, causing mortality to double up (Daniels et al. 2011). Europe has also experienced an increase in number and size of wildfires due to global warming (Rego 2004). In South Africa there is an increase in fuel accumulation and fire hazard situations in certain forestry regions due drought conditions that have persisted in the past decade (Calvin and Wettlaufer 2000).

As a result of the drought conditions, Southern Africa has experienced an exponential increase in wildfire damage, particularly in the summer rainfall regions. Thousands of hectares of commercial timber plantations have been devastated by uncontrollable fires, especially between 2005 and 2007 (e.g. de Ronde 2008). This has seen local sawmilling and timber processing plants increasingly experiencing saw log shortages. In some regions the occurrence of wildfire damage has caused timber resources to diminish and manufacturing plants to close down, because of the negative effect on the profitability (de Ronde 2008). With a likely increase in greenhouse gas concentration, and a projected increase in mean temperatures, drought conditions are likely to be more frequent (Christensen et al. 2007). This will further increase the number of fires and intensify forest destruction (Allen et al. 2010), further threatening the sustainability of the forestry industry in certain regions.

2. Forest fire research

There has been a range of fire-related research and development programs all over the world to address the increased occurrence of wildfire damage (Goldammer 1999). In Southern Africa various studies having been conducted in commercial pine plantations to determine the effect of fire on forest ecosystems and its role in forest dynamics (e.g. de Ronde and du Plessis 2002). However, not much research has been done to increase understanding of individual tree responses to fire damage. Knowledge of the natural resistance of trees to fire damage and the fire-related implications on survival, growth and health is crucial for defining management standards and options in the wake of increased fire occurrence. The aim of this study is to create an understanding on the natural fire resistance of commercial and indigenous species. The objective is to quantify the fire resistance capacity of the bark relative to bark thickness and moisture content.

3. Methodology

A current study, conducted at the Department of Forest and Wood Science of Stellenbosch University, is aimed at scrutinising fire effects on trees. It involves a bark char experiment to test the insulative capacity of bark of commercial exotics and non commercial indigenous trees. The trees were sampled in the Western Cape province of South Africa. The natural vegetation is dominated by Fynbos, forming a biome which covers approximately 5.3% of South Africa. The biome occupies coastal areas of the Western and Eastern Cape Provinces. This region experiences Mediterranean climate with warm, dry summers and wet, temperate winters. Rainfall ranges from 200 to 3000 mm per year. Dry summer temperatures have been recorded to be between 22 and 26°C (e.g. van Wilgen 1982). The vegetation is dominated by Fynbos which consists mainly of evergreen sclerophyllous heathlands and shrublands (Huntley 1984). Pine stands have been established commercially within the Fynbos shrublands. The Species include *P. elliottii, P. pinaster and P. radiata* (de Ronde 2008).

The selected trees for the study include *Pinus pinaster*, *Pinus radiata*, *Pinus elliottii*, *Eucalyptus cladocalyx*, as commercial species and *Rhus viminalis*, *Olea africana* and *Ekebergia capensis* as indigenous species. From each species, five live and healthy trees were selected for the study. Diameter at breast height (DBH) was taken at 1.30 m above ground and tree heights measured before felling them. Four discs of 25 cm height were taken from the bole of each tree at approximately 0.2 m, 15%, 30% and 70% heights.

By using a BD1602/HID 1600W electric heat gun as a fire simulator, heat was directed onto the bark of each disc. The discs with intact bark were heated at a constant temperature of 400°C which mimics that of high intensity surface fires (VanderWeide and Hartnett 2011). A heat sensor was used to monitor heat conduction through the bark to the cambium. The sensor used was a portable data logger, Testo model 177. It consists of a 2 channel LCD display and offers several advantages including a large memory of up to 48000 readings, allowing for extensive logging periods. The measurement point and the data logger were connected by means of an external probe with a heat sensitive tip. The data logger was connected to a PC via a USB interface installed in the PC alongside a driver. The sensor's probe was firmly attached to the data logger before being connected to the measurement disc (*Testo instruction manual, available online*). The readings from the sensor were transmitted by testo comfort software installed on the PC. The software was used to program the data logger to suit required measurement criteria.

A hole of 3.5 mm in diameter was meticulously drilled into the wood, under the bark layer, to about 5 cm depth. The bark thickness was measured using a vernier calliper and recorded. The probe was inserted into the hole prior to heating. The heater was placed directly in front of the disc and an insulator shield made of aluminium and steam gasket used to prevent the probe from direct heat. The duration of time taken by the heat to conduct through the bark to the cambium and to heat it to the lethal temperature point (60^0 C) relative to bark thickness and moisture content, was taken as a measure of the insulative capacity of the bark. The timing was done using a stop watch (see Figure 1 for experimental set up).

It took approximately 20 seconds for the heat to reach a maximum of 400^0 C from the time the heater is switched on. A lapse period of 20 sec was therefore allowed before timing started. In cases where the bark of discs flamed or smouldered before the 20 sec elapsed, timing was started at the point when flaming or smouldering started. Based on prior measurement it was determined that at this point that the bark temperature had reached 400 °C.

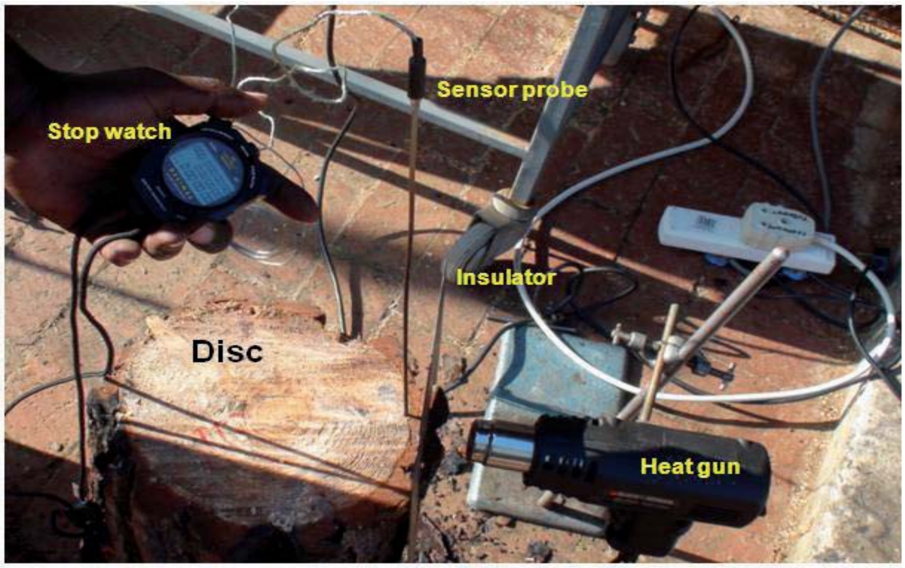

Figure 1. Experimental setup.

After the heater was turned on, temperature progression at the cambium region towards the upper limit set at the lethal temperature point was observed on a graph in the comfort software basic. This limit was delineated by a red line and once the graph reaches the red line, the watch was stopped, heating was stopped and the time was recorded.

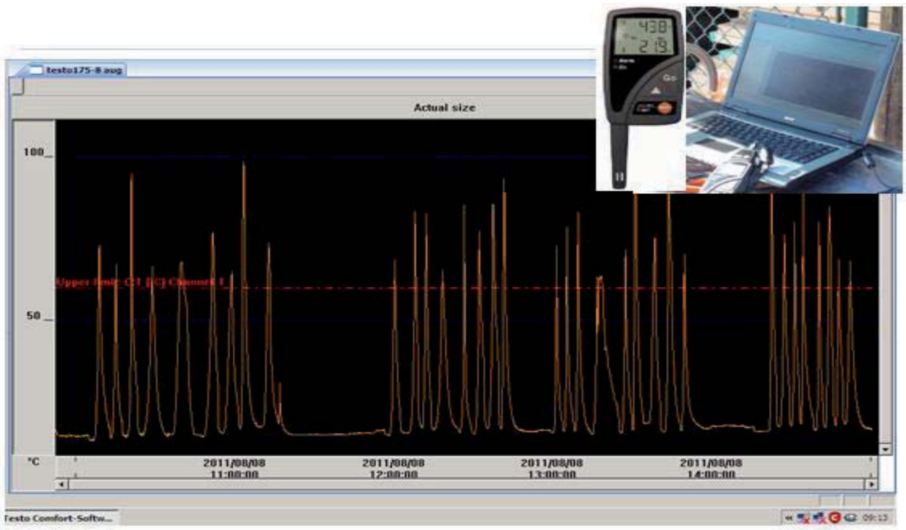

Figure 2. Data logger and PC (inset) and a Testo comfort graph.

An uncharred section of the bark and the adjacent regions of cambium and sap wood was extracted for moisture content determination. The piece was weighed while wet before being oven dried at 103°C for 24 hours. The dry weight was determined and the percentage moisture content calculated by taking the difference between moist and dry bark as a percentage of the dry weight. The aim of this was to account for role of available moisture in influencing the insulative capacity of the bark.

4. Results

First results show that the bark insulative capacity increased with increasing bark thickness and that this correlation is species specific (Figure 3).

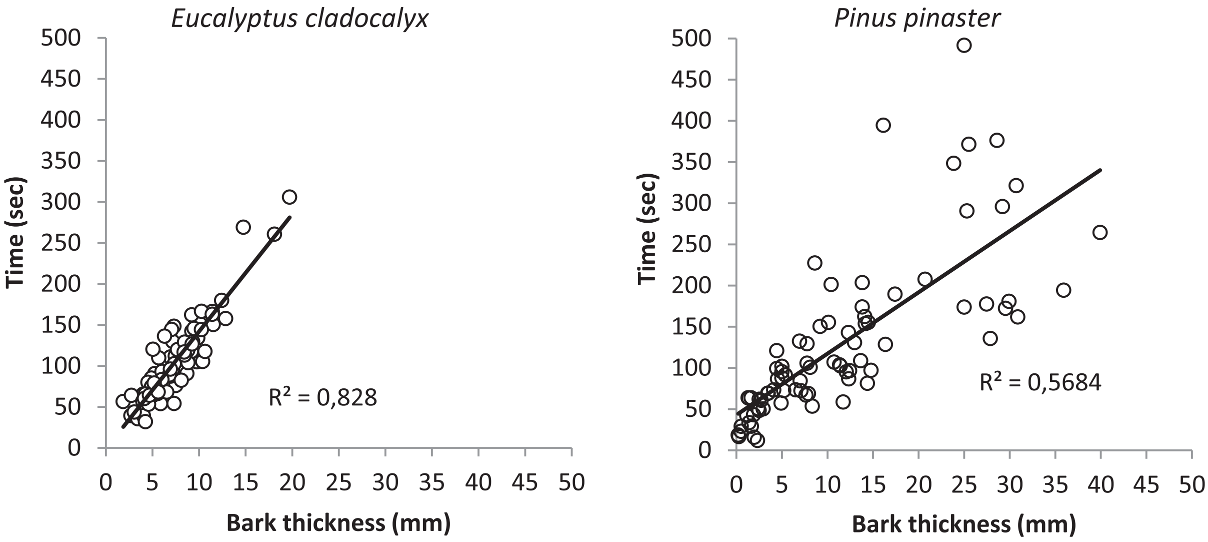

Figure 3. *Insulative capacity of the bark of two commercial tree species.*

A further analysis of the results once all the data has been gathered is expected to increase knowledge on species-specific resistance to fire damage which is unknown for most species due to lack of data. Such knowledge would guide management decisions and options in the wake of high fire frequency in areas like:

- selection of species for post-fire restoration
- selection of species for fire prone sites
- decisions of salvage logging
- classification of economic use for partially burnt wood
- improvement of prescription burning

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Chapter five

Potential for REDD: Examples and Case Studies

Reducing emissions from deforestation and forest degradation: the potential and challenges for Mozambique

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Abstract

This paper presents a preliminary discussion on the potential and challenges of implementing REDD+ activities in Mozambique. The starting point is the list of REDD+ activities suggested on the draft national strategy. The major activities and current practices in agriculture, energy and forestry, are evaluated in terms of their carbon emissions and the potential impacts and the challenges of their implementation. The analysis concludes that selecting efficient REDD+ activities is site specific, and the potential of these activities to reduce emissions varies among tree-based crops and annual crops.

Keywords: REDD+, Mozambique, agriculture, energy, forestry

1. Introduction and background

Mozambique has engaged in the process of preparing the national strategy for REDD+ in response to the global debates on the potential reduction of emissions associated with forest cover change. The proposed national baseline scenario, and the REDD+ objectives, suggest a significant reduction of emissions. The national REDD+ strategy suggests a set of measures to reduce deforestation and forest degradation and increase carbon stocks in forests. Yet, the amount of emissions that could be reduced and the amount of carbon that could be sequestered from each activity are still unknown. There is also no clear definition of how reduction of carbon emissions and carbon sequestration will be shared across sectors. This paper is a preliminary attempt to analyze (i) how deforestation and degradation drivers operate and affect forest conditions and carbon emissions, and (ii) the potential and challenges of reducing tree felling and planting. The starting point is the list of proposed activities for REDD+, which are evaluated in their potential to effectively reduce the carbon emissions. The list of proposed REDD+ actions is long, therefore, we do not attempt to cover all the aspects, but to concentrate on the technical aspects within three main sectors indicated as the main drivers of deforestation and forest degradation: agriculture, energy, and forestry.

2. Agriculture

2.1 How does slash and burn agriculture contribute to emissions

In Mozambique, agriculture is mainly done by smallholder farmers (99% of the farms are smallholders), with average cultivated land of 1.4 ha (INE 2011). The main aim of the household farmers is to ensure the provision of food production within the household, and the sale of surplus. Crops such as maize, cassava, beans, etc. are mainly consumed within the household. In addition, cash crops (cotton, tobacco, sesame) are largely produced by smallholder farmers through contract farming. Only 3.7% of the total smallholder farmers use fertilizers (INE 2011). Therefore, they use slash-and-burn practice as a mechanism to recover the nutrient lost during the cropping period. Burning biomass from the forests releases mineral nutrients to the soil, but also releases carbon to the atmosphere. Therefore, the conversion of forest into agricultural land by slash and burn agriculture is the major source of carbon emissions.

2.2 How REDD can improve the situation

Since agriculture is one of the largest drivers of deforestation, slash and burn agriculture has been targeted as a potential area for reduction of emissions. Tomich et al. (1998) suggest that since smallholder farmers have economic motivations to convert forests into agricultural land, any measure to reduce pressure over the forest will need to deal with alternatives to slash-and-burn farming. It was in this context that a global project was put in place to evaluate the alternatives to slash-and-burn (ASB) as measures to simultaneously meet local interests (poverty reduction, food security, profit, etc.) and global interests (supply global markets with agricultural commodities, biodiversity conservation, reduce greenhouse gas emissions, etc.) in the humid tropics. Palm et al. (2004) summarize part of the ASB experiments and conclude that many tree-based agricultural systems reduced net global warming potential by 11-35%, compared to annual cropping and pasture systems. In the situation of Mozambique, little has been reported in terms of technological alternatives to slash-and-burn options, however, local agricultural systems as well as the lessons learnt from other regions may be explored as potential alternatives.

2.2.1 Tree-based crops

a) Cashew trees are commonly grown as monoculture or intercropped in the Nampula province (with almost a half of the cashew trees in the country) and in most of the coastal region of Mozambique, particularly Inhambane, Cabo Delgado and Zambézia. Currently, about 1.38 million farmers (of which 1.37 are smallholder farmers) grow cashew trees (INE 2011). Cashew ranks 8th in Mozambique exports (and third among agricultural products, after tobacco and sugar), with 28.5 million USD in 2009 (INE 2011). There is high potential to improve agriculture in this field. Presently a supporting institution, INCAJU, has been put in place to promote and develop not only the production, but also the development of industry for cashew processing.

b) Coconut palm plantations cover approximately 160000 ha, mainly in four provinces (Cabo Delgado, Nampula, Zambézia and Inhambane) of which Zambézia has 110000 ha (or 70% of the total coconut palm plantations in Mozambique). Smallholder farmers, with an average 0.75 ha planted with palms, have the major share, and have shaped the coastal region economy[5]. Coconut was among the five most important agricultural export products during the decade of the 70´s, when more than 50000 tons/year were exported (in 1975)[6]. However, a combination of the war effects on the economy, aging of the palms (more than 75% of the palms are >45 years), and the outbreak of the lethal yellowing disease (LYD) that decimated the coconut palm plantations in Zambézia, production has been decreasing to about 10000 tons in 2008. Coconut is a major source of oil and soap, but alternative products include charcoal/brickets from the husk/fiber as well as timber from the stem.

c) Fruit trees are commonly grown in home gardens or in different agroforestry arrangements within agricultural fields. INE (2011) lists twelve fruit tree species grown mainly (99%) by smallholder producers. Among these, there are exotic species such as the naturalized mangos, oranges, guava, grown almost all over the country, and native species such as *Trichilia emetica* (mostly grown in the southern provinces) and *Ziziphus mucronata* (grown mainly in the central provinces). Mozambique has a large potential to grow fruit trees, and the current involvement of smallholder farmers in the production of a large variety of exotic and native fruit trees provides an important entry point to promote tree-based crops as sources of food and income. Presently, most of the fruit produced is consumed within the household (contributing to food security), and sold in the domestic market.

2.2.2 Agroforestry systems

Considering agroforestry a collective category for farming systems that mix tree crops and annual crops and/or animals in space and time, we can easily recognize that some of the tree-based options discussed above can be classified in the context of agroforestry systems. In fact, these trees are normally grown in arrangements that can be classified as woodlots, home gardens, boundary planting, etc. However, the ideal objective of agroforestry systems to maximize production, biodiversity conservation, and economic profitability is not given. Considering that the major motivation to slash and burn agriculture is nutrient availability, we suggest that alternative agroforestry techniques should focus on soil conservation, such as those that improve soil fertility (e.g. nitrogen fixing leguminous trees), and spatial and temporal arrangements that reduce the risk of nutrient loss and soil erosion, while ensuring good production levels over time. The use of improved fallows would also represent an advantage in terms

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[5]http://pt.scribd.com/doc/39104654/OPORTUNIDADES-DE-INVESTIMENTO-NO-SECTOR-DO-COQUEIRO-EM-MOCAMBIQUE
[6] http://imigrantes.no.sapo.pt/page2mocEconomia.html

of reducing the time for soil nutrient recovery in cropped land and the rehabilitation of degraded lands. Little has been done in this area locally, therefore, some experiments should be conducted and capacity building will be required to ensure the adoption of these techniques by smallholder farmers.

2.2.3 Annual crops

Reducing carbon emissions from smallholder farmers while producing annual crops is not an easy task. Effective and durable changes would require changes in the current farming system procedures. If we consider low productivity and loss of soil nutrients together with limited access to agrochemicals as the underlying causes of slash-and-burn, then potential changes could be suggested in the farming systems on this basis. Conservation agriculture, where a combination of techniques such as composting, the use of green manure, intercropping with nitrogen-fixing crops and integrated pest management are used, has a great potential as alternative to slash-and-burn farming. Although there is a dispute in the literature regarding the effectiveness of most of these practices, Ching (2009) reports examples from 286 projects in 57 countries indicating that productivity of ecological agriculture increased by 79-92% when compared to that using agrochemicals. However, there are limited experiences with these practices in Mozambique (Singh, pers. comm.), and there is no adoption of the existing ones, although reported to have shown success on trial farms.

3. Energy

3.1 Biomass-based energy as a major source of energy in Mozambique

Biomass is presently the key source of energy in Mozambique. Burning of firewood and charcoal is estimated to account for up to 80% of the total household energy use. The connection between biomass use for energy and GHG emissions is mainly due to biomass being obtained from unsustainable sources of energy. Reports (e.g. Pereira et al. 2001) indicate that more than 90% of the charcoal and firewood vendors are informal and without license. There is therefore a lack of management of the forests from where the biomass is collected. Wood biomass for energy and agriculture are indicated as the major drivers of deforestation and forest degradation in Mozambique (Saket 1994, Marzoli 2007).

3.2 How can REDD+ improve the situation

Among the mitigation measures to reduce emissions from biomass burning for energy, the actions that are suggested can be grouped as following: (i) continue the use of biomass, but improve efficiency of biomass burning such as improved stoves, improved efficiency of charcoal making process; (ii) produce biomass through tree plantations and the growing of crops for liquid biofuels; (iii) promote sustainable management of wood biomass source; and (iv) promote alternative sources of energy such as electricity, gas, coal, solar energy. These actions are not mutually exclusive and can be implemented in combination. An analysis of these actions for the conditions of Mozambique follows.

3.2.1 Efficient use of biofuels

Improving efficiency of energy use means making maximum use of each energy unit. That is, improving current energy use patterns. This action is suggested after studies have shown that making charcoal is only 18% efficient (Pereira et al. 2001). In addition, the cooking stoves are open, with high energy losses. Only 10-40% of energy produced in the traditional cooking stove is actually used for heating the pot (Kshirsagar 2009).

Studies (e.g. Pereira et al. 2001) suggest that increasing efficiency would mean changing the current practices, including the charcoal kiln form and procedures, and the type of cooking wood and charcoal stoves. Experiments conducted in Mozambique and Tanzania (Pereira et al. 2001) found that changing the traditional boat-like charcoal kiln to the Casamance kiln improves the charcoal production efficiency from 18% to about 35%. However, the workload of the charcoal makers also increases. In addition, changing the traditional open charcoal stove to the improved wood stove (IWS) may increase energy efficiency up to 30-50% of the traditional stove[7].

The Sitoe et al. (2007) simulation model for the region of Northern Sofala suggests that improving energy efficiency (if possible), may have limited impact on the forest if no additional measures are put in place to increase wood biomass production and management. Adoption of the Casamance kiln may not be easy as it implies increase in labor, while adoption of the IWS would require the establishment of a local maker of the stove, promotion and financing of the adoption, as well as energy saving discipline from the users. No reports were found indicating the level of adoption of IWS in Mozambique. However, we suggest that adoption is still very limited.

3.2.2 Energy plantations

Planting energy crops is generally seen as a sustainable way of energy use as indicated above. Plants use CO_2 from the atmosphere to grow and accumulate biomass. Therefore, if biomass production is done in an efficient manner, the CO_2 released during the combustion can be used back to grow biomass again, making it a closed cycle.

During the initial energy crisis of the 80´s, Mozambique conducted extensive campaigns to produce wood biomass from forest plantations for energy. Recognizing that urban use of wood biomass for energy was the major source of deforestation, reforestation projects were established close to large cities of Maputo, Beira and Nampula to supply biomass for these cities. While technical aspects of forest establishment were taken more seriously in these projects, economic and social aspects do not seem to have been given similar importance. These experiments were to fail before they could not produce the results for which they were established.

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[7] http://other90.cooperhewitt.org/design/kenya-ceramic-jiko

With the global fuel crisis of the early 2000´s the world has experienced a biofuel rush. Mozambique became one of the major destinations for investments in biofuels, mainly with jatropha for biodiesel and sugar cane for ethanol (Batidzirai et al. 2006, Schut et al. 2010). Although there is clear indication that Mozambique´s production of liquid biofuels is mainly to supply international markets, there is a growing awareness that these biofuels could be used to supply domestic markets as well, particularly the use of jatropha oil as substitute for firewood and charcoal[8]. There is no clarity yet on whether biofuel production (and use) is a net sink or source of GHG as they require extensive areas of land and also use fossil fuels for mechanization. Land requirement would sometimes mean conversion of high carbon woodlands to grow biofuels feedstock. Biodiversity loss and food insecurity among others, are some of the side effects of biofuel use which still need to be properly scrutinized. For instance, Arndt et al. (2010) suggest that jatropha feedstock production through outgrower schemes would lead to replacement of food production areas by jatropha plantations.

The adoption of biomass production for biofuels entails social and economic aspects that need to be tackled. Managing biomass plantations successfully must not be seen as just planting trees, but also as taking into account the economic incentives, social and cultural aspects, and forest governance.

3.2.3 Sustainable management of biomass sources

The key issue of biomass burning being a source and not a sink of GHG emissions is that there is lack of sustainable management of the biomass sources. This is true for both natural woodlands and plantations. The previous section explained the contours of the plantations for wood energy, and concludes that lessons have been learnt, but little is being done to make energy plantations sustainable. Currently, firewood and charcoal are produced in natural woodlands without management, resulting in high deforestation rates around areas of high demand in urban areas. Sitoe et al. (2008) estimated that at national scale, burning of biomass for energy is surpassed by the wood biomass growth, making the use of wood for energy a clean process. However, it is at a subnational scale, particularly close to urban centers, where the use is higher that the production, creating areas of high emissions.

Managing the sources of biomass for energy sustainably, in the case of Mozambique, would mean not only reducing emissions, but also reducing the rate of deforestation associated with the use of forests as sources of energy. Although not currently producing net emission at national level, in the long term, unsustainable use would result in a net source of emissions. Sustainable management, in the long term, would result in resource use efficiency by promoting good forest governance. There are costs associated with the management: social and economic (affecting mostly those involved in informal trade of firewood and charcoal, and those who have been using woody energy).

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[8]http://www.theecologist.org/News/news_round_up/529755/jatropha_better_suited_to_local_communities_not_biofuel_markets.html

3.2.4 Alternative sources of energies

Reducing emissions from deforestation caused by the demand for wood biomass as source of energy may be attained by moving from the wood biomass-based energy (as presented above) to alternative sources of energy. This option suggests that if people have access to reliable and viable alternative sources of energy they will be willing to adopt them. There are studies (e.g. Egas 2006), however, that show that changing from wood-based energy to their alternatives may be highly complex. It takes more than just the comparative low price, including social, cultural, and economic aspects needed for the change.

The potential for alternative sources of energy is high, but mostly remains unexplored. Mozambique has the largest hydropower generating dam in Southern Africa, the Cabora Bassa, with the installed capacity to generate 2075 Mega Watts[9]. This is by far the demand of domestic energy, but currently most of the energy generated is exported to South Africa. Another smaller hydropower dams is located in Manica, the Chicamba dam, while plans are well progressed to build another large hydro power dam on the Zambezi river in the locality of Mpanda Nkua[10]. There are challenges yet to come, as even within the urban areas a significant proportion of the population does not have access to electricity. In addition, part of the urban population with access to electricity, still relies heavily on charcoal for cooking.

Mozambique has one of the largest natural gas reserves and coal, but currently only a small proportion is being explored and it is fully exported. Other alternative sources of energy include solar and wind power which are also not explored.

4. Forestry

4.1 How forestry activities contribute to emissions

This section focus mainly on industrial wood, while wood used as firewood and charcoal is dealt with in the section of energy above. Although most of the logging is classified as unsustainable, it rarely produces deforestation directly. The selective nature of logging, based on species and size, which typifies the timber sector in Mozambique, removes few trees per hectare. Saket (1994) estimates an average of 3-4 mature commercial trees per hectare, out of a total of 175-250 tees/ha (>10 cm dbh) in Mozambique. Even in areas with high density of gregarious species such as *Millettia stuhlmannii*, the number of mature trees that are logged is relatively small (up to 10 trees/ha). In addition, given the openness of the forest, with scattered trees, little or no logging damage is done to the remaining stand. Products from forest logging are normally used as structural timber (sawn timber or sold as logs). Sawmills have little efficiency and may have up to 50% of the log volume produced as timber, with the by-products being burnt locally (in the industry) to generate energy. However, the current pattern of forest industry in Mozambique, means that the majority (90%) of wood is exported as logs,

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[9] http://en.wikipedia.org/wiki/Cahora_Bassa_Dam
[10] http://www.gpz.gov.mz/documentos.html

mainly to China (Canby et al. 2008). GHG emissions from the forestry sector may not be a direct effect, but have an indirect one, mainly in tandem with the collection of firewood and charcoal making, and eventually agriculture. Among the indirect effects, there are wildfires, which propagate and cover extensive forest areas, affecting the regeneration and growth of the trees. Outside forest concessions, in areas logged under simple annual logging permit, the forest roads opened by loggers are later used by firewood explorers and charcoal makers.

