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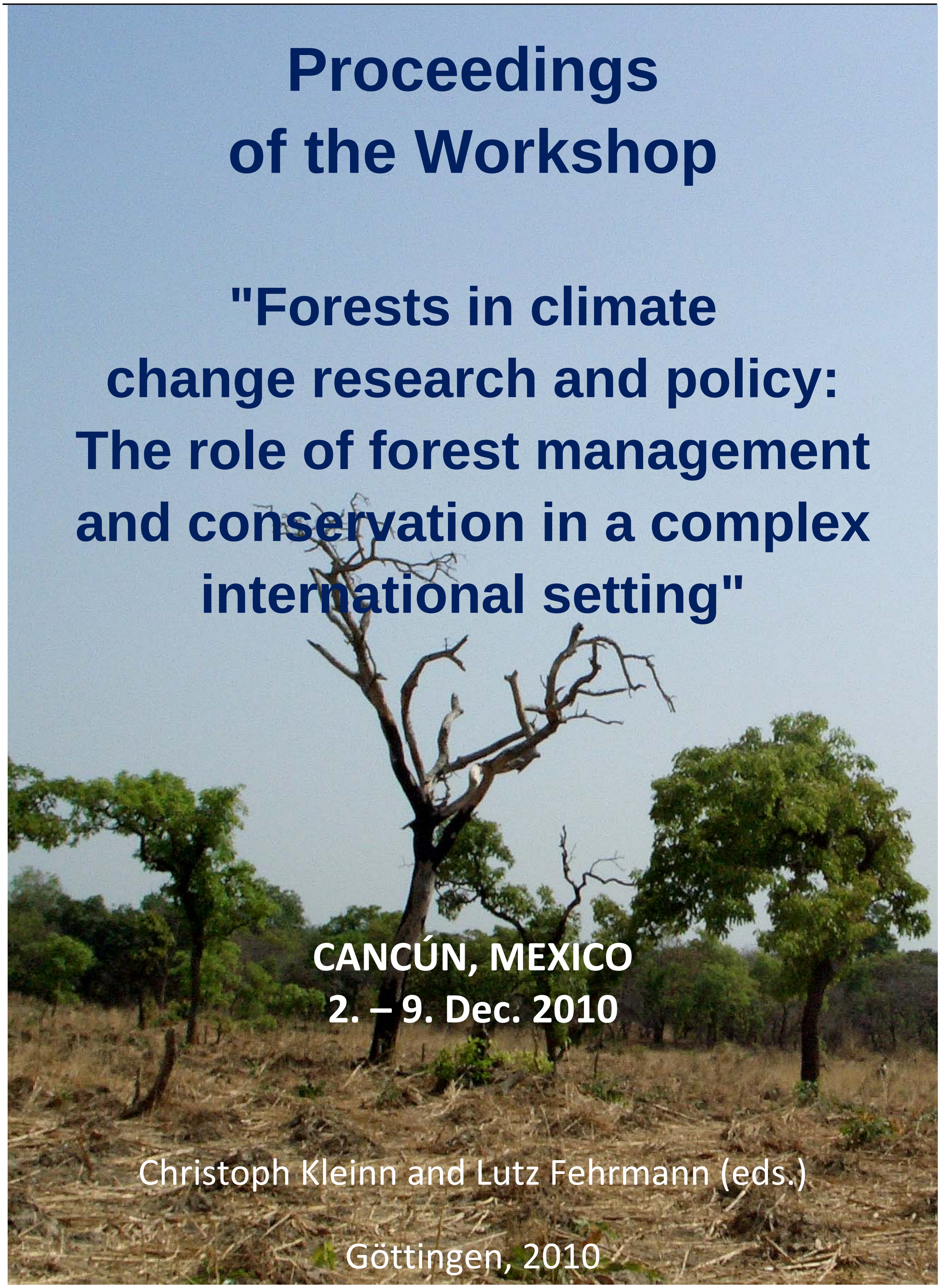

Proceedings of the Workshop

"Forests in climate change research and policy: The role of forest management and conservation in a complex international setting"

CANCÚN, MEXICO
2. – 9. Dec. 2010

Christoph Kleinn and Lutz Fehrmann (eds.)

Göttingen, 2010

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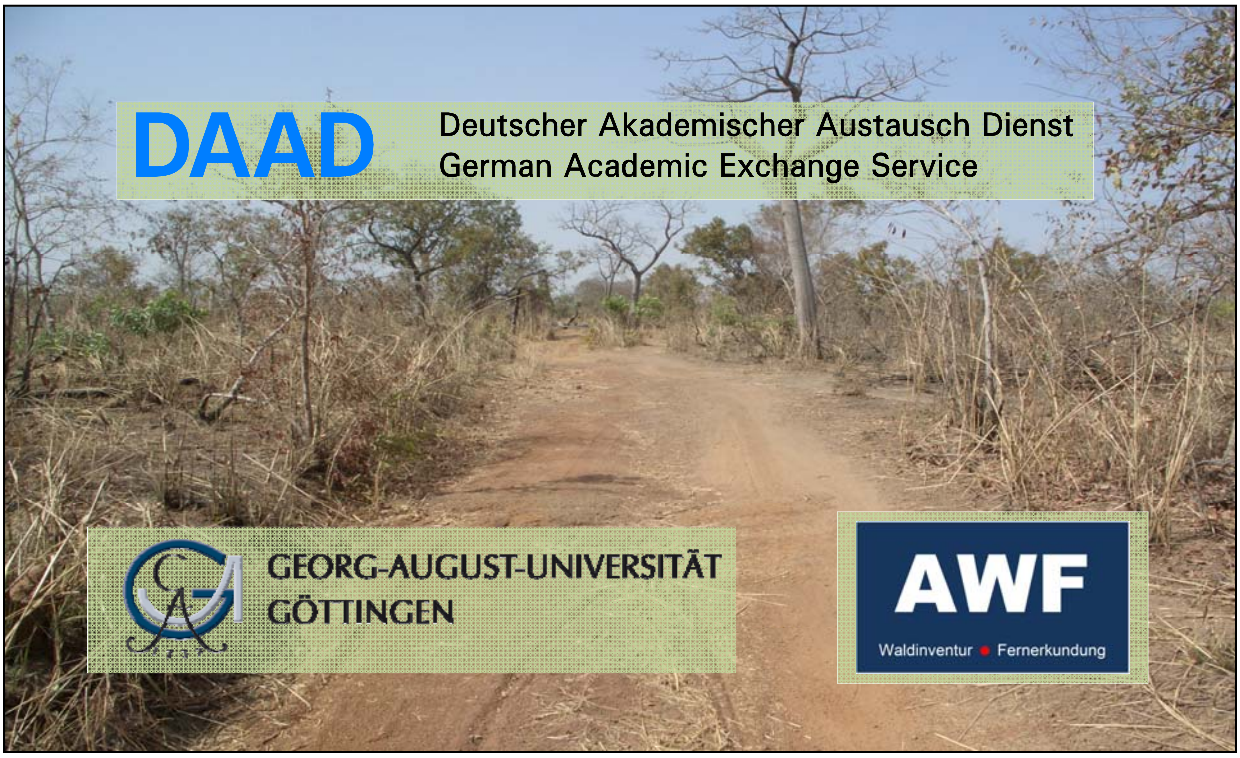
Burckhardt-Institut,Abteilung Waldinventur und Fernerkundung
Fakultät für Forstwissenschaften und Waldökologie
Georg-August-Universität Göttingen
Göttingen, 2010



Preface

Forests and any other trees outside the forest play a relevant role in the global carbon cycle. Deforestation contributes to about 20% to global greenhouse gas emissions - more than the whole transport sector. At the same time, forests house the largest terrestrial biodiversity, contribute to water and soil conservation, offer space for recreation in many industrialized countries and are essential elements for rural livelihoods in many developing countries. Protection and sustainable management of forests has, therefore, more and more become a global issue. And global conventions are in place that do also make reference to forests and their management, including the UN-FCCC, the UN-CBD and the UN-CCD.

Along the annual UN-FCCC Conference of the Parties, CIFOR organizes since COP13 in Bali (2007) an international conference, the “Forest Day”. This year, in 2010, with the generous support from the German Academic Exchange Service DAAD, the Faculty of Forest Sciences and Forest Ecology at the Georg-August-Universität Göttingen had for the first time the opportunity to organize a Workshop along COP16 in Cancún to enhance the knowledge of students from the Course “Tropical and International Forestry” (TIF) in the field of “Forests and Climate” and to facilitate their access Forest Day 4 and their understanding of the complex discussion process on REDD. We were also able to invite PhD students who supported the TIF students in preparing their papers and presentations, and we could also invite professors and students from our partner universities in Chile, Costa Rica, Colombia and Mexico.

We believe that this workshop and the visit to Forest Day 4 was an unforgettable experience for all participants, both in scientific-technical terms and also in terms of international networking.

Organization and implementation 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 helpfulness and efficient explanation of many important bureaucratic details. We are grateful to MSc Antje Henkelmann for assisting in many organizational matters and to BSc Alina Kleinn for editorial support to finalizing this proceedings volume. MSc Christoph Fischer edited the workshop programme, MSc Philipp Beckschäfer implemented successfully the preparatory video-conferences among all partners and Dr. Wibke Himmelsbach and Prof. Marco Gonzalez from the Universidad Autónoma de Nuevo León UANL in Monterrey did the local organization of the workshop in Cancún which included a lot of logistics – and which worked out perfectly. Great thanks to all of you!

We are very grateful also to the organizing team of Forest Day 4, in particular to Dr. John Colmey and Mr. James Maiden for making it possible that our group of students and lecturers could attend to that international conference which has been a probably lasting experience for all of us.

Not the least do our great thanks go to all participants of this workshop who contributed through their active participation to making this event a success.

We hope that this volume does equally serve as a memory to the workshop and also as a useful reference in scientific-technical issues related to the highly relevant topic “forests and climate”.

Prof. Dr. Christoph Kleinn
Dean, Faculty of Forest Sciences and Forest Ecology
Head, Chair of Forest Inventory and Remote Sensing

Dr. Lutz Fehrmann
Research Associate
Chair of Forest Inventory and Remote Sensing

Göttingen, 29.12.2010

On this volume

This proceedings volume contains the seminar papers as presented at the DAAD funded workshop “Forests in climate change research and policy: The role of forest management and conservation in a complex international setting”. These manuscripts were formatted and language-edited. They did not undergo a scientific review.

For reference, we also include, as Annex, the summary statement of Forest Day 4 which we consider very relevant for the upcoming concretization of the REDD process. Attendance to Forest Day 4 was part of the DAAD funded workshop and the programme of Forest Day 4, a huge one-day conference with more than 1500 participants, is also given in the Annex.

We also include, as Annex, the currently (26.12.2010) available draft version of the Cancún Agreement, one of the successes of COP16, where we cut and pasted those sections that are immediately relevant for forestry.

We hope that this volume does serve as a memory to the workshop for those who participated, and also as a useful reference in issues related to the highly relevant topic “forests and climate”.

Great thanks to all who provided their manuscripts complying with a very thight deadline!

Christoph Kleinn
Lutz Fehrmann **29.12.2010**

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How can silviculture contribute to 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. Additionally the frequencies of forest fires and pest outbreaks have increased, where often forests of high ecological value are concerned. In consequence these forests changed form carbon sink to carbon sources and thus emit extra greenhouse gases. Hence, it is an important challenge for forestry, and accordingly silviculture, 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 to reduce 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 with forest or silvicultural instruments: carbon sequestration through afforestation activities. But to achieve an even carbon balance it will be necessary to bind some 4 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.

How can silviculture contribute to carbon sequestration?

In many fields affecting land use, it has become a frequently asked question how far this sector can make a contribution to reduce greenhouse gases. In the forestry disciplines this is true particularly for silviculture.

Therefore, in the following, it should be discussed whether silvicultural measures can have a significant impact on global carbon sequestration and if so, how a climate-relevant impact is possible. For this it is necessary to outline the meaning of silvicultural activities first.

By definition silviculture is the track of forestry dealing with the development and care of forests.

This contains, in consideration of the usually long-lasting life cycle of forests, in chronological order: the establishment of new forests by sowing or planting as well as subsequent culture maintenance. For care in a broader sense, of course an effective protection against abiotic and biotic antagonists is necessary, a task which will become more and more difficult because of significant changes of the basic ecological conditions. A central task of silvicultural management is to control the competitive relationships in forests.

This concerns in particular the young stands for interspecific competition control when young trees are to be favored to understory vegetation such as herbs and grasses.

During the longest section in the life time of a forest manipulation of intra-specific competition, such as by thinning, is done by the forest managers to optimize the qualitative development of stocks.

When, towards the end of a generally over a one hundred years lasting forest development, an alternation of generations should be initiated and the harvestable forest should be converted into a profitable consecutive forest stand, silviculture management develops sustainable concepts of natural regeneration of forests.How is it then that silvicultural measures can have a positive effect on the global carbon issue?

Locally or regionally already, the choice of tree species, a major component of forest management, offers substantial opportunities through the use of powerful, i.e. very productive tree species, to influence carbon sequestration of forests.

But it needs to be kept in mind that highly productive species will meet the claim of a high carbon sequestration if they are adapted to each location.

This adjustment relates to both the climatic conditions as well as soil science.

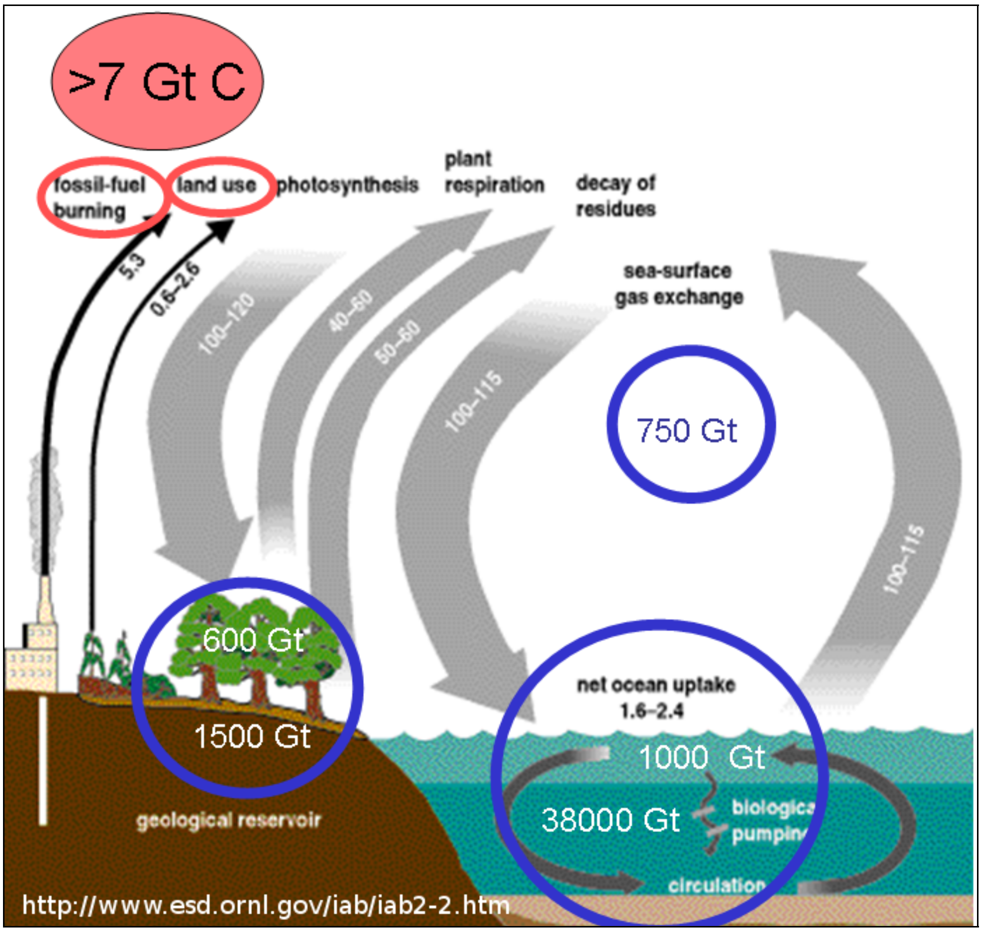

Figure 1: Scheme of the natural carbon cycle

Let's first have a look at the climate problem we try to influence by silvicultural means. The so-called greenhouse effect is caused by greenhouse gases, carbon dioxide, which is one of them, remains by far the highest share of the global warming however. Therefore it is important to consider the global carbon cycle (Fig. 1). 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 these huge amounts of carbon stored in the water, only a very small part is located in the superficial layers and thus has the possibility to commit gas exchange 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 is increasing, the balance of carbon uptake and release can become imbalanced. However, during 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 to the mentioned large flows, are comparatively small disturbances of the carbon cycle, at a magnitude of at least 7Gt/year.

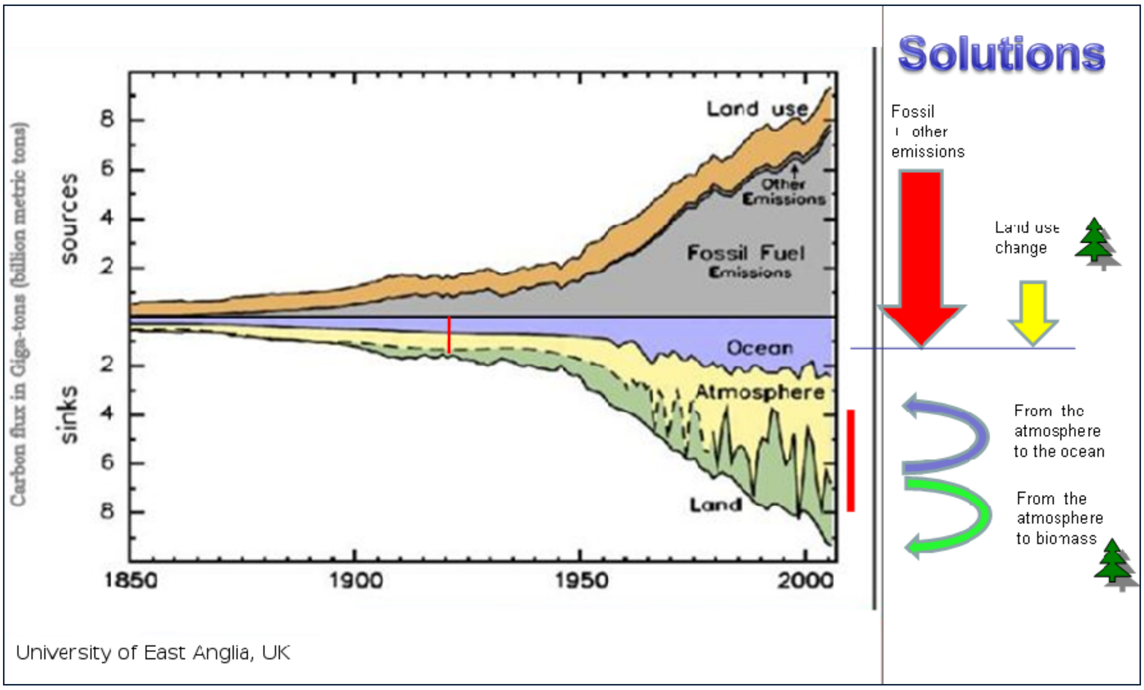

Figure 2: Quantification of the cumulative human perturbation of the global carbon cycle from 1850 through to 2006

Such forwarded disorders, leading to a unilaterally increasing of CO_2 in the atmosphere, can derive of natural origins like volcanic eruptions for instance. In recent decades, however, causes which can be held responsible for the increase of CO_2 in the atmosphere are overwhelmingly anthropogenic. 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 (Fig. 2).

From the middle of last century, we observe 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 at 80%. Overall the global carbon cycle, which naturally was in equilibrium, is burdened by an annual amount, currently around 7 Gt additionally. 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.

Which global solutions are possible for this problem? Considering first the possibility that aims to turn the screw on carbon source (discharge side), the most effective measure by far would be the reduction of emission from the combustion of fossil fuels .This without out 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 and pose a direct result of deforestation and degradation. At this point it is necessary to analyze the role of forestry and silviculture.

Possible solutions are also conceivable on the receiving side (carbon sink). Thus, 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 these problems are quite possible and are required from many sides.

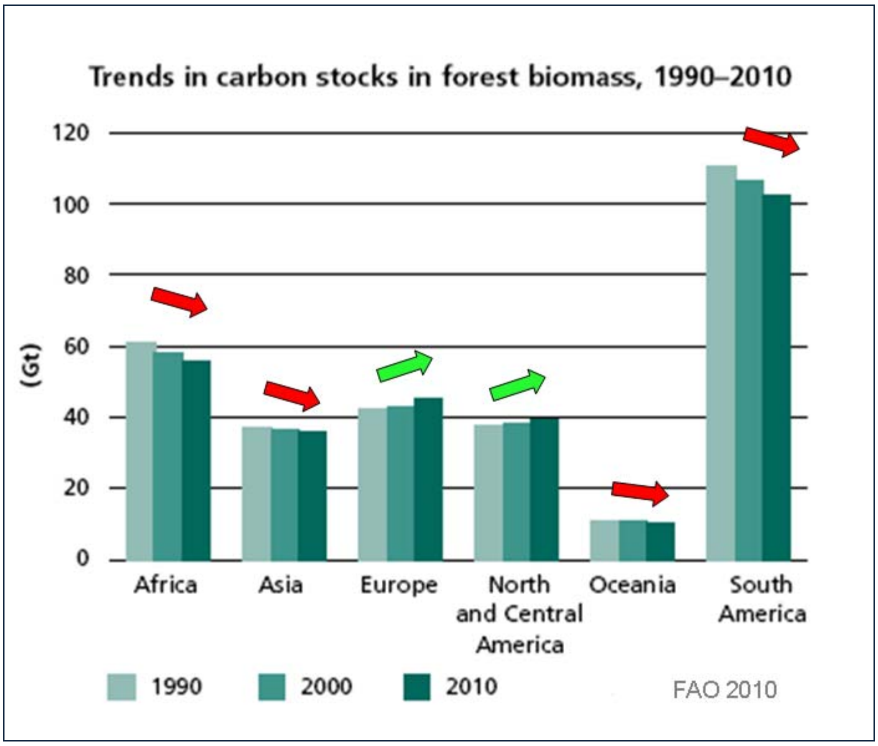

Figure 3: Carbon stock in forest living biomass by region

In summary, there are two main prospects of forestal activities to reduce 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)

Let's have a closer look at the first opportunity, to achieve a relief at the side of the causer (output side): again, here there are at least two possible alternatives:

(a) no direct forest destruction (no shifting cultivation and deforestation and other degradation processes)

(b) active conservation of forests (mainly improved forest protection)

In this case direct forest destruction means a conscious, deliberate deforestation, often followed by degradation. Although the world's deforestation rates have slowed down, there are still dramatic developments observable in many regions of the world (Fig. 3). Globally, in the past 20 years from 1990 to 2010 carbon stocks stored in wood biomass decreased by 10.4 Gt to an amount of now 289 Gt.

This trend is particularly dramatic in South and Central America, Africa and Asia. Whereas in Europe a significantly increase and in North America a slight upward trend of forest areas can be observed, respectively.

It is getting increasingly difficult for forestry, to conserve intact forests as such.

A worrying example is the boreal forests of Canada, which is amongst the world's largest forest formations. Here it is observed with concern that these forests, which have always been regarded as an effective carbon sink, are now turning into a source.

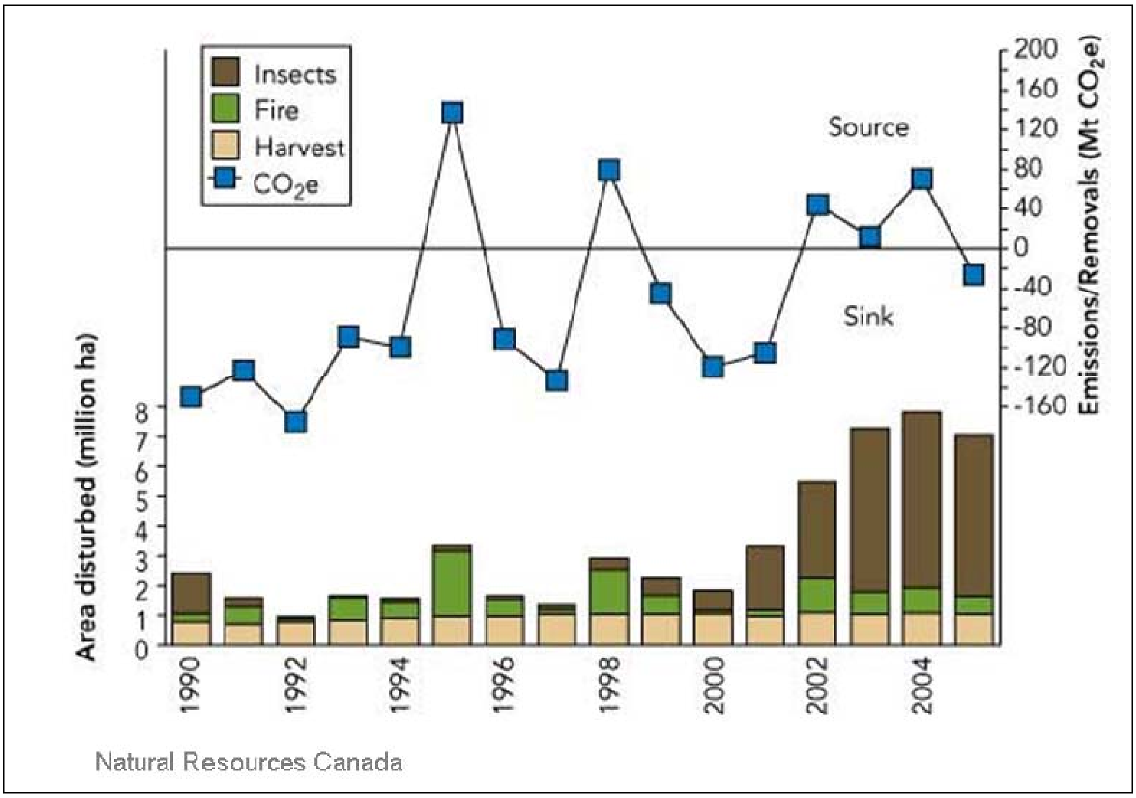

Figure 4: Managed forest sources and sinks of Canadian's Forest 1995-2005

In the 1990s "only" individual forest fires of considerable extent were responsible for the negative carbon balance, which means that carbon emissions were higher than the uptake in the years 1995 and 1998 (Fig. 4).

Since the beginning of this decade in addition to the fire events worse insect outbreaks have occured, which finally turned Canada's forests from a certain sink to an almost permanent carbon source. In only a few years the mountain pine beetle (*Dendroctonus ponderosae*) harmed more than 10 million hectares of Canada's forest area. This equates nearly the entire forest area of Germany.

Obviously the expansion of insect pests is a direct consequence of global warming, which is especially noticeable in the higher latitudes because the significant warming is primarily a phenomenon of temperate zones. The development cycle of insects will be shortened with increasing temperature. For instance, the life cycle of bark beetle *Ips typographus* at 19°C, lasts on average 50 days, from the egg to the instar and pupation to the adult beetles. At 24°C, the whole live cycle only lasts 35 days (Wermelinger and Seifert, 1998). This leads to an increasing number of beetle generations in the vegetation period and the total number of beetles increases disproportionately.

The example of Canada shows that also forests which are not under anthropogenic pressure and are seen as the last intact forest ecosystems globally, are by now threatened by climate change impacts indirectly (missing adaptation) and thus accelerate the global warming in terms of positive feedback.

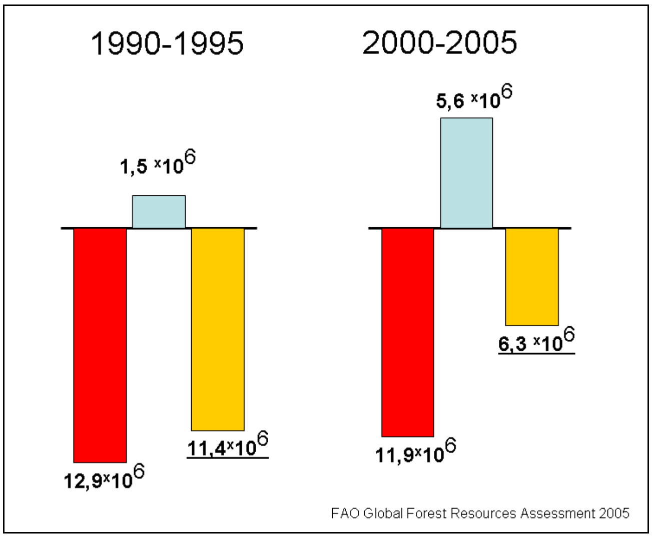

Figure 5: Global annual change of forest area in ha

High hopes are placed in the second major solution strategy with forest or silvicultural instruments: carbon sequestration through afforestation activities.

Indeed, in recent years, some things have taken place: In the first half of the 1990s there was a loss in global forest area by some 13 million hectares, almost 9 times as high as the area that was afforestated in the same period (fig 5). The net forest losses were in fact at 11.4 million hectares.

A decade later, during the period from 2000 to 2005, the loss of forest area of 11.9 million hectares hasn't changed much in comparison to the previous decade but afforestation activities, however, increased significantly. With 5.6 million hectares, the area had almost quadrupled and the ratio of destroyed forest area to the newly created one changed from 9:1 in the 1990s to nowadays 2:1.

This almost halved the net annual forest loss by 11.4 million hectares in the 1990s years to 6.4 million hectares in the first half of this decade. On a regional perspective, mainly at the forests of the tropics and subtropics significant losses occur, while depletion in the temperate forest cover is only little or even increases.

The increase in forest area can be distinguished into three categories:

- Afforestation is the establishment of forest plantations in areas not previously in forest.
- Reforestation is the establishment of forests (through planting, seeding or other means) after a temporary loss of the forest cover.

- Natural expansion of forests refers to the expansion of forest through natural succession at previously non-forested lands, usually abandoned farmland.

The largest afforestations by far have been carried out in China, especially in the northwest of the country. Finally the afforestation activities, started in 1970 have resulted in a positive carbon balance, since 30 years. As positive as the balance has developed for a few countries, as critical the expectations have to be when considered on global level. But how realistic are the expectations that are always addressed to the forest management? Is afforestation an actual approach to improve carbon balance or is it possible to compensate the negative carbon balance solely by the increasing forest areas?