4.2 What can REDD+ do to reduce emissions associated with logging

Although the emissions associated to logging itself do not seem to be important, as indicated above, the forestry sector can contribute to the enhancement of carbon sequestration through a series of activities that promote forest regeneration, forest conservation, sustainable forest management, and the establishment of forest plantations. Particular observation should be done on the fact that logging in unmanaged forests opens roads for further forest damage by firewood collectors, charcoal makers, and slash-and-burn agriculture (see sections on agriculture and energy above).

a) Forest concessions: promoting sustainable forest management through a system of concessions is one of the main aims of the forest regulation in Mozambique. Presently, 179 forest concessions have been approved, covering more than 4 million ha (Sitoe et al. in prep.). The appropriate implementation of the SFM principles in these concessions is still a challenge. In fact, most of these just work as annual logging licenses and little is done for the implementation and enforcement of the management plans. The timber market structure, dominated by log exports and illegal operations, and the institutional weakness of the Forest Service, are commonly indicated as the main limitations for the appropriate implementation of the SFM principles (Sitoe et al. in prep.).

b) Natural forest conservation: Mozambique has about 8.9 million hectares of forest within conservation areas. Estimations of the deforestation rate, although not giving specific figures of the amount of forest loss within conservation areas, make clear that deforestation and degradation takes place within these areas as well, for the same reasons as those outside the conservation areas (Marzoli 2007). Conservation areas in Mozambique have the particularity of also being settlement areas, with the population practicing all sort of subsistence activities, including slash-and-burn agriculture, hunting (with fire), extraction of wood for local use as well as for commercialization (e.g. growing cotton and tobacco). One of the big challenges for the implementation and enforcement of conservation measures is related to the need of integrating community development activities which are compatible with conservation objectives. Suggestions for the use of non-timber products, such as honey, wood carvings (from dead trees), proved to not be efficient compared to the extractive activities such as charcoal making, or the conversion of forests to agriculture.

c) Commercial and community forest plantations: planting trees may represent an option for fast carbon sequestration. To make a contribution to REDD+, plantations (i) should not replace native trees, (ii) should represent higher carbon stocks compared to the original vegetation, (iii) should contribute to the reduction of deforestation and degradation of neighboring forests, and (iv) integrate the interests of people who may have caused deforestation or degradation and avoid leakage. Whether industrial forest plantations should be classified as potential REDD+ is to be defined, but the lack of additionality of these plantations is a common reason to exclude them from REDD+. That is, industrial wood production will continue to take a place independent of REDD+.

Several forest plantation setups can be established with a potential to contribute to REDD+. These may include energy plantations, agroforestry systems (discussed above), and other initiatives of tree planting that can be established with the purpose to generate income for local communities, while diverting them from makin their living from extractive activities. Attention should be paid to the fact that impact of forest plantations (on carbon sequestration, and on the local economy) may not be evident in the short term. Note that planting trees may have social and cultural dimensions (see above on energy plantations).

5. Conclusion

There are potential and challenges for REDD+ implementation in Mozambique. Lessons of good practice and carbon saving land use options exist. Some of these practices, particularly the use of tree-based crops became traditional practices, resulting in large areas of agriculture with high carbon stocks. For some other practices, such as agroforestry systems, energy plantations and conservation agriculture, small scale experiments exist, but a large scale adoption is still to come. Challenges to implement REDD+ activities include not only the need for extensive investments, but also experimentation, and adaptation (social and cultural). Deforestation and forest degradation may also result from unharmonized sector policies and technological limitations. Choosing a REDD+ activity from the long list of options, where resources are limited, may not be easy. First, the options should be in line with the local (subnational) causes of deforestation and forest degradation. Second, cost efficiency is desirable to make REDD+ worth using. Activities with a high impact on carbon stocks and low risk (likelihood of success) are the ones that would eventually deserve higher priority.

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The effect of income from non-timber forest products on rural poverty and income inequality: a case study from the dry woodland areas of Tigray, Ethiopia

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Abstract

The aspiration of this research is to analyze the distributional and poverty effect of common pool forest resources, using a case study of the rural Kafta Humera and Tanqua Abergelle districts of Tigray, Ethiopia. The paper explores determinants of dependence on non-timber forest product (NTFP) use to identify the connection to sustainable forest resource use by rural households in the two districts. Determinants of household dependence on a given forest product are probed using Ordinary Least Square (OLS); while the effect of forest income on household poverty and inequality is measured by employing Foster-Greer-Thorbecke (FGT) and Gini Indices respectively. The result shows that forest income is the third largest income source, constituting 9% of the total per capita income. Dependence on NTFP use is significantly lance by per capita income, availability of working households, gender variation, access to commonly used land, and ownership of oxen. Additional income from NTFP significantly reduced poverty by 8.08% and income inequality by 2.2%.

Key Words: Non-timber forest products, poverty, income inequality Ethiopia

1. Introduction

The role of NTFPs for sustainable forest management and poverty reduction has received increased attention starting from the early 1990s (Mirjam 2003, Arnold and Pérez 2001). Since then, the need to invest in accurate empirical knowledge on NTFPs is growing. Since they are freely accessible, rival, and commonly used by rural poor households, exploitation of them is ecologically less destructive than timber harvesting and their sustainable use could decrease tropical deforestation. Very few papers examined the link between poverty, forest income, and the pattern of household dependence on it. According to the World Bank (2001), around 1.6 billion people depend on forest resources for their livelihood, out of these almost 1.2 billion live in extreme poverty. Studies in natural resource economics identified the significance of income from forest products in alleviating rural poverty and reducing inequality by serving as a means for earning cash and subsistence, creating an asset, and increasing the capacity to participate in high return production. Cavendish (2000), found that dependency on NTFPs declines with income, from 40% of the poor, to 30% of the rich households in Zimbabwe, and suggested natural resources have a significant role in alleviating rural poverty. Fisher (2004), showed how various household characteristics affect dependence on forest income in Malawi and indicated that asset poor households are more reliant on both low return and high return forestry activities compared to the better off. A similar study by Babulo et al. (2009) in the Tigray region (Northern Ethiopia) explored the significance of forest resources in reducing measured poverty and income inequality. A study by Narain et al. (2005) from the Jhabua district in India reached a conclusion different from the common empirical finding of an "inverse 'U' shaped relationship between dependence on forest and household income" for different categories of forest products[11].

Most of the research in developing countries showed the significance of natural resources for poverty alleviation. However, these studies focus on the economic importance of all environmental resources rather than specifically addressing the effect of NTFPs and identifying their features. They did not explicitly identify the determinants of dependence on forest products. Cavendish's (2000) main objective fails to identify the basic determinants of a forest dependence–income relationship, and the contribution of forest income to household poverty and inequality reduction as separate from other natural resources. Babulo et al. (2009) emphasized the economic importance of forest products on poverty and income inequality reduction in the Tigray region-Northern Ethiopia. In this respect, the main theme of this thesis is in line with their conclusions; however, our study is aimed at exploring the main factors affecting dependence on the forest product groups jointly with the indicated objective. The most related review is the one made by Fisher (2004), who observed the basic determinants of household dependence on forestry activities[12]. Yet, a classification of forest products in a more informative and logical way, can reveal a more realistic relationship and the real characteristics of volume and type of NTFPs produced in the study area. Narain et al. (2005) reverted the common empirical finding of a forest dependence-income relationship by dividing forest products according to their nature of usage (fuel wood, construction, animal food and fodder, other forest products), to observe how dependence varies with household permanent income[13]. However, their study did not further incorporate important explanatory variables such as access to market and modern transportation services exhaustively.

Therefore, this study investigates the significant determinants of dependence on forest products. It is also aimed at assessing the extent to which inclusion of income from each class of forest product, and the total income from all forest products, could affect inequality and poverty measures of poor rural households in the study area.

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[11] The term forest product in the study refers to the categories within the definition of NTFPs.

[12] High return forestry activities (HRFA) → according to Fisher (2004) include charcoal sell, timber exploitation, logging employment and others whose annual return ranges from 4895 to 5705MK; while, Low return forestry activities (LRFA) include fuel wood marketing and other forest products not remunerative or of a produce return between 626 to 4895 MK per year . However her classification of this product needs more explanation.

[13] Permanent income refers to the flow of income that the household can expect to derive from private assets (land, livestock, farm capital, financial assets) (Narain et al, 2005).

2. Methods

A structured household survey was conducted in March 2009 on 260 stratified random sample rural households from the Kafta Humera and Abergelle districts of Tigray, northern Ethiopia. We used livestock wealth for stratifying the sampling frame into rich, medium and poor, and selected proportional samples from each stratum. Both districts are predominantly lowlands and the main occupation of people in this area is mixed farming (crop production and livestock rearing). To explore the determinants of dependence on NTFP use, we applied a semi-log ordinary least square in which socio-economic variables, asset variables, gender, and location dummies are used as independent variables. Dependence on NTFP use is measured as the ratio of a household's income derived from NTFPs in a given year to its total income in that same year (Cavendish 2000, Fisher 2004, Narain et al. 2005).

To measure poverty and income inequality, we account for the net income of rural households under study from different sources, employing the methodology used by existing research (Babulo et al 2009, Cavendish 2002 and Narain et al. 2005). Current income is the income obtained from sample households in the study year within the 12 months (February 2008 to March 2009) from six sources, namely 1) net crop income 2) net livestock income 3) off-farm income 4) fuel-wood income 5) income from NTFPs except fuel wood 6) rent income. The net income from each source is the difference between total values gained and total input costs used in the production process. These totals included both market transactions and imputed values for those which do not have an observable market price.

To examine the effect of income from forest products we used the Foster-Greer-Thorbecke FGT (1984) poverty index. According to FGT (1984), of all the poverty measurement indices developed, the Foster-Greer-Thorbecke (FGT) poverty index is found to meet the fundamental axiomatic requirements of poverty indices most: consistency, additive and decomposability. Moreover, the poverty orderings correspond precisely to the α – degree stochastic dominance of partial orderings. The Foster-Greer–Thorbecke (FGT) class of poverty measures is given as:

$$P_a = \frac{1}{n}\sum_{i=1}^{q}\left(\frac{z-y_i}{z}\right)^{\alpha} \qquad (1)$$

Where α = poverty aversion parameter; n = total number of individuals; q = total number of poor individuals; z = poverty line; yi = per capita income below poverty line; and i = 1, 2, … q.

- If $\alpha = 0 \rightarrow P_0 = \frac{q}{n}$. This index indicates a head count ratio index that reflects the proportion of poor in total population, measuring the indices of poverty in the whole population. A head count poverty measure is advantageous in that it shows the progress in reducing poverty. However, it is insensitive to the depth or severity of poverty and hence suggested not to be good for policy measures (Hagos et al., 2000). This problem is captured by the poverty gap index.

- If α = 1→$P_1 = \frac{1}{nz}\sum_{i=1}^{q}(z - y_i)$. This measure is known as poverty gap and helps us estimate the average distance separating the poor from the poverty line. The poverty gap could be understood as the amount of income transfer needed to close up the gap. P_1 is sensitive to the gap of poverty but not to the depth of poverty (World Bank, 2008).
- If α = 2→$P_2 = \frac{1}{nz^2}\sum_{i=1}^{q}(z - y_i)^2$.This depicts the severity of poverty not only by assigning each individual a weight equal to his\her distance from the poverty line, but also the inequality among the poor. The effect of gross forest income on poverty is analyzed using DASP 2.3 version.

Poverty measures are used both to compare growth across different states, wherever the requirement for global comparability is vital, and within a particular country to tailor the approach and definitions. As the African Development Bank (2006) stated, the most frequently used poverty line for international comparisons by the United Nations (UN) and, the World Bank is \$1/day and a \$2/day. Different countries define and measure poverty in a variety of ways; hence, there is a need for an uniform international scale. This is possible by converting the local currency at the purchasing power parity (PPP) rate. PPP can be defined as the number of units of a country's currency needed to buy the same amount of goods and services in that country as one U.S. dollar would buy in the international market. As stated by the World Bank (2008), the \$1 international poverty line has been readjusted at \$1.25 a day using 2005 basic price as bench mark. Based on the purchasing power parity index, every country formulates its implied purchasing power conversion rate in terms of one US dollar for a particular year. The USD 1.25 per day PPP for ETB on average in the year 2009 is calculated following Schreiner and Chen (2009) as follows, taking the 2005 PPP exchange rate as a base:

PPP_{2009} = (2005 PPP exchange rate)

$$= \text{USD } 1.25^* \left(\frac{CPI_{2009}}{CPI_{2005}}\right) = \text{USD}1.25^* \left(\frac{289}{138}\right)$$

$$= 2.254^*1.25^*2.094 = 5.90\text{ETB}$$

To measure the effect of income from NTFPs on income inequality, we applied the Gini index. The Gini index is the most appropriate index used to decompose and see the effect of several income sources on inequality. The Gini Index represents income inequality through the Lorenz curve. It measures the ratio of the area between the Lorenz curve and the equal-distribution line, termed as 'the concentration area', to the area of maximum concentration (FAO, 2006). The Gini coefficient for total income inequality 'G' is the summation of each income source Gini 'G_k' that a rural household received symbolized as:

$$G = \sum_{K=1}^{K} R_k G_k S_K \quad (2)$$

Where, 'S_k' represents the share of income component 'k' in total income of a given rural household under study, 'G_k' the distribution of k^{th} income source among rural households, and 'R_k' is the Gini correlation of income from source 'k' with distribution of total income.

Additional significance of the Gini index is that it allows us to decompose and see the effect of a small percentage change in income from forest products on inequality, keeping the other source of incomes constant or using the 'ceteris paribus' assumption (Stark et al., 1986). For instance, if there is a small percentage change in income from source 'f_y' (income from forest) equal to 'μ' such that $y_{fy}(\mu) = (1+\mu)y_{fy}$, Then:

$$\frac{\frac{\partial G}{\partial \mu}}{G} \quad \frac{S_{fy}R_{fy}G_{fy}}{G} - S_{fy} \tag{3}$$

Where S_{f_y}, G_{f_y}, R_{f_y} represent the source 'f_y'(forest income share), distribution of forest income, and the correlation of source Gini (forest income) with the distribution of total income, and G denotes the Gini index of total income inequality before a change in income from f_y^{th} income source, which in our case is income from forest product (World Bank, 2008)

3. Results

3.1 Determinants of Dependence on NTFPs

From the regression result, we observed that there are certain socio-economic variables which can affect the rural household's dependence on gross NTFPs significantly while keeping other factors still constant (see Table 1). Relatively better off households (in terms production factors like land size and rented land, number of family members in the productive age group, and number of oxen) are less dependent on NTFP income than households who are less endowed with these factors. Gender of the household head is a significant determinant for dependence such that female-headed households are less dependent on gross forest income than male-headed households at a significance level of 10%.

Table 1. *Determinants of dependence on gross forest income.*

Variables	Coefficient	Standard Error	t-value	Sign.
Sex	-0.362	0.196	-1.850	0.066
Age	0.001	0.004	0.300	0.762
Education	0.118	0.142	0.830	0.407
Family labor	-0.128	0.042	-3.070	0.002
Number of oxen	-0.102	0.023	-4.510	0.000
Land size	-0.015	0.034	-0.440	0.660
Area of fallowed land	0.159	0.115	1.380	0.168
Rented out land	0.074	0.176	0.420	0.674
Rented in land	-0.153	0.091	-1.680	0.095
Village dummy	0.131	0.134	0.980	0.326
Distance to all weather road	0.000	0.002	0.100	0.924
Distance to market	-0.002	0.003	-0.700	0.486
Constant	-0.645	0.303	-2.130	0.034

3.2 Effect of gross forest income on rural poverty and inequality

In Table 2, the poverty measure before including gross forest product and after including gross forest income is presented. The difference between these two is measured and tested for severity or depth of poverty from both absolute and relative viewpoints. Head count poverty measure shows the percentage of the rural population lying below the poverty line. In our study the percentage of total population that could be poor reached 51.93%, if per capita income from gross forest products is left unmeasured. Addition of per capita gross forest income, however, reduced measured poverty in US dollar purchasing power parity terms to 43.85% in relative terms. Per capita income from forest products contributes an 8.08% reduction of poverty head count, and it reduces the poverty gap and severity by 4.49 and 3.58% respectively. All the effects are significant at 1% error probability.

Per capita income from forest products is the third largest income in the rural economy supplying 9.23% of the total income share.

Table 2. *Effect of including income from NTFPs on Poverty*

Index	% Without NTFPs income	Effect of including NTFPs income in %
$\alpha = 0$	0.5193	-0.0808***
$\alpha = 1$	0.2168	-0.0449***
$\alpha = 2$	0.1284	-0.0358***

The Lorenz curve in Figure 1 below shows the effect of gross forest income on income inequality. The 45° straight line shows perfect equality in per capita income distribution while the outer smooth curved line shows the Lorenz curve indicating the gap of inequality before the addition of gross per capita income from forest products. After the inclusion of NTFPs income, the Lorenz curve shifts inward towards the perfect equality line. As can be observed from the graph, forest income has the effect of narrowing the gap of income inequality ob-

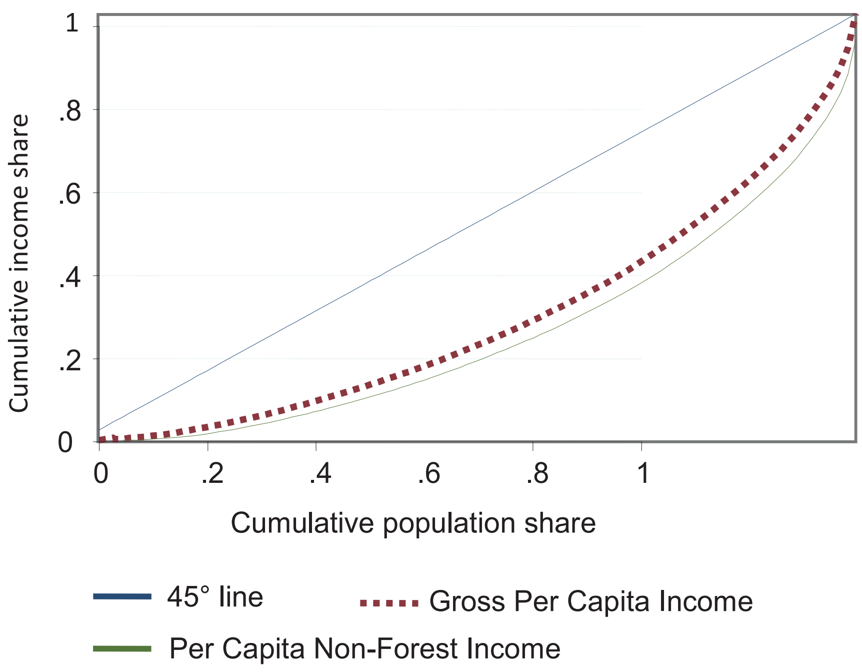

Figure 1. *Lorenz curve.*

4. Conclusions

This study has revealed that NTFPs represent a very significant component of the household livelihood and income options. These results are consistent with previous studies by Cavendish (2000) and Babulo et al. (20009). We found that household dependence on NTFPs is not caused only by a progress in per capita income. It is also influenced by changes in the number of working households, availability of more land plot for agriculture, availability of factors of production like oxen, and the capacity to rent in other's plot of land to produce farm crops. Although rural poor households are highly dependent on this product, it is the richer households who exploit the NTFPs in a large amount in absolute terms. Dependence on fuel-wood declines sharply with an increase in per capita income; yet, it becomes slightly higher and flatter when we take the per capita income from all forest products as a whole. This suggests their participation in one or more forest product types in a gross perspective rather than specifically.

The finding on the contribution of NTFPs is seen from three points of view; specifically, from the two classifications of forest products namely fuel-wood, and non-fuel wood forest products, and more generally, from the gross forest products included in the study area. The contribution of these forest products is significant both at equalizing and measured poverty reduction. Gross per capita income gained from the total NTFPs contributes 9.23 percent of the total income and reduced poverty by 8.08% and income inequality among rural households by 2.02% on average, other things being constant.

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Methods for valuing dry land forests in the context of REDD+ and the role of multidisciplinary sciences

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Abstract

Dryland forests provide a number ecosystem services important for human welfare. The objective of this paper is to identify the best available methods for valuation of dry land forest ecosystems. According to the total economic value (TEV) approach, the values of dry land forests can be broadly classified into use and non-use values. A number of scientific disciplines are required for efficient and careful identification and quantification of the various ecosystem services of dryland forests. After determining the physical quantities, appropriate valuation methods are required to determine the economic values. A number of revealed and stated preference valuation methods are discussed in the framework of dryland forest. These methods include direct market price, effect on production or opportunity cost, preventive expenditure, replacement cost, dose response, travel cost, hedonic pricing, contingent valuation, and choice experiments.

Key words: Economic valuation, dry forests, ecosystem services

1. Introduction

Forest ecosystems as natural capital and the ecosystem services they provide make significant direct and indirect contributions to the global economy and human welfare. They store about 80% of all aboveground terrestrial carbon and 40% of belowground carbon (Dixon et al. 1994, Goodale et al. 2002). Next to the energy and industrial sectors, tropical deforestation and land degradation rank third among the contributors, accounting for 17% of to the global green house gas emissions from anthropogenic sources that are fueling the global temperature (Rogner et al. 2007). If managed sustainably, forests can be a sink to green house gas emissions from other anthropogenic sources and thereby contribute to climate change mitigation. However, they were not included in the 2008-2012 first commitment period of the Kyoto Protocol due to concerns about diluting fossil fuel reductions, sovereignty, and methods to measure emission reductions (Gullison et al. 2007, Gibbs et al. 2007, Bond et al. 2009). The importance of emission reductions from avoided tropical deforestation in the global climate change policy has been growing following the COP 13 decisions on the possibility for reducing emissions from deforestation and forest degradation in developing countries (REDD) to become part of a post-2012 global climate regime (Bond et al.,2009). The United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (UN-REDD Programme) established in 2008, has the objectives of assisting developing countries to build capacity to reduce emissions and to participate in the post 2012 REDD+ mechanism.

Valuation of forest ecosystem services has been recognized as an important tool that can aid decision makers to evaluate trade-offs between alternative forest management regimes and courses of social actions that change the use of forest ecosystems and the services they provide (MEA 2003). Although dry land forests provide a variety of ecosystem goods and services there is inadequate documentation and evaluation. This is mainly the case in Africa where these forests account for more than 43% of the land and provide a number of ecosystem services in the day-to-day life of more than 235 million people in the region (FAO 2010). Valuation of dry land forests could help with land use planning, macroeconomic policy analysis, and for assessing the potential of REDD for climate change mitigation. The implementation of REDD+ Programme objectives namely reducing carbon emissions from deforestation and maximizing the associated benefits (biodiversity conservation, poverty reduction, sustainable management of forests and enhancement of forest carbon stocks) in developing countries requires feasible and scientific approaches (Gibbs et al. 2007). These must enable the monitoring, reporting and verification (MVR) of carbon emissions from deforestation and forest degradation. Valuation of the forest to be subject to REDD+ financing in a way that involves data from multidisciplinary scientific results is essential in both implementation and evaluation of such mitigation efforts. Thus, this paper gives an overview of the values of forest ecosystem services and the valuation methods used in the environmental valuation literature. It describes the major valuation techniques and the important role that different disciplines play in generating information on the physical flows of benefits and costs of managing dry forests in the REDD+ framework.

2. Values of forest ecosystem and valuation methods

Since the late 1990s, many conceptual frameworks and valuation methods have been realized for forest ecosystem services and for promoting their inclusion in national economic accounts (Wu et al. 2010). Following the work of Pearce (1993), a number of authors (Kengen 1997, Bishop 1999, Cambell and Luckert 2002) proposed a framework for valuing forests and accordingly classified the total economic value of forests into two main categories: use values (UV) and non-use values (NUV). The use values further include direct use values (DUV) and indirect use values (IUV).

Direct Use Values: are the goods and services that directly accrue to the consumers. Forest goods and services with direct use value include timber, fuel wood and charcoal, non-timber forest products (resins, rattan, natural gums, coffee, honey, bush meat, mushrooms, wild edible fruits, livestock feed etc.), recreation (ecotourism), research (educational value),and cultural and religious values among others. Consumers may or may not pay market-clearing prices for these goods and services and therefore some are marketed benefits and others may be non-marketed ones.

Indirect Use Values: refer to some special functions of forest ecosystems that accrue indirectly to either users and non-users of forests. Examples of forest benefits in this category include ecological services (climate regulation functions like carbon storage, carbon fixing and ameliorating weather events, watershed functions like soil conservation, improved water supply and water quality, flood and storm protection, fisheries protection), biodiversity and local amenity services.

Option Value: Weisbrod (1964) first introduced the idea of option value, which refers to the potential future benefits of forest resources. It can be viewed as an insurance premium that one would be willing to pay to ensure the supply of the direct and indirect uses of a given resource later in time.

Non-Use Values: These values refer to those elements of value that are unrelated to current, future or potential uses (Krutilla, 1967) of forests. *Existence value* is a category of non-use value that refers to the intrinsic values that non-users are willing to pay purely for the existence of the resource without the intention of directly using the resource in future. A *bequest value* refers to people's willingness to pay for ensuring that forests will be preserved for the welfare of future generations.

Valuation of forest ecosystem services first requires quantifying the different ecosystem services at spatial and temporal scales. Generating such data requires the expertise of different scientific disciplines. It is possible to make a sound valuation exercise if only the physical quantities of the ecosystem services are derived from scientific studies of respective disciplines. Such an interdisciplinary approach entails a greater level of accuracy in the estimated values since it allows minimizing the use of generalized assumptions and hence reduces the associated uncertainties and errors in the valuation exercise. For undertaking the work of estimating the opportunity cost of REDD+ at a national level, for example, White et al. (2011) proposed a team of experts which included geographers (spatial analyst), foresters and carbon specialist, forest economists, agricultural economists, hydrologists, biodiversity experts, and sociologists.

Once the physical quantities of ecosystem services are determined, converting to monetary values using the appropriate valuation method is the next step. Most of the forest ecosystem services are non-marketed benefits. In the valuation literature, the methods to value the marketed and non-marketed benefits of forest ecosystem services are classified into revealed and stated preference methods. In the revealed preference method, the value of an ecosystem services is measured in terms of the market price for that particular service in the market, or indirectly by examining the purchase of a related service (complementary or substitute service) in the private market place (Garrod and Willis 1999). The revealed preference techniques include:

i. *Direct market price:* this involves the valuation of an ecosystem service using its market price. For some of the direct use value elements of forests like timber, fuel wood, and resins there are markets and the prices of these goods can be used directly to value them.

ii. *The effect on production or opportunity cost approach:* this approach values the benefits of environmental protection (for example the benefits of assigning a given natural forest area of a country for REDD+ framework objectives) in terms of what is being forgone to achieve it, such as profit from alternative land use options like agriculture, livestock production, agro forestry, palm oil plantations, shifting cultivation.

iii. *The preventive expenditure and averting behavior approach:* in the case of the preventive expenditure approach, the value of an ecosystem service (say a forest near urban areas providing air purification service through absorbing dust particles and pollutants) can be inferred from the expenditure on technologies required to reduce the pollutants. For the same environmental service it is possible to infer the value from what people are prepared to spend to prevent themselves from the negative externalities of the pollutants (like possible health risks). This approach is termed as the averting (mitigating) behavior approach. Conceptually, both approaches are closely related.

iv. *The replacement cost approach:* values an ecosystem service in terms of the cost required to restore the ecosystem service to its original state after it has been damaged.

v. *The dose response approach:* this approach requires information on the effect that a change in a particular pollutant has on the level of an economic activity (for example fertilizer or pesticide application on agricultural crop productivity) or a consumer's utility. Urban forests regulate air temperature and minimize the formation of smog (ozone). During summer time trees help to reduce the ground level temperature and hence to minimize the possibility of smog which is the product of a chemical reaction between NOx and volatile organic compounds (VOCs) in the presence of sunlight and requires rising temperatures. Ozone is a very unstable and reactive oxygen molecule that can cause human health problems, damage crops, and can affect tree growth.

vi. *Travel cost method:* this method helps estimate the demand or marginal valuation curve for recreation sites. Forests and particularly the wildlife they shelter are important recreational sites. These values of forests can be inferred from observing how the number of visits to the sites varies according to the prices of private goods (like transport costs) with the travel distance.

vii. *Hedonic pricing:* is based on the consumer theory that every good provides a bundle of characteristics or attributes (Lancaster, 1965). The value of a real estate near forest compared to another real estate with similar conditions but no forest in the nearby will be different. The forest as a public good provides different amenities to the nearby real estate. Therefore, the difference in prices of the two real estates can be attributed to the services that the forest provides.