Let's have a look at the maximum demand which is expecting that the whole amount of carbon straining the carbon cycle can be compensated only by forest reproduction. This is a particular challenge for forestry

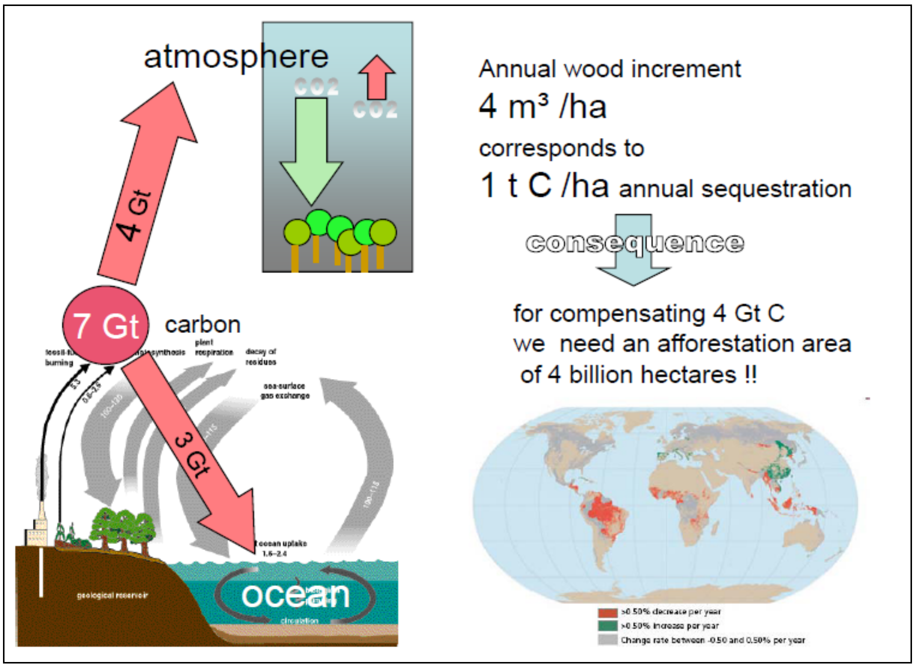

Figure 6: Anthropogenic carbon emission an consequences

As shown in Figure 1, the goal is to bind about 7 billion tons of carbon each year.

At best half of the carbon emissions can be stored in the oceans and at least 4 billion tons remain in the atmosphere (Fig. 6). Assuming a global, average growth potential of only 4 m, which can be committed per year per hectare of newly established forests, this corresponds to an overall tree species average specific weight of 500 kg dry mass /m and an average carbon content of 50 % of each 1 ton of carbon (Of course, under favorable site conditions significantly higher growth rates can be achieved).

Hence, to bind 4 billion tons of carbon, about 4 billion hectares has to be afforestated. This is an area that roughly corresponds to the current forest area of the earth. This shows how unrealistic the implementation of such a claim is.

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 it is rather a political, socio-economic challenge. 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. This refers to both the biotic and abiotic causes of the possible damages to forests. The expectations addressed to the forestry in general and in particular to the 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, a global solution, the forestry sector can not be afford on its own.

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Estimation of carbon emissions from deforestation in South Central Chile during the period of 1993-2007

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Abstract

The change in land-use and deforestation is well known because of its ecological and socioeconomic implications for both land and population. In this present work, we will analyze the change in the land-use's rate in the period of 1993-2007 emphasizing native forest deforestation and balance of carbon stock for the forest cover. Against this background, we elaborated a digital cartography from orthorectified aerial photos, scale 1:1000.000, with a special resolution of 6.25 ha. The analysis of the change of soil was developed through the elaboration of static and dynamic matrices. Later the magnitude in the change of the carbon stock was estimated against changes in the use of forest land via the gain-loss method. For the native forest, an expansion of 7202.3 ha was identified which results out of the use of grasslands and scrubland. In this area, a loss of 29636.1 ha is due to sub-use plantations with an annual deforestation rate of 0.5%. The highest degradation and decrease of the native forest area is equivalent to secondary forests with a total stock of 1794.79 Mt C. The sub-use plantations have increase by 62%, presenting a gain of 24241.96 Mt C. in the stock between the years 1993 and 2007. These results show the tendencies of this region which has evolved from a past of extensive forest cover to present extensive agriculture and strong expansion of exotic plantations. It was not possible to determine the area of degradation of the native forest given the special resolution of base material, which is considered a future challenge for the adequate monitoring of the vegetation resources.

Key words: change in the use of soil, carbon stock, native forest, plantations

1. Introduction

Human settlements and economic-productive activities change land-use according to society's needs, either for the exploitation of natural resources or adaptation to agricultural land (Sanhueza & Azocar 2000). This results in the loss or gain of a type of cover and creates a direct impact on the biotic environment such as land degradation, carbon emissions, and the deterioration of the system's ability to meet human needs (Lambin et al. 2003, Torrejon & Cisternas 2002, Torrejon et al. 2004, Chase et al. 1999).

It is important to quantify temporal and spatial dynamics of the landscape at different scales, local, regional and global, in order to compare patterns of change according to socio-economic pressures in a territory. This relationship produces information about the nature and direction of land-use change. Such knowledge is highly relevant for linking the effects of land-use alterations and modification of the flow of CO_2 in the atmosphere, with implications in altering the climate system (Simpson et al. 1994; Dale 1997).

South Central Chile landscape was modified during the 30's primarily by the expansion of the agricultural frontier at the expense of felling or burning of native vegetation (deforestation) (Lara et al. 2005, Armesto et al. 2010, FAO 2010; Sanhueza & Azocar 2000). Subsequently, the state promoted a policy of reforestation through the Forests Act 1931 with the aim of controlling soil erosion.l It was not until 1974, however, with the Decree Law 701 (grant of forest management) that a new wave of reforestation was encouraged (Pellet et al. 2005; Aguayo et al. 2009).

Biotic systems take carbon emissions and contract the emissions produced by human activities. Reforestation, restoration of degraded areas, and deforestation control are activities that enhance the mitigation of human impacts (Lipper & Cavatassi 2003). In this paper, we study land-use changes in South-Central Chile during the period of 1993-2007 as well as the source of change in order to obtain the deforestation rate and land conversion as well as the balance of carbon stock changes caused by the forest pool.

2. Material & Methods90

2.1. Change in land use

The detection process of land-use change and deforestation was carried out in the period between the years 1993 and 2007. Digital cartography was evaluated for the year 2007, from orthorectified aerial photos, scale 1:1000.000, with a special resolution of 6.25 ha. The resolution was increased to 1 ha for the exotic plantations, and the native species *Araucaria araucana* and *Astrocedrus chilensis*. The photo-interpretation process of homogeneous units (HU) was made through stereoscopy and the software ArcGis 9.3, annexing the information on: type of land-use, type of plant formation, structure, density, specie, and change in the plant cover to each HU interpreted-photo.

The classification of plant formations and the types of land-use was done through the map of land-occupation, COT, (CEPE of Montpellier); adapted to Chile (CONAF et al. 1999). This classification includes nine categories of soil-use: (1) urban and industrials areas, (2) agriculture lands, (3) grasslands and shrublands, (4) forests, (5) wetlands, (6) areas without vegetation, (7) snow and glaciers, (8) bodies of water, (9) unrecognized areas.

2.1.1. Forest Category

The land-use “forest” was subdivided into three subcategories:

- Plantations: artificial establishment of natural or exotic species.
- Native forest: ecosystem constituted by native species that present a height ≥2m and canopy closure ≥25%.
- Mixed Forest: a mix of the last two categories.
  Each HU corresponding to the forest category was described through the cover and structure criteria. The canopy cover was measured using the quarter scale and indirectly pointing out the forest degradation of a same place over time.

(1) Very dense 75-100%
(2) Dense 50-75%
(3) Open 25-50%
(4) Presence <10%

Structure evaluation, it is exclusively used for the native forest subcategory and it is divided into:

- Mature Forest (MF): primary forest originated from the normal forest reproductive cycle.
- Second-growth Forest (SF): second-growth forest originated after a natural disturbance (landslides, storms, fires) or anisotropy (clear cutting, intentional fires/arson, soil-use changes, etc.).

- Mature/ Second-growth Forest (MS): a mix of the last two mentioned
- Krummholz (KA)

After photo-interpretation work, an extensive ground campaign was carried out which allowed allocating and correcting the information of HU attribution by minimizing the error of the cartographic process. This error was measured through the development of a confusion matrix and the Kappa index.

For the corresponding cartography of 1993, the project "Catastro de los recursos vegetacionales del país" (CONAF et al. 1999), XI region, with a resolution of 6.25 ha was used as a base of information.

The land-use change analysis process was carried through the elaboration of static and dynamic matrixes for each soil-use, with emphasis on the corresponding usage of forest and plantation categories. The static matrixes show the surface of each usage in each studied year. From this information, the gain and loss was determined in order to calculate the effective change of each land-use over the studied period (1993-2007). Subsequently, dynamic matrixes were developed that allow obtaining information of the direction of land-use change from one period to the following one (Sandoval 2001).

For the native forest, an annual change rate was estimated based on the formula that incorporates the compound interest rate (Puyravaud 2003).

$$\frac{P = \frac{100}{t_2 - t_1} \ln S_2}{S_1} \quad \mathit{Equation\ 1},$$

where S_1 and S_2 are the surface area (ha), the time t_1 and t_2 respectively, and P the percentage of change per year.

2.2. Change in carbon stock

The study focused on the changes in carbon stock caused by land-use change in the forest category and its degradation.

To estimate the changes in the forested areas between 1993 and 2007, the factor C/ha defined in the national inventory of the CONAF (2009) was applied according to forest type and structure. In this way, we obtained the amount of C set per unit area.

The magnitude in the change of carbon stock was approached to the land-use changes according to the IPCC Chapter 3:

(1) Sites without changes in the land-use: This refers to a change in the classification from one year to another where the surface area apparently does not change for a particular site but its current stratification differs from the previous period (forest degradation)
(2) Sites that changed in usage: carbon stock changes for the sector is estimated as the sum of changes in Forest Land
$$\Delta C_s = \Delta C_{FL} \quad \mathit{Equation\ 2}$$

The change in the carbon stock stored in south central Chile was calculated for the period 1993-2007, through the Gain-Loss method equation proposed in the IPCC standards (2006):

$$\Delta C_s = \Delta C_g - \Delta C_l \quad \mathit{Equation\ 3},$$

where

ΔC_s = Change of carbon storage in the pool in ton/year.
ΔC_g = Annual carbon gain in ton/ha/year.
ΔC_l = Annual carbon loss in ton/ha/year.

The difference in the same pool over a particular period of time is obtained per hectare, in which case it is estimated by:

$$\Delta C = C_{t_2} - C_{t_1} \quad Equation\ 4,$$

where

$\Delta C =$ Annual change of carbon storage in ton/year.

$C_{t_i} =$ Carbon storage in the pool during the period *i*

3. Results & Discussion

3.1. Evaluation of cartographic precision in the detection of land-use change

The reliability of the maps elaborated for detecting modifications in land-use was estimated by calculating the Kappa index. This index calculates the error associated to the assignation of different categories of land-use in the photo-interpreted polygons not visited in the field. A Kappa index of 0.88 was determined with an overall acceptability of 0.96, which provides an adequate level of reliability in the allocation of the different types of land-use.

3.2. Land-use changes

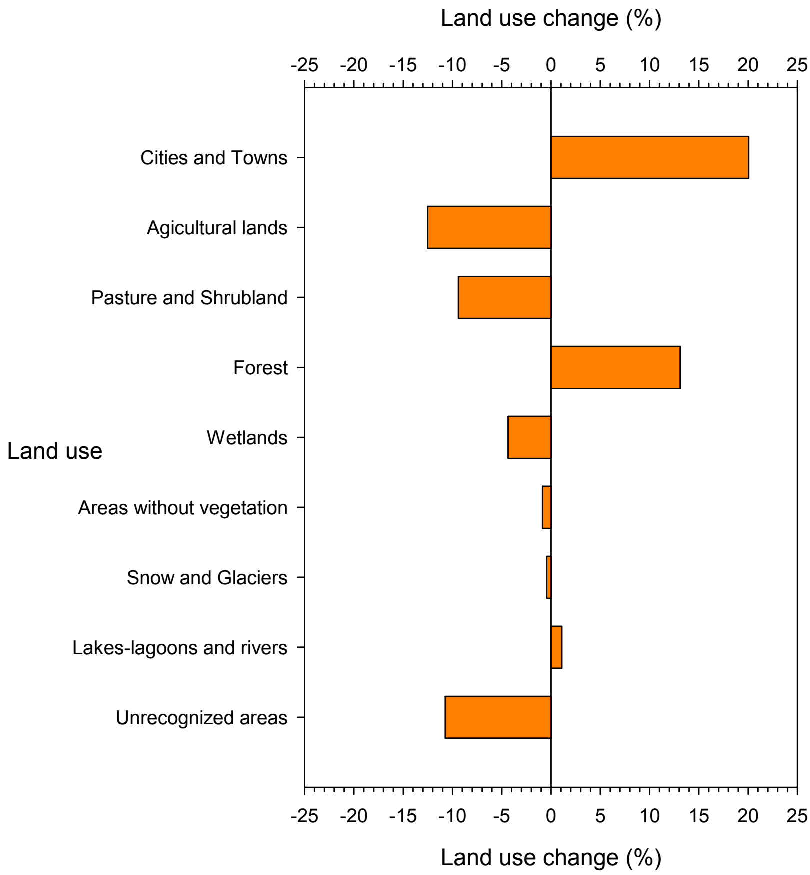
The analysis for each study period shows that the category of land-use corresponding to urban and industrial areas is the one with the largest surface of change (20%) from 1993 to 2007. This urban growth is shown in studies such as the Araucanía region development strategy; in which, an intense migration from the countryside to the city is suggested, reaching a total of 67.7% (INE 2002) and focused primarily in the city of Temuco.

The Forest land-use is still changing in the surface area, increasing by 13% between 1993 and 2007 (Table 1).

The land-uses that reduce their share are mainly agricultural land and unrecognized areas by 12.5 and 10.7% respectively. Agricultural land-use category decreased mainly due to surface transfer to the plantations sub-use category. Other land-uses that decreased are shrublands/grasslands and wetlands with 9% and 4% during the period 1993-2007.

Table 1. Surface area per category of land-use to each studied year (ha, %)

Land use	1993		2007		Change	
	Surface (ha)	(%)	Surface (ha)	(%)	Surface (ha)	(%)
1Cities ad Towns	11409.1	0.4	13696.9	0.4	2287.8	20.1
2 Agricultural lands	932431.8	29.1	815602.2	25.4	-116829.6	-12.5
3 Pasture and Shrubland	675153.9	21.2	611686.5	19.2	-63467.4	-9.4
4 Forest	1369494.3	43.0	1548934.4	48.7	179440.1	13.1
5 Wetlands	27717.4	0.9	26507.3	0.8	-1210.1	-4.4
6 Areas without vegetation	78740.9	2.5	78047.2	2.5	-693.7	-0.9
7 Snow and Glaciers	31032.4	1.0	30896.6	1.0	-135.8	-0.4
8 Lakes- lagoons-Rivers	55405.3	1.7	56018.2	1.8	612.9	1.1
9 Unrecognized Areas	39.1	0.0	34.9	0.0	-4.2	-10.7
Total	3181424.2	100.0	3181424.2	100.0	0.0	0.0



Graphic 1. Percentage of land-use change by category of land-use.

Within the land-use type forest, this information can be broken down into sub-uses: native or natural forests, exotic plantations, mixed forests, and protected areas. Table 2 shows the forest land-use behavior during the period 1993-2007. The plantation sub-use presents the greatest increase in forest participation with an increase of 62% between both periods. This situation is different from the native forests which decrease their representation to 4%. Mixed forests also present a decrease of 5% within the total for forests.

Table 2. Forest land-use surface are for each studied year (ha, %)

Land use	1993		2007		Change	
	Surface (ha)	(%)	Surface (ha)	(%)	Surface (ha)	(%)
4 Forest						
4.1 Exotic Plantations	351330.6	11.0	572184.7	18.0	220854.1	62.9
4.2 Native Forest	977139.6	30.7	937312.3	29.5	-39827.3	-4.1
4.3 Mixed Forest	30538.5	1.0	28951.8	0.9	-1586.7	-5.2
4.4 Protection Areas	10485.6	0.3	10485.6	0.3	0.0	0.0
Total	1369494.3	43.0	1548934.4	48.7	179440.1	13.1

Table 3 presents the native forest category by type of structure and cover. It can be observed that the largest percentage of change corresponds to mature forest/second-growth forest and second-growth forests with a decrease of about 5% in their participation in comparison with the year 1993. The mature forests and Krummholz also present a decrease of 2.9 and 1.2% respectively.

Table 3. Surface for the native forest sub-use for each studied year (ha, %) by structure and types of canopy closure.