The stated (expressed) preference approach involves valuing an ecosystem service by estimating peoples' expressed or stated preference for the service relative to their demand for other ecosystem services. This approach does not require finding a complementary good or service, or a substitute good, to derive the demand curve and hence estimate how much an individual implicitly values the ecosystem service. The stated preference technique asks people explicitly how much they value an ecosystem service. The two basic types of this approach are:

i. *Contingent valuation:* this method first describes the ecosystem service to be valued and then asks how much respondents are willing to pay for the specified service. The conventional contingent valuation method values an ecosystem service in its entirety and nothing is revealed about the values of the different attributes of the service.

ii. *Choice experiments:* in choice experiment valuation, the characteristics of the ecosystem service are explicitly defined; vary over choice cards along with a monetary metric. Then, individuals have to choose different combinations of characteristics of the ecosystem service over other combinations at various prices.

A conceptual framework of valuation that distinguishes between values of assets (forest as natural capital stock) and products (flow value of forest ecosystem services) is essential to integrate such data into the national account (green GDP) of a country. A stock is a quantity existing at a point in time and a flow is a quantity per period. Stocks, flows, and their relationship are crucial to the operation of both the natural and economic systems (Common and Stagl 2007). The following framework (Table 1) for valuation of forest ecosystem services proposed by Hou and Wu (2008), based on the United Nations et al. (2003) handbook on Integrated Environmental and Economic Accounting and the Millennium Ecosystem Assessment (2003), can be applied in the valuation of dry land forest ecosystem services. The table also provides detail classification and description of forest ecosystem services, the disciplinary expertise required in determining the physical flow of these services, and the methods for valuing.

The forest as a natural capital stock includes the value of the forestland as an asset, the value of standing volume of timber that are both elements of the direct use value. From the indirect use value of forests, the value of carbon stored in the forest (both soil and biomass carbon), as well as the value of the biodiversity it contains (like forest wildlife) can be considered as part of the natural capital stock. The products that forests provide as annual flow of forest ecosystem services include annual stand volume increment, fuel wood, and charcoal and non-wood forest products that are all elements of direct use value. Most of the indirect use values are flow variables and include the annual carbon sequestered and oxygen supplied from the process of photosynthesis, water, soil, flood and storm protection services, air purification and temperature regulation. Other flow variables, from the indirect uses, include the services that forests provide for research and education, ecotourism, cultural and religious services, and local amenities to people living near forests. According to the Millennium Ecosystem Assessment, the forest ecosystem services are provisioning, supporting, regulating and cultural services (MEA 2003).

3. Which part of the forest values are opportunity costs of REDD+?

Forests can also be converted to other land uses and valuation of these land uses is important in making land use decisions. With the rapidly growing world population, particularly in the tropics, and the associated increase in the demand for food, forests are converted to agricultural land uses. Shifting cultivation, industrial plantations and animal ranching are the main drivers for tropical deforestation.

According to the UN-REDD + Programme, countries must reduce deforestation and forest degradation to get funding. That means they have to make land use decisions. Reducing deforestation implies reducing, if profitable, conversion of forests to other land uses (like agriculture with commercial or shifting cultivation, commercial monoculture plantations, and pastures). Conversely, reducing forest degradation implies reducing extraction of different forest ecosystem services like fuel wood, charcoal, and timber that would lead to the degradation of the forest. Therefore, such a decision entails opportunity costs. The opportunity costs of REDD+ are the forgone benefits that deforestation and forest degradation would have created to forest dwellers and the economy of the country at large when entering the REDD+ programme.

4. Conclusions

Farmers in dry lands of Africa make a number of decisions over the use and management of dryland forests. These decisions include, exploitation of the resource base, conversion of the resource to alternative uses, and conservation of the resource for future use or in the framework of REDD for climate change mitigation. Rational decisions on sustainable use of dryland forests require appropriate information on the value of dryland forests and alternative land use options. In the valuation of forest ecosystems in general and dryland forests in particular, quantifying the different ecosystem services based on multidisciplinary scientific knowledge can provide robust valuation results, which are important for decision makers.

Table 1. *Classification and description of forest ecosystem services, scientific expertise for determining the physical flow of these services, and valuation methods.*

MEA		Stock/flow	Value category	Description	Examples of scientific expertise required for generating data	Value measures
Direct Use Values	Provisioning Services	Stock	Forest land assets	Value of the forest land according to its sub categories (by vegetation type, density and species)	Forest Ecology, Forest Inventory, Geography	Market price, ratio of exchanged forest property
			Standing timber	Total volume of the standing stock by species, diameter and if possible wood quality	Forest Inventory, Wood Science, Geography	Stumpage value (residual value)
			Annual stand volume increment	Annual increment of the forest stand by species, diameter and if possible wood quality	Forest Inventory	Stumpage value (residual value)
		Flow	Non-wood forest products	The value of all non-wood forest products	Forest Inventory, Socio-economics,	Market prices, surrogate prices
			Fuel wood and charcoal	The value of extracted fuel wood and charcoal	Forest inventory, Socio-economics	Market prices, surrogate prices
Indirect Use Values	Supporting Services	Stock	Biodiversity	Biodiversity embodies a stock of genetic information, its existence is an insurance to protect the entire range of goods and services, including information, provided by the diversity	Biology, Ecology	willingness to pay estimates from contingent valuation and choice experiment studies
			Carbon stock	Carbon stock in soils and biomass	Soil Science, Forest Ecology, Geography	Carbon prices, damage cost
	Regulating Services	Flow	Carbon sequestration and oxygen supply	Carbon sequestered by forest biomass and soils, and oxygen supply due to net primary production	Plant Science, Forest Ecology, Soil science	Market price
			Water protection	Green reservoir services of forested watersheds include the capture and storage of water and purification of water through filtering of contaminants and the stabilization of soil	Hydrology, Water resource engineering, Soil science	Replacement cost, damage cost
			Soil protection	Stabilizing soils, reducing erosion, sedimentation and maintaining soil fertility	Soil Science	Replacement cost, damage cost, market prices
			Flood and storm protection	forest shelter belts protect residential areas and agricultural lands from flooding and storm damages	Meteorology	Damage cost, market prices
			Air purification and temperature regulation	Forests provide services in cleaning polluted air of industrial emissions like sulphur dioxide, nitrogen oxide and fluoride, and dust particles	Forest Ecology, Plant Science (physiology)	Damage cost, air pollution charges
	Cultural Services		Research(education)	Forests provide services for scientific research and education		Expenditure approach
			Recreation(ecotourism)	Value of forests as ecotourism sites	Socioeconomics	Travel cost method
			Cultural(religious) services	Forests provide places for religious and cultural practices of many indigenous forest dwellers	Sociology, socio-economics	Contingent valuation
			Local amenity	Local people living near forests secure a benefit in terms of amenity	Economics	Hedonic pricing
Option Values						Contingent valuation
Existence Values						Contingent Valuation
Land Conversion Values			Agriculture	Forest lands may be converted to other land uses (shifting cultivation, commercial agriculture like seam, commercial mono culture plantations like palm oil, biofuel, livestock ranch)	Agronomy, Forest Ecology, Forest Inventory, Economics	Opportunity cost
			Infrastructure	A part of forest land may be converted to infrastructure (road, dams)	Engineering, Economics	Opportunity cost

Source: Adapted from Pearce 1993; MEA, 20003; Hou and Wu, 2008, and Wu et al., 2010.

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When there is not enough milk and meat! Would improved management of dryforests and product marketing contribute to the adaptive capacity of pastoral and agro-pastoral communities and to environmental resilience in Ethiopia?

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Abstract

Climate change and environmental degradation are adversely impacting the socio-economic development and ecological processes in the pastoral and agro-pastoral regions of Ethiopia. Livestock production (the main livelihood) is becoming increasingly unable to support the growing number of population even during years with normal rainfall, calling for additional interventions. Professional discussions strongly support the need for strategic integration of dryforests management in the landscape development planning. Key rationales justifying sustainable management of dryforests include: (I) dryforests are well adapted to the arid and semi-arid landscapes and their contribution to combating alarming desertification and biodiversity conservation remains significant; (II) almost all of the livestock feed comes from dryforests and grasslands, hence improving their management will contribute to meeting increasing feed demand for livestock sector; (III) agricultural expansion and demand for wood and charcoal is increasing deforestation of dryforests; (IV) given the predicted effects of climate change, crop and livestock production are likely to be constrained and dependence on dryforests and forest products is likely to increase and; (V) as challenges facing drylands are social and ecological, future interventions should target improving both livelihood and ecological outcomes and dryforests offer such an opportunities. This paper highlights the ecological and socio-economic significance of managing dryforests and products, mainly in the form of gum and resins production and marketing, for reducing rural vulnerability. The discussions made are based on a review of available literatures. This paper will contribute to towards better understanding of the opportunities that dryforests can offer and hence facilitate crafting of policy instruments to realize such opportunities.

Keywords: Drought, desertification, pastoralists and agro-pastoralists, vulnerability, dryforests, gum and resins, adaptation, mitigation.

1. Introduction and background

The altitudinal gradients and the Great Rift Valley system coupled with the age-old cultural land use complexity have resulted in quiet large agro-ecological zones in Ethiopia (Teketay 2004). Categorized into super arid, arid, semi-arid and dry-sub humid, dryland agro-ecology is one among the dominant climatic zones in the country. According to Lemenih and Teketay (2004), drylands cover over 75% of the landmass in Ethiopia. About 55% is arid and semi-arid with marginal potential for rain fed agriculture (Hawando 1997). Although characterized by shortage of moisture, drylands in Ethiopia still host one of the country's most diverse biological resource bases. According to Woldu (1999), seven of the nine forest vegetation types in Ethiopia are found in drylands and are recognized as dryforests and or dry woodlands. Drylands are also known to support quite large endemism in Ethiopia (Teketay 2004-5).

In dryland ecosystems, pastoralism and agro-pastoralism have been the historical modes of life (Dalle et al 2005, Kassahun et al. 2008). Currently, between 12 % and 14 % of the 86 million inhabitants of the country live in these ecosystems and with increasing trend (Kassahun et al. 2008). Traditional livestock production is the main economic pillar for the majority, and a complex indigenous resources management system governs the common resources base (Dalle et al. 2005, Angassa and Oba 2008). Livestock production is not only the mainstay, but also their social pride and security and hence their livelihood (OXFAM 2008). According to Dalle et al. (2005), however, since the past few decades, pastoralism and agro-pastoralism in Ethiopia has shown a continuous sign of vulnerability due to the frequent and extended droughts. Recent studies (e.g. Angassa and Oba 2008, OXFAM 2008) show that the socio-economic and ecological conditions in drylands call for studies that promote intervention measures capable of harmonizing livelihood issues, but at the same time, ecological integrity. To this effect, ongoing professional discussions suggest strategic management of dryforests, especially these that support diverse gum and resin bearing species. According to Dall et al. (2005) dryforests and the diverse plant composition they support are the main feed for livestock production. The gum and resin bearing genera in particular besides the provision of nutritious fodder for the livestock sector (Dalle et al. 2005), they offer high value gum and resin products, which significantly contribute to enhance livelihood resilience via creating access to income. The income from the gum and resin resources is important as it is available when other income sources are either scarce or unavailable (Lemenih and Kassa 2011, Worku et al. 2011a). This paper summarizes key ecological and socio-economic challenges facing drylands in Ethiopia and the importance of integrating the gum and resin bearing dryforests to enhance social-ecological adaptation of the pastoral and agro-pastoral communities.

2. Current extent, distribution and challenges facing drylands in Ethiopia

2.1 Extend and distribution

Drylands cover quite a significant portion of landmass in Ethiopian. Table 1 presents the details of climatic zones and the size of landmass covered by each of them. According to Lemenih and Teketay (2004) the extent of dryland ecosystems is in a continuous increasing trend in the country. Many of these areas currently being categorized as drylands were important production zones of major food crops such as sorghum, maize and millet (Hawando 1997).

Table 1. *Estimates of area size for different climatic zones in Ethiopia (Source: Lemenih and Teketay (2004).*

Climatic Zones	Area (‘000 km²)	
	Lowest estimate	Highest estimate
Hyper-arid	53	55
Arid	300	310
Semi-arid	207	250
Dry sub-humid	300	300
Total	860	915

Drylands in Ethiopia are predominant in the lowlands of the country and hence highly synchronized with altitude (Figure 1). They are more extensive at the northern, eastern, central, southern, southeastern and northwestern low lying regions of the country. Aridity is more extensive in the southeastern and northeastern regions, while semi-arid areas predominate the central, south and southwestern regions of the country (Ethiopian NAPA 2007).

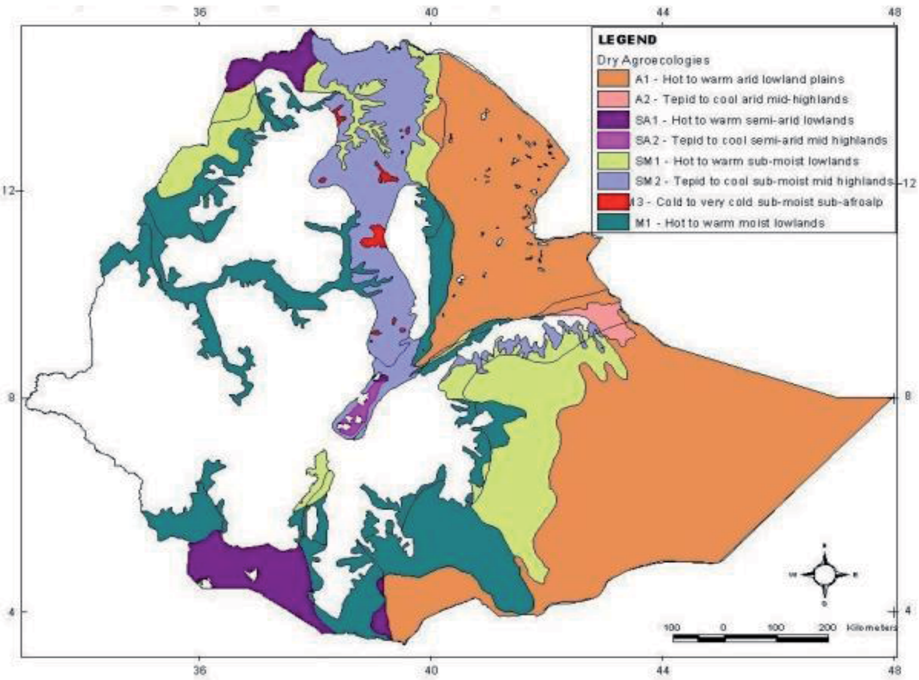

Figure 1. *Map of Ethiopia showing distribution and coverage of the different categories of drylands. The colored areas are all drylands.*

2.2 Major challenges facing drylands and dryforests

The major challenges facing drylands and sustainable management of dryforests are those related to adverse effects of climate and land use changes (Teketay 2004). Drought is becoming more recurrent and extended in time and space, exerting huge socio-economic and ecological imbalances in drylands (Sara and Wekesa 2008). Some historical records show that drought used to happen once in every 30 years (Coppock 1994), but this trend has been shortened to every 7 years during the last two decades and almost a yearly phenomenon during recent years (Ethiopian NAPA 2007, OXFAM 2008). The major economic activity in drylands, notably livestock production, is in state of deteriorating and hence unable to support livelihood. Despite their vulnerability to climate change, dry land ecosystems became the major recipient of legal re-settlers and illegal migrants during the past few decades. According to Rahmato (2011), drylands are almost the major land donor to the rampantly growing irrigated commercial farms in the country. This is resulting in massive deforestation of dryforests, exposing the fragile landscape which might trigger and alarm desertification. For instance, various case studies (e.g. Eshete et al. 2005, Worku 2006) show that various socio-economically and ecologically important dryforest tree species are poorly regenerating demonstrated via a very limited number of seedlings and saplings. Among the threatened high value dryland species with a "J" shape population structure is that of Boswellia papyrifera, a principal sources of frankincense, a commodity with local and global significance (Eshete et al. 2005).

Changing mode of life from pastoralism to a more sedentary lifestyle is resulting in the formation of small urban centers which in turn are increasing the demand for construction materials and charcoal, both of which are severely threatening healthy regeneration of dryforest species (Worku 2006, Lemenih and Kassa 2011). The other major challenge is the fact that drylands have poor infrastructural development; hence technology transfer and awareness creation is relatively slow. Communities in drylands lack alternative livelihoods and hence dependence on natural resources is high. Drylands as such are also marginalized from central economic and political activities in Ethiopia (Rahmato 2011).

3. Dryforests of Ethiopia – Resource base, distribution and ecological significance

3.1 Resources base and distribution

Ethiopia is one of the countries in Africa characterized by its rich and unique plant biodiversity and endemism. The country ranks 5th and 25th in terms of species diversity in the region and world respectively (Woldu 1999). Ethiopia has nine forest vegetation types (Woldu, 1999). According to world forest assessment data FAO (2010), large portions of Ethiopia's ever remaining vegetation are dryforests (table 2). These forests are also known for their floristic diversity, rarity and endemism (Teketay 2004). In accordance, seven of these vegetation type, namely lowland dryforests, lowland semi-desert and desert vegetation, Combretum–Terminalia (broad-leaved) deciduous woodlands, Acacia–Commiphora (small-leaved) deciduous woodlands, dry evergreen afromontane vegetation, riparian (wetland) vegetations and evergreen scrubs, are classified as dryforests and or dry woodland and shrub land vegetations (Woldu 1999). The detail description of dryforests in Ethiopia is presented in Lemenih and Kassa (2011).

Table 2. *Estimate of high woodlands and low woodland and bushlands in Ethiopia (FAO, 2010) and based on the years 2000 WBISPP national assessment report.*

Regions	High woodlands (ha)	Low woodlands and bushlands (ha)
Oromia	5257683	9806112
SNNPR	560000	1349431
Gambella	899578	422042
Dire Dawa	0	36635
Harari	0	7497
Amhara	841896	7863448
Tigray	0	1416368
Beneshangul	2471761	1416368
Afar	0	3169871
Somali	18160	20090489
Regions total	10,049,078	45,578,261
Country total		55,627,339

3.2 State and distribution of high value gum and resin bearing resource base

Dryforests of Ethiopia are endowed with diverse woody species that are principal sources of gum and resins (Vollesen 1989, Lemenih et al. 2003, Worku et al. 2011). According to WISPP (2004), the country has over 3.5 million ha of dryforests rich in gum and resin products bearing species. In these forests, the genera Acacia, Commiphora, Boswellia and Sterculia are predominant (Lemenih and Kassa 2011). Although differ in terms of species, abundance and population structure, the gum and resin bearing resources are distributed all over the drylands of the country, offering huge potential for socio-economic development of these regions (Table 3).

Table 3. *Frankincense/olibanum, myrrh/opopanax and gum acacia production potential in Ethiopia by Administrative regions (sources Lemenih and Teketay, 2004). Note (nd) represent no data.*

Regional State	Estimated total area (ha)	Estimated production potential (tons)			Total in tons
		Olibanum	Myrrh/ opopanax	Gum acacia	
Afar	65.000	250	500	600	1.350
Amhara	604.382	200.000	1.192	1.800	202.992
Benishangul	100.000	500	nd	700	1.200
Somali	150.000	2.500	6.500	1.700	10.700
Gambella	420.000	nd	nd	1.100	1.100
Oromia	430.000	6.000	1.500	10.000	17.500
Tigray	940.000	57.700	770	2.100	57.700
Southern Nations Nationality and People	70.000	nd	nd	nd	
Total					292.542

The gum and resin bearing species are more diverse in southern and southeastern parts of the country compared to other regions. For instance, Worku et al. (2011a) identified 19 woody species (Table 4) known to produce gum and resins in Borana Zone, south Ethiopia. Such a high level of species diversity is an opportunity to integrate dryforests in an effort to diversify livelihood and ecosystem restoration in drylands.

Table 4. *List of gum and resin bearing trees/tree-shrubs species encountered at selected study sites in Borana lowlands and their products types (sources Worku 2006).*

Scientific name	Family	Product type
Boswellia neglecta	Burseraceae	Incense
Boswellia micrphylla	Burseraceae	Incense
Boswellia rivae	Burseraceae	Incense
Commiphora myrrha	Burseraceae	True myrrh
Commiphora africana	Burseraceae	Hagar
Commiphora baluensis	Burseraceae	Hagar
Commiphora confusa	Burseraceae	Myrrh
Commiphora habessinica	Burseraceae	Myrrh
Commiphora kua	Burseraceae	Myrrh
Commiphora terebinthina	Burseraceae	Myrrh
Commiphora boranesis	Burseraceae	Myrrh
Commiphora schimperi	Burseraceae	Myrrh
Acacia seyal	Fabaceae	Gum talha
Acacia senegal	Fabaceae	Gum arabic
Acacia mellifera	Fabaceae	Gum acacia
Acacia drepanalobium	Fabaceae	Gum acacia
Acacia oerfota	Fabaceae	Gum acacia
Sterculia stencarpa	Sterculiacea	Gum karaya
Lanea revea	Anacardiaceae	Gum lanea

3.3 *Ecological significance of dryforests*

According to UNCCD (1997), desertification is prevailing in various parts of the world. Ethiopia in particular is under serious encroachment of recent desertification processes and dryland ecosystems are the most vulnerable (IPCC 2007). Los of biodiversity and stored carbon is also prevalent in dry land ecosystem. Most water bodies including these with international significance Rift valley lacks are in danger of severe habitat degradation in Ethiopia (Ethiopian NAPA 2007). According to this report, unless urgent and appropriate interventions will be taken the ecological situations in drylands are scary. Lemenih and Kassa (2011) on the other hand argue that the presence of dryforest vegetations, mainly those with economic importance trees and shrubs offer significant opportunities to combine economic utilization with fight against alarming desertification, biodiversity conservation and enhancing C-sequestration and soil fertility. The various species composing dryforests have proven use as windbreaks and shelterbelts, their canopies intercept raindrops and their root systems effectively reduce soil erosion (Jaiyeoba, 1996, cited in Lemenih and Kassa, 2011). Managing dryforests therefore have the potential to enable Ethiopia to successfully comply with the various ratified international conventions (Lemenih and Teketay 2004).

4. Dryforests of Ethiopia – socio-economic significance of dryforests in the context of changing livelihoods of the pastoral and agro-pastoral communities

Pastoralism and agro-pastoralism are expected to continue as ways of life in moisture deficit drylands of Ethiopia (Coppock and Desta 2004, Angassa and Oba 2008). However, it is also clear that livestock productivity is in a declining situation (Kassahun et al. 2008). According to de Haan (1999) it may be possible to herd more productive livestock breeds, but until that happens, the focus should be less on production increase *per se* and more on diversifying livelihood and maintaining environmental goods and services. Lessons from Ethiopian drylands also suggest diversifying the current one-sector (i.e. livestock) dominated nature of livelihood (Lemenih et al. 2003, Kassahun et al. 2008). According to Oxfam (2008), when the traditional cycles of herd accumulation, collapse and re-building is not anymore enough, and when the residents are subject to frequent lose of productive assets, there will be no way-out from the vicious circle unless additional or alternative livelihood means will be studied and implemented.

Barrett et al. (2001) argue that there is no single way to mitigate or adapt to climate change and or desertification, implying that diversified livelihood strategies are crucial to distribute risks. That is why diversification of asset, income and activity is becoming more and more important. In this regard, the role of dryforests in offering products such as gum and resins, herbal medicines, wild food, livestock feed, wood and cultural value shouldn't be overlooked. According to Lemenih and Kassa (2011) the gum and resin sub-sector offers huge opportunities to facilitate adaptation in drought prone regions of the country. For example, gum and resin collection share 32 % of the household annual income in the Liben Zone, Somali region, hence second largest income (Lemenih et al. 2003). The subes-ector was also among the major livelihood occupations in Borana Zone, Oromia region (Worku et al. 2011). Recent case studies show increasing participation of local communities and private sector on gum and resin business (Worku et al. 2011). Arnold & Ruiz-Perez (2001), argue that the role of NTFP collection and marketing is becoming increasingly necessary to support livelihood by way of diversifying income sources, increasing income size and rationally distributing seasonal availability of income in addition to creating access to income. Seasonality, for instance is among the main determinant of adaptation in the pastoral region (Dalle et al., 2005). Household may access milk and meat in time of abundant fresh grasses. However, for the majority of the dry months, these goods are only hardly available. Preliminary studies show that gum and resins collection and marketing play great role in filling such vacant (Lemenih et al. 2003, Worku et al. 2011a).

Beside their local importance, dryforests, mainly in the form of gum and resin export play key role in the national economy of Ethiopian. The country is major gum and resins exporter in the region (Kassa et al. 2011). Without including the unrecorded gum and resins traded over domestic and illegal transboarder market, between 1991 and 2000, the export of the country was 28,601 ton with a total return of over 31 million USD (Lemenih and Teketay 2004). According to Kassa et al. (2011) since 2001, these figures are in an increasing trend.

Thought not estimated to monetary value, the role of dryforests in supporting the livestock sector is immense. The pastoral and agro-pastoral system in Ethiopia support large portion of livestock (Kassahun et al. 2008). This sector contributes to 15 % of the national GDP. Most member species of dryforests, of course, including the grass species, are the main sources of browse and grazing for traditional livestock production (Dalle et al. 2005). Dryforest provide herbal medicine for livestock health care. They play key role in providing shade and hence reduce weight lose (Kassahun et al. 2008).

5. Opportunities and challenges to integrate dryforests and commercialization of gum and resins

5.1 Opportunities

Recent case studies (e.g. Lemenih et al. 2003, Esthete et al. 2005, Worku and Yebeyen 2008, Worku et al. 2011a) reveal existences of various opportunities that encourage integration of dryforests and develop products. The main opportunity imamate due to the fact that there is huge and diverse resource base, well distributed over extended areas in drylands of the country (WBIPP 2004). According to Lemenih and Teketay (2004), dryforests have an estimated annual gum and resins production potential of 300,000 metric ton. However, the present production is 3000 metric ton year^{-1} (less than 1 % of the potential), implying the possibility to dramatically expand production and export quantity (Worku et al. 2011b). There is also opportunity to produces different types of gum and resins, implying the possibility to tap into different market niches (Kassa et al. 2011). More importantly, gum and resin collection and marketing can be integrated with other production systems, for instance livestock production, ecotourism, agroforestry, hydropower development, watershed management and the like (Lemenih and Teketay 2004) hence allow diversified livelihood strategies. It is also less destructive to the resource base compared to either of crop or livestock production. As elaborated in Lemenih and Kassa (2011) gum and resin collection and marketing needs relatively low financial, human and technological inputs and hence gives room for mass local participation (Worku et al. 2011a). Due to the fact that gum and resins have a wider application, ranging from local to some of the sophisticated western industries (e.g. pharmaceuticals, food, beverage, cosmetics, printing, among others), there is a persistent and increasing market demand (Lemenih and Kassa 2011). Other opportunities are related to climate change and change in national policy. For instance, in Ethiopia, there is a tendency to integrate locally available resources, such as forests in an effort to enhance local adaptation where various NGOs are engaged. The gum and resins are for sure among the preferred commodities to attract such a policy support. Global policy direction (example REDD+) may also support responsible management of dryforests (ICRAF 2009).

5.2 Bottlenecks to sustainable management of dryforests and value added gum and resin collection and marketing

Although literatures mention various opportunities due to integrating dryforests and gum and resin products to enhance social-ecological resilience, serious of issues, constraints and challenges are hindering realizing such opportunities. According to Teketay (2004) dryforests in Ethiopia suffer due to policy marginalization, and hence are not integrated in national and sub-national landscape development planning. Despite some success stories related to area enclosure prevalent at the northern and northwestern parts, there is an ongoing massive conversion of dryforests, mainly at the pastoral and agro-pastoral regions (Rahmato 2011). Unlike moist forests, dryforests in Ethiopia attract little research and hence there is wide knowledge gap, mainly at policy making level, hindering their acknowledgment as a development opportunity (Teketay 2004). In Ethiopia the overarching policy is crop dominated and hence it is not abnormal to see sacrificed vast tracts of dryforests to other land uses (Yonas et al. 2009). Equally important, traditional institutions are in a state of rapid transformation, their ability to re-enforce community responsibly to manage dryforests is weakened (Angassa and Oba 2008). Other bottlenecks include: Inadequate technological, knowledge and human supply; inadequacy of access to finance and information; inaccessibility of the resource base in some areas, mainly due to lack of infrastructure such as transportation; rapid dryforest degradation; lack of quality and quantity control; low level of awareness; thin representation of the private sector; lack of value adding; and illegal boarder trades (Teketay, 2004-5; Lemenih and Kassa 2011, Worku et al. 2011b). Combinations of such gaps undermine the potential benefits of dryforests and gum and resin sub-sector.

6. Conclusions and recommendation

In some of the Ethiopian drylands, pastoralism may be the only way of converting sunlight into food. However, these areas are increasingly becoming vulnerable due to a continued global warming. Fortunately, drylands have quite diverse and extensive dryforest resources, often adapted to aridity and hence offer development options in such areas with limited socio-economic alternatives. Gum and resin collection and marketing and dryforest based ecotourism for instance, playing key role in creating access to income and thereby improve adaptive capacity of poor people. Dryforests are the main sources of human food and feed, shade for livestock production. More importantly, without the various traditional medicinal plants, it would be too difficult to herd in such areas with intense disease outbreaks but no or little formal health services. In same vein, dryforests provide dynamic environmental services. They buffer desertification, hence options for landscape restoration. As they harbor some of the rare and endemic species, they offer key service in conserving biodiversity. Although little research is done so far, dryforests are expected to sequester huge CO_2. Despite all these and other unmentioned social-ecological uses, they are under severe threat of rapid land use change, policy marginalization and climate change. They are the most victim of the current large-scale land transformation via resettlement programmes and commercial farming. Unmonitored degradation of dryforest however will have far reaching consequences and hence care must be given. Research has to be done on their current extent, their economic and ecological values and how they could be integrated into the overall development planning. The role of policy and institutions to coordinate efforts and manage dryforests is indispensable and hence impact oriented forestry institutions have to be in place. There should be a massive development of value added chain for lesser known products (example, medicinal products) including the well known gum and resins to improve access to market and to price.

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Mountain Forest Conservation for Ecosystem Services in the Climate Change Context: Experience from Nepal and Tanzania

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Abstract

The Terai region and Siwalik Hills were chosen to represent the lowlands and mountains respectively in Nepal. Attention was given to the important Tropical Mountain Forests in Tanzania, including the Eastern Arch Mountains, to highlight the importance of upland forest conservation for improving the alarming state of ecosystem services. Mountain forests are more important than other forests as they are not only responsible for their own landscape but also for the lowlands. The effects of climate change are clearly visible in mountains, for example through change in land use and vegetation patterns. There is a two-way relationship: Climate change contributes to forest degradation and forest degradation contributes to climate change. Mountain forests provide different ecosystem services such as groundwater regulation, reduction of sedimentation, climate regulation, carbon storage, pollination, seed dispersal, natural pest control, biodiversity conservation and tourism. Ways to restore the balances in the uplands and help to generate more ecosystem services are: their protection against encroachment and other threats, promotion of local communities' access to and benefit sharing from the mountain resources, domestication and commercialization of not-timber forest products, agroforestry practices in the marginal lands, use of traditional knowledge and skills of the people and institution, awareness raising among lowland people, and formulation and effective implementation of people-centered policies. The suggested strategies can be applied to both countries in one or the other way although the two countries lie in different ecological zones: Nepal in the subtropical and Tanzania in the inner tropical.

Keywords: Carbon, degradation, erosion, forest management, landscape, lowland

1. Introduction

Forests provide different ecosystem services such as groundwater regulation, erosion and landslide control, climate regulation, carbon storage, pollination, seed dispersal and natural pest control. Mountain forests are more important than other forests as they are not only responsible for their own landscape but also for the lowlands (Price and Butt 2000). The effects of climate change are clearly visible in mountain forests through increasing anthropogenic pressure in the forests and change in land use and vegetation patterns among others. There is a two way relationship: climate change contributes to forest degradation and forest degradation contributes to climate change (Nabuurs et. al. 2007). However, this interaction depends on different ecological, economic and social aspects. This article tries to explore the effects as well as the role of mountain forest conservation for the provision and safeguarding of ecosystem services in Nepal and Tanzania.

2. Mountain forests in two countries

Both Nepal and Tanzania are developing countries and have mountain forests which are extremely threatened by anthropogenic pressure and are affected by global warming and climate change. Mountain people in both countries are highly dependent on forest and forest resources for their livelihood and forest degradation, deforestation and encroachment is common. There are not only similarities in these two countries however. The most important difference in terms of ecology is their position: Nepal and Tanzania lie in the subtropical and inner tropical region respectively. The choice for the two countries was due to the similarities and differences on the key issues, including mountain forests, lowlands, anthropogenic factors leading to deforestation and the geographical location.

2.1 Nepal

Nepal is located between latitudes $26^0$22' and $30^0$27' N and longitudes $80^0$40' and $88^0$12' E. The average length and width of the country are 885 km and 193km respectively. Wide altitudinal variations and diverse climatic conditions have resulted in five main physiographic zones: High Himal (23%), High Mountains (20%), Mid-hills (30%), Siwalik (13%) and Terai (14%) (GoN 2002). Altitude varies from some 60 m in the lowlands to Mount Everest at 8,848 m. For the purpose of this paper, Terai was chosen as lowland and Siwalik as mountain.

Southern part of Nepal (the Terai) is valuable fertile agricultural land which is the part of alluvial Gangetic plain. This part lies an an altitude of 60-300 m between the Indian border and Siwalik. The Siwalik Hills Zone rises abruptly from the Terai plains and reaches an elevation of 700-1,500 m (GoN 2002), is wider in the western and far-western regions of Nepal and narrower in the east. It is mainly composed of sedimentary rock and big boulders.

Siwalik comprises 13 types of ecosystems (GoN 2000). Having tropical and subtropical climate, this zone hosts the economically important *Shorea robusta* forest with *Terminalia*, *Adina*, *Anogeissus*, *Lagerstroemi*, *Syzygium* and *Semicarpus* as common associates. Though the area is fragile, around 3.5 million people live in Siwalik with the growth rate of 2.91 percent (Deuja 2008). Most of the Siwalik dwellers are forest dependent poor who were migrated from the Middle Hills. Raute and Chepang, among others, are aboriginals to these Hills who totally depend on forest and agricultural resources for their livelihood (Ojha 2010).

Subsistence agriculture practices are rampant, even in the steep Siwalik hills. In average, people rear 21 animals (including goats) per household for milk, meat and manure, totaling 11.85 million animals in Siwalik. Because of free grazing system, however, less manure is available for agricultural fields. Similarly, animals are not healthy and productive (Ghimire 2009).

Because both migrated and aboriginal people in Siwalik heavily depend on forest for food, animal rearing, grazing, firewood, timber, agricultural implements and other non-timber forest products, it is being continuously degraded and deforested. The deforestation rate of Siwalik is 2.08 percent (GoN 2008).

2.2 Tanzania

Tanzania has a vast mountain forest including the Eastern Arch Mountains in the Kilimanjaro, Tanga, Iringa and Morogoro regions (MNRT 2009). The main economic value of the mountains is not found in the timber but rather in the services provided by the forests, including climate stabilization, carbon storage and protection of hydrological function, provision of water and biodiversity conservation. They also provide firewood, medicinal plants and other forest-related products. Local villagers depend on these forests for their livelihood.

The Eastern Arc Mountain Forests of Tanzania are recognized as one of 24 globally important "hot spots" for forest biodiversity according to Conservation International (TFCG 2005). These forests are typically montane in nature, characterized by large trees such as *Ocotea usambarensis, Allanblackia usambarensis, Prunus africana, A. ulugurensis, Ochna holstii, Podocarpus latifolius, P. falcatus, Ilex mitis, Cornus volkensii, Newtonia buchanii and Pachystela msolo*. According to the government of Tanzania, ministry of and natural resources and tourism (2010) the soils from these mountains are not rich, being old and leached in character. However, they are often better for agriculture than those of the surrounding lowlands. The favorable climate and moderately fertile soils and have attracted people for agriculture. The area surrounding the Eastern Arc forests support some of the highest population densities in Tanzania (MNRT 2009).

3. Mountain forest degradation and ecosystem services

Forests provide different goods and services. Ecosystem services can be defined as the outcomes from ecosystem functions that benefit human beings. In principle, these could include both forest products (timber and non-timber) and services (Nasi et al. 2002). Our focus here will be on services in the strict sense - i.e. the less tangible benefits derived from forests. Ecosystem services cannot be characterized apart from human contexts and require some interaction with humans. For the functions to be services they must be a part of human value system and the system systems of value generation (Nasi et al. 2002). Some important ecosystem services of mountain forests in Nepal and Tanzania and their present status quo in the context of climate change and degrading and deteriorating conditions have been briefly described below.

3.1 Groundwater regulation

In explaining the importance of ground water regulation as one of the ecosystem services Nasi and colleagues (2002) argued that denuded landscape helps the rain to compact the surface and turn the soil to mud which in turn closes the surface cavities reducing the infiltration and increasing runoff and thus enhancing pollution and reducing water quality. The Mountains are the primary source of ground water in lowlands. In Nepal's Terai 61.1% of total cultivated land is irrigated from ground water harvesting but the average ground water level has been decreased from one meter in 1988 to 1.7 meter in 2007 (Malla 2008), making both agriculture and household activities difficult and less productive. S. S. Negi, the director of Forest Research Institute (FRI), says that the decrease in groundwater level caused heavy attacks on *Dalbergia sissoo* by *Fusarium solani and Ganoderma lusidum* and that massive destruction happened in India, Pakistan, Bangaladesh and Bhutan (Personal communication 2011). The mountain forest is the main source of ground water in lowland in Nepal and Tanzania.

3.2 Erosion and landslide control

Mountain forests contribute to reduce and/or control erosion and landslide in mountain hills. Erosion and landslide in each country contributes to damage and loss on forest as well as agricultural land in both uplands and lowlands. Though there is a data deficit, it is obvious that the potential agricultural field in the lowlands is being decreased day by day through the accumulation of silt, sediment, gravel and boulders. The damage to infrastructure as well as animal and human casualties are immense.

3.3 Climate regulation

The mountain forests are one of the key factors for regulating climate through air, water and moisture movement. The effect of forest cover on local temperature extremes is significant as it moderates local temperature extremes under cover providing shade and surface cooling. Forests act as insulators, blocking searing winds and trapping warmth by acting as a local greenhouse agent (Nasi et al. 2002). Because of mountain degradation, availability of water in the lowland is becoming less and less, resulting in an increase in temperature, change in vegetation type and microclimate. The movement of hot air from lower areas cannot be consumed in the upstream because of absence of vegetation and therefore helps to increase the temperature. In both countries, the condition of this ecosystem service is worsening year to year because of the degradation of mountain forests.

3.4 Carbon storage

Mountain forests are more carbon sink than source. Furthermore, these forests hardly contribute to other greenhouse gases emissions because of less water availability to produce Methane. Trees and forests store carbon. The mountain deforestation and degradation is contributing to the loss of sources of carbon sinks. The forested areas have been converted to agricultural land which stores less carbon than forests and is also a carbon source. Though there is a data deficit, when mountain forests are degraded, the migration from mountains to lowlands have increased considerably, also increasing the pressure on remaining lowland forests for timber, firewood, fodder, litter and other non-timber forest products. Furthermore, people from mountains exploit the resources from the lowlands while living upstream because the forests there are decreasing. Thus, carbon stores with considerable potential are being destroyed day by day both by mountain people and lowland dwellers.

3.5 Pollination

One important agent for pollination is the honeybee. Because of decrease and deterioration of mountain forests, its population has been decreased sharply, affecting pollination in agriculture as well as the remaining forest crops. These wild pollinators are often forest species and are sustained by natural forest habitats adjacent to farmlands. Most forest plant species, either valuable timber trees or other forest products, depend on animal pollination for reproduction. The decrease in population of the honeybee negatively contributes to the overall production system. A major disruption in the pollination processes implies that yields of important crops would decline precipitously and many forest plant species would become extinct.

3.6 Seed dispersal

Many plants require the presence of animals for successful seed dissemination. Without thousands of animal species acting as seed dispersers, many forest plants would fail to reproduce successfully. Animal dispersers play a central role in the structure and regeneration of many forest trees. Because of massive destruction in the mountain forests, there is decline of animal numbers which are responsible for seed dispersal, making it difficult and expensive to restore the barren land and newly formed areas from sediment deposition. Similarly, the seed dispersal by wind and gravity has also been negatively altered.

3.7 Natural pest control

An estimated 99 percent of potential crop pests are controlled by natural enemies, including many birds, spiders, parasitic wasps and flies, lady bugs, fungi, bacteria, viral diseases, and numerous other types of organisms (DeBach 1974). These natural biological control agents save farmers thousands of dollars annually by protecting crops and reducing the need for chemical control. But because of the decrease in these biological enemies, the natural pest control is becoming unrealistic and farmers are using insecticides, herbicides and pesticides that cost thousands of dollars. *Sapium insigne* is traditionally proven in Nepal to have toxic effect for several nematodes. Similarly, *Aegle marmelos,* is widely used as a insecticide throughout south Asia. The natural wild population of both tree species has declined sharply.

3.8 Tourism

In general, tourists do not want to see the denuded hills. They enjoy the green landscape from the lowland to the mountain. In time, as the mountains are being denuded, the possibilities of no tourists in the areas to observe the beautiful mountainous landscape cannot be rejected.

3.9 Biodiversity conservation

To conserve biodiversity we also need forests in the mountains as biodiversity is not static. The general concept is that the more transitional landscape, the higher the biodiversity. Some animal species are highly mobile and need distinct climate for their lifecycle. For these animals, it is necessary to have a continuous corridor from one climatic zone to another. Because of the destruction of mountain forests, the movement of such animals has been limited which in turn contributes to loss in biodiversity. The declined number of plant species and some amphibians proves the general statement of biodiversity loss as true and factual.

4. Strategies for mountain forest conservation

Conservation and protection of mountain forests is important for different aspects depending on different ecosystem services. Some nine have been shortly described above. Some strategies have been suggested based on the experience from these two countries for mountain forest conservation. These strategies are both biophysical and social. No single strategy is sufficient to reverse the condition. Combination of different strategies would be effective and efficiency.

4.1 Protecting against encroachment and other threats

One of the major threats to the mountain forests is agricultural encroachment. Including fire and illegal logging, agricultural encroachment contributes to deforestation. There is a need to increase resources for protecting these forests. It is also important to motivate and encourage all the foresters and other stakeholders involved in conservation and management of the forests. A landscape approach to address other problems should involve improving sustainable agricultural practices which will sustain the productivity of the agricultural land already in use and therefore help to avoid encroachment in the forests.

Other measures are raising awareness with the public about conservation and the importance of the mountain forest as well as the consequences of climate change. More attention should be given to combat illegal logging and address the problem of corruption in the timber business.

4.2 Promoting domestication and commercialization of NTFPs

Non-timber forest products are an important source of food (vegetables, fruits, nuts, tubers, roots and shoots), medicines, fodder, dyes, spices, stimulants, gums and resins. Due to their localized importance there a lack of recognition of non-timber forest products in forest management, as source of income and nutritional value to both rural and urban communities.

An important challenge to participatory forest management success in many tropical countries such as Tanzania, is poor participation of communities in joint forest management activities. This is caused by a lack of sustainable income generation activities, hastened by poor income generation diversification. Non-timber forest products have income generation potentials which can foster effective forests by increasing community participation.

Non-timber forest products such as indigenous nuts and fruits play a significant role in forest conservation through encouraging tree planting and retention on the one hand, and by reducing dependence on forest products as source of income on the other hand. This is because these products have a ready market and if strongly promoted, improved domestication could increase production.

4.3 Promoting agroforestry

Agroforestry practices are seen as an opportunity to take pressure off the remaining natural forests and to increase the diversity of vegetation on existing farms. Agro forestry has a potential to increase farm productivity, food security, and diversify incomes for improved livelihoods in the dry lands of Africa. Agroforestry has other benefits including the provision of wood services, which helps to reduce dependence in natural forests. The contribution made by agroforestry to household food security is the key to encourage communities in tropical countries to increase agricultural production and diversify income. Since many upland farms do not seem to be productive due to loss of fertility because of soil erosion, there is a need to provide incentives for both men and women to increase their efforts towards agroforestry.

4.4 Promoting community based forest management schemes

Managing the forests in these mountains by state alone is almost impossible because of the heavy dependency of local people on the forest resources. The forests here need to be managed *by the community, to the community, for the community,* like community forests in Nepal and joint forest management in Tanzania. However, the active participation of all community members must be ensured so that there a promotion of the sense of belonging which will ensure successful mountain forest conservation.

4.5 Promoting people's access to and benefit sharing from the mountain resources

Conservation, protection and management of mountain forests without people's participation is proved to be unsuccessful. Already, there is participation of the local communities in forests conservation. However due to the low level of local communities' participation in forest management, the expected results have not been achieved. Providing incentives will increase community participation in conservation of the mountain forests. This will play a vital role in addressing the problem of climate change. Therefore, local people's active participation must be emphasized.

To avoid mountain degradation we have to translate some of the social importance of ecosystem services into income value, and ensure that this income accrues to the owners of the ecosystems as a reward for their conservation. Providing the right incentives is not the same as valuing the services. Too often, we value the services without providing incentives for conserving them. Ecosystem services from mountain forests will increase in importance and value over the next decade, relative to "classical" forest products. At the same time, forest plantations, trees on farms, secondary forests and non-tropical forests will provide an increasing share of supplies.

4.6 Strengthening traditional knowledge and institutions

Traditional knowledge and institutions provide various methods aimed at forest conservation, they facilitate capacity building, participatory decision-making, and they can also modify the effect of factors thought to be the driving forces of deforestation. Application of traditional knowledge and institutions needs to be recognized as one of the strategies for effective and sustainability in forest management.

4.7 Making lowland people aware on the importance of mountain conservation

The people living in the lowlands have yet to realize the magnitude of the threat to their safety and security from the degradation of mountain hills. They depend on and use significant amounts of natural resources from the mountain area but hardly contribute towards their conservation. Furthermore, the much-needed conservation and development efforts have not been directed at the mountain hills. Generally, the people from the lowlands are in decision-making positions, and govern development and conservation activities of the districts. If the lowland people could realize the importance of conservation and investment in the mountain, they would pay greater attention to the protection and development of the area.

4.8 Policy matter

Effective conservation cannot be achieved unless there is effective police formulation and implementation. Though there are some policies for forest, water and land resource management in both the countries, these are for the countries as a whole. The same policy in all geographic regions, for example in Terai, Siwalik, Mid-hills, High mountains, Himals and High Himals in Nepal, does not properly address the problems of mountain degradation because of different soil, climate, forest, social, economical, cultural as well as political environments. Therefore, separate policies for Siwalik in Nepal and Usambara in Tanzania are needed. These policies must secure the rights of local peoples over all sorts of resources and a clear mechanism on benefit sharing must be included in the respective policies.

5. Conclusions

Nepal and Tanzania lie in two different climatic zones. Mountain forests are not similar in terms of ecological requirements, composition, density value and other many aspects. Socioeconomic setting of these mountains is also not similar. However, these mountain forests face similar problems of degradation. Anthropogenic pressure is high in the forest for timber, firewood, leaf litter, animal bedding material and several non-timber forest products. Climate change and global warming is further pushing people to be more dependent on forest resources while it is at the same time degrading, deteriorating and decreasing the resources because of several cause such as agricultural expansion. The strategies outlined in this paper can be applied in both the countries in similar or different ways to stop or reverse the mountain degradation. The success of these strategies, however, depends on several biophysical and social phenomena and characteristics.

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Community Forest Enterprises in Developing Countries: A Potential Strategy for Climate Change Mitigation and Adaptation

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Abstract

Forests are important natural resources which can contribute to climate mitigation and adaptation by providing a variety of goods and services. Increased community ownership and equitable benefits through community forests (CFs) and community forest enterprises (CFEs) have led to the conservation and sustainable management of forest resources. Cases from Nepal and Mexico indicate that CFEs secure the rights, access and benefits for local communities, protect forest from fire, landslides and floods, reduce overgrazing, unsustainable harvesting, illegal cutting, secure and diversify livelihood sources of communities, reduce deforestation and forest degradation and increase the resilience of the forest ecosystem and biodiversity. Thus, CFEs can be a potential strategy in developing countries for mitigation and adaptation against climate change.

Key words: community forests, community based forest enterprise, climate change mitigation and adaptation

1. Background

Forests have a higher species diversity and endemism than any other terrestrial ecosystem in the world (WRI 2005) and cover 31% of the world's land (FAO 2010). Forests are inhabited by about 350 million people and approximately 1.6 billion people depend on them for food, water, shelter, and livelihoods (FAO 2010). Forests employ about 40-60 million people and contribute 8% of the GDP of most of the developing countries. It is estimated that there are some 140 million individuals working in informal forestry micro-enterprises around the world (Mayers 2006). The value of annual wood and non-wood forest product removals amount to about US$ 100 billion and US$ 18.5 billion respectively (FAO 2005). Forest ecosystem services have been estimated to be worth in average US$ 6,120 per hectare per year in intact tropical forests (CBD and GIZ 2011). However, information is still missing from many countries in which non-wood forest products are highly important and the true value of subsistence use is rarely captured. As a result, the reported statistics are largely underestimations. Forests provide a variety of goods and services which are important for food, fiber, fuel wood, medicine, shelter to people, biodiversity and play a vital role in maintaining stable global climate and environment, carbon sequestration, watershed conservation, tourism and recreation (FAO 2010, WRI 2005).

Deforestation[14] and forest degradation[15] leads to the loss of about 13 million hectares of forest annually (FAO 2010). This consequently leads to the loss of ecosystem services that provide income possibilities, material welfare, livelihoods, security, resiliency, social relations and health (MEA 2005). The disappearance of natural forests in developing countries is a problem as it negatively affects the livelihoods of people dependent on forest products and services. Deforestation and degradation in the tropics (non-annex 1 countries) is a major source of carbon emissions and can contribute towards global warming. The Intergovernmental Panel on Climate Change (IPCC) estimated that 1.7 billion tonnes of carbon are released annually due to land use change, mainly through tropical deforestation (IPCC 2001) and contributed about 17% of green house gases (GHGs) emission.

The role of forests in mitigating and adapting to climate change have been recognized and incorporated in international agreements and policy instruments. The contribution of afforestation and reforestation is acknowledged in the clean development mechanism (CDM) of the Kyoto protocol (Locatelli et al. 2008). The UNFCCC meeting 2007 on Bali developed a road map including five “building blocks”: adaptation, mitigation, finance, technology transfer and capacity building for reaching a secure climate future. Subsequent UNFCCC meetings have been trying to specify those issues through international negotiation processes. Currently, many developing countries have developed National Adaptation Programmes of Action (NAPAs) and National Mitigation Plans of Action (NAMAs) and recommended afforestation/reforestation, community based sustainable forest management and diversification of forest based livelihoods as measures for reducing deforestation and forest degradation; to enhance forest and ecosystem resilience; and to increase adaptive capacity of the local people.

2. Overview of CFEs in developing countries

Ownership structure and nature of the linkages to natural resources are the two principle dimensions of community-based forest enterprise (CFE)[16] modalities. Community forestry (CF) is being recognized as a potential means for promoting sustainable forest management and restoring degraded forests, enhancing the livelihoods of forest dependent communities, promoting community rights to forests, enhancing forest sector governance and local democracy and mitigating the effects of climate change (Jodha 1990, Malla et al. 2003 and Dev et al. 2003). Governments in developing countries are handing over forest areas to local communities under a variety of community forest management schemes like in Burkina Faso, Cameroon, India, Mexico, Nepal, Papua New Guinea, Peru and Tanzania. In the 1990s, 7% of the world’s forests were under communal ownership, or owned by the state but administered by

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[14] Removing the tree cover below the threshold value that defines a forest and converting the land to another use (MEA, 2005).

[15] Removing part of the vegetation cover leading to reduced capacity of the forest to provide specific goods and services (MEA, 2005).

[16] CFE are forest industries managed by indigenous and other local communities for livelihoods and profit and are engaged in the production, processing and trade of timber and wood products and commercial NTFPs, and may participate in markets for environmental services (Clay 2002).

communities. Currently, 11% of the global forests are community-owned or community-administered, rising to 22% (377million ha) in developing countries (Molnar et al. 2007). Projections estimate community forest ownership to reach 540 million ha by 2015, this would be around 45% of the developing world's forest estate (Nurse and Malla 2005, Molnar et al. 2007). By slowing deforestation and increasing forest regeneration, community owned and managed forests have the potential to sequester 12-15% of expected emissions by 2050 (Klooster and Masera 2000).

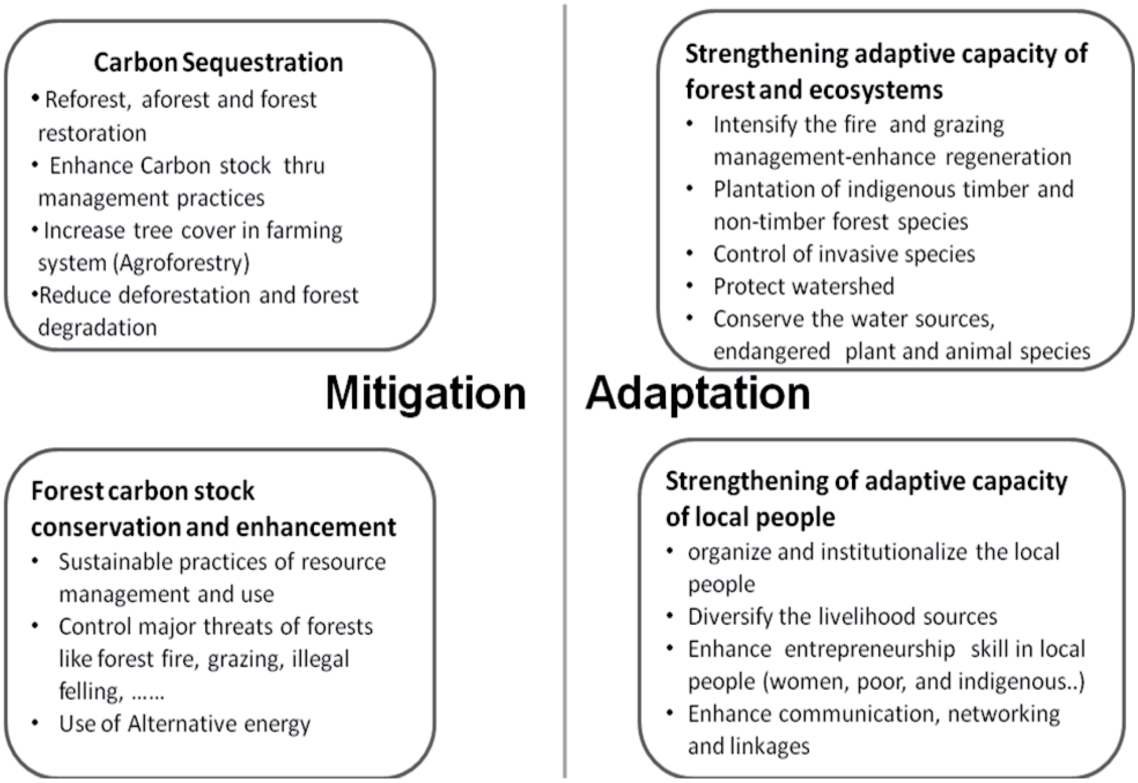

Figure 1. *Adapted and modified from: collaborative partnership on forest 2008.*

As shown in Figure 1, CFEs can serve not only for mitigation by sequestering carbon but can also increase resilience of forest ecosystems as well as the adaptive capacity of local people through the diversification of livelihood options. Bray (2010) argues that the regions where Community Based Forest Management (CBFM) dominates the landscape have low to non-existent deforestation, sustainable forest management, enhancement of carbon stocks, forest conservation and substantial generation of sustainable livelihoods. CFEs are organized in such a way that entrepreneurs can equally participate and can respond to market forces while at the same time ensuring access and control of the raw material supply (Subedi 2006). Enterprise activities motivate and guide for the better management of forest and biodiversity resources, diversify income and employment opportunities for indigenous groups and facilitate the country's economic development (Subedi 2006).