Structure of Forest	Canopy cover (%)	Surface (ha) 1993	(%)	Surface (ha) 2007	(%)	Surface change (ha)	(%)
Mature Forest	Very dense	172672.1	17.7	167724.5	17.9	-4947.6	-2.9
	Dense	87831.4	9.0	84788.2	9.0	-3043.2	-3.5
	Open	25788.5	2.6	25427.4	2.7	-361.1	-1.4
Total		286292.0	29.3	277940.1	29.6	-8351.9	-2.9
Second-growth Forest	Very dense	205889.1	21.1	194736.8	20.8	-11152.3	-5.4
	Dense	227837.5	23.3	216541.9	23.1	-11295.6	-5.0
	Open	66999.3	6.9	64212.1	6.9	-2310.4	-3.4
Total		500725.9	51.3	475490.8	50.7	-24758.3	-4.9
Mature/Second-growth Forest	Very dense	52442.6	5.4	49273.6	5.3	-3169.0	-6.0
	Dense	37174.4	3.8	35649.9	3.8	-1524.5	-4.1
	Open	12194.1	1.2	11719.5	1.3	-474.6	-3.9
Total		101811.1	10.4	96643.0	10.3	-5168.1	-5.1
Krummholz	Very dense	41011.8	4.2	40379.3	4.3	-632.5	-1.5
	Dense	34875.1	3.6	34610.7	3.7	-264.4	-0.8
	Open	12423.7	1.2	12248.4	1.3	-175.3	-1.4
Total Structure		88310.6	9.0	87238.4	9.3	-1072.2	-1.2
Total		977139.6	100	937312.3	100.0	-39827.3	-4.1

3.2.1. Direction and Causes of Change

Table 4 provides necessary information to analyze in detail the dynamics of land-use change, quantifying from and to where the various sub-uses of the forest land-use category over time have been redistributed. The main loss of native forest is due to the surface transfer to plantations and shrublands-grasslands with 29636.1 and 16451.1 respectively. The type of native forest structures that possess the biggest transfer to plantations is the second-growth forests with about 25000 ha.

The analysis of the causes of change shows that the clearance for forestry plantation (28.2%) changed from agriculture farming to forestry plantation (25.3%) and harvesting of grown plantation (20.7%) which are the main causes of land-use change in the region of Araucanía, all of which are linked to the forestry production of exotic species (Table 5). It is important to be noted that the loss cause of Native Forest that is unidentified reached 6.2%

Table 6 demonstrates an evolution of the change movements (gains-losses) for the native forest surface area through the studied period. The total surface area gain for this usage is 8256.9 ha, with a loss of 48084 ha, giving a total balance for native forest of 985396.5 ha. It is possible to identify that the main gain in surface area comes from the usage of shrublands and grasslands, and the main loss is due to the plantations sub-use and the usage of shrublands and grasslands.

Table 4. Native forest surface area, for each studied year (ha, %) by structure and types of canopy cover.

Use 1993	Uses 2007													Total 1993 (ha)	(%)
	1.0	2.0	3.0	4.1	4.2				4.3	5.0	6.0	7.0	8.0		
					4.2.1	4.2.2	4.2.3	4.2.4							
4.1 Plantations															
Total Sub0use	68.6	3284.8	9127.4	98935.8	0	487.8	0	0	343.4	0	8.1	0	0.9	112256.8	67.6
4.2 Native Forest															
4.2.1 Mature Forest	0	71.6	5909.4	2307.0	0	153.3	0	0	76.0	0	0	0	0	8517.3	5.1
4.2.2 Second0growth Forest	39.2	662.9	6629.8	25052.7	72.9	0	125.2	0	350.5	0	15.3	0	526.2	33474.7	20.2
4.2.3 Mature/Second0growt	0	103.8	2969.1	2215.5	33.2	99.0	0	0	138.8	0	9.7	0	0	5569.1	3.4
4.2.4 Krummholz	0	0	945.8	60.9	0	65.5	0	0	0	0	0	0	0	1072.2	
Total Sub0use	39.2	838.3	16454.1	29636.1	106.1	317.8	125.2	0	565.3	0	25.0	0	526.2	48633.3	28.6
4.3 Mixed Forest															
Total Sub0use	0	7.6	200.4	4957.9	0	0	0	0	0	0	0	0	0	5165.9	3.1
Total 2007 (ha)	107.8	4130.7	25781.9	133529.8	106.1	805.6	125.2	0	908.7	0	33.1	0	527.1	166056.0	100
(%)	0.06	2.49	15.53	80.41	0.06	0.49	0.08	0	0	0	0.02	0	0.32	100	

Table 5. Surface area of change according to identify causes (ha, %)

Causal Exchange	Surface (ha)	(%)
Natural Mass Growth	20937.2	5.1
Agricultural use	12326.3	3.0
Forest Plantation	116826.4	28.2
Culture change from agricultural to forest plantation	104701.4	25.3
Forest Plantation Harvest	85608.9	20.7
Forest plantation growing	31635.1	7.6
Silvicultural interventions in Native Forest	607.1	0.1
Loss of Native Forest by unidentified causal	25569.4	6.2
Fire and/or Burning	12093.2	2.9
Landslides. Avalanches	25.0	0.0
Floos reservoirs construction	969.2	0.2
Advances dune. Desertification	63.3	0.0
Urban Growth. industrial areas	2587.0	0.6
Total (ha)	413949.5	100.0

Table 6. Evolution of the native forest surface area (ha).

Uses	Total	977139.6
	Gain	Loss
1 Urban and industrial areas	0.0	39.2
2 Agricultural land	362.0	838.3
3 Grasslands and Shrubland	7202.3	16454.1
4 Forests		
4.1 Forest Plantation	487.8	29636.1
4.2 Native Forest		565.3
5 Wetlands	6.5	
6 Areas without vegetation	75.4	25.0
7 Snow and Glaciers	118.7	
8 Lakes- lagoons-Rivers		526.2
9 Unrecognized Areas	4.2	
Subtotal	8256.9	48084.2
Balance	985396.5	937312.3
Within the application	1194.8	

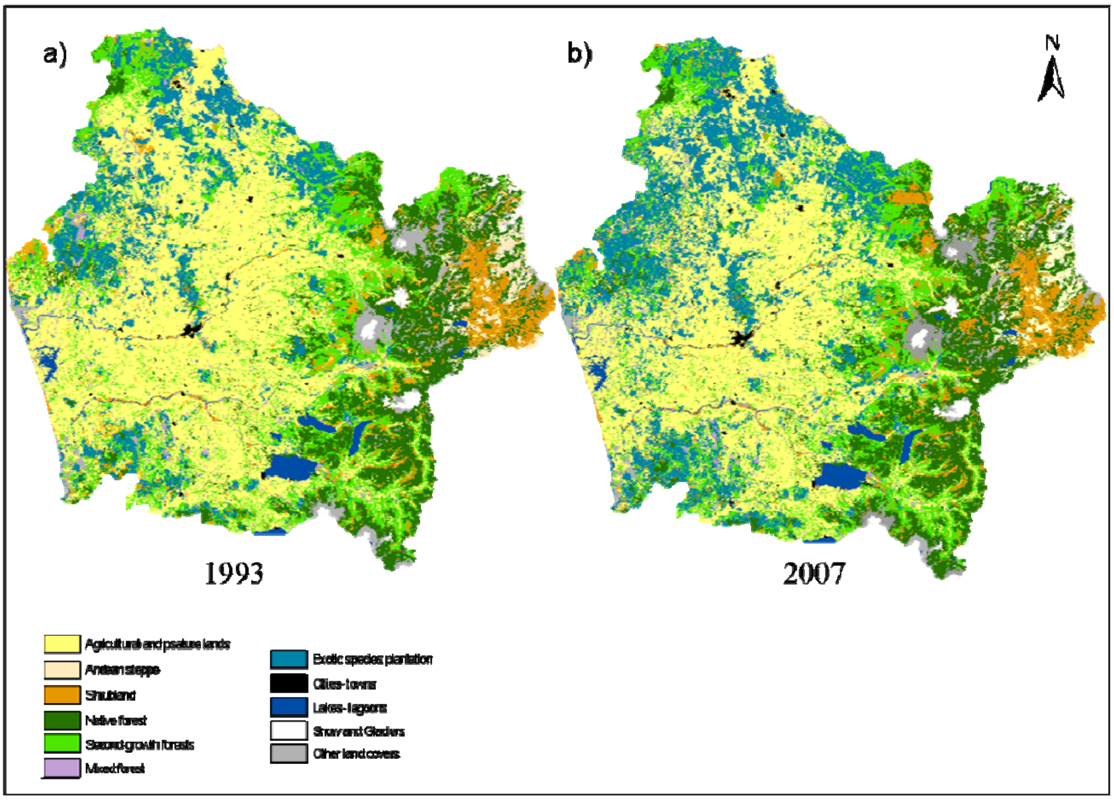
Table 7. Evolution of plantation surface area (ha)

Uses	Total	351330.6
	Gain	Loss
1 Urban ans industrial areas	7.7	68.6
2 Agricultural land	116388.0	3284.8
3 Grasslands and Shrubland	82489.8	9127.4
4 Forests		
4.1 Forest Plantation	29636.1	487.8
4.2 Native Forest	4957.9	343.4
5 Wetlands	390.3	0.0
6 Areas without vegetation	188.6	8.1
7 Snow and Glaciers	0.0	0.0
8 Lakes- lagoons-Rivers	116.7	0.9
9 Unrecognized Areas	0.0	0.0
Subtotal	234175.1	13321.0
Balance	585505.7	572184.7
Within the application	118092.6	

To analyze the situation of the plantations sub-use, in table 7 we can see that the surface area gain is 234175.1 ha and the loss reaches 13321 ha with a total balance of 585505.7 ha. The greatest gains come from agriculture land and shrublands-grasslands categories. It is also important to consider the contribution of the native forest sub-use with about 29636 ha. The losses corresponding to this sub-use are primarily due to the shrublands-grasslands land-use.

3.2.2. Deforestation

Over the period (1993-2007), the annual deforestation rate specifically for second-growth forest and mature second-growth forest structure, corresponding to the native forest sub-use for the region, was 0.5 % according to the compound interest rate formula. In the case of mature forest and Krummholz, the deforestation rate was slightly lower (0.3%). The main geographically concentration of this change was found in the region’s coastal sector (Graphic 2).



Graphic 2. Temporal and spatial variation of land-use types in the Araucanía Region for the years (a) 1993 and (b) 2007.

3.3. Carbon stock changes

3.3.1. Native Forest

The region monitoring was carried out with low spatial resolution images (1:100000) which did not allow estimating in detail the forest degradation for a particular site over time. In this case, the calculations and the carbon estimation were done by associating the latter to the forest surface area modification.

Table 8 indicates the carbon fixation for a particular place with determined characteristics in canopy cover density and by forest structure category.

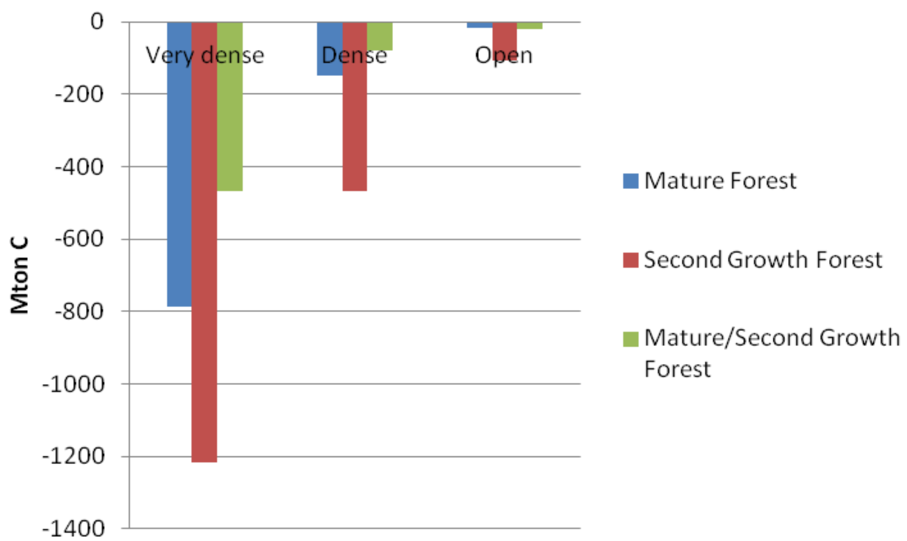
The very dense mature forest has the largest quantity of carbon, 26652.94 Mton C and 25867.28 Mton C, with an amplitude range of 5000 Mton C, approximately, for the years 1993 and 2007 (Table 8). The difference with the other forest structures is a slight alteration level in the mature forest area that produces 0.111 Mt C/ha of loss in the carbon stock per area unit that possess more above ground biomass (Table 9).

Table 8. Carbon fixation quantity (Mton C) in native forest according to the type of canopy closure and forest structure

Structure	Year	Very Dense (100%-75%)	Dense (75%-50%)	Open (50%-25%)
Mature Forest	1993	26652.94	4572.44	1258.89
	2007	25867.28	4424.70	1242.79
Second-growth Forest	1993	23126.32	10557.35	2734.36
	2007	21908.32	10088.60	2626.33
Mature / Second-growth Forest	1993	7171.23	1891.27	565.51
	2007	6702.64	1812.15	544.47

Table 9. Change in the stock (Mton C) for the cover of native forests.

Type of structure	Very dense	Dense	Open	Loss (Mton C)/ha
Mature Forest	-785.66	-147.74	-16.10	-0.111 %
Second-growth Forest	-1218.00	-468.75	-108.03	-0.054 %
Mature/ Second-growth Forest	-468.59	-79.13	-21.04	-0.102 %



Graphic 3. Change in the carbon stock for a period of 14 years in south central Chile.

Table 9 indicates the forests' general diminution in carbon stock. The amounts are negatives for the sites with very dense, dense, and open cover in the mature forest, second-growth forest, and mature/second-growth forest structures. Only 1.8% of the mature forest was transferred to a secondary structure as second-growth forest. These occur for two types of alterations, anthropic or natural, in which case it is not possible to determine the degradation root. We should consider that the native forests have already some alteration degree and previous degradation since they were exposed to selective harvesting in the past; therefore, the degradation probabilities as causes of product extraction are lower (Bertran & Morales, 2008).

It was determined that the forest corresponding to second-growth forest structure has total stock values of 10000 Mton C for the dense cover, and 2600 Mton C for the open cover (Table 8). These values are greater than the rest of the forest structures for the same canopy cover. This takes place because the native second-growth forest covers the most surface area of the region.

In general, this structure presented the greatest stock decrease, between 1218 and 108.03 Mton C for very dense and open covers (Table 9) respectively. It is probable that the loss in the second-growth forest land-use is due to the forest gradual degradation for forestry product extraction such as wood, which produces the aboveground biomass diminution and eventually brings about the substitution from forest to forest plantations. In this case, 75% of second-growth forest is now used for forestry plantations.

The pressure on forest due to wood extraction is the main factor of degradation in Chile (FAO 1996). The south is characterized by the high consumption of wood products for thermal energy and house heating with a consumption resulting in 1487181 m^3/year in the region (Sandoval & Meneses, sf; Burschel et al. 2003). According to Cepal (2009), 73% of the emissions produced in 2008 in Chile are results of energy sources that have increased the emissions 166% since 1984.