3. Cases from Nepal and Mexico

3.1 CFEs in Nepal

The concept of CF arose as a response to the deteriorating condition of the state managed forests in the late 1970's. Nepal's forestry sector has undergone a paradigm shift that indicates devolution of forest resources from state control to community control (Karkey 2008). Under state management, forests were prone to 'the tragedy of the open access'. This was turned around by implementing community based forest management in the 90's under which usufruct rights were spelled out for the commons (Gilmour and Fisher 1991) and deforestation rates were considerably reduced, particularly in the hills (Acharya & Sharma 2004). Community forestry is recognized as a successful environmental management and development program (Luitel et al. 2009). Community forestry has slowed the rate of deforestation and forest degradation, increased regeneration status, canopy density and biodiversity and basal area (Pokharel et al. 2009, Pandit et al. 2011).

Pandit et al. (2011) also identified social and economic benefits associated with CF, including an expansion in social capacity through regular decision-making and management activities and investments in local development such as potable water, trail and road improvements, and rural electrification. An earlier study of 2 700 households from 26 Community Forest User Groups (CFUGs) found that 46 percent of poor members had increased their well-being in part through CFUG livelihood support and capacity-building activities, and the average household income had increased by 61 percent (Ohja et al. 2009). Benefits tended to occur at the household rather than individual level (Ohja et al. 2009).

Currently there are more than 16283 community forest user groups, representing more than 40% of Nepal's population and managing 1515593 ha - about 25% of the country's forest with 93% of this is in the hills and 7% in the tropics (Luintel et al. 2009). Similarly, the Forest Act of 1993 makes a provision for CFUGs to spend at least 25% of their funds for forest development and it permits them to spend the remaining 75% on community development, community welfare, poverty reduction, and institutional development activities according to their own interests and priorities (Luitel et al. 2009). Approximately 71 community-based forest enterprises are operating among thousands of formal and informal forest enterprises in Nepal (Subedi 2006). Due to the emergence of payments for environmental services, payments are offered for diverse types of forest products, biodiversity, watershed conservation, ecotourism and carbon sequestration. There is an increasing trend for establishing such enterprises because they contribute not only to local income and employment but also to conservation and sustainable management of forests and ecosystems (Subedi 2006).

The assembly of a Forest User Group (FUG) is responsible in making all decisions. Assemblies prepare the constitution and forest management plan (FMP), define and recognize use rights, decide all kinds of rules, and make forest management decisions including protection, harvesting, benefit sharing, and mobilization of FUG funds for community development works. The assembly elects a forest user committee (FUC) for the execution of FUGs decisions and to conduct day to day work. This process is participatory, although there is still low representation of women and socially excluded people in decision making processes. The trend of including women and excluded people's voice in decision making processes is positive (Charmakar 2007, Luitel et al. 2009).

CFUGs assess the total and annual harvestable stock of timber and non-timber forest products and incorporate them in their forest management plan (FMP) with support of forest technicians. CFUGs identify and rank major climatic and non-climatic threats to forests and communities through participatory resource mapping exercises and implement the participatory mitigation plan and monitoring system (Subedi 2006). The major threat mitigation activities in the CFs include: the plantation of indigenous timber and non-timber forest species, construction of fire lines, monitoring of the forest (daily or periodic basis), forbidding tree felling around the natural water sources, maintaining old growth and seed trees, control of grazing, agroforestry promotion in private land, conservation of landslide prone areas, forest product extraction, applying silvicultural treatment (thinning, pruning, bush clearing) and diversification of livelihood options (Subedi 2006). These activities have contributed to enhance regeneration and growth of forest, reforest and afforest the degraded land and increase social, economical and environmental functions of the forest ecosystems.

Every year forty-two thousands tonnes of NTFPs have been harvested in Nepal with a trade value of 26.8 million US dollars. This forestry sector provides 15% of total GDP in the country (Subedi 2006). Over 90% of NTFPs collected from Nepal are sold to India in almost unprocessed form (Luitel et al. 2009). The contractor system caused a decline in the species and stock of the forest as well as low benefit to the local harvesters. In this context, CFEs have played an important role to conserve, manage, process and market the products. CFEs cover a wide range of products such as timber, non-timber and ecosystem services (water conservation, carbon sequestration, ecotourism).

NTFPs are important forest products in developing countries which have always been used for food, medicine and energy in times of food scarcity, illness and natural disasters. Only recently has there been some consideration and realization that substantial economic benefits can be derived from biodiversity and more particularly from NTFP enterprises (Subedi 2006). A promising model of CFE from Nepal which has successfully enhanced both local economic benefits and conservation objectives is briefly described here.

Example 1: Bhimeshwor NTFP production and processing enterprise

Bhimeshwor, a CFE, is located in a rural setting of eastern Nepal. The enterprise currently produces traditional Nepali handmade paper using Lokta (*Daphne bhoula*) and Argeli (*Edgworthia gardneri*) as raw materials. Up to 2005, only few local contractors were involved in the trade of such products by receiving permission from the government agency. It resulted in resource depletion in the forest on the one hand and exploitation of local cheap labour on the other. Realizing the resource depletion, exclusion of the poor and low benefit at the local level, the Bhimeshwor NTFP production and processing enterprise was formally registered through support from the non-governmental organization Asia Network for Sustainable Agriculture and Bioresources (ANSAB) and the District Forest Office (DFO). This enterprise has been owned by a consortium of 10 CFUGs (2300 households, including 20 poor households, Lokta and Argeli harvesters and private entrepreneurs as well as well off households) and two national level entrepreneurs. In case of identified poor (IPs) the non-governmental organization and CFUGs supported them by buying their enterprise share.

Each of the four stakeholders sends members to the General Assembly, including 34 members, which meets every six months to discuss and decide general policy and framework decisions. A nine member executive committee and other three sub-committees such as the raw material collection, processing and marketing committee (which meets monthly), is comprised of general assembly members and focuses on business management and operational issues. The CEO/Chairman of Bhimeshwor reports to the executive committee. Poor people moved from being harvesters to company owners.

The total investment of the company is about NRs. 2 million out of which 10 FUGs have invested NRs. 500 000.00. There are about 200 people (including 50% women) who are involved directly or indirectly in collection, processing and firewood collection. These jobs are not exclusively for harvesters. Among them there are 15 workers who are fully involved in processing and factory work as full time job holders. The traditional collectors who were getting low wages are able to get NRs. 300-500 /day through the enterprise system which is more than a 200% increase to the previous income (Paudel 2007). According to Gywali (2011), about 800 Kg of paper are produced every year from 12 tons of raw material. They have been selling it to Kathmandu buyers for varied prices. The enterprise has increased their profit by 15 to 25% in average.

Bhimeshwor has developed a model which controls immature harvesting because it does not buy Argeli and Lokta bark which has been harvested at an immature stage. Since then, six of ten community forests have been awarded forest sustainable management certification by FSC through facilitation of ANSAB which assures that enterprise development and promotion is the backbone for the sustainable forest management (Source: ANSAB 2005, Poudel 2007, Gouttierre et al. 2005). As a result vulnerability, poverty and social conflict have been reduced; skills of people have been developed at the local level and groups have been organized. This has helped to diversify the income sources of local communities and increased water regulation and resiliency of the plant and forest ecosystems. Among 10 CFUGs, 6 CFUGs have already measured the forest carbon and found 216.36 Mt/ha with an annual increment of 2.49Mt/ha. The forest carbon measurement was done first in 2010 and second in 2011. Based on the carbon increment they have been paid USD 3.5/Mt from the project level carbon trust fund established under the first REDD+ piloting project in Nepal (ANSAB 2011).

Example 2: Carbon sequestration by Community Forests in Nepal

A total of 105 CFUGs (including the 10266 hectare forest area of three watersheds: Charnawoti, Kayarkhola and LudiKhola), are involved in designing and setting up the governance and payments for Nepal's community forest management under REDD (ANSAB 2011). The annual forest carbon stock increased in three watersheds by 1.38-5.31t/ha, depending on the forest types, 2.7t/ha in average (ANSAB 2011). CFs have undoubtedly reduced deforestation and forest degradation in Nepal. Community forestry is carried out in only about a quarter of the country's forests. Still, the national deforestation trend has been reduced from 1.90% per annum between 1990 to 2000 to 1.35% between 2000 to 2005 what coincides with the rapid expansion of CFM (FAO 2005).

According to Karkey (2008), the forest carbon increment was found to be 7% per year (3-4Mt/ha). The study was conducted in three community forests from three ecological regions. Similarly, CIFOR (2006) presents the cases of six developing countries such as Guinea Bissau, Mali, Nepal, Senegal, Tanzania, Uganda and Uttranchal (India) where community forests have been conserving a huge quantity of forest carbon stock with an annual increment of 1-5t per hectare depending on the type of forest.

3.2 CFEs in Mexico

Mexico's forests cover 64,238,000 hectares (FAO 2005). This area is divided between coniferous and broadleaf forests. Large areas of shrubs and woodlands can also be found in the country. It is estimated that 12 to 13 million people live in forest areas in Mexico and about 5 million of them are indigenous people. The 1960s and 1970s were periods of rapid tropical deforestation in Mexico, with rates in some sub-regions and forest types higher than 10%, due to both assisted and spontaneous colonisation of lowland tropical areas (Bray 2010). National deforestation rates for the 1976–2000 period have been estimated to be 0.76% for tropical forests and 0.25% for temperate forests (Bray 2010).

The community forestry in Mexico is based on nucleated communities of well defined rights holders who now have a nearly complete bundle of rights over a given territory and its forests (Bray 2010). Community forestry makes forests communally owned and brings about community benefit sharing and sustainable extraction of timber resources thus community forestry has the potential to bring socio-economic change. CFEs focus on the commercial production of timber, thus presenting chances of diversifying into other forest-based industries such as ecotourism, water bottling and payment for environmental services (Brays 2010). The scope of community forest in Mexico is given as in Table 1.

Table 1. *CFEs in Mexico.*

Number of communities with legal logging permits (1992-2002)	2300 (many may log only occasionally)
Hectares under management plans	8.1 million
Percentages of national forests owned by communities	60-70%
Number of communities certified by FSC (as of October 2010)	31
Number of FSC certified ha (as of October 2010)	717 424

Source: Anta 2007

Community forests in Mexico changed after the 1980s. Although some previously deforested tropical areas are now showing clear trends of forest recovery, some 'temperate deforestation hotspots' have also emerged (Bray 2010a). Recent studies show that there are around 2300 communities with legal logging permits harvesting timber on some 8.1 million ha of forest, mostly temperate pine and oak forests (Anta 2007, Bray et al. 2007). However, it also seems that the widespread presence of CFEs in Mexico has been an important contributing factor, in both temperate and tropical areas. In total 31 communities with 717 424 ha have been certified by the FSC.

The general assembly of the community was vested with the power to make decisions about the community forest. The decisions ranged from demarcating areas designated for agriculture, wildlife, firewood collection and grazing of livestock. Practices such as reforestation and annual harvestable volume and decisions concerning the saw mill where also determined by the general assembly (Bray et al. 2005). The community forest also claims to provide aesthetics, wildlife habitat, and watershed protection, sustainable management of timber, non-timber and endemic species conservation (Ganz and Burckle 2002). Areas are zoned for restoration, protection, or production. It is primarily harvested through single-tree selection, group selection, and seed tree systems (see Ganz and Burckle 2002).

Example 3: CFE in El Balcón in Mexico

El Balcón is an *ejido* in the state of Guerrero in the highly diverse temperate forests of southern Mexico. The ejido has an area of 25 000 hectares with about 750 people. El Balcon is FSC-certified carrying out sawn wood operations that is producing first-grade, dried pine lumber round wood logs and fuelwood from its natural forests (Molnar et al. 2007). The forests have high pine and oak forest biodiversity and have an area of about 400hectares under protected forest and contain endemic wildlife. The enterprise has managed to generate employment for about 120 people and about 180 jobs have been created during the timber harvesting season. Most of the timber from El Balcón was sold to a FSC-certified US company, Westwood and in 2005, the *ejido* posted profits of US$3.6 million after taxes – 82% of which was reinvested in the CFE, including environmental investments and 18% in social goods and services. Due to the high profits made, El Balcón could afford social protection of workers is covered by health and accident insurance, community emergence funds, community buildings and scholarship funds got from timber sales (Molnar et al. 2007).

The profits from CFEs are reinvested in new equipment or a diversification of productive activities; this increases the assets of the entire community, and of each household, as a “shareholder” in the community enterprise. When profits from the community enterprise are used for investing in public goods such as potable water systems and clinics, then the assets of each individual household also increase, although again not through direct acquisition by the household.

It is through forest diversification that the Mexican CFEs have taken an adaptive measure against climate change. Thus, in this regard, community based forestry enterprises in Mexico have the potential to contribute to climate change mitigation as carbon dioxide sources are made into carbon dioxide sinks. The total net carbon sequestration potential of 170.70 Mt/ha was noted in community forests (Klooster and Masera 2000).

4. Conclusion

Forest is an important source of timber, non-timber and ecosystem services. CFE organizes and motivates the people for a common goal of conservation and livelihood improvement. Further, the CFE process follows sustainable forest management and promotes rural development in active participation of the local people. It also reinvests the CF’s funds for forest development, reducing deforestation and forest degradation.

The cases from Mexico and Nepal have clearly shown that CFE diversifies livelihood options; generates entrepreneurs, income and employment at the local level; promotes sustainable forest management and carbon sequestration; strengthens social, economic and ecological functions of the forest and ecosystems; and increases the adaptive capacity of the local communities. Thus the introduction of CFE could be an important strategy of mitigation and adaptation to withstand effects of climate change in developing countries. The Mexican example of CFE is more relevant to those countries with large forest masses inhabited by communities, such as Indonesia, countries of the Amazonian Basin and Central Africa. The case of Nepal is suitable for those countries that have been managing small to large patches of forests. However, there should be a strong incentive mechanism, capacity building, good governance, technology transfer and favourable national policy for the success of CFEs in climate change mitigation and adaptation.

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The role of tropical forests in counteracting climate change and poverty: Case studies from Colombia and Ecuador

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Abstract

Tropical forests are highly threatened by climate change. Consequently, the ecological functions and benefits provided to ecosystems and rural and urban communities by tropical forests could be considerably affected in the coming years. In Latin American countries, tropical forests have additionally faced extreme forms of deterioration through logging and the conversion of forested land to farm systems. Both have been considered sources of emissions. However, in order to generate adequate responses to climate change threats, some strategies created to reduce the vulnerability of these ecosystems are being implemented. The implementation of these strategies is done in accordance with the specific biophysical conditions, the socioeconomic aspects, and the ecosystem services provided by forests. This paper presents two case studies: a) Land use and household income of colonist and Kichwa communities in the Sumaco Biosphere Reserve (SBR) in Ecuador. It seeks to analyse the current land use and living conditions in the SBR to obtain information that could be considered in the implementation of pilot projects for environmental services or REDD+ in order to improve the environmental situation while improving the livelihood in the SBR; b) the Otun river watershed in the Andean ecosystems of Colombia. Here, adaptation measures have been defined according to the vulnerability and specific conditions of each ecosystem in an attempt to guarantee that the ecosystem services in higher demand by the surrounding population are protected. Currently, efforts are focused on measures that aim to guarantee the provision of water from highland ecosystems to the local population. Additionally, the conversion of farming systems to agroforestry alternatives in the lowlands has been a means to promote both the conservation of natural resources and the livelihoods for rural communities.

1. Introduction - background

Tropical forests cover about 1664ha around the world, approximately 54% of which are in Latin-American countries (FAO 2010). The importance of tropical forests for climate change has been widely discussed (Philips et al. 1998; Cramer et al. 2004; Lewis 2006), not only because they contribute to carbon sequestration (Cramer et al. 2004; Le Quéré et al. 2010) and are, in fact, an important carbon sink, but also because they can be a source of CO_2 emissions from deforestation and degradation (Soares-Filho et al. 2006; Denman et al. 2007; Coomes et al. 2008). Research has shown that the conversion of tropical forest and woodlands to farmland has been estimated to occur at a rate between 12-18% (IPCC 2007; van der Werf et al. 2009).

Tropical forests fulfil additional crucial ecological functions including the provision of habitats that promote biodiversity, contributing to soil protection and water regulation (pe. Bayon 2009, Kenny 2009, Veiga 2009). Furthermore, the livelihoods of many rural communities also depend on forests (Nkem et al. 2007). Consequently, the role of forests transcends mere carbon sequestration. It extends toservices to the people who manage and live within them, in addition to potential benefits that can be provided by the abundance of natural resources found within these forests.

Forests have supported the two general strategies implemented to face climate change mitigation, and adaptation (FAO 2008). Actions on mitigation have been emphasized mainly, which means that reforestation and afforestation have been the goal of many projects. Local actions are expected to have a global impact on the effects of carbon sequestration. However, adaptation initiatives have recently been growing in importance; actions on the reduction of agroecosystems' vulnerability to different threats associated with climate change are emphasized, with the hopes of having local measures producing local effects. It is also possible that adaptation actions can contribute to climate change mitigation (FAO 2008).

Mitigation and adaptation are currently the aim of different initiatives which can be applied through a number of unique strategies, such as clean development mechanisms (CDM), REDD+, and other incentive programs for financial compensation for ecosystem services. The success of implementing these strategies depends on technical, political, and socioeconomic aspects, some of which are clearly defined and others that are still being developed. Institutions and organizations from many countries have promoted the implementation of these strategies, some of them with promising levels of success with CDM projects (Hamilton et al. 2007). For REDD+, there are some pilot projects (e.g. Ortega et al 2007; Sabogal 2008) being implemented in Nicaragua at national and sub-national levels as well as in other countries (e.g. Ortega et. al 2011). However, aspects such as financing and monitoring are still not well defined (Saunders & Reeve 2010; Arango et al. 2010). Strategies for payments for ecosystem services, different from those related to carbon sequestration, are scarce initiatives. If found they are only available locally, being implemented according to the social, political, and biophysical conditions in the area, and the services that are expected to be marketable.

In this paper, we will discuss and analyse two case studies from Ecuador and Colombia, where biophysical conditions of ecosystems, socioeconomic aspects, and other facets of climate change not related to carbon sequestration are considered in order to promote specific alternatives to counteract climate change.

2. Tropical forests in the context of climate change

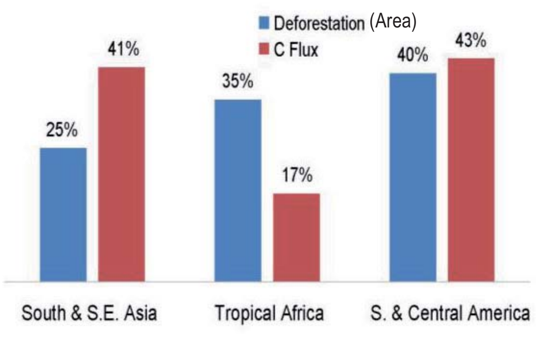
Tropical forest cover has been estimated to cover approximately 1,664 million hectares of the earth's surface (FAO 2010; OIT 2011). The majority of these forests (54%) are located in 20

Latin American countries, which also have the largest area of forests under primary protection (about 76% of total forested area) (Table 1). Within this area, the Amazon forests are the largest worldwide, with 778 million ha (RAISIG 2009), equivalent to 47% of the total coverage of tropical forests found in Latin-America.

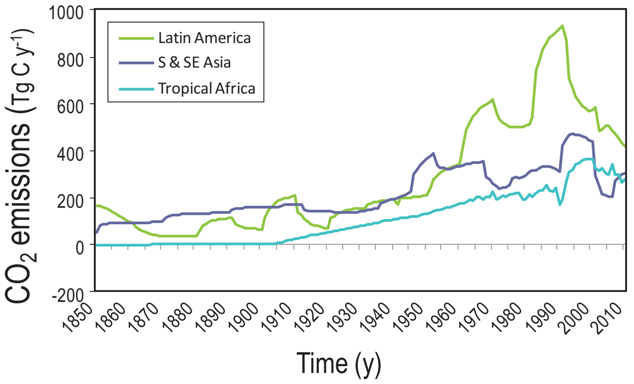
Table 1. *World area covered by tropical forest (from: FAO 2010 and OIT 2011).*

Region (number of countries)	Total forest area (millions of ha)	Primary forest (millions of ha)
Tropical Africa (26)	440	102
Tropical Asia and Pacific (16)	317	108
Tropical Latin-American and Caribbean (23)	907	678
Total world	1664	887

Because the deforestation process is associated specifically with the conversion of forests to agriculture, tropical forests contribute highly to emissions of CO_2. This is due to an anthropogenic process, which includes the elimination of forest cover thereby causing emissions equivalent to the original biomass (carbon). According to Houghton (2010), South and Central America have higher values of emission equivalents related to deforestation, due to the kind of vegetation found in these areas, than Africa and Asia, (Figure 1a). Values of emissions analysed during a period of 159 years show how the tropical forests from Latin America were highly eliminated between 1970 and 1990 (FAO 2010). After this period, emissions tended to be lower and more comparable with those from Africa and Asia (Figure 1b).



a)



b)

Figure 1: *Emissions from land use change according to region a) 2000-2005 (From: Canadell et al. 2009, Biogeosciences), b) 1850-2009 (From:R.A. Houghton 2010, personal com-munication; GFRA 2010. From http://www.globalcarbonproject.org/carbonbudget/).*

The results in Figure 1b are also consistent with the emissions accounted for in the nineteenth century of about 1,6 billions of tons per year in tropical areas, which represented 20% of global emissions (UNFCC & SBSTA, 2006; IPCC 2007). On the other hand, according to climate change trends, tropical forests are threatened especially by increasing increments of temperature (IPCC 2007). Consequently, a displacement of ecosystems and the presence of invasive species could generate an important alteration of forest dynamics (CBD 2007). In addition, the fragmentation and the intensive logging of some forests will continue to contribute to the deterioration of the state of these ecosystems, with negative consequences for biodiversity and the communities that depend on the benefits and services provided by them.

Within the framework of possibilities to handle climate change, which include mitigation and lately adaptation measures, two countries in South America have adopted different approaches in order to provide a proper response to different threats that have arisen in the context of global warming. In Ecuador, a strategy to consolidate the baseline required for implementing a REDD+ initiative is being developed. Amazon ecosystems are the goal of this initiative, which include the forests and the different communities in this area. In the Colombian Andeans, adaptation measures are being developed based on the vulnerability of each ecosystem. Measures are being implemented and prioritised in order to guarantee the provision of ecosystem services needed by the rural and urban population. These experiences are presented as case studies in the following sections.

3. Ecuador Case Study: Land use and household income of colonist and Kichwa communities in the Sumaco Biosphere Reserve (SBR), Ecuador[17].

3.1 Ecuadorian Forest Context

Ecuador is located in the northwestern part of South America, and is bordered by Peru, Colombia, and the Pacific Ocean. It is composed of four principal regions, which include the Galapagos Islands, the coastal region (Coast), the Andean highlands (Sierra), and the Amazon (Oriente). All four regions differ greatly due to a variety of diverse characteristics which are a result of topography and geographical locations. The total land area in Ecuador is 256,369 km^2 (INEC, 2001), 47.7% of which is covered by forests (Cannien, et al., 2007,7). The total population is about 13´605.485 (INEC, 2001), with 14 different indigenous nationalities.

The area of Amazon forest covers 11.660.604 ha (47% of national territory), and is one of the most heavily forested areas in Ecuador. This region is also one of the areas most protected by government mandated environmental policies. Furthermore, this area is still inhabited by many groups of indigenous people that have lived in isolation from the developed world for their entire lives (Finer, *et al* 2008). The vegetation in this region is very sensitive to changes and creates the conditions that make Ecuador the most biodiverse country in the world, in relation to its size (Thomas, 2008).

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[17]The results presented in this section belong to an extensive research project on land use and livelihoods in the SBR, which is still being analyzed and will be published in 2012. The data is also part of the global database of the PEN / CIFOR network for the international assessment of the millennium development goals in tropical countries, specifically within the Amazonian Network for Life and Environment (RAVA).

According to the REDD+ analysis in eight countries of the Amazon basin, conducted by the Regional Amazon Association (ARA), the main drivers of deforestation in Ecuador are agriculture, cattle, logging, oil exploitation, and mining (Cenamon *et al*, 2011). To explore this subject further, some scientists suggest that deforestation in the Ecuadorian Amazon began after rapid settlement in the area by small-scale farmers following the oil discovery at the end of 1960s. They insist that these small-scale farmers are the primary agents of land conversion from forest to agriculture (Bromley, 1989; Rudel and Horowitz, 1993; Southgate Whitaker, 1994; Pichon and Bilsborrow, 1999; Barbieri *et al*. 2003; Bilsborrow *et al*. 2004; Pan *et al*. 2004; Barbieri, 2005).

3.2 General Contexts of the Study Area

The case study is located in the SBR, where 931,930 ha of tropical forest were declared a biosphere reserve by UNESCO on November 10, 2000. Its core area of conservation is the Sumaco Napo Galeras National Park (*PNSNG*), which has been installed in March 1994 by the Ministry of Environment of Ecuador and is composed of 205,249 ha of protected area. The SBR is located in the northeast of the Ecuador Amazonian region, including parts of the Napo, Orellana, and Sucumbíos provinces (Figure 2).