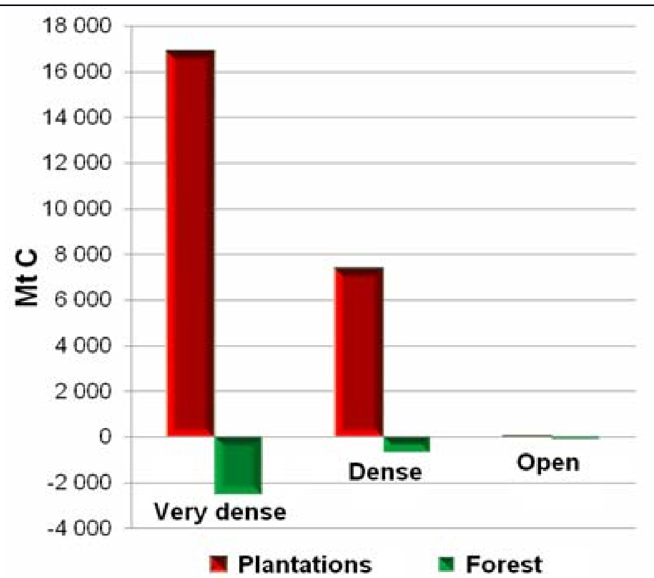
3.3.2. Forest Plantations

Previously mentioned, the main change in land-use is due to forest plantations with approximately 68% in favor of vegetation. This corresponds to 20329.57 Mton C in the region.

The difference among the canopy closures is due to the forest plantations stage; an open cover corresponds to young plantations or freshly harvested ones; thus, a dense plantation might indicate sites that have been thinned out and have reached to close the canopy.

Table 10. Carbon reception (Mton C) by forest plantations according to canopy cover in 1993 and 2007.

Forest	Year	Very Dense (100%-75%)	Dense (75%-50%)	Open (50%-25%)
Plantation	1993	34473.45	4467.07	103.28
	2007	51332.32	11831.22	122.23
Balance		16858.87	7364.15	18.95



Graphic 4. Carbon stock balance in a period of 14 years.

The increase in the forest plantation surface area produces a positive balance in the carbon stock, which increased 24241.96 Mton C in the period 1993-2007 (Table 10). The native forest losses are offset by the growth of forestry plantations (Graphic 4).

This is considered a gain in the carbon drain and hence in the land protection, since sites that were previously used for grain harvesting demand soil nutrients that gradually degrade the land. Against this background, forest plantations can become sources for carbon fixation and can also protect the soil from erosion provoked by rain (Schlatter 1987).

According to Ortiz (1997), secondary forests can present better efficiency in carbon fixation than the primary forest due to the fast grow; the carbon is rapidly fixed in the wood because these species produce more biomass. The plantations continue being a faster alternative for carbon fixation in comparison to native forest.

Nevertheless, in sites with various rotations of plants, an inverse effect might occur. There is an extraction of the soil nutrients and in the long term the plantations growth can decrease. It can also happen in degraded forests if there was no control of the harvesting individuals; the rich genetics are being eliminated and the development and recovery of this decreases according to the intervention degree in the forest (Schlatter 2010).

4. Conclusions

Forest land-use showed an increase of 179440.01 ha, which is attributed by 62.9% to exotic forest plantations, unlike the native forest sub-use decreased 4.1% in its area. Exotic plantation area increased from sites with previous uses in agriculture (50%), pasture (35%) and native forest (13%).

125.3ha have been degraded from second-growth forest to open second-growth forest; extraction of wood is one of the possible causes of forest degradation. The pressure is mainly produced for second-growth forests which in turn helped the establishment of forestry plantations. However, it was not possible to detect degraded forests due to the scale of work.

The native second-growth forest has stock values of 10088.6 Mt C and 2626.33 Mt C for the dense and open structures, respectively, while the mature native forest dominates the stock to the category of very dense 25867.28 Mt C in 2007.

The carbon stock decreased for the native forest category but increased for the forest plantations. In total, a positive balance of 20861.1 Mt C was presented due to the increase in reforestation plantations.

5. Recommendations

The need is shown to increase the spatial resolution of the territorial information for detecting internal changes in the forest (degradation) for the same structure.

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CLIMATE CHANGE MITIGATION AND ADAPTATION STRATEGIES IMPLEMENTED IN BUFFER ZONES IN COSTA RICA: CASE STUDY LA AMISTAD BIOSPHERE RESERVE

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Abstract

Searching for solutions to cope with the effects of global climate change has become one of the most pressing challenges facing humankind. IPCC, states that the emission of greenhouse gases (GHG) is the principal driver of this phenomenon. In Costa Rica, the generation of energy, agriculture and waste management have been identified as the main sectors contributing to national GHG emissions. In this context, ecosystem management plays a central role in climate change adaptation and mitigation, because ecosystems provide important regulating services such as resilience against climatic extreme events and carbon sequestration. Due to the tight relationships between biodiversity conservation and climate change impacts, in Costa Rica, the consolidation of the country's protected areas and their respective buffer zones has been proposed as a central adaptation strategy.

This paper aims to present a variety of climate change adaptation and mitigation strategies in buffer zones of the La Amistad Biosphere Reserve, which have effectively been implemented by the AMISCONDE project between 2004- 2007. Strategies such as: improving the biological connectivity, a Conservation Coffee™ Program implementation, flagship species definition and Payments for Environmental Services (PES) will be presented and the lesson learned during the project period will be discussed. This information can serve as a basis for future initiatives in protected area buffer zones in tropical areas within the context of biodiversity conservation and climate change adaptation and mitigation policies.

Keywords: Climate Change, Adaptation, Mitigation, Buffer Zones, AMISCONDE, Costa Rica.

1. Introduction

The search for solutions to cope with the effects of global climate change has become one of the most pressing challenges faceing humankind (Créach et al. 2008). Climate change refers to effects which are caused directly or indirectly by human activities that contribute to changing the composition of the global atmosphere (UNFCCC 1997). The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), states that the emission of greenhouse gases (GHG) is the principal driver for recently observed phenomena such as an overall warming of the climate system, drastic changes in precipitation regimes, more frequent and severe droughts and floods in tropical and subtropical regions, an increased activity of tropical storms in the Atlantic as well as shifts in plant and animal ranges, among others (Solomon et al. 2007).

For coping with the effects of climate change, two categories of responses have been defined: mitigation and adaptation. Mitigation aims at reducing the accumulation of GHG in the atmosphere by decreasing emissions or enhancing GHG sinks. Adaptation refers to reducing the vulnerability of societies and ecosystems to the impacts of climate change, and may further refer to taking advantage of potentially beneficial opportunities (Locatelli 2010).

Costa Rica is currently meeting its commitments as a party of the United Nations Framework Convention on Climate Change (UNFCCC) by implementing its National Climate Change Strategy. Furthermore, the country is going beyond its commitments from international agreements by officially declaring the goal of becoming carbon neutral by 2021 (MINAET 2009a).

For this country, the national climate change agenda has been defined around six strategic components, mitigation and adaptation, GHG inventories, capacity building and technology transfer, education and public awareness and finally financing mechanisms (MINAET 2009a).

The generation of energy, agriculture and waste management have been identified in Costa Rica as the main sectors contributing to national GHG emissions (MINAET, 2009b). In 2005, agriculture was the second most important emitting sector, being responsible for 37% of net GHG emissions. Land use change on the other hand decreased the country's GHG emissions by 3.5 Mt (CO2 equivalent); due to the recent growth of forest cover (MINAET 2009a). These data clearly show the importance of agriculture, forestry and conservation efforts in the context of the national climate change policy.

Global and regional climate change is in turn already affecting biodiversity and agriculture in Costa Rica. The observed impacts include climate induced changes in productivity and alterations in harvesting cycles for important staple crops such as rice, beans and maize (Villalobos & Retana 1999, CEPAL 2010).

In terms of ecosystems, a wide range of effects from climate change has been detected recently, such as shifts in bird species ranges (Powell & Hamilton 1999), alteration in cloud forming patterns in the Tilarán mountain range (Lawton et al. 2001), widespread amphibian extinctions (Pounds et al. 1999, Sasa et al. 2010) and climate induced tree growth reductions and physiological deficiencies that could potentially turn tropical forests into GHG sources as a result of higher temperatures (Clark 2007).

According to UNEP (2009) ecosystem management plays a central role in climate change adaptation and mitigation, because ecosystems provide important regulating services such as resilience against climatic extreme events and carbon sequestration. Climate change induced ecosystem degradation in turn increases the vulnerability of natural systems and human societies to the negative impacts of climate change. Due to the tight relationships between biodiversity conservation and climate change impacts, in Costa Rica, the consolidation of the country's protected areas and their respective buffer zones has been proposed as a central adaptation strategy (Jiménez 2009, INBio 2009). Currently, 166 protected areas of different categories make up roughly 26% of the national territory (INBio, 2009). However, it has become increasingly evident that the establishment of protected areas alone is not enough to ensure effective biodiversity conservation and the provision of critical regulating ecosystem services.

Dudley et al. (2010) state that protected areas could maximize their beneficial role in climate change adaptation and mitigation by spatially extending the functions of protected areas, considering that protected areas do not exist in isolation and function as part of a larger landscape. Thus, protected areas must be linked to biological corridors and furthermore rely on actively managed buffer zones, in order to fulfill their conservation objectives.

In this context buffer zones are defined as any area peripheral to a protected area, in which activities are implemented that aim at enhancing the positive and reducing the negative impacts of conservation on neighbouring communities and of neighbouring communities on conservation efforts (Ebregt & DeGreve 2000). Some land uses, such as forestry or agro-forestry are particularly suitable for buffer zone management. These land use systems are potentially beneficial for the ability of wild life species to move through changing landscapes. Benefits may also result for human populations that rely on natural resources and on regulating services provided by (agro-) ecosystems, which are resilient to impacts from climate change (Dudley et al. 2010). However to be effective, these areas must be of sufficient size (Hagerman & Chan 2009), and landowners must be willing to adjust their activities to have the least impact on the natural resources as possible. Conservation cannot be separated from issues relating to human wellbeing, and those involved in conservation are usually also concerned with social justice and sustainable development (WWF 2004).

The project AMISCONDE (Amistad, Conservación y Desarrollo - Friendship, Conservation and Development) was a conservation and development initiative in the buffer zone of the La Amistad Biosphere Reserve (ABR), executed between 1992-2007 with the aim to promote communities' sustainable development and to improve the local peoples' quality of life in the buffer areas of the ABR, reducing pressure on natural resources of protected areas (Granda & Jiménez 2002). This project was implemented by Conservation International and the Tropical Science Center (Murillo 2007) and in 23 communities in the buffer zone of the ABR (**Fehler! Verweisquelle konnte nicht gefunden werden.**). During those years a broad range of strategies were implemented with the goal of ensuring sustainability among the development of rural communities and the environment. It has become evident that many of these measures such as environmental education, reforestation and biological monitoring, among others, overlap with some of the strategies currently promoted by Costa Rica's government as part of the National Climate Change Strategy.

This paper aims to present a variety of climate change adaptation and mitigation strategies which have effectively been implemented by the AMISCONDE project between 2004- 2007 and to discuss the lessons learned during this process. This information can serve as a basis for future initiatives in protected area buffer zones in tropical areas within the context of biodiversity conservation and climate change adaptation and mitigation policies.

2. Material & Methods

2.1. Study area

The AMISCONDE project was implemented between 1992 and 2007 in 23 rural communities located within the bufferzone of the Amistad Biosphere Reserve (ABR), between the geographical coordinates 9º24'26''N and 82º56'20''W. This reserve covers an area of 567,845 hectares, ranging in elevation from sea level to 3820 m.a.s.l. (see **Fehler! Verweisquelle konnte nicht gefunden werden.**). Most of its area is located in the Tropical Montane Rain Forest life zone according to Holdridge (1947). Land use in the study area is dominated by small holder shade grown coffee farms, dairy farming, subsistence agriculture, and fragmented primary and secondary forests.

2.2. Governmental and private Partners of the AMISCONDE Project

An important aspect of the project's strategy consisted in its participatory approach, as it involved different governmental institutions, NGOs, and local groups as project partners, with the aim to achieve sustainability in time of the actions promoted. These partners contributed directly to the implementation of the project by facilitating coordination and co-execution of related activities in the focal communities in which they were working. Principal actors included the Ministry of Environment (MINAET), Ministry of Agriculture (MAG), the National Coffee Institute (ICAFE), National Training Institute (INA), among others.

Figure 1. Location of the communities related with the AMISCONDE Project, Costa Rica (pink areas).

2.3. Mitigation and adaptation strategies to climate change applied by the project.

The main objective of the AMISCONDE project was to promote sustainable development in rural communities and to improve the life quality for local people in the buffer areas of the ABR. Twenty years ago, when the project was planned, the issue of global change was not incorporated originally. Nowadays, several of the project strategies defined at that time turn out to coincide with the current National Climate Change Strategy, outlined in Costa Rica's Second National Communication to the United Nations Framework Convention on Climate Change (MINAET 2009a).

Many of the strategies such as promotion of biological connectivity, sustainable agricultural practices, payments for environmental services and environmental education programs, among others which were originally implemented in the context of buffer zone management, are currently considered as climate change adaptation and mitigation strategies (**Fehler! Verweisquelle konnte nicht gefunden werden.**). In this context, the AMISCONDE project can be regarded as a pioneer in the implementation of mitigation and adaptation strategies.

2.3.1. Environmental education program

The environmental education program represented one of the central strategies of the AMISCONDE project. This program promoted the awareness and dissemination of important topics about conservation in the area. The program was divided into three major components, which aimed to integrate the central concepts of the project.

(1) Instruction component: this part of the program was directed towards local primary school children as well as to community members in general. School children were involved through classroom presentations, which were formally integrated into the schools´ curricula. Community members were involved during informal instruction sessions, where an interactive, hands-on, learning-by-doing approach was used. These sessions usually took place in the field and included activities such as tree nurseries, reforestation and conservation soil practices and biological monitoring

among others. During these sessions it was of central importance to provide capacity building for community leaders, in order to assure the long term success of the project.

(2) Environmental classrooms: this component was directed towards primary school children and to selected community members who were trained by project members and another NGO´s like INBio (Biodiversity National Institute) as environmental educators. Project classrooms were built and provided with the necessary equipment and materials concerning the environmental topic.

(3) Environmental Festivals: These festivals were held at the primary schools of the area. The children participated in activities like painting contests, singing and plays, among others, which addressed environmental issues relevant to the communities.

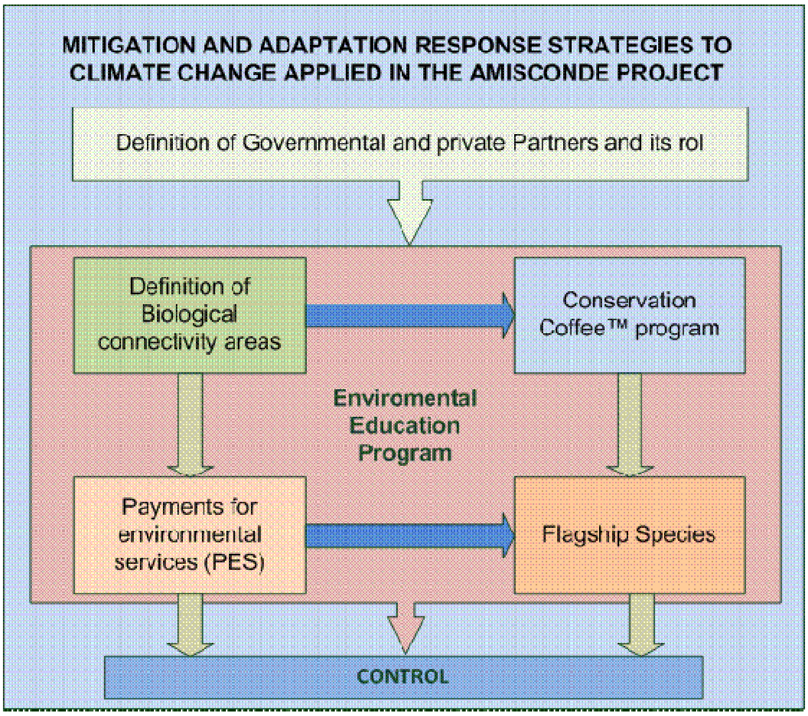

Figure 2. The Mitigation and adaptation response strategies to climate change carried out by the AMISCONDE Project, Costa Rica

2.3.2. Identification of areas of high biological connectivity

The concept of biological connectivity allowed determining priority areas for the allocation of efforts to promote conservation, reforestation, and environmentally friendly production. Areas of high connectivity between protected areas, agroforestry systems (coffee) and forest fragments were identified during the following steps (Canet 2003):

(1) Mapping of forest cover and shade grown coffee plantations in the buffer zones, using GIS software.