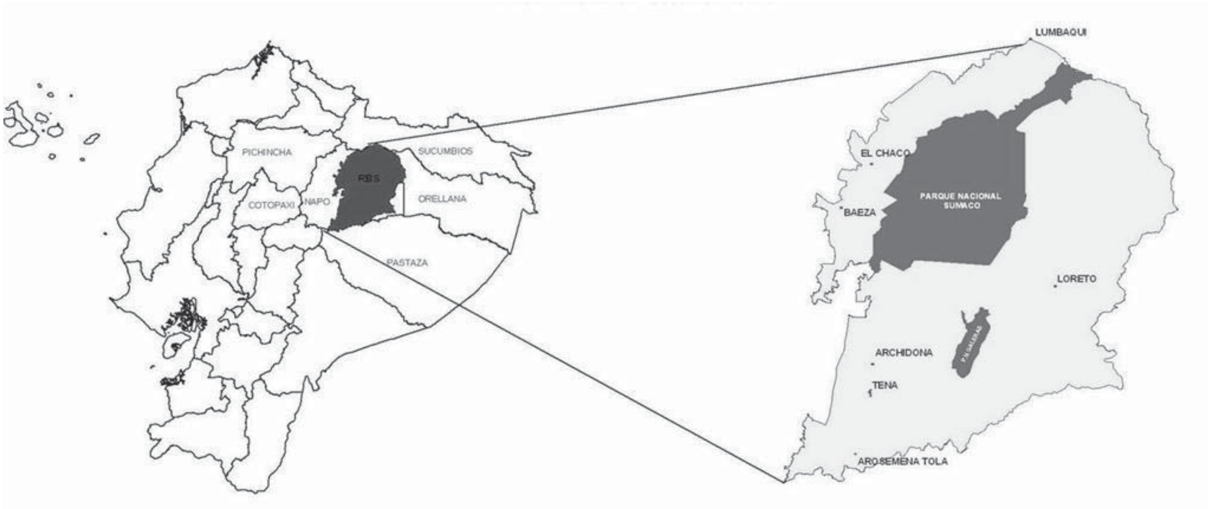

Figure 2: *Geographical location: Sumaco Biosphere Reserve and Sumaco National Park*

3.3 Land Use and Land Cover

The results of a recent, multi-temporal study conducted by the Ministry of Environment of Ecuador (*MAE*) and the German Technical Cooperation (*GTZ*), now known as the German International Cooperation (GIZ), provide some information about the land use and vegetation cover in the SBR. Figure 3 shows a mosaic analysis of land use and vegetation cover from 2002 to 2007, with a cover analysis of 97% of the total SBR area (MAE/GTZ, 2008).

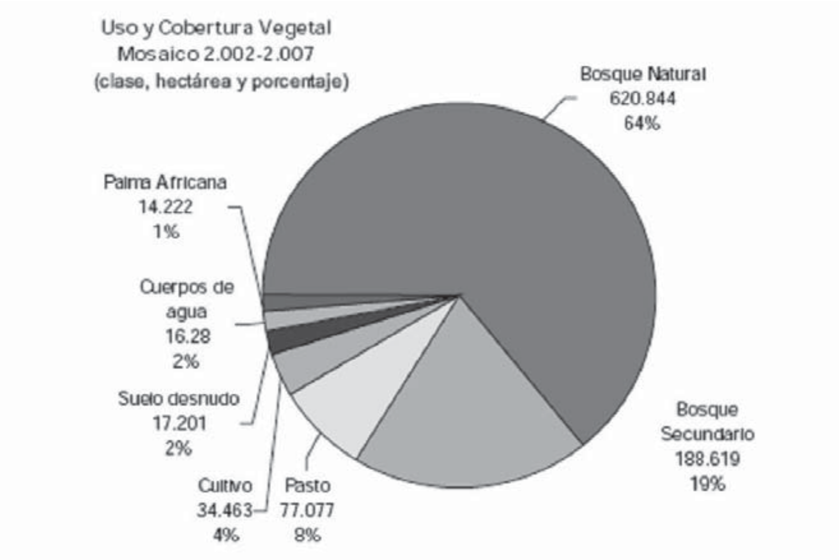

Figure 3. *Land use and forest cover by percentage. (RBS, 2002-2007).Source: MAE/GTZ, 2008*

The results of the aforementioned study reveal that in the SBR, comprises 64% of natural primary forest, 19% of natural secondary forest, and 8% of pasture, which leaves: 4% crops, 2% empty land, 2% water, and 1,4% industrial palm oil. Figure 3 shows the percentages of land use and forest cover.

3.4 The survey

The current results of this study are part of an overall project with a group of 45 members from Poverty Environment Network (PEN) and RAVA. With this contribution to a global data set for international and regional analysis, the results will allow for a better understanding of the local conditions and conflicts. In turn, this will assist local authorities in making decisions that will create more effective sustainable development policies.

3.4.1 Sampling method used for the selection of households.

The sampling method used to select households was completely random and was applied in the first meeting with community members, interviewers, research supervisors, and the research principle. The traditional method used consisted of collecting numbers on pieces of paper that corresponded to the total number of families in the community. All numbers were placed in a hat for someone from the community to choose five to seven random, representative sample households.

3.4.2 Number of households selected

Of all the 270 communities found within and around the Biosphere Reserve Sumaco, 32 communities (12%) were chosen; the selection of the communities was done in a random way, resulting in 21 Kichwa communities, 7 settler communities and 4 mixed communities (Kichwa/settler). In every community, 5 to 7 households were randomly selected. Altogether, 224 households were selected initially. The study finally concluded with 190 households that fully participated in the survey.

3.5 Summarized general Results

3.5.1 Demographic aspects

The results indicate that in the SBR, the population is primarily composed of youth, found in a generally equivalent balance of males and females (Table 2).

Table 2. *Average population by age groups and gender, SBR.*

Groups	Gender (%)		Average	Accumulated %
Ages	Male (M)	Female (F)	(M & F) %	
0 - 14	41,4	44,4	42,7	42,7
15 – 25	24,5	23,0	23,8	66,5
26 - 35	11,2	11,5	11,3	77,8
36 - 45	9,9	9,5	9,7	87,5
46 - 55	7,2	7,1	7,2	94,7
56 - 65	4,3	3,3	3,8	98,5
65+	1,5	1,5	1,5	100
Total	100	100	100	

About 67% of the total population is composed of individuals under the age of 25. The accumulated total shows that as age increases, smaller amounts of the total population are represented (Table 2).

3.5.2 Land Ownership

The results concerning the differences in crop land practices between Kichwa and settler communities can clearly be seen in the figures 4 and 5. The large majority of land dedicated to cattle among settler groups shows a very unique cultural preference as well as a difference in capital holdings, as cattle farming requires a more sizeable initial investment.

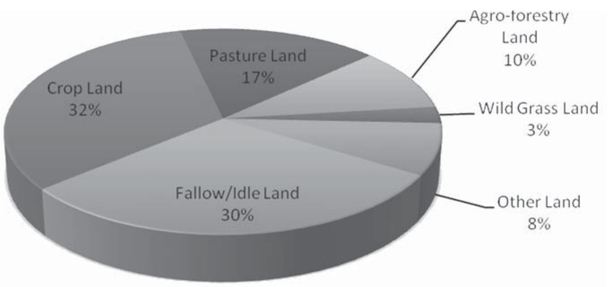

Figure 4. *Kichwa land use practices, SBR*

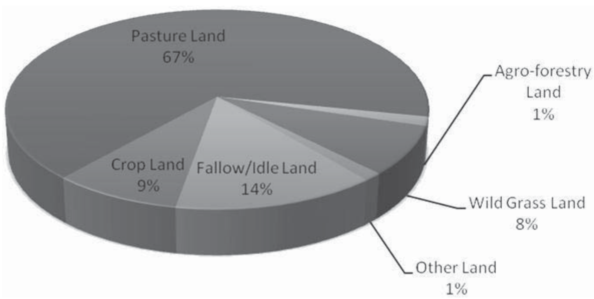

Figure 5. *Settlers land use practices, SBR*

Wild grassland and fallow land seem to have a relationship with pasture land as well. In some combination, these three land types represent the past, current, and future grazing lands for cattle farming for those with cattle.

Among the Kichwa communities, these three land types (wild grass, fallow land, pasture land) more closely relate to general agricultural practices. It appears that the Kichwa people within the studied communities have planted on approximately one-third of their non-forest covered land. Agro-forestry cultivation land holdings are represented here as well. The largest proportional discrepancy between the two community types is shown within this variable. Kichwa communities dedicate proportionately ten times more crop land holdings toward this locally advantageous poly-culture practice than do those within settler communities.

3.5.3 Income resources

Within the studied area, an expected 38% of households reported wage income. Of those, Kichwa communities reported a slightly lower proportion of 35.4% while the remaining population reported 43.1% of wage income. The differences here are actually somewhat smaller than expected, possibly due to some of the communities' proximity to the larger cities in the area such as El Chaco, Archidona, Tena, Loreto, etc.

Small scale agriculture makes up the majority of job types for wage earners in the studied area (55.42%). Government employees (e.g. teachers, law enforcement, etc.) make up the second largest category with 16.41%. This effectively constitutes a 6% per capita mark among all households, meaning that the state is quite a large employer in this area. Construction and carpentry make up 9.29% of wage income for all households reporting income, the third largest category. For Kichwa communities, these three categories especially combine to account for 84.1% of all job types (72% and 74% for Settler and Mixed communities, respectively). Logging and other wood extraction work stayed fairly consistent between community types, resulting in a representation between 4% and 5%. Below is the breakdown of job categories (Figure 6):

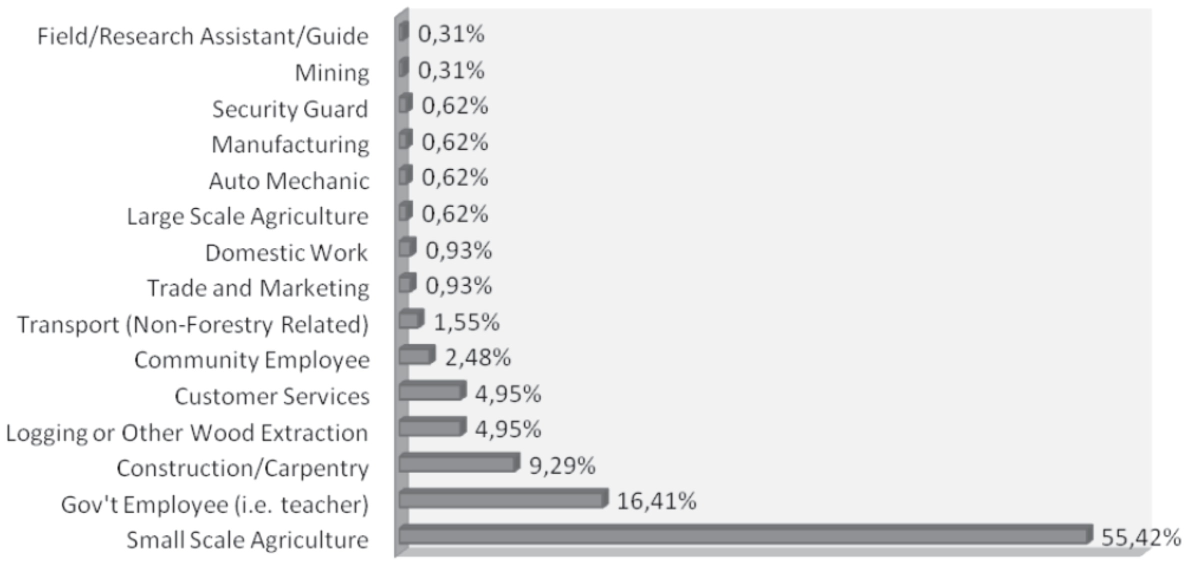

Figure 6: *Wage work breakdown – all community types.*

4. Case of study in Colombia. Otun river watershed

4.1 The general forestry context

Colombia is located at the north of South America. With about 1.114.000 km^2, it is the third largest country of this part of the continent after Brazil, Argentine and Peru. In Colombia forests cover about 64 million ha (56% of the total area) and about 10 million ha of this area correspond to protected areas (Duque 2003). In 1995 forest plantations covered 265,000 ha, 38% of them for profit and 62% for protection (Sanchez et al. 2001). Most of the forest plantation area (80%) is composed of species such as *Pinus sp., Cupressus sp.* and *Eucalyptus sp.* Other native species planted in low proportion are: *Cariniana pyriformis, Alnus jorullensis, Cordia alliodora, Cordia gerascanthus, Tabebuia rosea and Ceiba pentandra* (Duque 2003).

Topography, soil and climate as well as the altitudinal gradient, provide a wide range of possibilities of finding different forest ecosystems. In this sense, forests of Colombia have been classified into 16 types of ecosystems (FAO 2002). Therefore, the composition and the structure of forests vary from the sea level up to 4000 m.

Rates of deforestation for Colombia significantly vary according to period of time, the surface considered, the remote sensing images used and the source. IDEAM (1996), estimates that approximately 91.900 ha (0.14%) of forest were logged every year. Between 1990 and 2005, the rate was accounted for 273.334 ha/year (0,42%) by using Landsat images. Thereafter, and by using MODIS images, the rate was estimated to be 337.000 ha/year (0.52%) between 2000 and 2007 (IDEAM 2010). Then, in the study carried out by Jarvis et al. (2010), 151,754 ha/year (0,23%) were accounted between 2004 and 2009 by using Terra Images. On the other hand, information on the Pacific region of the country, which is very important because of the riches of the forests and the deforestation processes (Ortega et al. 2010), has not been properly included within the studies referenced since the use of remote sensing images is limited due to the presence of clouds. In any case, studies show that Colombia loses thousands of forest hectares every year, which is a real problem with deplorable consequences.

In terms of volume, 1,496,034 m^3 of timber were extracted from natural forests during the 1998, and 982,228 m3 from forest plantations (MINAMBIENTE 1999). However, about 27,000,000 m^3 of timber and timber products were imported in 2001 (Duque 2003). Although the information presented above is not updated, Colombia cannot supply the demand of timber by itself in spite of the largest areas of natural forest in addition to those being used for forest plantations.

Even though most of the deforestation hotspots are localised in the Pacific and the Amazon region (IDEAM 2010; Ortega et al. 2010), the situation in the Andeans is tricky. Mostly of the Colombian population is settled in this area, forests are habitually protected areas and correspond to remnants, especially in the highlands where they provide important ecosystems services. In addition, climate change scenarios predict the reduction of precipitation by up to 30% and an increment of temperature up to 4 °C (IDEAM 2010a). Therefore, Andeans ecosystems are highly threatened.

4.2 Otun river watershed and strategies to face climate change

The Otun river watershed is located at the west side of the Central Cordillera in the Colombian Andeans between 900 m and 4500 masl. This altitudinal gradient, the topography which is mostly steep, the variety of climate conditions and the geological dynamics influenced by volcanism, are the cause of the ecosystem diversity found in about 467 km^2 of surface (40% forest). In addition, the city of Pereira, the largest in the coffee region, with about 500.000 inhabitants demanding food and water, is also situated within the watershed.

Most of the forests (30%) are located above 2000 masl and correspond to protected areas. In the lowlands (900-200 masl), forests are highly fragmented and coincide with riparian ecosystems dominated by a bamboo species. Besides, the urban zone of Pereira city and farm systems are also found in this part of the watershed.

Without climate change threats, the complexity is already high, however, as above mentioned, Andeans ecosystems are highly threatened and strategies should be implemented in order to counteract climate change and, in this case, to guarantee the ecosystem services required by the rural and urban population. Possibilities to implement CDM projects, REDD+ or even those schemes of marketing carbon within voluntary approaches, have low feasibility. The cost of the land, the almost inexistent deforestation and the presence of forests long time ago, do not fit with the requirements of the mentioned schemes.

In this sense, a group of measures embedded within the approach of adaptation based ecosystems is being implemented with the support of different institutions and rural communities. The implementation therefore arises with the definition of ecosystems which are nival (>4000 masl), paramo (3000-4000 masl), andean high forest (2000-3000) and sub- andean forest (900- 2000 masl). The strategies are developed as adaptation measures, but are not necessarily focused on directly handling climate change. Thus the monitoring, promotion of proper practices for managing farming systems, ecosystem restoration and policies, are promoted and implemented for improving the current conditions and to increase the level of resilience of ecosystems. However, it is remarkable that according to the climate change scenarios, the Otun watershed river will be affected by an increase of temperature (up to 3°C) and the reduction of precipitation (up to 20%).

In the *nival* ecosystems, threats are associated with the retreat of glaciers. This process is advancing fast and there are few possibilities of stopping it due to the direct connection to global warning. Nevertheless, activities of monitoring are carried out yearly to define the rate of retreat. Although the expectations are pessimistic, fortunately water resources of the watershed do not depend on the glacier.

Paramo ecosystems are highly vulnerable to any activity (Buytaerta et al. 2007; Luteyn 1992), hence, in the context of climate change, this condition could become worsen. Although a large part of these ecosystems in the zone of study is within the protected areas (Figure 7), currently agricultural and cattle activities are being carried out in the buffering area with a considerable impact on natural resources. Additionally, these activities trigger fire events as have occurred in 2006 with devastating consequences (Lotero et al. 2007).

In paramo ecosystems soil deterioration after fire events is considerable (Poulenard, et al. 2001) and the ecological restoration is very complicated, because chemical, physical and biological properties cannot provide the support required by the vegetation (Camargo et al. 2010). Furthermore, physical properties of soils that determine proper water dynamics significantly decline and the function of water regulation is seriously affected.

Figure 7. *Paramo ecosystems. Spring of the Otun river. Otun lagoon.*

Figure 8. *Andean high forest ecosystems. Otun river watershed.*

Figure 9. *Sub- Andean forest ecosystems. Above the limit between forest and farm systems. Impact of agriculture is evidenced in yellowish colours of soils.*

Figure 10. *Sub- andean Forest ecosystems. An example of agroforestry systems with coffee with timber trees of* Cordia alliodora*.*

In order to guarantee the ecosystem services supplied by paramo ecosystems which are mostly related to water regulation, a set of activities is being implemented. In this sense, information from monitoring (soil, water and vegetation) is used for making decisions about restoration processes. Besides, activities of control as well as alternatives for relocating of farms towards areas suitable for agriculture are managed by the institution in charge of administering the protected area (Unit of Natural Parks from the Ministry of Environment, Housing and Territorial Development UPNNMAVDT).

In the Otun river watershed about 30% of the total area corresponds with protected areas mainly located in the *andean high forest* **(**Figure 8**)**. Within these ecosystems anthropogenic activities are controlled and the state of forests in ecological terms is satisfactory. Besides, the higher values of precipitation and the presence of wetlands are essential to water regulation and the biological biodiversity represented by animals and vegetation is significant as well.

The managing of these areas corresponds to UPNNMAVDT and to the company in charge of the Pereira city aqueduct (aguas & aguas). Efforts of both institutions are articulated, forests have a proper protection and additionally the monitoring of biodiversity and water (quality and quantity), permits chanelling actions towards controlling the factors threatening forest ecosystems.

The complexity associated with urban settlements, agriculture and cattle correspond to the *sub – Andean forest* ecosystem. Agriculture and the cattle have contributed to forests fragmentation and the degradation of soils and water (Figure 9). However, a big part of food requirements from the population of Pereira is supplied by farms located in the watershed. Therefore, actions are focused on the inclusion of trees into farm systems to consolidate agroforestry systems (AFS) and to promote agroecological practices (Figure 10). Thus, the supply of food and the reduction of impacts on the environment can be guaranteed. In addition, strategies for managing the fragments of forest have been implemented and are currently contributing to their conservation. Information on these strategies is procured to be incorporated within the city territorial plan in order to avoid that the urban expansion threatens the forest fragments and those areas with AFS.

The implementation of these actions is articulated and coordinated by government institutions which represent the environmental (CARDER) and the agricultural ministry, the local government and centres of research and /or education. Besides, rural communities are being involved in the processes significant for the adoption of the strategies proposed. Although the reconversion process is still ongoing, the preliminary results show that this is a proper approach to improve the current conditions.

7. Conclusions

Facing climate change requires local actions which do not depend only on those schemes promoted from UNFCCC. In this context, tropical forest ecosystems represent an important element to configure strategies that should include the promotion and consolidation of protected areas, forest governance, institutional joint and coordinated actions and the participation of rural communities. In this sense, it is required to proceed with adequate measures according to the specifics ecological and socioeconomics conditions to enhance the possibilities of counteracting climate change. It is also crucial to consider that forests are more than carbon. They provide ecosystems services and support the livelihoods of rural communities.

Tropical countries such as Ecuador and Colombia, with a wide variety of ecosystems, are reacting in accordance to the possibilities of their governments. Local actions include policies, planning and implementation simultaneously. Nevertheless, the success of the programmes or schemes depends on the adoption level reached by communities. The set of measures adopted should be focused on alleviating the conditions of the population while respecting the limits of ecosystems. These actions promoted from and for specific local conditions certainly have a global effect and contribute to counteracting climate change.

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Opportunities and challenges for tree crop integration in REDD+: Cocoa crops in Ghana and Colombia

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Abstract

The main objective of this article is to review the situation of cocoa plantations in both countries (Ghana and Colombia), identify similarities and convergences between them, and identified the challenges and opportunities to implement agroforestry cocoa systems under REDD+ mechanisms. The available information shows that Colombia and Ghana are tropical countries where cocoa production has a major impact in terms of economic and social benefits. In both countries cocoa is an important source of rural employment, especially for small scale farmers. In Ghana the trend of deforestation is related to cocoa plantation expansion, while in Colombia the favorable conditions to expand cocoa plantations represents a threat for natural forest. One of the actions than can be applied to properly manage these circumstances is the adoption of intensive and sustainable practices like cocoa agroforestry systems. This is the case especially at forest margins, where forest can be protected and the community livelihoods can be improved. The REDD+ mechanism could be an option for the development of these practices. In order to achieve well ground REDD+ strategies, however, specific actions have to be taken in terms of governance and land tenure. At the same time, it is necessary to consider the opportunity cost of foregoing the conversion of forests into cocoa plantations. Mechanisms and incentives should be implemented in order to promote forest conservation.

Key words: cocoa agroforestry systems, Ghana, Colombia, REDD+

1. Introduction

Agriculture and related activities account for about 20 percent of the global greenhouse gas emission, with 80 percent of the agricultural related emissions, including deforestation, coming from developing countries (UNFCCC 2010, Benhin 2006). Reducing emissions from deforestation and forest degradation, and enhancing forest carbon stocks in developing countries (REDD+) is a global initiative as defined in the Bali Action Plan (UNFCCC Dec 1/CP.13) and subsequent COP. REDD+ discussions are geared towards managing emissions over entire landscapes, including agriculture with inclusion of both above ground and below carbon stocks (Campbell 2009). Cocoa sector production options can result in a net increase in carbon stocks through a greater use of agroforestry and shade tolerant cocoa species. Cocoa agroforests (with some forest trees) contain higher a carbon stock than other agricultural land uses and offer better opportunities for mitigating climate change (Seidu 2010). Additionally, cocoa is sensitive to climate change (Anim-Kwapong & Frimpong 2008) and this makes mitigation measures crucial for sustainable production.

Co-benefits (e.g. alleviating poverty, improving governance, conserving biodiversity and providing other environmental services) are greatly enhanced by REDD+ (Campbell 2009). The mitigation agenda opens the access to emission reduction payments to the rural dweller which can serve as supplement to crop production (Campbell 2009).

This review therefore seeks to identify the opportunities and challenges for Ghana and Colombia with respect to cocoa agroforestry and the potential of REDD+ to contribute to mitigating emissions from cocoa production.

2. Agroforestry as a strategy to control deforestation

In tropical regions, extensive conversion of forest and intensification of agriculture are the main sources of land-use change and biodiversity loss (Wright 2005). The high levels of poverty and high population growth rates, lead to the conclusion that any approach aiming to mitigate tropical deforestation and protect biodiversity should address the livelihoods and needs of local communities (Bhagwat et al. 2008).

An agroforest is defined as a complex system which looks and functions similarly to a natural forest ecosystem, but is integrated into agricultural management systems (Michon and de Foresta 1995). Agroforestry systems have proven to be an effective strategy to mitigate the effects of forest fragmentation (Righetto et al. 2011), enhance conservation of biodiversity and alleviate the resource-use pressure on protected areas (Bhagwat et al. 2008).

It offers forests-like habitats (Greenberg et al. 2000) that can function as fauna refuges (Griffith 2000), and provides corridors for the movement of animals and dispersal of plant propagules between forests (Saatchi et al. 2000). Also, agroforestry interventions provide other benefits such as the enhancement of social stability in terms of land tenure, aesthetic/recreation values of the landscape (Muschler and Bonnemann 1997), and provide corridors for migration of any forest-dwelling species that will face the effects of changing climate in the future (Bhagwat et al. 2008).

Another aspect of agroforestry is the effectiveness in increasing ecological and economical sustainability of existing land use systems (Muschler and Bonnemann 1997), since these systems maintain soil fertility on a reasonable level, providing income to the farmers as well as reducing the clearing of primary forest and carbon emissions (Schroth et al. 2002). In the climate change scenario, agroforestry contributes to mitigation by enhancing carbon sequestration and strengthening the system's ability to overcome adverse impacts of changing climate conditions (Verchot et al. 2007).

Despite the positive features that agroforestry offers when it's applied in a proper way, there are also restrictions arising from bio-physical, socio-economic and political conditions (Muschler and Bonnemann 1997). It has been proven that agroforestry does not compare with primary forest (Donald 2004), in terms of species richness, natural succession, and gap dynamics (Rolim and Ciarrello 2004). When agroforestry systems are establish on previously cleared fallow or secondary forest land, carbon is release from the removed vegetation, interrupting the successional process which would have led to progressive further accumulation of carbon biomass litter (Schroth et al. 2002).

A research conducted in central Amazonia shows that in the short term, the environmental cost of forest conversion into cash crop plantations was the net release of different amounts of carbon into the atmosphere (Schroth et al. 2002). The net effect of forest conservation depends on the time-averaged carbon stock for the whole growth cycle of the forest or fallow and the land use systems by which it is replaced (Palm et al. 2001). Therefore, agroforests should be placed on low standing biomass land, and secondary forest should be conserved (Schroth et al. 2002).

On the socio-economic aspect of agroforestry systems, many basic features such as risk, uncertainty, impact of labor, market or tenure policies among others have not been properly integrated (Mercer and Miller 1997). The scarcity of social, cultural and policy considerations led to ineffective agroforestry initiatives (Pollini 2009). The potential of agroforestry to contribute to adaptation to climate change is basic and more information is required; studies in the field with small-scale farmers will allow us to learn important lessons through practical experience (Verchot et al. 2007).

3. Cocoa in agroforestry systems

Cocoa (*Theobroma cacao*), a neotropical understory rain forest species, is one of the most important perennial cash crops worldwide, cultivated in tropical areas. Millions of farmers, mostly smallholders, depend on cocoa for their livelihoods. Traditional cultivation systems are established by planting cocoa under primary or older secondary forest with minor modifications to the original forest canopy. However, cocoa cultivation takes place in a range of management systems from shaded agroforests to no shaded monocultures (Rice & Greenberg, 2000). On shaded agroforests, cocoa is planted in the cleared understory, or through planted shade trees, but when cocoa trees mature, removal of shade trees increases (short-term) yield. This situation leads to dwindling yield and increasing pressure from pests, forcing farmers to clear forest areas to establish new crops. The ephemeral nature of shade in cocoa agroforestry, starting with shaded young cocoa plants and gradually developing into mostly or completely shaded monocultures, is a great environmental drawback (Schwendenmann et al. 2010).

Nevertheless, well managed cocoa agroforestry systems provide food and non-food resources, stimulate litter decomposition and nutrient recycling, provide erosion control, increase carbon storage, reduce greenhouse gas emissions, mitigate climate change effects and enhance functional biodiversity (Tscharntke et al. 2011).

4. The cocoa sector in Ghana and Colombia

Ghana

Sixty percent of the world's cocoa is grown in West Africa, with Côte d'Ivoire and Ghana leading the production (WWF, 2006). Cocoa is a major export cash crop in Ghana. Ghana's economy, despite recent crude oil exploration, is agriculture based with lots of income from cocoa exports. Cocoa from Ghana has always enjoyed an immense reputation for its quality in international markets and regularly exceeds international guidelines (Williams, 2009).

The contribution of cocoa in agricultural GDP rose from 13.7 percent between 2000 and 2004 to 18.9 percent in 2005/2006 (Breisinger et al. 2008). It accounts for 25-30% of total export earnings and also employs over one million people, giving livelihood support to six million farmers (Canatus and Dakoa, 2009). The role of cocoa in development includes employment, foreign exchange and revenue for government, education, and infrastructural development. In Ghana, the cocoa growing regions are the forest areas. Cocoa farm sizes are relatively small ranging from 0.4 to 4.0 hectares with an estimated total cultivation area of about 1.45 million hectares (Canatus and Dakoa, 2009) with a current estimation of 1.6 million hectares (MOFA, 2010).This has resulted in large tracts of tropical forest being cleared to support increasing cocoa cultivation. Cocoa farming is viewed as both a direct and indirect driver of deforestation (UNEP, 2008).