(2) Prioritization of buffer zone areas according to their ecological importance, e.g. size of present forest fragments, ecological condition and proximity to other forest patches or to the protected area.

(3) Elaborate a draft map of prioritized connectivity areas

(4) Validating the localization of areas with high biological connectivity with community members; this step was crucial because it allowed completing information gaps, such as missing data in the GIS database.

2.3.3. Conservation Coffee™ Program

Conservation Coffee was an initiative developed by Conservation International and Starbucks Coffee Company, as a response to the importance of this crop for biodiversity conservation in the producing regions (Austin and Reavis 2004, CI 2006). It promoted the adoption of conservation principles for coffee production (Conservation Coffee Best Practices, CCBP), in order to ensure the continuity of biological processes, and to mitigate negative impacts such as habitat loss and soil erosion, among others.

When AMISCONDE started to implement the initiative in 2004, it had already been a great success in other countries like Mexico and Colombia, since it allowed the commercialization of environmentally friendly coffee without the cost of certification.

In order to implement the Conservation Coffee initiative within the ABR buffer zone, we adopted the following methodology:

(1) Selection of sites and farms: Participating communities were selected based on their location within priority areas of biological connectivity (as defined above) and on quality standards met by the coffee produced in these areas.
(2) Context assessment: Two major studies were conducted in order to assess the agroecological and socioeconomic context within the ABR, as well as to analyze market structure and access for the commercialization of coffee; for more details see Avila (2003) and Chavez (2003), respectively.
(3) Project design workshop: We gathered potential partners such as Coffee Institute of Costa Rica, coffee cooperatives, coffee associations, Ministry of Agriculture, Ministry of Environment and Energy in order to define a hierarchical matrix of program objectives and assumptions, indicators for milestone and key results, the role of each partner and the fundraising strategy.
(4) Validation of the CCBP: The CCBP were developed by CI, however, it was necessary to adjust these practices to the national and local context. CCBP include commitments to: sustainable coffee production, natural resources conservation and social responsibility.
(5) Baseline study: in 2004 we surveyed 128 farmers' households on their current farming practices and socioeconomic situation.
(6) Start-up Workshop: During this activity partner organizations were defined and cooperation agreements were signed with each of the involved institutions. Further, we used a participatory approach to develop the program implementation plan for two years.

2.3.4. Selection of flagship species

Local flagship species were determined with the objective of raising awareness about the importance of globally threatened species which were present around the communities, to facilitate environmental education, and to promote conservation and sustainable coffee cultivation practices.

Flagship species were defined based on the IUCN Red List of Threatened Species. In cooperation with the National Biodiversity Institute (INBio) the presence of globally threatened species in the study area was determined by generating maps of the potential altitudinal distribution of each listed species within the ABR. Using GIS software, potential distribution maps for all species were superimposed to identify those areas with the highest density of globally threatened species.

The flagship species approach was fundamental for meeting the environmental education objectives and for participative research that generated information about the presence and habitat use of threatened species in local agroecosystems and in adjacent forest areas. For this purpose the "Handbook for monitoring globally threatened species in coffee plantations" (TSC 2005) was designed. This monitoring tool included illustrated descriptions of 24 species that could be easily identified by the farmers in the area.

2.3.5. Payments for environmental services (PES)

The Costa Rican government compensates landowners for important ecosystem services provided by forests and forest plantations on their property by implementing a payment for environmental services program (PES).

This mechanism is regulated by national law and provides financial incentives for GHG mitigation, watershed protection, and biodiversity conservation, among others, through the National Fund for Forestry Financing (FONAFIFO 2010).

Currently, the amounts to be paid for environmental services range from $US 1.3 per newly planted tree in agro forestry systems in a period of 3 years, to $US 980 per hectare in a period of 5 years for reforestation (Costa Rica, 2010).

During the AMISCONDE project, the participation of farmers in the national PES program was promoted, in order to maximize the benefit that producers could gain from conservation efforts on their farms. We initiated an information campaign within the communities and then recorded all interested persons who were eligible for the program. The farmers were supported throughout the necessary registration with FONAFIFO, the documentation of legal requirements and we further facilitated technical advice by an accredited forest engineer who monitored and certified the entire process.

Finally, farmers who met all requirements, signed a contract with FONAFIFO in which they pledged to plant and maintain a defined number of trees in their agroforestry systems, as established in the implementation plan previously elaborated by the forest engineer with the approval of the land owner.

3. Results and Discussion

3.1. Environmental Education Program

Regarding the training sessions, one may conclude that a learning-by-doing approach was more successful than formal instruction, as appreciated in the field, where farmers put in practice what they had learned.

Four classrooms were built during the project to provide a sustainable option for the environmental education activities. Currently the environmental community organizations are responsible for these classrooms by securing financial support through different donors in the region or promoting different fund-raising activities.

Environmental festivals attracted local governments, NGO's and other organizations with political impact in the region, who took the opportunity to promote their conservation activities in the area and strengthen the cooperation efforts between different partners.

One key aspect observed throughout the project that should be taken in consideration by any development project is the capacity-building issue. Using local organization for the training ensured that currently, even though the project is no longer in place, local organizations continue to deal with some of the issues set forth by the project.

3.2. Biological connectivity

A total of 7 438 hectares within the region of the project were selected as an area of biological connectivity (Canet 2003). Identifying these areas ensures the positive impact on the protected area, where design elements of landscape ecology were taken in consideration.

The focus of this selection of connectivity areas generated positive impacts: the amount of reforested areas (more than 2 000 ha), capacity-building and instruction (more than 10 000 people), the promotion of conservation best-practices activities in agriculture (200 families) and watershed protection, among others.

The participation of local communities in validating the connectivity area allowed to have better outputs and gave the local farmers the opportunity to learn the value of their farms in terms of biological connectivity.

3.3. Conservation Coffee™ program

A network of local partners was established, with COOPEAGRI (a local coffee-producing cooperative), the Ministry of Environment and Energy and the Coffee Institute of Costa Rica acting as the main partners, who in turn coordinated a common agenda to implement this initiative.

Conservation Coffee Best Practices (CCBP) was promoted in the communities surrounding the buffer zone of the ABR, involving about 150 farmers (Murillo 2007).

An effort to find new coffee markets was unsuccessful, since this type of coffee did not guarantee a higher price due to the fluctuation of the coffee market worldwide. Nevertheless, the initiative provided a platform for many producers to establish their own microprocessors of coffee. Currently there are 4 microprocessors in communities where the project worked.

As part of the implementation of the CCBP, 450 000 trees of native species were planted. These trees were used to recover degraded areas, conserve water and provide shade in coffee plantations.

3.4. Flagship species

Of the 181 globally threatened species found in Costa Rica, 24 (13%) are potentially present in the AMISCONDE project area. These species include 7 species of amphibians, 1 species of birds, 4 species of mammals and 12 species of plants, which represent 22%, 8%, 36% and 11% respectively of all globally threatened species present in Costa Rica for each group (Herrera et al. 2004).

Particularly astonishing is the fact that 21% of these 24 globally threatened species are distributed in an altitudinal range between 1100 and 1600 masl, which coincides with the area of coffee production, which confirms the relevance of including productive activities in conservation strategies in the ABR (Herrera et al. 2004).

The handbook for monitoring globally threatened species in coffee plantations proved to be a useful and effective tool to monitor species and environmental education.

3.5. Payments for environmental services (PES)

The Payments for Environmental Services program (PES) proved to be an effective tool to promote forest conservation and establish agroforestry systems. In the case of the AMISCONDE project, this initiative was particularly useful to improve coffee production systems by diversifying the shade canopy used for this crop. At the same time, PES changes the producers` perception that conservation is an economically unproductive activity.

Twenty producers in the PES program planted between 350 and 2000 native trees species in their farms. These species were selected because of their capacity to provide ecosystem services with coffee plantation.

4. General discussion

In the last three decades, countries and international organizations worldwide have implemented treaties, national policies and made other efforts to apply strategies and instruments to deal with mitigation and adaptation to climate change. During this period, it has been clear that reduction of GHG is a key, if altogether insufficient, issue, to promote strategies aimed at minimizing the vulnerability of fragile areas (FAO 2009).

In the case of Costa Rica, the government has committed to offset the emissions of greenhouse gases in the country by 2021 (FONAFIFO s.f). In the pursuit of this objective, the country has been working on a National Climate Change Strategy based on mitigation and adaptation key actions.

Among the main areas proposed in this strategy, which overlap with some of the actions undertaken by the AMISCONDE project, is the biodiversity axis: reducing the fragmentation of ecosystems by creating biological corridors and promoting biodiversity connectivity, as well as the agricultural axis: reducing greenhouse gases by promoting better agricultural practices(MINAET 2009).

Biological connectivity strategies increase tree cover by natural regeneration or agroforestry actives, which have a positive effect on greenhouse gas balance, since degraded areas recover, and essential forest areas are preserved and conserved. De Melo (2008) also reports that preservation of natural forests and agroforestry systems, especially the cultivation of coffee, are the types of land use that provide the largest number of Eco-systemic services.

Another aspect also taken into consideration by the AMISCONDE project was consolidating protected areas for biodiversity conservation, which, according to INBio (2009) is a strategy in the adaptation process to Global Warming, based on the premise that ecosystems protected by conservation areas are less vulnerable and more able to adapt to climate change than those found outside the protected area networks (Anderson et al. 2008).

According to the experience of the AMISCONDE project, the Payments for Environmental Services program works as an appropriate tool to promote the increase of biological connectivity coverage areas, which has a direct impact as a mitigation tool and also allows integrating agricultural production and conservation. However, PES needs support from other strategies, such as environmental education and dissemination of best agricultural practices in production, to reach the best results.

It is crucial to keep in mind that the experience of the AMISCONDE project showed that setting in place these strategies, such as PES, has primarily legal limitations, such as land tenure, and most of the time access to these resources are reserved for small producers, in the sense that procedures are complex and lengthy and require to be partially financed by the producer.

5. Conclusions

The strategies proposed by the AMISCONDE project, although not designed with the specific purpose of mitigating and adapting to climate change, showed a synergy with actions proposed nationally in this field in Costa Rica.

The latter proves that before Global Warming issues played a key role, projects dealing with the issue of Nature Conservation used strategies such as creating biological corridors, promoting best agricultural practices and paying for environmental services, among others, nowadays used as mitigation and adaptation strategies to this phenomenon.

Throughout the implementation of the AMISCONDE project, it was also observed that national policies, legal support, and the active participation of society are key elements to ensure the sustainability of any strategies to mitigate and adaptate to climate change over time.

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Using research-based innovations to support the restoration of a dry-forest ecosystem in the Colombian Caribbean and the sustainable use of forest products for improving human communities' welfare.

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Abstract

Public academic institutions in countries like Colombia do not have the availability to invest in development projects for human communities. The Universidad de Antioquia received 4000ha of land for carrying out research projects in the dry-forest ecosystem of the property and to continue to exploit a traditional commercial plantation enterprise. The University is now interested in support projects aiming for biodiversity conservation in its farms with environmental and social impact for humans living on the terrain. The goal of our project is to design a multi-purpose program for supporting the restoration of the dry forest ecosystem in the University-owned land that integrates economic, social, and environmental dimensions, aiming for a self-sustaining scheme. We will take advantage of research products that have been developed at the University which could be used to support conservation-based objectives of forest restoration, and for the sustainable use of wood and non-wood forest products that could help improve the standard of living of the human communities inhabiting this ecosystem.

We plan to use differentiated but parallel strategies for the restoration of the dry forest, such as mixed plantations and assisted natural regeneration. In order to make the project viable, we plan to use international financial tools like REDD, and national ones like CIF (certified forestry incentive). In addition, we will develop research-based protocols for the sustainable use of forest products and environmental services that could represent financial alternatives for the human communities and an incentive for the conservation of the forest in the long-term. Ultimately, the presented multi-purpose program intends to propose a protocol for forest restoration, conservation, and sustainable use of biodiversity by applying research-based innovations, which could be applied in other places in Colombia with similar environmental and social conditions.

Keywords: tropical dry forest (TDF); restoration; conservation; sustainable use

1. Introduction

The University of Antioquia, located in Medellin – Colombia, received 4400ha of land in the mid 1990´s, called 'hacienda San Sebastian'. The purpose of this donation was to carry out research projects and to continue the exploitation of a traditional commercial plantation company that was already in place (UdeA 2002).

Today the hacienda has a lease contract with Madeflex S.A. (a wood production company) which dates January 2000 and has a legal bind of agreement of 13 years. This gives the University a framework of 2 years for preparing new activities and research projects that are going to take place in the hacienda (UdeA 2002).

The predominant ecosystem in this region is tropical dry forest (TDF) within an area, which has a monomodal regime and an average precipitation of 1511 mm/year, an average temperature of 28 °C, and an evaporation average of 1754 mm mm/year (Marulanda, *et al.* 2003). There are many definitions of what constitutes a TDF, one of the main characteristics of this ecosystem is water stress presented by a pronounced dry season with little or no precipitation (Mendoza 1999), having plant formations which are featured between 0 – 1000 m above sea level, presenting an average annual temperature higher than 17 ° C, with annual precipitation levels between 600 and 1800 mm, and two dry periods per year, usually one of them long and the other one short (Murphy & Lugo 1986).

When referring to deforestation in Latin America and the Caribbean, the focus is usually in areas of tropical and subtropical rainforests, forgetting that the losses can be of equal or greater magnitude in the TDF (Miles, *et al.* 2006). The dry forests have received much less attention regarding scientific and conservation supervision compared to rain forests (Prance, 2006), but indeed, many authors refer to this ecosystem, as one of the most threatened in the Neotropics (Linares & Fandino 2009).

In Latin America, approximately 66% of TDFs have been destroyed (Quesada, *et al.* 2009) and about 97% of the TDFs are threatened by destruction (Rangel, 2009). Despite their high levels of endemism and diversity of species, TDFs are poorly protected (Pennington*, et al*. 2006). It is estimated that area of dry sub-humid tropical forests amounted to 80000 km^2 in 1950, and today only to 1200 km^2, 1.5% of its original extent, constituting the most heavily degraded biome in Colombia (Etter 1993; Echeverry & Rodriguez 2006; Rangel 2009). Public academic institutions in countries like Colombia do not have the possibility to invest in the development of projects for human communities, such as this one. Within this framework, the restoration of a TDF is a critical concern, and a very pertinent line of work and research.

The University is now interested in supporting projects that aim for biodiversity conservation in its farms, with environmental and social impacts for communities articulated with the land. In this context, the hacienda San Sebastian is a perfect setting for the development of a restoration of this type in this TDF ecosystem. This is the reason why this multipurpose-program intends to propose a protocol for forest restoration, conservation, and sustainable use of the biodiversity of the TDF that can be transferred and applied in other places in Colombia with similar environmental and social conditions.

2. Material & Methods

2.1. Study area location

The project will be located in the municipalities of San Sebastián, San Zenon, Santana and Pijiño del Carmen in south of the Department of Magdalena 74° 21´ W and 9° 15´ N (figure 1), on the right bank of the Magdalena River, about thirty minutes from the city of Mompóx and in total includes some 4,400 hectares. The land is composed of three farms that were donated to the university in the mid-nineties and are called: Los Álamos, Terranova y Nueva Esperanza that are subdivided into El Porvenir, El Enredo, Villa Cata, La Infancia, El Paujil, Guineo Abajo, Sal si puedes, El 96 o Vuelta de los terneros.

Figure 2. Map of the study area of a tropical dry forest fragment in the municipality of San Sebastian, Magdalena (Colombia)

2.2. Methodology

The first step in the multipurpose-program is to develop an integral base research line including social, economic, cultural, physic and biotic topics of the area in which the San Sebastian hacienda is located. In order to perform this step, students from different areas of the university will be working on their thesis in the hacienda.

Students from different areas are going to be collaborating in interdisciplinary form in the scope of this initiative, for example: There are law related theses for aspects like: legal rights of the resources and land, non-traditional contracts that have to be made in order to receive the financing, and structure for the sustainable use of forest products in order to improve the way of life of the adjacent native communities.

There is going to be an engineering thesis called 'evaluating land use in the san Sebastian hacienda using geographical analysis tools', aimed to evaluate the eligibility of the different compositions of the San Sebastian hacienda for REED and for voluntary carbon markets. Also, the participation of the economics department inside the Faculty of Economic sciences intends to establish the viability of the program in different fields. These include financial analysis and microeconomics studies to see the articulation of the communities into the planned projects for San Sebastian.

There is a permanent plot that was established by the end of the 1990´s. The full report was published in Actualidades Biologicas and goes by the name 'Structure and composition of the vegetation of a dry forest fragment in San Sebastian, Magdalena (Colombia)'. We are doing a second visit to this plot in order to have a view over time of the evolution of the TDF relict that is placed in the hacienda and we want to involve other biology students in order to do inventories on fauna (birds, mammals, reptiles etc.) and fungi. Also, a Master's thesis in carbon and hydrological cycles in the forest relicts of the hacienda is planned.

In the mean time, extensive secondary bibliography has been studied in topics such as, biodiversity monitoring, carbon stocks monitoring, spatial and geographical analysis, conservation and restoration methodologies, socioeconomic inclusion, etc.

We have listed research-based innovations like evaluation of *Eucaliptus sp* as a source of bioactive molecules, evaluating fungi of the TDF as an economic source, evaluation of Cebú cattle on silvopastoreo San Sebastián hacienda, and others made by the university research groups that can be articulated with the dynamics we have observed in the TDF literature. Several visits are likewise expected within the next time to carry out the necessary fieldwork as basis for the research activities.

3. Results

The first results for the project are already achieved in terms of decision-making by the institution, defining the project’s main lines to be developed within the multipurpose-program.

The short term objective consists in designing services which generate financial, technical and ecological alternatives for the forest conservation and it´s ecological relations. Consequently, the middle term objective will be the development of productive strategies integrating the human communities in a sustainable form in the TDF ecosystem. Finally the long term objective is to structure a research facility centered in the TDF ecosystem, considering it´s dynamics, and it´s possibilities.

Since the general aim of the multipurpose-program is to integrate economic, social, and environmental dimensions for a self-sustaining scheme, there are specific lines of work to be included such as described in Table 1.

Table 1. Specific lines of work

From the social point of view	• Community participation in structuring decisions. • Articulation with regional and national policies. • Involvement of traditional use of resources in the design of the restoration protocol.
From the environmental point of view	• Baseline studies and long term ecological monitoring. • Evaluation of different restoration schemes. • Sustainable resource management.
From the financial point of view	• Certified emission reduction • Biodiversity protection certificates • Certified forestry incentive • Non forestry product commercialization

In order to ensure the feasibility of the multipurpose-program, international financial tools like REDD or other voluntary carbon standards and national ones like CIF (certified forestry incentive) will be used. In addition, research-based procedures and schemes for the sustainable use of forest products and environmental services that can represent financial alternatives for the human communities, as well as an incentive for the conservation of the forest in the long-term will be developed.

Differentiated but parallel strategies for the restoration of the TDF, like mixed plantations and assisted natural regeneration will also be considered. Ultimately, the final aim intends to design and implement a multi-purpose program based on innovative research products for supporting the restoration, conservation, and sustainable use of the biodiversity of the TDF ecosystem in a University-owned terrain.

4. Discussion

In Colombia, the remaining dry forest relicts are distributed between the Caribbean plain and the valleys of the Cauca and Magdalena rivers, in jurisdictions of the departments of Valle del Cauca, Cauca, Tolima, Huila, Cundinamarca, Antioquia, Sucre, Bolivar, Cesar, Córdoba, Magdalena, Santander, North Atlantic, south of La Guajira (von Humboldt Institute 1998). But this does not mean that these geographic areas are completely dominated by this ecosystem. As a matter of fact, nearly 677 km^2 of existing dry forests have been strongly intervened (Diaz & Arango 2006). It is estimated that the original area of dry sub-humid tropical forests for the 1950´s was of 80000 km^2, of which today remain only 1200 km^2, i.e. 1.5% of its original extent (Etter 1993; Echeverry & Rodriguez 2006), being the most heavily degraded biome in Colombia (Rangel 2009). TDF are considered to be the most fragile ecosystems because of the slow regeneration capacity they possess, and the continuous threat of deforestation due to natural or anthropogenic factors (Uslar, *et al.* 2003).

There are some identifiable factors that have led human settlements to continue to be located near these ecosystems in Colombia, among which the fact that the climate in these places is more favorable and generally soils are more fertile. Therefore, there has been a focus on agricultural development and livestock, consequently these ecosystems become subject of an intense transformation process (Vieira & Scariot 2006). Due to lower leaching, the fertility of the soil in the TDF is higher than in wetter areas, giving a higher concentration of nutrients, making it easier for weed and pest control more difficult. Also, the succession processes tend to be less aggressive and therefore the establishment of this type of vegetation and its associated species for multiple purposes tends to be lower (Murphy & Lugo 1986; Janzen 1988).

In general terms, human activities have a strong influence in the decline of species, the number of species inhabiting a specific area, and the irreversible loss of the environment and ecosystems such as TDF (Squeo 2008). In Colombia, most dry forest remnants are located in areas of intensive livestock, agricultural use and wood for fuel (Galmez & Komett 2009). All of these anthropogenic decisions in the environment are aimed for the sustainability of the communities living in them as is the case in the Caribbean and the Andean valleys (Cauca and Magdalena) (IAVH 1998). Given these pressures, this ecosystem is referred to in terms of extreme habitat loss and maximum fragmentation by many scientists. Since only small fragments of forest have been conserved and the relicts left are in a poor state of preservation, and since most of them are surrounded by a matrix of pastures and crops with a high conversion rate, they have been classified in the category of "Critical Condition" (Dinerstein, *et al*. cited by Marulanda 2003).

Prance (2006) highlights that the vast expanse of this ecosystem has not often been considered in conservation efforts, despite the significant biodiversity and ecosystem services, and the fact that they shelter great potential for use through the range of food products (this includes the animals), medicine and timber (Vieira & Scariot 2006). In addition, there is a large number of endemic species in these environments, and according to the study conducted by the Institute Alexander von Humboldt (IAVH 1997) in the Colombian Caribbean, 73% (180) of woody plant species are sampled in 0.4 ha restricted to a locality. This determines that each remaining TDF in the Colombian Caribbean region has assemblages of group species and individuals, and that in existing conservation units in dry forests, all of the typical species of this ecosystem are not represented.

As documented in the National Report on progress in “knowledge and Biodiversity Information 1998 – 2004” at the level of sub-ecosystem studies (Arango & Diaz 2006), the same low representation of this ecosystem is present in different levels of protected areas relating to national, regional and local categories (IAVH 2002). Colombia is clearly misrepresented in this ecosystem in the protected area system (Ruiz & Fandrich 2007, Arango, *et al.* 2003; IDEAM, *et al.* 2002), with remnants protected only in two national parks: the Tayrona Park in the department of Magdalena and the Old Providence & McBean Lagoon in Providence.

Based upon the critical state in which the TDF ecosystems are found in Colombia, it is urgent to devote efforts so as to implement strategies focused on restoration processes in these ecosystems. And in this context, it should be noted that it will in no way be possible to perform a restoration against the will of the affected population that is conscious of only being kept afloat by a dependence on land resources (Andres 2009; Galmez & Komett 2009, Barnsley 2009).

Due to drought conditions experienced by dry forests, seed recruitment and growth rates are affected and are lower than those of tropical rainforests. Also, some of the dry forests are subject to large-scale forest fires due to the accumulation of not decomposed, dry organic matter, although there is evidence that these forests are less prone to such events due to the plant adaptations (Vieira & Scariot 2006).

In this sense, ecological restoration aims to restore an ecosystem that has been degraded, damaged or destroyed, through the stimulation and acceleration of natural succession in order to restore the forests' ability of self-regulation (Rodriguez 2009) and finally, to allow not only the establishment of core conservation, but also the recovery of the functionality and environmental services a previously degraded ecosystem provides or may provide.

This gives great importance to each existing remnant when seeking to preserve a representative sample of TDF in Colombia. Particularly the San Sebastian hacienda has almost 200 hectares of forests that have not been touched in at least 40 years; thereby exists a great opportunity in contributing to the study and conservation of this type of ecosystem.

Given the significant emissions from deforestation and forest degradation, especially in developing countries, several parties have focused their attention on creating positive incentives for those countries, so as to reduce their deforestation rates and forest degradation (Barnsley 2009). In this sense, emissions from deforestation and forest degradation in developing countries account for about 20 percent of total emissions of greenhouse gases (GHG) annually, and it is precisely in this context that the initiative of reducing emissions from deforestation and forest degradation in developing countries (REDD) is a must (Angelsen 2009). The basic idea behind REDD is the creation of a system of positive incentives that will persuade developing countries with tropical forests to reduce deforestation rates, by financially rewarding them (Barnsley 2009).

Colombian TDF are included in the Andean forest ecosystems (EFA) which according to Etter & Villa (2000) are the most diverse and threatened terrestrial ecosystems, recognized as a major global hotspot and representing a priority for conservation because of their extraordinary richness and endemism, as well as several of its constituent species being severely threatened (Miles, *et al*. 2006). In addition to be a priority for biodiversity conservation in the great hosting, EFAs are the living basis of populations in surrounding areas, due to the multiple social, economic and environmental resources they provide (Quesada, *et al.* 2009).

Forestry activities offer an attractive potential for climate change adaptation and mitigation of adverse effects. By promoting conservation of forest through management practices, forest carbon emissions into the atmosphere are reduced, helping to mitigate climate change and its impacts (Galmez & Komett 2009).

In this sense the REDD systems have great potential to generate collateral benefits for the conservation of biodiversity and other ecosystem services (in addition to carbon sequestration). It is considered that tropical forest conservation has been underfunded in recent decades, both in terms of scale and duration of the funding cycle (Galmez & Komett 2009). In this sense, the financial flows related to REDD offer new possibilities providing collateral benefits in terms of conservation. The ecological importance of these ecosystems is becoming obvious as a source of storage and water sources regulation, since they are a determining factor for soil protection and stabilization, reservoirs for different types of species of plants and animals - many of which are scarce - constituting likewise a potential source of genetic resources for industry alignment and medicine, etc. (IPAM, *et al*. 2010).

Colombia has a legislation that can also be articulated to this kind of projects like Decree 154 of 1969, which is intended to regalements, deductions for investments in plantations, or Agreement 20 of 1987 "which establishes a framework of measurements for the foment of reforestation".

There is also Law 139 of 1994 in which the Certified Forestry Incentive (CIF) is created, and the Decree 1824 of 1994, which regalements Law 139 of 1994". Decree 1715 of 1978, about scenery protection. Decree 2787 of 1980 regarding industrial forest plantations, and reforestation programs. Agreement 20 of 1981 "by which the establishment and exploitation of artificial forests in private areas is regulated".

In terms of forestry Credits and legal funds related to the forestry sector, the former Forest Financial Fund created by Law 26 of 1977 is no longer available. Consequently, economic incentives result of reduced emissions from deforestation and forest degradation in developing countries. REDD adds new possibilities for the investment in conservation and restoration of degraded ecosystems such as TDF.

Moreover, the use of greater diversity (up to 140 species), is not only a way to encourage potential environmental services that can provide these ecosystems, but also an alternative for biodiversity conservation in situ (Rodriguez, *et al*. 2009). Research-based procedures and schemes for the sustainable use of forest products and environmental services can represent financial alternatives for the human communities and an incentive for the conservation of the forest in the long-term.

Knowledge of dry forest ecology is far from satisfactory, leading to disagreements over how to proceed with their restoration (Rangel 2009; Marulanda, *et al.* 2003; Mendoza 1999, Carrillo-Fajardo, *et al.* 2007; Echeverry & Rodriguez 2006) so it is the purpose of research institutions in Colombia to produce this kind of knowledge.

Based on its structure (less complex than that of tropical rainforests), the most abundant species in it are anemocorous sleepers. The re-growth capacity of some TDF components has suggested that simple withdrawal of exploitation could allow spontaneous restoration of the remaining patches and natural regeneration on abandoned pastures (Vieira & Scariot 2006).

The enrichment of the matrix of grass with nuclear tree planting, isolated as part of hedges or windbreaks, has proven to be effective for two additional reasons: on the one hand, these trees act as focus attractor for wildlife dispersal of seeds over long distances from the forest nuclei, and on the other hand, when the species are well chosen, they are a source of incomes and resources for communities in the area, in the form of firewood and supplementary feeding for livestock, thereby reducing pressure on forests that are still preserved (Vieira & Scariot 2006, Rodriguez*, et al*. 2009). In protective plantations, either mixed or of single species, especially when surrounded by natural forest, secondary succession could catalyze under their canopies, allowing gradual replacement by secondary mixed forests (Vieira & Scariot 2006).

Thus, ecological restoration in countries like Colombia can no longer be studied by a single branch of science and requires an interdisciplinary collaboration between science, technology and humanities, as well as a close cooperation between the technical, economical and social actors at different scales (Galmez & Komett 2009). This justifies a necessary effort to be made by a research institution such as the University of Antioquia.

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Possibilities of guadua bamboo forests in the context of REDD+: A case study in the coffee region of Colombia

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Abstract

In order to evaluate the possibilities of integrating guadua bamboo forests in the framework of a REDD+ initiative, different factors associated with this bamboo resource were analysed and incorporated in a structure defined by four blocks: scopes, level of reference, distribution and financing. Thereafter, it was possible to establish where it would be required to concentrate efforts if the project is implemented. The capability for carbon sequestration of 109±54 t ha^{-1} in average as well as the institutional and political development are remarkable and might contribute for easing REDD+ project implementation. Nevertheless, aspects related to monitoring and strategies for mainstreaming REDD+ initiatives as a priority within territorial, sector and institutional planning process must be consolidated.

Keywords: carbon, degradation, REDD+, *Guadua angustifolia*

1. Introduction

The species *Guadua angustifolia* Kunth (guadua) is one of the most important woody bamboo resources. In Colombia, and particularly in the coffee region, the guadua has been traditionally used by farmers to build products such as houses, furniture, handicrafts, agglomerates, veneers and flooring. After the last guadua inventory, the total area was estimated at 28,000 ha in the coffee region (Kleinn & Morales 2006), most of them natural stands. These guadua forests are almost the only existing forest cover left in this region between 900 and 2000 meters above sea level, because forests have been progressively changed first to agricultural use and lately to cattle pastures.

In the coffee region, commercialised timber and timber used for domestic applications originates mainly from natural forests located along the pacific coast of Colombia (Camargo et al. 2007). Nevertheless, guadua is the most harvested species to obtain wood for different applications. Culms of guadua with mean diameter of 12 cm, as well as average length of 21 meters are harvested daily. Although culms are hollow these can be used, and are for some specific cases split to obtain other kind of products. Some reports show that between 2000 and 2004 roughly 2,420,000 culms of guadua were logged from 2,557 ha (Moreno 2006). This means that about 90 % of Guadua stands were not harvested in this period of time, but guadua bamboo forests have been significant for consolidating enterprises (Held 2005) and have improved the possibilities for expanding markets to Europe (Becker 2004). Unfortunately, information related to harvesting of Guadua has not been registered after 2004. However according to the number of harvesting permissions asked for, and the poles of guadua sold in timber stores, we know that commercialisation continues to be high.