Additionally, new research conducted by the International Center for Tropical Agriculture (CIAT), indicates that an expected annual temperature rise of more than two degrees Celsius by 2050 will affect West Africa's cocoa-producing areas because of the increasingly warm conditions. Cocoa trees will struggle to get enough water during the growing season and farmers in these areas are particularly vulnerable since cocoa production is their primary source of income. For these reasons it is important to increase the resilience of existing production systems as much as possible (Läderach et al. 2011).

Colombia

Colombia is the third largest cocoa bean producer in Latin America after Brazil and Ecuador (FAO 2010). The quality standard of Colombian cocoa, regarding its characteristic taste and smell, are recognized in the world market (ICCO, 2006). The organoleptic characteristics of the national product make it eligible for the best prices on the market (ICCO, 2006). Colombia exports 100% high quality cocoa, but the volumes that are exported are small (Sanchez et al. 2008).

The main reasons why the international distribution is low is the lack of standards in the post-harvesting process (Sanchez et al. 2008), and the attack of plagues, mainly the fungi *Moniliophthora roreri* and *Crinipellis perniciosa,* that have been increasing in the last two years because of the severity of the rainy seasons (El Expectador 2011).

In Colombia, cocoa plantations are typically found in subsistence farming systems (90% below 5 hectares), and reach an approximate yield of 500 kg of dry cocoa ha/year (Rojas and Sanchez). The age of cocoa plantations are 30% above 20 years; 50% between 7 and 20 years; and 20% less than 7 years. The main cocoa producing regions include 10 departments. The main producers are Santander, Norte de Santander and Bolivar with 62.500 hectares of cocoa bean plantations. Studies conducted by the national government and two main Colombian research institutes, Instituto Agustin Codazi and Corpoica, estimate that there were 143.601 hectares of cocoa plantations in Colombia until 2010, and about 660.000 hectares with soil conditions that allow the growth of cocoa plantations.

The cocoa crop management in Colombia is characterized by the use of low levels of technology, cultured in association with other crops such as plantains, bananas, cane, coffee, annual crops like maize, beans among others, and in association with timber and fruit trees planted in hybrid seed plantations (FEDECACAO 2011).

Cocoa agroforests in Colombia have a great importance because of the capacity to fulfill the internal demand and export high quality products, increasing the sources of rural employment (FEDECACAO 2004), promoting economic and social alternatives to illicit crop production (USAID 2003), and encouraging sustainable practices that can be applied to enhance the protection of forest and natural resources.

5. Cocoa agroforestry systems in Ghana and Colombia under REDD+ mechanisms

A large amount of atmospheric CO2 has been sequestered by tropical forests, but deforestation reduces the benefits considerably (Pan et al. 2001). To decrease the risks of climate change, REDD+ has the potential to reduce emissions from deforestation and forest degradation, delivering social and environmental benefits (Angelsen et al. 2011). In this mechanism, developed countries pay developing ones to protect, restore and sustainably manage their forests (Angelsen et al. 2011). The payments are based on the difference between realized emissions and projected emissions from a historical baseline (Sandker et al. 2010).

In many tropical landscapes commercial agriculture is the main agent of deforestation (oil palm, cocoa, rubber, and soy) (Lambin et al. 2001). In contrast, agroforestry systems have proven to be an effective strategy to alleviate forest destruction while providing ecological and economical sustainability to land use systems. Therefore, cocoa agroforestry systems financed by REDD+ mechanisms seem to be a good opportunity to reduce deforestation and forest degradation, if the proper methods are implemented. However, in many tropical landscapes governance is weak, and there are difficulties that have to be solved for this mechanism to succeed. A potential source of conflict is the unclear tenure over carbon, in order to solve this, carbon payments and benefit sharing needs to be negotiated (Pan et al. 2001).

In both countries cocoa is an important source of rural employment, especially for small scale farmers. In some of the cases however, this happens at the cost of large areas of forest destruction. In Ghana, the trend of deforestation is highly related to cocoa plantation expansion, while in Colombia the favorable conditions to expand cocoa plantations represent a threat for natural forest.

Cocoa agroforestry systems under REDD+ mechanisms have the potential to ensure sustainable management of cocoa plantations (intensification), enhancing cocoa carbon stock, reducing clearing of forest and encouraging maintenance and planting of trees in cocoa farming systems. However, in order to achieve well-grounded REDD+ strategies in cocoa agroforestry in Ghana and Colombia, we need to consider the opportunity cost of foregoing the conversion of forests into cocoa plantations (Swallow 2007), and the importance of the information relays in the scenario where REDD+ strategies limit livelihood activities. In this case, the opportunity cost will arise, affecting the community interest and maintaining the pressure on forest (White and Minang 2011).

Through simulations, researchers have found that in Southwestern Ghana REDD+ payments may not compete with the opportunity cost of cocoa producing areas (Sandker et al. 2010), meaning that REDD+ payments based on current carbon prices may not outcompete cocoa production in the region (Sandker et al. 2010). For Colombia, and in general in Latin America, researchers are focusing on ways to calculate the opportunity cost of land use change and deforestation, so far, we didn't find calculations of the opportunity cost of foregoing the conversion of forests into cocoa plantations. In general, Large-scale and nationwide assessments of the opportunity costs would be necessary to generate estimates of the payments that would be needed to provide land users with sufficient incentive to reduce deforestation (White and Minang 2011).

6. Conclusions

Cocoa agroforestry can be an opportunity to avoid deforestation and contribute to improve livelihoods of local communities, if the already recognized, proper techniques are implemented. To achieve this, it is necessary to integrate land tenure, market and policy in to the equation. Efforts should be focus on the recovering of degraded land, diversification of farming landscape and redirecting extensive livestock systems towards sustainability.

The voluntary carbon market may be an alternative to achieve the challenge of increasing carbon stocks and improve cacao production in areas where natural forest needs to be conserve. Taking into account that the voluntary carbon market is not bound to any legally binding agreement, but maintains its integrity as it observes the accounting and verification systems of compliance markets, this mechanism may enable the cocoa sectors in Ghana and Colombia to deliver effective responses to climate change, despite their complex situation, due to its flexibility.

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Analysis of the sustainability of Adaptation to the Impact of Rapid Glacier Retreat in the Tropical Andes Project (PRAA) in the Shullcas sub-basin of the Mantaro river, Junín, Peru

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Abstract

This paper describes the results of the Climate Vulnerability and Capacity Assessment (CVCA) methodology run by CARE within the Project of Adaptation to the Impact of Rapid Glacier Retreat in the Tropical Andes in the Shullcas Sub basin in the Mantaro watershed, as well as the implemented reforestation program in this area. An exploratory analysis of the sustainability shows that in order to promote this issue it is necessary to enhance activities less sensitive to climate change, institutional strengthening, intersectoral coordination and participatory research.

1. Introduction

The central Peruvian Andes are considered an area with a great climatic vulnerability, especially when the economic activities are limited by climate (Seltzer and Hastorf 1990). In the Mantaro River basin, the population relies heavily on the water supply that the rivers from the basin provide. These depend on the glaciers of the western ridge and the glacier on the Huaytapallana mountain. The Mantaro River also supplies 34.3% of the electricity demand of the country and is the main center of agricultural activity, providing several kinds of agricultural products for the city of Lima (IGP 2005), thereby becoming one of the most important rivers of the region.

These facts are critical if we consider that from 1976 to 2006 the surface of the glacier on the Huaytapallana glacier has retreated by 59.4% (IGP 2011). Another climatic effect according to IGP (2011) is alteration of the intensity and frequency of precipitation, frosts and droughts that could by climate change, as well as an increase in landslides and soil erosion due to the intensity of precipitation.

In light of these facts, the Project of Adaptation to the Impact of Rapid Glacier Retreat in the Tropical Andes (PRAA) has the objectives of evaluating the impacts of climate change through the CARE´s Climate Vulnerability and Capacity Assessment (CVCA), of implementing adaptation measures to climate change including a reforestation program in the Shullcas sub basin and glacier monitoring. The latter includes the characterization and evaluation of the behavior of the selected glaciers relating to water availability scenarios.

Due to the fact that the project is still ongoing and an impact assessment is not yet done, an exploratory analysis based on the results of the vulnerability and capacity assessment on the communities in the Shullcas sub basin is performed taking into account the reforestation program by the PRAA in the same area.

2. Evaluation of the climate vulnerability and capacity in the Shullcas sub-basin

The PRAA seeks to strengthen the resilience of local ecosystems and economies against the background of the impact of rapid glacier retreat caused by climate change in the tropical Andes. Hence, an evaluation of the impacts of climate change must be performed in order to design adaptation measures and implement a capacity-building plan among the communities. In order to achieve this, CARE developed the Climate Vulnerability and Capacity Assessment methodology (CVCA), using community and scientific knowledge to reach a better understanding of the local impacts that climate change brings with it.

Through the compilation, organization and analysis of information about vulnerability and adaptability of the communities, and through participatory tools as the “Hazard Mapping”, “Seasonal calendar”, “Historical Timeline”, “Vulnerability Matrix” and the “Venn Diagram”, the perceptions of events by the local population is analysed. The information can shed light on how the communities have adapted in history and how they are currently doing so. These participatory tools give the local actors awareness of their resources and livelihoods in order to design a plan accordingly.

This methodology was applied in 8 communities of the Shullcas sub-basin, with a gender quota of 42% female and 58% male participation.

The results showed that the main economic activity of the families within the sub-basin is agriculture. In agriculture, however, production and productivity do not cover the average costs of investment, due to the inadequate technologies and the low productivity levels. The reason is that farmers obtain one crop campaign per year depending only on the rainy season.

Climate change is affecting different local ecosystems of the sub-basin, principally those whose populations are particularly vulnerable. The results of the CVCA showed the main climatic changes that the communities in the sub-basin perceived:

- Severe climate events became more frequent since the year 2000;
- Rise in droughts due to the reduction in the water flow in the Shullcas River which most of the populations rely on;
- Increase of insect infestations due to excess rain and the resulting need for pesticides;
- Instability of rainfall has resulted in significant changes in the window of when to plant and harvest crops;
- Higher incidence of hail events related to droughts, and
- Higher frequency in respiratory diseases among the children

As we can notice in the previous results, the area shows high climatic variability which has increased over the last years.

According to the Geophysical Institute of Peru, "the development of future climatic scenarios for the study area are coherent with the observed meteorological trends and the population perception" (IGP 2005). The results for the central area of the Mantaro watershed shows for the year 2050:

- Temperature increase of 1,3°C
- 19% reduction of precipitation during the rainy season (December-February)
- 6% reduction of relative humidity

Regarding the institutional context, referred to by CARE as the "enabling environment" (Fontenla pers. Comm. 2011), the CVCA analyses led by CARE in all three countries (Ecuador, Peru, Bolivia) shows that the institutional and political context related to climate change tends to be non-existent or incipient. The Shullcas sub-basin is not an exception.

In the areas where more advances have been made and where a range of adaptation initiatives exist, the lack of a solid institutional structure makes these initiatives uncoordinated. In the same way, the analyses revealed that no strategies are currently being envisioned to deal with new climate scenarios. In addition, there is a lack of knowledge about the planning processes which can be undertaken to respond to the impacts of climate change at different levels among the population. The same is true for policies for disaster risk management.

Concerning this topic, the local government developed a Regional Plan of Prevention and Attention of Disasters in 2007, which states that the weaknesses of the region are:

- The lack of incorporation of risk management in the processes of regional development;
- The limited prevention culture among the authorities and the population; and
- The limited implementation of the National Civil Defense System and the lack of budget on prevention (INDECI 2007).

In this context, a number of strategies including programs and sub-programs involving the responsible institutions were established to promote risk management. However, in the communities where the CVCA methodology was carried out, a civil defense committee was not identified among their most important institutions. If it was, they gave it minor importance and located it outside the community. Furthermore, they did not carry out prevention activities. There are also no brigades or other organizations working on disaster risk reduction in the communities and, according to CARE, in general in all pilot areas.

With regard to climate information, meteorological stations do not disseminate much information to rural areas in general. Even though some communities recognized the importance of the Huaytapallana Glacier, there is a lack of knowledge about the contribution to the water balance of the sub-basin.

Box 1. *Facts on the Project of Adaptation to the Impact of Rapid Glacier Retreat in the Tropical Andes (PRAA) .*

- The initiative is lead by the Ministries of Environment of Ecuador, Peru and Bolivia on behalf of the governments
- The management of the project is performed by the Andean Community Secretariat
- Mainly funded by the Global Environmental Facility (GEF), which channels funds through the World Bank (GEF Implementing Agency)
- Partnership arrangement with CARE in the three countries
- In Peru, agreements with the Rural Agrarian Productive Development Program (AGRORURAL), the National Meteorological Center (SENAMHI) and Santa Teresa Municipality.
- Works in two sub basins in Peru: Santa Teresa within the Urubamba river watershed and Shullcas within the Mantaro river watershed.
- It started in July 2008 and concludes in September 2012

3. A reforestation project as adaptation measure of the PRAA in the Shullcas river sub basin

The CVCA results also showed social capacities in some communities related to reforestation and forest management. AGRORURAL, which is a program from the agriculture ministry of Peru and is in charge of the reforestation program of the PRAA is considered an important institution outside the community. The local population, receiving some income for the sale of planted "eucalyptus", also recognized the existence of forest resources in the area.

The forest history of the Mantaro region can be divided into three stages. The first one were reforestation activities with eucalypt during the 19th century. This region is considered to be the first place in Peru where this specie was introduced (Dourejanni 2009 cited by Medina 2011). The second one could be called 'internationalization', due to the strengthening of international organizations in the area. Among these were: the Agency for International Development (AID), the Inter-American Development Bank (IDB) and the Food and Agricultural Organization of the United Nations (FAO). The activities relied on technical skills (Pretzsch 2005), and the objectives of the initiative, according to Dourejanni (2009), cited by Medina (2011), were household and local consumption.

According to Medina (2011), a quality assessment of these plantations indicated that, already in 1982, 59% of the total area presented a regular or bad management or even nonexistent management (Schwartz and Parraga 1982 cited by Medina 2011).

After that, during the 1980s, the polarization stage (Pretzsch 2005) started. In this third stage, NGOs appeared leading to capacity-building activities and agroforestry support, mainly in order to address the issue of energy supply. In the 1990s, more autonomy for the communities was realized with the support of local municipalities.

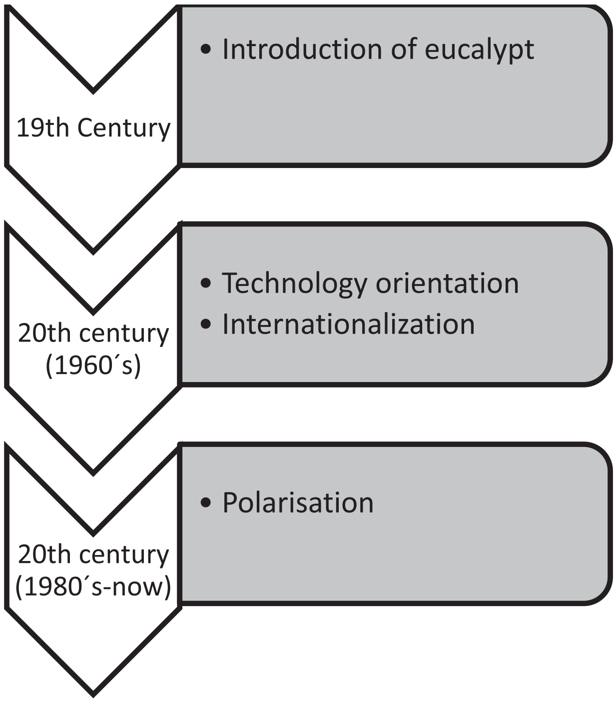

Figure 1. *Historical development of forestry in the study area (Based on Pretzsch 2005 and Medina 2011).*

Some constraints in the establishment of large plantations are related to the bad site conditions, a lack of proper management, the high elevations limiting the growth of some species, and socio economic factors such as the lack of investment and the use of rudimentary technology (Medina 2011).

Despite the fact that the local population has a long history of crop cultivation and livestock grazing as their main activity, they also have a long history of tree planting. It is important to mention that, besides the efforts to reforest after the 19th century, the species traditionally planted in the area since pre-colonial times were *Alnus acuminata* (aliso), *Escallonia sp.* (chachacomo), *Polylepis sp.* (quinual), *Buddleja incana* (quisuar) *and Schinus molle* (molle), which were already a part of traditional agroforestry systems (Medina 2011). However, the most used tree specie today is eucalyptus, due to its characteristics for rapid growth and economic marketability. This should be taken into account since income diversification for poverty alleviation is also an important aim for reforestation in the Andes (Medina 2011).

Recently, vegetation coverage loss on the slopes in the area has gradually been happening due to the expansion of agricultural area. This situation worsens the problem of water availability in the region due to the loss of water infiltration affecting underground water recharge. This has resulted in streams which were before available the whole year only being available in the rainy season (CARE 2011).

In light of this reality, the project decided that in order to increase the infiltration rates and decrease runoff, it was necessary to reforest some areas, as an adaptation measure to climate change.

The reforestation project is part of the second component of the PRAA for climate change adaptation. Its goal is to recover the degraded slope soils in the Shullcas sub-basin. The goal is to reforest 1900 ha. From this, 500 ha of *Pinus sp.* (pino) are designated to have production objectives and 1400 ha protection purposes. The elected species for protection purposes were native species like *Buddleja incana* (quisuar) and *Polylepis sp.* (quinual). AGRORURAL is in charge of the technical expertise for the project, including the purchase of the plants, reforestation, plant fencing, training and raising awareness for the beneficiaries.

Box 2. *Adaptation measures based on integrated management as part of Component 2 in the Shullcas river sub basin, Mantaro watershed, Peru.*

- Conservation of prairies and forestation to recharge aquifers
- Modern irrigation systems
- Improvement of irrigation infrastructure and water storage

4. Sustainability of the Project of Adaptation to the Impact of Rapid Glacier Retreat in the Tropical Andes

The results of the vulnerability analyses show that the population is exposed to high extreme event risk and has a high vulnerability to climate change, mainly because they rely on the climate to maintain their productivity. The PRAA project has developed a series of programs in order to improve their production technology and to temporarily palliate the effects of degradation. However, the sustainability of the project is not assured because there is no information about the favorable conditions that the project has generated. This is necessary in order to promote the continuation to the goals of the PRAA with the decision makers.

In any case, some considerations have to be made in order to promote sustainability. Even though agriculture is the main economic activity, the peasant economy combines different activities in time and space (Kervyn 1987). This implies that specialized programs should be flexible and should integrate various activities (Kervyn 1987b).

In this context, activities less sensitive to climate change and which exert less pressure on water and other natural resources should be developed. A possible alternative to improve the agricultural activities lies in forestry, or agroforestry. These practices are conceived and promoted as a sustainable approach to land use management, capable of providing solutions to problems and issues that “were not being satisfactorily addressed by modern agriculture and forestry” (Nair 1998 cited by Guo 2003). Some benefits of forestry and agroforestry include soil erosion reduction and increase of soil matter among others (Guo 2003).

As the results and the history of forestry in the area show, there is a great potential for production forestry. However, the project is more focused on reforestation with protection purposes. In any case, the areas designated for production purposes and the areas for protection are not well demarcated (Medina, pers. Comm. 2011). Most of these plantations are found in areas with difficult accessibility, and together with the fact that the resources for forest managing have to come from the community, this makes the future of the plantations very uncertain. Therefore, it could be suggested that the productivity of commercial plantations could decrease in the future.

The development of forestry with low water requirement species like pine is a good parallel activity to agriculture, taking into consideration the avoidance of competition with land necessary for food security. Covering the cash requirements for plantation tending with low interest credits until first income from felling is received, could be an attractive alternative.

Another consideration necessary to achieve sustainability is the strengthening of institutions.

At the local level:

- The already existing “committees” show that a social organization could be reached for marketable reasons like cooperatives. These allow associations to improve their situation since they transform their common needs into objectives which they achieve through common activities (Müller, 1993).
- Awareness raising and advocacy towards climate change issues, considering that natural hazards and climate variability of the recent past and present prevails in people’s memory (FAO, 2008). This could lead to the development of risk management strategies among the communities.
- Climate adaptation should focus on support for the decision-making and capacity-building processes that shape social learning, technology transfers, innovations and development pathways (FAO, 2008). This includes the enhancement of the administrative capabilities of the local people, considering that the maintenance of the water infrastructure that the project is implementing will be, or has to be, made by the local population.

At a regional level:

- Junin is one of the regions in Peru that has a well-developed natural resource and environmental management department. This department manages a regional environmental information system. It also manages the development of the ecological and economical land use process, implying that the region manages a budget for natural resources.
- However, institutional capacity building on risk management strategies and strengthening of organizational networks across all levels and sectors is necessary (FAO, 2008)
- There is a need to integrate top-down and bottom-up perspectives and capacities (FAO, 2008)
- The establishment of intersectoral coordination, especially in activities such as planning, communication and operations at field level is necessary, in order to achieve alternatives which are more likely to result in the highest overall welfare gains (Hogl, 2003)

Finally, research should be managed in a participatory and practical way. Projects like the meteorological mini-net of the Mantaro valley from Maremex-Mantaro should be promoted.

This project installed low budget and simplistic equipment in the Shullcas and two other sub basins. This allows a better risk management by the communities and the study of physical meteorological events complementary to those currently made by the National Meteorological System.

7. Conclusions

The Project of Adaptation to the Impact of Rapid Glacier Retreat in the Tropical Andes achieved its goal of assessing the vulnerability and strengths regarding climate change impacts among the communities in the Shullcas sub basin.

To reduce vulnerability and enhance adaptation, activities less vulnerable to climatic change such as agroforestry could be developed. In order succeed; a good level of organization must be achieved by the local actors. This would assist them in participating in decision-making processes and empower them.

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REDD+ Strategy beyond the Forestry Sector: Analysis of the Agricultural Policies and their Impacts on the Drivers of Deforestation in Brazil and Zambia

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Abstract

Failure to address the fundamental drivers of deforestation and the tendency to view the forestry sector in isolation from other sectors have been identified as main reasons for past failures to prevent tropical deforestation. Considering that those failures must be overcome for an effective implementation of REDD+ at the national level, this paper analyzes the accomplishment of climate change mitigation policies of the agricultural sector in Brazil and Zambia that address drivers of deforestation. It aims to recognize synergies and competing objectives between policy instruments of the agricultural sector and the REDD+ strategy.

Keywords: drivers of deforestation; agriculture policies; REDD+; Brazil; Zambia

1. Introduction

On the debate of a post-Kyoto agreement, reducing emissions from deforestation and forest degradation and enhancement of carbon stocks (REDD+) has been tabled as a mechanism to financially incentivize developing countries to avoid green house gas emissions (GHG). Deforestation is estimated to account for 20% of the total global emissions and maintaining existing forests has been promoted as one of the least expensive climate change mitigation options (Kanninen, et al. 2007). While the design of the international mechanism is still in maturation, national REDD+ strategies and policies are under development in many tropical countries (Angelsen et al. 2009). Brazil and Zambia are some of those countries involved in drafting REDD+ strategies. Through this process many policy challenges call for special attention and consideration.

Angelsen, et al. (2009) point out that many past efforts have failed to prevent tropical deforestation from continuing at high speed for two reasons: the failure to address the fundamental drivers, and the tendency to view the forest sector in isolation from other sectors. Agriculture is an important activity for people's livelihood and for the economy of developing countries. However it has been considered the activity with highest contribution to deforestation (Kanninen, et al. 2007). For a climate change mitigation strategy to be consistent, policies from the agriculture and forest sector must be coherent.

Through a case study of Brazil and Zambia, this paper seeks to analyze the accomplishment of climate change mitigation policies of the agricultural sector in addressing the drivers of deforestation. It also aims at identifying how those existing policies could serve as stepping stone in the crafting of REDD+ national strategies for Brazil and Zambia.

As conceptual framework, the paper draws on stages of the policy making process as proposed by Crabe & Leroy (2008). It first seeks to analyze the coherence of the output stage of policy implementation, namely national plans, laws and agreements. Furthermore, the case studies considered the outcome stage, that is, the effect on target group behavior; and eventual impacts of the policies on deforestation.

1.1 Objectives

The objective of this paper is to analyze whether climate change mitigation policies in the agricultural sector in the Brazilian Amazon and Zambia address the drivers of deforestation.

Additionally, the paper aims to understand how the goals of agricultural policies compete with those of REDD+ strategy and how this knowledge could be used to find the appropriate instruments to meet the desired ends of both the agricultural policies and the REDD+ strategy.

2. Methods

The agricultural drivers of deforestation were identified in the literature for both Brazil (Amazon region) and Zambia. The stated focuses of agricultural policies were checked against the drivers of deforestation in both countries. The policies were classified according to the Kuhndt et al. (2006) typology for policy instruments.

The objects of analysis were Brazil's National Plan on Climate Change (NPCC) and Zambia's National Adaptation Program of Action on Climate Change (NAPA). Special attention was paid to the existing policies on agriculture. Additionally, literature related to REDD+ strategies was reviewed. The paper presents the cases of Brazil and Zambia and then draws conclusions on the robustness of agricultural policies in REDD+ strategy preparedness.

3. Analysis of Brazilian policies

Historically, the production of agricultural commodities has led to deforestation in Brazilian biomes. Through the colonial period, Brazil experienced successive commodity cycles (sugarcane, cattle, coffee and cotton) that shaped its landscape (Prado Jr 2008). In modern Brazil, agriculture still plays a major role in pushing the conversion of biomes and deforestation. In the period from 1990 to 2005, approximately 420 km^2 of forests were converted to other uses, especially for livestock and growing crops such as soybeans and corn. Till 2007, the Amazon has accumulated a loss of about 18% of its original forest since the beginning of deforestation in the1970s (Brasil 2008).

According to the literature, the major drivers of deforestation of the Brazilian Amazon are: infrastructure (transport and energy), colonization, price of commodities (soyabeans, biofuels, timber, beef), public policy and credit, land grabbing and illegal logging (May 2009, Margulis 2003). Land grabbing and illegal logging are closely associated to cattle ranching through a process of land speculation (Margulis 2003, Favaretto 2011). This study focuses on the drivers associated with the agricultural sector: commodities production, rural credits, land grabbing, and illegal logging.

As emphasized in the NPCC, "a reduction in the magnitude of historical levels of competition between *agricultural activities* and biomes is the most important goal of the National Plan on Climate Change, as it is considered *the largest source of GHG emissions in the country.*" (Brasil 2008). The document highlights the challenge of competing land use change such as forest conversion and a consistent shift to a carbon efficient economy. Overall, the mitigation policies and actions enumerated for the non-forest sector are mainly concerned with reducing emissions. However, some of those actions have impact on land use and forests, contributing to GHG emissions, as in the case of the Agroenergy National Plan, meant to promote biofuel production and consumption. Even though crops for biofuel are expanding on previously used land, it can indirectly impact land use change by moving the rangeland frontier into native habitats (Lapola et al. 2010).

To assess whether the policies on the agriculture sector are in line with the goal of reducing deforestation, the focus of the policies contained in the NPCC were analyzed against the identified agricultural drivers of deforestation in the Brazilian Amazon. Table 1 summarizes the results.

Table 1. *Analysis of agricultural policies in the NPCC, evaluated at the output level.*

Policy	Main focus	Instrument	Drivers of deforestation				
			P	S	R	C	L
Action Plan to Prevent and Control Deforestation in the Amazon, 2004	Reduction of deforestation in the Brazilian Amazon through integrated planning, monitoring and control, and fostering sustainable productive activities. Incentives for better use of already deforested areas on a sustainable basis and incorporation of abandoned areas in the production process.	Regulatory Economic Information	x	x	x	x	
Federal Decree nº 6.321/2007	States in the Amazon Biome, actions relating to the protection of areas threatened by degradation and the rationalization of land use, to prevent, monitor and control illegal logging. Regulate rural credits. Accountability of the production chain.	Regulatory economic aspects	x	x	x	x	
Reduction of sugar cane straw burning, 1998	Set standards of care relating to the use of fire in forest and grazing practices.	Regulatory	x				
Soya Moratorium, 2006	Accountability of the production chain. Not to trade soy from deforested areas within the Amazon Biome.	Cooperation regulatory aspects	x	x	x	x	
Beef Moratorium, 2009	Accountability of the production chain. Not to trade cattle raised in deforested areas within the Amazon Biome.	Cooperation regulatory aspects	x	x	x	x	
Agro-Ecological Zoning of Sugarcane to produce ethanol, 2009	Provide technical support for public policies aimed at expanding and sustainably producing sugar cane in Brazil. Exclusion of areas with native vegetation, the Amazon and Pantanal areas; environmental protection, indigenous lands, forest remnants.	Information regulatory aspects	x				
Research Program for Energy Forests	Research on the production of forest to replace the use of native forests for energy purposes.	Research			x		
Agroenergy National Plan, 2006	Support the shift of energy in the pursuit of sustainability, and provide conditions for increasing the share of renewable bioenergy in the energy matrix. Contribute to reducing emissions of greenhouse gases.	Research Economic					
Pro-recovery credit line, 2008	Regularization and recuperation of degraded areas, object of legal protection.	Economic					x
National Policy of Minimum Price, 2008	Improve the productive capacity and self-reliance of indigenous people and traditional communities	Economic					x

Policy	Main focus	Instrument	Drivers of deforestation				
			P	S	R	C	L
Low Carbon Agriculture Program, 2010	Finances initiatives such as no-tillage, recovery of degraded pastures, crop-livestock integration, forest planting of commercial forests, biological nitrogen fixation.	Economic					x
National Program for watershed and Soil Conservation, 1999	Promote practices such as soil cover, organic agriculture and agroforestry, riparian restoration and protection of fragile areas, rehabilitation of degraded areas	Economic					x
Action Plan to Prevent and Control Deforestation in the Amazon, 2004	Reduction of deforestation in the Brazilian Amazon through integrated planning, monitoring and control, and fostering sustainable productive activities. Incentives for better use of already deforested areas on a sustainable basis and incorporation of abandoned areas in the production process.	Regulatory Economic Information	x	x	x	x	

C: commodities production; P: credits; I: illegal logging; G: land grabbling; L: reforestation, sustainable use

The table shows that policies that assign accountability to the productive chain are meant to tackle all or most of the agriculture drivers of deforestation (policies number 2, 3 and 4). From those policies, one is a legally binding regulatory instrument (Federal Decree nº 6.321/2007) and two are cooperation instruments on soya and beef production, the most relevant segments of agriculture in the Brazilian Amazon. Besides those policies, the Action Plan to Prevent and Control Deforestation in the Amazon tackles the drivers through a policy mix design, combining regulatory, economic and information instruments.

In contrast to the above mentioned policies, all the pure economic instruments currently in place are designed to give incentives for reforestation, recuperation or sustainable use; measures that can only indirectly release the pressure on forests. In addition, the Agroenergy National Plan (Ministério da Agricultura, Pecuária e Abastecimento 2006), a policy that is currently relying on research and economic instruments to promote biofuel crop production, does not touch upon the problematic of deforestation despite the scientific debate on its impact on land use changes.

To directly address deforestation, the economic instruments now in place could be complemented with incentives such as payment for environmental services (PES), as proposed in the basic design of REDD+. However, in the Brazilian Amazon, commodity production (soya, beef, sugarcane) has an elevated opportunity cost due to the high prices and increasing demand of the products as well as the additional rents available from timber generated by land clearing. As Wunder (2007) has demonstrated, if the undesired land use is already privately more profitable than the in accordance with REDD+ , PES is unlikely to encourage a shift.

Given that the drivers of deforestation are often part of the dynamics of illegal expansion of the agricultural frontier (Margulis 2003, Börner et al. 2011), they can be better addressed through strategies that hold the productive chain accountable for illegal activities, using penalties, sanctions and restrictions on credit. However, if the drivers appear to be addressed at the output level, a more complex picture presents itself.

According to the NPCC, an analysis of the land market showed that the expansion of cattle ranching into the Amazon had become increasingly difficult by the time of their report. The NPCC suggests that this could be an effect of the Federal Decree nº 6.321/2007 (Brasil 2008), a policy that set new rules for rural credit access in order to prevent public funds from financing activities that cause illegal logging. The policy also holds supply chain actors accountable in case they acquire, broker, transport or market products from illegal logging.

Although this case illustrates the strength of such regulatory instrument, it is not the full picture. The agricultural sector reacted to the implementation of the Federal Decree nº 6.321/2007 by lobbying for the modification of the Forest Code (Federal Law nº 4.771/1965) (Ganem et al. 2009). Following this, a new law proposal was made by the Chamber of Deputies. Among many modifications, the new law promotes the regulation of areas that have been illegally converted for productive use before July 2008, weakening the effect of the Federal Decree. While around 80% of the Brazilian population is against the new law (Datafolha

2011), the proposal was supported by 87% of the Chamber. This case can be taken as an emblem of the political vulnerabilities of regulatory policies in Brazil.

In the context of Brazilian Amazon, economic incentives don't seem to be enough to deal with the deforestation dynamics. REDD+ will require other tools that can regulate agricultural activities and enforce existing forest laws. However, for such a policy mix to be effective, deeply rooted governance failures will need to be wrestled with.

4. Analysis of Zambian policies

Zambia is one of the most urbanized countries in the Southern African region, with a growing population. With a surface area of 752 614km^2 and a total population of about 13 million people, Zambia's population growth rate is estimated to be 3.1% (Index Mundi 2011). This means the pressure on land as resource for 70% of the total population has been equally rising. Agricultural activities have increased to respond to the nutritional needs of the growing population. Consequently, deforestation has been occurring, impacting on the availability of carbon stocks in the country. According to Chunduma (2009), infrastructure development, agricultural conversion, forests product extraction, and natural events constitute direct drivers of deforestation in Zambia.

In 1992, the government embarked on policy reforms in the agriculture sector, which were part of the overall economic reforms pursued under the Structural Adjustment Program. The main policy thrust of the reforms was liberalization of the agriculture sector and promotion of private sector participation in production, marketing, input and supply, processing, and credit provision (National Agricultural Policy 2004). The agricultural policies however, have to contend with the climate change realities to deliver on their promises. According to the NAPA Report (2007), Zambia has been ravaged by droughts and floods and in recent decades the frequency and severity of these climatic hazards has increased. In the last seven years of this decade Zambia has had to endure droughts in the rainy seasons of 2000/01, 2001/02 and 2004/05, while floods have occurred in 2005/06 and 2006/07. The impacts of these droughts/floods have included widespread crop failure/loss, outbreaks of human and animal diseases, dislocation of human populations and destruction of property and infrastructure.

To survive, more food has to be produced, making agriculture one of the significant drivers of deforestation in Zambia (UN-REDD Program NPD, 2010). The NAP vision is "to promote development of an efficient, competitive and sustainable agricultural sector, which assures food security and increased income." Depending on the strategies and the actual implementation for the vision, there are opportunities in favor of a REDD+ strategy for Zambia through its emphasis on irrigation, conservation farming, afforestation and agroforestry. However, its support for large scale farming and commercial land expansion is a threat to a standalone REDD+ strategy.

Table 2 shows the agricultural policies that have relevance to climate change. In line with the vision of NAP (2004), most of the policies in the table are economic instruments, followed by regulatory ones. The policies also have a recognizable informative and education and research role in the sector. Some of the agricultural policies can directly or indirectly help combat the recognized drivers of deforestation in the agriculture sector, most notably subsistence agriculture. About 54% of the agricultural policies with relevance to climate change have the capacity to enhance the efforts for afforestation as well as the sustainable use of land.

The National Adaptation Program of Action on Climate Change was drafted in 2007 with the goal to communicate priority activities to address Zambia's immediate needs for adapting to the impacts of climate change to the international community. Its objectives were to serve as a roadmap for the country to develop adaptation strategies to the identified adverse impacts of climate change; contribute to the national objectives of poverty reduction through sustained economic growth, employment creation and enhancement of food security as stated in FNDP and other policy documents; contribute to the achievement of the Millennium Development Goals (MDGs); raise public awareness of the urgency to adapt to adverse effects of extreme weather events; and build capacity to address vulnerabilities to climate change and climate variability (NAPA 2007). NAPA recognized the agricultural policies shown in table 2 as policies in the agriculture sector with positive impacts on the effects of climate change.

In line with the vision of NAP (2004) to promote the development of an efficient, competitive and sustainable agricultural sector (which meant to ensure food security and increased income), the agricultural policies were drafted with the goal to increase yields, promote environmentally sustainable practices and expand agricultural land. This is consistent with the about 91% of the agricultural policies in the NAPA being economic instruments. Through these economic instruments, the government of Zambia has put programs such as the Farmer Support Program (FSP) in place, and established the Food Reserve Agency (FRA) to deliver on the promises of the agricultural policies.

Table 2. Output analysis of agriculture policies in the NAPA.

	Policy	Main focus	Instrument	Drivers of deforestation				
				P	S	R	C	L
1.	National Agricultural Policy, 2004	To develop an efficient, competitive and sustainable agricultural sector for food security and increased income.	Economic, Regulatory				x	
2.	Crops and Soils Research	To develop technologies for increased and sustainable agricultural production and high quality, appropriate, cost effective and efficient service to farmers.	Economic , Education, Research		x	x	x	x
3.	Land Husbandry Policy	For improved and sustainable productivity of farms and agricultural lands.	Economic	x	x	x	x	x
4.	Farm Power and Mechanization Policy	To increase agricultural production through use of appropriate farm machinery and equipment, appropriate tillage techniques, farm structures, crop storage, processing and packaging techniques suitable for small-scale farmers.	Economic, Regulatory, Informational, Education, Research	x		x	x	x
5.	Livestock policy	For productive efficiency of the livestock sector in a sustainable manner and support to marketing of both livestock and livestock products to contribute to food security and income.	Economic, Regulatory, Informational, Education, Research		x		x	
6.	Fisheries Policy	For fish production and sustainable utilization of fish resources, to contribute to the economy through the generation of employment, income and improved availability of fish.	Economic, Regulatory Education, Research, Cooperation					
7.	National Action Plan for Combating Desertification, 2002	For sustainable environmental management through the control of land degradation, contributing to poverty reduction, food self sufficiency, & economic growth	Economic, Regulatory, Informational Cooperation	x	x		x	x
8.	Poverty Reduction Strategic Paper, 2004	To make agriculture a leading sector to ensure food security, reduce poverty levels	Economic, Education, Research					
9.	Fertiliser Support Program, 2002	For household and national food security, incomes, and access to agricultural inputs by small farmer households.	Economic Cooperation		x			
10.	Irrigation Policy and Strategy, 2004	For a well-regulated & profitable irrigation sector, attractive to both private investors and the country's partners.	Economic, Regulatory					x
11.	Decentralization Policy, 2002	For a decentralized & democratically elected system of governance - open, predictable & transparent policy making & implementation processes, effective community participation in decision making.	Regulatory, Informational Cooperation	x	x	x	x	x

P: plantation (exotics/biofuel); S: subsistence agriculture; R: resettlement schemes; C: cash cropping; L: potential capacity for reforestation and or sustainable use of land.

Through FSP the government has been subsidizing farm inputs so that poor subsistence farmers can have access to agricultural inputs. Through FRA farmers have access to ready markets for their produce. Thus, farmers have been encouraged to expand their farms and use artificial fertilizers notwithstanding their contribution to GHGs emissions.

Building on the agricultural policies as economic instruments to draft a meaningful REDD+ strategy in Zambia will require a REDD+ strategy which will compete favorably with the returns and benefits that ensue from agriculture. Forests have economic, cultural and social values for which people must be compensated for avoiding deforestation on their own land. In this sense, the financial mechanism to incentivize the protection of forests and avoid land use change should outdo interests to increasingly convert forest into agricultural land. The potential capacity for sustainable land use and reforestation needs more explicit emphasis in the agricultural policies. At the same time, it must promote the economic value of land and forests to the owners of the land. The link between the focus of the agricultural policies and the drivers of deforestation needs to be strengthened to ensure sustainable use of land and reforestation.

According to Adams (2003), Zambia covers a total landmass of 75 m ha, of which state land comprises only 4.5 m ha (6%), and customary land comprises the rest (93.9%). This type of land tenure in Zambia has implications on investments in REDD+ programs as well as for the structuring of payment regimes for products and services. For a successful REDD+ strategy, there is therefore the need for revised land governance as well as strengthened institutional capacity to facilitate payments of environmental services and products. Given the economic, cultural and social value that people attach to their land and forests, it may be required to quantify the financial value of the services and products according to people's opportunity cost for adopting a REDD+ strategy.

Although the analysis of the actual performance of the agricultural policies has not been the objective of this paper, the analysis above shows that a country like Zambia is challenged to find the appropriate level of policy mix that will continue to economically incentivize farmers without undermining the goals and benefits that a REDD+ strategy promises. Economic incentives and regulation through command and control are feasible through governance and institutional capacity reforms. Policies supporting true devolution of property rights, combined with support to local governance of the resource and the right incentives, could go a long way in supporting more effective outcomes (Kaninnen 2007).

5. Conclusion

The paper has endeavored to explore the national adaptation plans as policy response to climate change in the agricultural sector in Brazil and Zambia. The policies were analyzed on the basis of their aim to address the drivers of deforestation in both countries. In addition, it was analyzed how they can contribute to drafting stand-alone REDD+ strategies.

Recognizing the cross sector and jurisdictional nature of a REDD+ strategy, some of the agricultural policies match well with the proposed REDD+ activities and safeguards. This paper revealed the impacts of the agricultural policies in their current state. In general, however, as economic instruments, the policies have competing interests with those of a REDD+ strategy or do not directly support forest maintenance.

Land tenure and governance will play an important role in the success of a REDD+ strategy. Land policies will have to be re-visited to determine the State's position on REDD+ investment on customary land which is 93.9% (Adams 2003) in Zambia, and reverse the prevailing land grabbing in Brazil. Mechanisms of payment of environmental services will have to be made clear to land owners so as not to leave room for corrupt practices. Additionally, other regulatory tools and cooperation instruments, applied in a well governed environment, will be indispensable to balance the competing interests.

Drafting REDD+ strategies in Brazil and Zambia requires the recognition of the economic function of agriculture for the people, governance structures as well as institutional capacities in the two countries. Thus, there is need for policy makers to find the appropriate regulatory and economically sound policy mix, without compromising the goals of a REDD+ strategy and those of the agricultural sector.

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Appendix

Workshop program

Wednesday, 30.11.2011 Arrival		
All day	Arrival of participants	
18:00 – 20:00	Internal meeting of Organization Panel (C Ham, T Seifert, L Fehrmann, C Kleinn)	
Thursday, 1.12.2011 DAY ONE		
9:00 – 10:00	Workshop Opening	Opening Address (tbc): *Mrs Janine Heynes* (Embassy of the Federal Republic of Germany Economic and Environ-mental Affairs, South Africa) Introduction of participants
10:00 – 10:30	Coffee break	
		Moderator: Hanns Höfle
10:30 – 11:00	Seminar paper	(How) can silviculture contribute to carbon sequestration? *Achim Dohrenbusch*
11:00 – 11:30	Seminar paper	Forest monitoring in climate change research and policy *Christoph Kleinn, Lutz Fehrmann, Alexander Knohl*
11:30 – 12:00	Seminar paper	Introduction to South African forestry and forest research *Thomas Seifert, Cori Ham*
12:00 – 13:30	Lunch break	
		Moderator: Marco Gonzales
13:30 - 13:50	Seminar paper	Gunung Walat Educational Forest: from Bare Land to Forest Stand *Yusuf Sudo Hadi*
13:50 – 14:10	Seminar paper	Technical framework of plantation management towards multi-functional service development *Yuanchang LU, Xiangdong LEI, Xian-zhao LIU, Jinghui MENG, Tingting LI*
14:10 – 14:30	Seminar paper	Forests and climate change: Research and policy issues in India *Sharad Negi*
14:30 – 14:50	Seminar paper	Droughts and its effect on Fire frequency in the Southern Cape region of South Africa *Hendri Jooste, Benedict Odhiambo*
14:50 – 15:20	Coffee break	

Thursday, 1.12.2011 DAY ONE		
		Moderator: Marco Gonzales
15:20 – 15:40	Seminar paper	Reducing emissions from deforestation and forest degradation in changing climate conditions: the potential and challenges for Mozambique *Almeida Sitoe, Rosta Mate, Benard Guedes*
15:40 – 16:00	Seminar paper	A multidisciplinary approach for valuing dry land forests in the context of REDD as a public good *Mesfin Tilahun, Erik Mathijs, Bart Muys*
16:00 – 16:20	Seminar paper	Forest Monitoring for REDD+: challenges in mapping forest carbon *Philip Mundhenk*
16:20 – 16:40	Seminar paper	South African policy aspects: Gearing up for Climate Change *Ralston Hans, Jeanne Roux*
16:40	Wrap-up	*Alexander Knohl*

Friday 2.12.2011 DAY TWO		
		Moderator: Yusuf Hadi
9:00 - 9:30	Seminar paper	Are there lessons to be learned from forestry in Germany? *Hanns Höfle*
9:30 - 9:50	Seminar paper	Forest fires threaten deforestation reductions of Mexican forest *Marco Gonzales*
9:50 - 10:10	Seminar paper	The role of tropical forests to face climate change. Cases of study from Colombia and Ecuador. *Juan Carlos Camargo, Bolier Torres*
10:10 - 10:30	Seminar paper	Exploratory analysis of sustainability in the reforestation program of the Project of Adaptation to the Rapid Glacier Retreat in the Tropical Andes (PRAA) in the Shullcas sub basin, Mantaro watershed, Peru *Natalia Reategui*
10:30 – 11:00	Coffee break	

Friday 2.12.2011 DAY TWO		
		Moderator: Yusuf Hadi
11:00 – 11:20	Seminar paper	Modeling global data of climate and vegetation to a local scale; the case of Costa Rica, Central America *Mauricio Vega*
11:20 - 11:40	Seminar paper	Promoting Mountain Forest Conservation in the Climate Change Context for Eco-system Services Provision at the Lowlands: Experience from Nepal and Tanzania *Ibrahim Mwkiru, Suman Ghimire*
11:40 – 12:00	Seminar paper	Community based forest enterprises: a potential strategy for climate change mitigation and adaptation *Emmerson Chivhenge, Shambhu Charmakar*
12:00 – 12:20	Seminar paper	Effect of income from non-timber forest products on rural poverty and income inequality: a case study of rural households in dry woodland areas of Tigray, Ethiopia *Amir Mohammed, Mesfin Tilahun, Erik Mathijs, Bart Muys, Atsede Gidey*
12:20 – 14:00	Lunch break	
		Moderator: Sharad Negi
14:00 – 14:20	Seminar paper	Opportunities and challenges for tree crop integration in REDD+: Ghana and Colombia *Maria Montes, Abdulai Issaka*
14:20 – 14:40	Seminar paper	Setting the national forest-climate change agenda: perspective from Uganda *Gilbert Wathum*
14:40 – 15:00	Seminar paper	When there is no enough milk and meat: Dryforests as alternative livelihood for climate change adaptation of the vulnerable pastoral and agro-pastoral communities in arid Ethiopia. *Adefires Worku, Jürgen Pretzsch, Habtemariam Kassa*
15:00 – 15:20	Seminar paper	A review on opportunities and constraints of A/R-CDM Projects in developing countries *Imani Kikoti, Phyu Phyu Lwin*
15:20 – 15:50	Coffee break	

Friday 2.12.2011 DAY TWO		
		Moderator: Sharad Negi
15:50 – 16:10	Seminar paper	Climate Change Response in the Forestry Sector-Kenya's Experience *Rose Akombo*
16:10 – 16:30	Seminar paper	"Assisted migration - epoch making idea or human haughtiness *Meike Piepenschneider*
16:30 – 16:50	Seminar paper	Risk mapping for forestry: The ICFR perspective *Ilaria Germishuizen (ICFR)*
16:50 – 17:10	Seminar paper	REDD+ Strategy beyond the Forestry Sector: Analysis of the Agricultural Policies and their Impacts on the Drivers of Deforestation in Brazil and Zambia *Priscila M. R. Franco de Oliveira, Andrew Chilombo*
17:10	Wrap-up	*Christoph Kleinn*
Saturday, 3.12.2011 DAY THREE		
07:00 – 19:30	Field trip (see also information at the end of the Program)	
07:00 – 12:30	Visit to Tala game reserve and to forest areas	
12:30 – 14:00	Lunch break	
14:00 – 19:30	Visit to Howick Waterfall	
Sunday 4.12.2011 DAY FOUR		
06:00	Departure from Hotel	
08:00	Photo session	
06:00 – 22:00	FD5	Participation at Forest Day 5 For info on FD5 and venue, please see at the end of this Program. Transport arrangements (pick-up times and places) will be announced during the workshop !!

Monday, 5.12.2011 DAY FIVE		
		Moderator: Achim Dohrenbusch
09:00 – 10:00	Workshop	Wrap-up of FD5 impressions
10:00 – 10:30	Coffee break	
10:30 – 12:00	Workshop	Design of the structure of the proceedings volume and assignation of tasks (i.e. reports on FD5 and on the entire project)
12:00 – 12:30	Workshop	Introduction to group work
12:30 – 14:00	Lunch break	
14:00 – 17:30	Workshop	Group work on summary papers & minutes of FD5 and on individual full papers
Tuesday, 6.12.2011 DAY SIX		
		Moderator: Alexander Knohl
9:00 – 10:30	Workshop	ctd. Group work on summary papers & minutes of FD5 and on individual full papers
10:30 – 11:00	Coffee break	
11:00 – 12:30	Workshop	ctd. Group work on summary papers & minutes of FD5 and on individual full papers
12:30 – 14:00	Lunch break	
14:00 – 15:00	Workshop	Plenary discussion on progress
15:00 – 15:30	Coffee break	
15:30 – 17:00	Workshop	ctd. Group work on summary papers & minutes of FD5 and on individual full papers
Wednesday, 7.12.2011 DAY SEVEN		
		Moderators: Hanns Höfle and Alexander Knohl
9:00 – 10:00	Workshop	Final discussion on workshop outputs Evaluation and compilation of suggestions
10:00 – 11:00	Workshop	Assignation / verification of responsibilities Verification of deadlines
11:00	Workshop Closing	
11:15	Final coffee session	
Thereafter		Departure of participants

Excursion Schedule

Forestry Field Day, KwaZulu-Natal Midlands

Co-hosted by the Institute for Commercial Forestry Research ICFR, NCT and Sappi

09h00-11h00	Visit to Tala Game Reserve		
FORESTRY VISITS AND PRESENTATIONS			
11h00-11h40	Travel to Baynesfield Estate		
11h40	An overview of the ICFR	Professor Colin Dyer	ICFR
12h10	A Private Grower Perspective of Commercial Forestry in South Africa – a view from NCT	Rob Thompson	NCT Forestry
12h40	LUNCH at Baynesfield Estate		
13h30-14h00	Travel to Grassland field stop (at Baynesfield)		
14h00	An overview of Grassland Conservation and Management in Plantation Forestry in South Africa	Steve Germishuizen	FSA
14h30-15h15	Travel to Sappi, Tweedie		
15h15	A Corporate Grower Perspective of Commercial Forestry in South Africa – a view from Sappi	Giovanni Sale	Sappi
15h45-16h00	Travel to Howick Falls		
16h00	Visit at the Howick Falls, Craft Market & Curio Shops		
17h00	End of Field Day		

FOREST DAY 5

Shaping the global agenda for forests and climate change

CPF Collaborative Partnership on Forests | agriculture, forestry & fisheries — Department: Agriculture, Forestry and Fisheries, REPUBLIC OF SOUTH AFRICA

Sunday, 4 December 2011 | Olive Convention Centre, Durban, South Africa | Coinciding with the UNFCCC COP 17

07.00-09.00	**Registration**				
09.00-10.30	**Opening Plenary**				Poster and Exhibition
10.30-11.00	Break				
11.00-12.30	**Parallel Discussion Forums 1:** How is REDD+ unfolding on the ground? An exploration of the social, political, and biophysical issues				
	Exploring Reference Levels and Monitoring for REDD+: Early country pilot activities	Biodiversity safeguards in REDD+	*Landscape approaches:* The place of agroforestry, afforestation and reforestation in REDD+		
12.30-13.30	Lunch				
13.30-14.30	**Issues Marketplace**				
14.30-14.45	Break/Networking				
14.45-15.30	Global updates on forests and climate change				
15.30-16.00	Break				
16.00-17.30	**Parallel Discussion Forums 2:** *Landscape approaches:* Change and adaptation in African drylands: reversing deforestation while contributing to food security				
	Financing opportunities and issues for mitigation and adaptation (focus on private sector)	Social safeguards: pro-tecting the rights and inter-ests of Indigenous Peoples and forest-dependent communities in REDD+	Addressing gender considerations in climate change adaptation and REDD+ efforts	Forests and the Rio+20 Conference	
17.30-18.00	Break				
18.00-18.45	**Closing plenary**				
18.45-21.00	**Cocktail reception**				

Workshop participants at the Ascot Conference Center, Pietermaritzburg.

Standing from left to right: Mrs. Pricila de Morais Rego Franco de Oliveira (Brazil/Freiburg), Prof. Dr Christoph Kleinn (Germany), Mrs. Intania Ekanasty (Indonesia), Mrs. Esi Fajriani (Indonesia), Mrs Nathalia Rategui (Peru/Dresden), Mr. Shambu Charmakar (Nepal/Göttingen), Mrs. Atsede Alemayehu (Ethiopia), Mr. Bolier Torres (Ecuador), Prof. Dr. Juan Carlos Camargo (Colombia), Mr. Andrew Chilombo (Zambia/ Freiburg), Prof. Dr. Yusuf Sudo Hadi (Indonesia), Mr Gilbert Wathum (Uganda), Prof. Dr Ben du Toit (South Africa), Mrs. Rose Akombo (Kenia), holding the banner left: Mrs. Phyu Phyu Lwin (Myanmar/Göttingen), Mr. Hendri Jooste (South Africa), Mr. Adefires Gizaw (Ethiopia), Mr. Amir Mohammed Yimer (Ethiopia), Mr. Ibrahim Mkwiru (Tanzania/Bonn), Mr. Suman Ghimire (Nepal/Bonn), Prof. Dr Knohl Alexander (Germany), Prof. Dr. Achim Dohrenbusch (Germany), Mr. Phillip Mundhenk (Germany), Mrs. Jeanne Roux (South Africa), Mr. Ralston Hans, Prof. Dr. Sharad Singh Negi (India), holding the banner right: Mrs. Meike Piepenschneider (Germany), Mr. Emmerson Chivhenge (Zimbabwe/Göttingen), Prof. Dr. Hanns Höfle (Germany), Mr. Mauricio Vega-Araya (Costa Rica), Dr. Hans Fuchs (Germany), Mr. Imani Kikoti (Tanzania/Göttingen), Mrs. Tingting Li (China), Mr. Issaka Abdulai (Ghana/Göttingen), Mrs. Maria Montes Arenas (Colombia/Göttingen), Mr. Cori Ham (South Africa), Prof. Dr. Yuanchang Lu (China).

Front row (kneeing) from left to right: Prof. Dr Almeida Sitoe (Mozambique), Prof Dr. Thomas Seifert (South Africa), Mr. Mesfin Gelaye (Ethiopia), Mr. Benedict Odhiambo (South Afica), Dr. Lutz Fehrmann (Germany).

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