The proper management of guadua forest is being promoted by government institutions. Therefore programs for training farmers and technicians, guides for sustainable management and forest certification have been implemented in the framework of forest governance projects (Bosques/Flegt Colombia 2010). However, currently some problems associated with inadequate silvicultural practices, urban expansion and the little motivation of farmers due to decreasing incomes from these forest, are contributing to illegal logging and consequently to degradation.

In this context, alternatives for promoting a proper management, forest conservation also including welfare for farmers are needed. Hence, initiatives such as REDD (Reducing Emissions from Deforestation and Degradation) or REDD+ (REDD enhancement of carbon stocks) might be appropriate to improve conditions of guadua forests. The specific objective of REDD+ projects is to reduce deforestation and degradation, or promote forest restoration, rehabilitation and conservation attempting to reduce carbon emissions (Jagger et al. 2010).

After the Bali Conference of the parties (COP 13) in December of 2007, about 150 REDD+ projects have been planned with the aim of implementing a variety of intervention to reduce deforestation and forest degradation, as well as to promote the conservation and sustainable management of forest to enhance forest carbon stocks (Jagger et al. 2010).

At different scales (local to global), and beyond carbon storage, forests are providing ecosystem services such as watershed protection, water flow regulation, nutrient recycling, rainfall generation and disease regulation (Parker et al. 2008). Therefore, these benefits can be considered in REDD+ initiatives and after implementing a project farmers could receive benefits.

The aim of this paper is to evaluate the possibilities of integrating guadua bamboo forests in the framework of a REDD+ initiative. Therefore, we will attempt to incorporate specific aspects of guadua bamboo forest within a structure for implementing a REDD project as suggested by Parker et al. (2008), which includes four blocks: scopes, level of reference, distribution and financing.

2. Material & Methods

2.1. The study area

This study is carried out in the coffee region of Colombia which includes the states of Caldas, Quindío, Risaralda, Tolima and a part of Valle del Cauca. The total area is 5.766.397 ha between 900 to 2000 meters above sea level. Along this altitudinal gradient, differences on soils, topography and climate conditions are evident. However, guadua bamboo forests are distributed through all area and have similar characteristics associated to dendrometrics variables of their culms, area of the forest patches and management.

2.2. Structure for evaluating the possibilities of implementing REDD+ project

Taking as a referent the approach suggested by Parker et al. (2008) to implement a REDD+ project, it is required to follow a process to develop a framework which comprises four basic building blocks, scopes, level of reference and distribution. In this sense, information on guadua forest related to each one of the blocks is evaluated to determine available inputs for consolidating a REDD+ project and also to elucidate gaps of information or how some aspects could be improved to make REDD+ possible. It means that most of the information was gathered from previous studies and also from some currently ongoing ones.

Therefore, for scopes, we tried to answer: what is eligible; which activities; which carbon pools, and where? For level of reference: how is it measured; over what period, and across what scale? For distribution: where / to whom does the money go, and what assets will be rewarded? For financing: where does the money come from, and are there multiple mechanisms?

3. Results

3.1. Scope

About 28000 ha (Kleinn & Morales 2010) of guadua bamboo forests of the Colombian coffee region are the target of this REDD+ proposal. These forests have a spatial distribution pattern highly fragmented with most patches of less than 5 ha (Camargo & Cardona 2005) and located mainly along of the rivers or streams as riparian arrangement (**Figure 1**).

Figure 1. Patches of guadua bamboo forest included in a matrix of pastures. Coffee region of Colombia.

Even though guadua is adapted to different site conditions, there are special environments which favour its growth and optimal development (Castaño & Moreno 2004). Guadua grows best between 900 and 1600 m above sea level, at temperatures between 20 and 26ºC, precipitation between 1500 mm and 2500 mm per year, and in slightly acidic soils (Cruz 2009).

The growth patterns of guadua and trees are completely different; therefore bamboo inventory and mensuration should be conducted by using different criterions (Camargo 2006).For reaching an adequate management of this resource basic information on the dendrometric attributes of culms, on stand variables as well as on stand management options is quite relevant. Also aspects such as stand productivity, behaviour in different environments and stand management should be considered (Camargo 2006, García 2004; Hincapie & Penagos 1994).

Because of the characteristics of guadua culms, logging and processing is usually conducted by using a machete. Only recently, have chainsaws been used for carrying out harvest in some forest. Harvesting of guadua forest consists of the extraction of a fraction of mature culms, it means that a significant number of standing culms with different stages of maturity remain after harvest in guadua forests. When harvesting, a portion of mature and over-mature guadua culms are cut, then each one is divided usually in four pieces according to the possibilities of the market.

3.2. Level of reference

The current situation of guadua bamboo forest is useful to determine historical trends of factors influencing forest cover in the coffee region of Colombia, because the existing forest area and its level of degradation is the consequence of the dynamics in land use and land change along time.

The highly fragmented pattern of guadua forest has been evaluated previously and this is the first evidence of the pressure exercised on forest cover. According to Camargo & Cardona (2005), landscape metrics are an evidence of fragmentation, with small patch area, high values of edge and shape index larger than 1, indicating a predominant elongate shape (Table 1 and Figure 1) which is in ecological terms a factor contributing to the so called edge effect (ie. Murcia 1995).

Forest cover has been gradually eliminated in order to establish first especially coffee plantations, and lately pastures. Traditionally, coffee plantations have less negative impacts on environment, because they were designed as agroforestry systems. During the last 20 years, however, trees have been removed and plantations without trees are now predominant. Besides, the area of pastures has rapidly increased and is currently the largest land cover in this region. In addition, the urban expansion process is also contributing with the pressure exercised on these forests. Cities of the coffee region have defined plans of growing towards rural areas where guadua forests are located. Hence the land price is increasing and this process continues accelerating more and more. Figures 2 and 3 show images of how guadua bamboo forests are influenced by both agriculture and urban expansion.

Table1. Landscape metrics estimated for fragments of guadua bamboo forest in the coffee region of Colombia (*n*=834)

Statistic	Mean Patch Size(ha)	Mean Patch Edge (m)	Mean Shape Index
Mean	7,9	2512	2,55
SD	19,15	3533	1,11

Source: Camargo & Cardona (2005). SD= Standar deviation


Figure 2. Evidences of soil degradation attributed to cattle (left) and agriculture (right) in the coffee region of Colombia.


Figure 3. Urban expansion. Cities of the coffee region are rapidly growing out toward rural areas where guadua bamboo forests are located.

Fragmentation of guadua bamboo forests has implications for silviculture because larger areas of guadua stands would be required to meet demands. A number of farmers is not managing the small guadua areas properly to avoid costs of forest planning and technical assistance. Although, most of the culms harvested are used for domestic applications and the intensity of harvesting is usually low, the silvicultural practices to obtain these are inadequate. Therefore, domestic harvest sometimes causes damages and contributes to increased susceptibility of guadua stands to pests, as well as to a decreased productivity and quality (Figure 4). For guadua bamboo forests, there is no adequate information on illegal logging. Nevertheless, institutions in charge of forests control have reported that a significant amount of guadua culms are illegally harvested and commercialised (ie. Moreno 2006a). Problems in control of illegal logging are also a consequence of difficulties to monitor the large number of small forest patches distributed along the coffee region and due to the fact that logged culms are used mainly for domestic purposes.

Figure 4. Evidences of guadua bamboo forest degradation associated to an inadequate harvesting.

Briefly, negative factors contributing to guadua bamboo forests degradation were described above. Now in the framework of REDD+, it is also necessary to show how guadua bamboo forests may contribute to mitigate climate change, to provide other ecosystem services and also which strategies (silvicultural, planning, policy) can alleviate the reduction of emissions as well as illegal logging.

Carbon sequestration has been preliminary estimated in natural stands and plantations (Camargo & Arango 2010). Results are separately shown because plantations are still growing and have different characteristics such as higher density of culms per hectare and smaller sizes (diameter and length). Total carbon stored by natural guadua stands with an average density of 4050 culms per ha is of 126±41,7 t ha^{-1} with about 85% corresponding to aboveground biomass (culms, branches and leaves) and 15% to belowground biomass (rizhome). For plantations with an average density of 7700 culms per ha, the total carbon stored is of 24,6±5 t ha^{-1} with 86% of aboveground biomass and 14% of belowground biomass. It is also important to remark that soil carbon under guadua stands and bamboo plantation measured at 0,5 m of depth, was estimated in 544±125 t ha^{-1} in average. Allocation of biomass in different compartments of is shown in Figure 5 and 6.

Apparently the allocation of biomass is similar between natural stands and plantations. However, biomass in branches and leaves is higher in plantations, probably because photosynthesis is optimised for growing and additionally there is more available space for the development of lateral branches and leaves. Changes in biomass allocation depending on availability of light and age of species have been reported by some authors (ie. Anten & Hirose 1998; King 2003). Also for bamboo species, allocation of biomass and nutrients can vary in accordance with the level of disturbance of the stands and the total density of culms (Kleinhenz & Midmore 2001). According to Camargo (2006), leaf area of guadua clumps within plantations increases fast during the first years after establishing and its increment tends to decrease when branches of culms reach those from other clumps. Increment of leaf area is associated with the emission of new culms which also represent an increase of total area occupied by each clump.

Carbon stored was also estimated in culms with different stage of maturity (Camargo & Arango 2010). Estimates were done on culms belonging to the same bamboo individual; it means each culm connected by rhizomes with others and with different stage of maturity. Total biomass has a noticeably increment during the two first years, then it remains constant until the fifth year when it starts to decrease, although in guadua plantations this is not observed because there were not found culms older than four years (Figures 7 and 8). Decreasing of biomass after 5 years is related to the loss of leaves and branches of older culms and because they break with the wind, therefore it represents less biomass. If guadua culms are left in the forest, after 10 or 12 years they die, consequently become emissions of CO_2. This is a significant aspect that should be considered for promoting an adequate silvicultural management, given that if culms are harvested CO_2 might be stored in subsequent products if proper treatments to guarantee durability are applied on these.

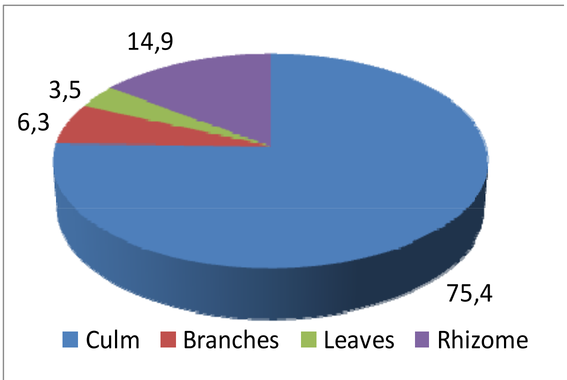

Figure 5. Distribution of carbon stored (%) by compartments of *Guadua angustifolia* Kunth within natural stands. Coffee region of Colombia.

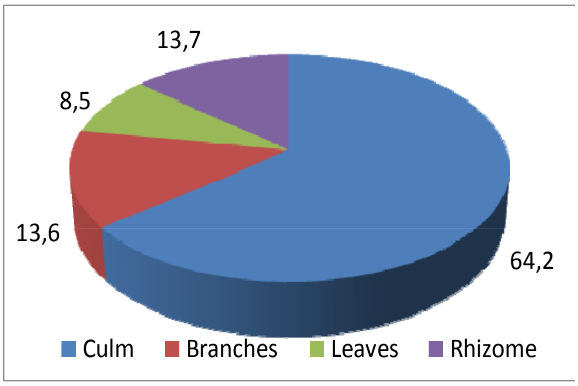

Figure 6. Distribution of carbon stored (%) by compartments of *Guadua angustifolia* in a plantation, eight years after established. Coffee region of Colombia.

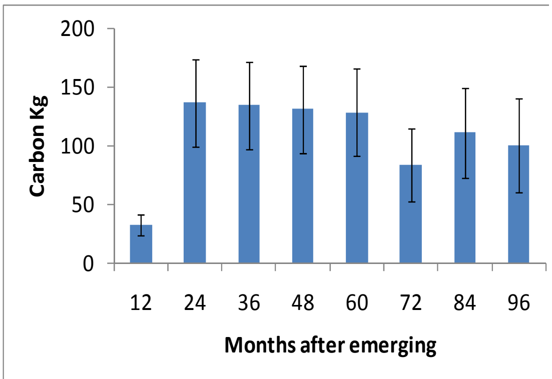

Figure 7. Total carbon stored (Kg) by an entire culm (cum, leaves, branches and rhizome) of *Guadua angustifolia* Kunth within natural stands according to its state of development.

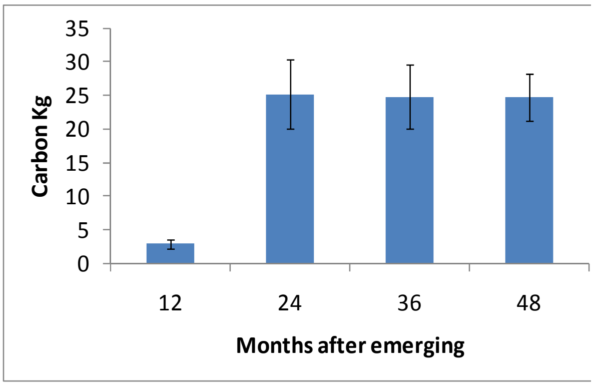

Figure 8. Total carbon stored (Kg) by an entire culm (cum, leaves, branches and rhizome) of *Guadua angustifolia* Kunth within a plantation eight years after established.

Protocols for monitoring carbon within guadua stands (natural and plantations) are being assessed (Camargo & Arango 2010), in addition approaches for sampling and plot design are available and permit appropriate estimates when inventories are conducted. Plot design has been evaluated by Camargo (2006); Schumacher 2006 and Rijal 2006. Also approaches for guadua inventory can also be observed in Kleinn & Morales (2006) and Camargo et al (2007).

Though other ecosystems services provided by guadua bamboo forests are not described in detail here, their functionality must be noticed, since they are an important refuge of biodiversity where more than 400 woody species associated to guadua, about 50 of birds and 18 of mammals (bats), have been recently registered within these forests (CIEBREG 2008). In addition, guadua bamboo forests are important as stepping stones for processes of ecological restoration, hence strategies orientated to improve their connectivity can significantly contribute to reduce the contrast with respect to predominant matrix of pastures. Figure 8 shows how fragments of guadua bamboo forest are connected with living fences of *Gliricidia sepium* which contribute to improve ecological conditions for a transformed landscape.

Figure 9. Guadua bamboo forests connected by living fences of *Gliricidia sepium*. Some of living fences are embedded in red lines.

3.3. Distribution and financing

Distribution and financing are simultaneously analysed because both are strongly related. To define how the benefits of reductions will be allocated, which distribution mechanism could be used, it is also necessary to know from where the money could come.

The implementation of REDD+ projects also requires a political framework which provides a proper legislation, institutional strengthening and possibilities of financing. Therefore some political initiatives supported by institutions and projects previously conducted, may be a linkage or taken as reference for the implementation of a REDD+ project.

To face the current situation of guadua forest and to contribute to its sustainable management, different strategies have been promoted. This process has been led by government institutions in charge of environmental control so called Corporaciones Autónomas Regionales (CARs) and throughout different projects. Also, the technological and scientific support of universities has been significant.

As a result of the above mentioned process, lineaments for an adequate management of guadua stands have been defined. One of the outcomes is the Unified Norm (Norma Unificada para el manejo sostenible de guaduales naturales), which defined the guidelines for an adequate management in the framework of the current legislation. In addition, the Terms of Reference for the Management and Harvesting of Guadua Stands (TRMHGS) was also defined as a mechanism to apply the Unified Norm.

The Unified Norm and the TRMHGS as well, aim to achieve the sustainable management of guadua stands. Therefore, those guadua stands, which fulfil the requests of the Unified Norm and the TRMHGS, are registered as guadua stands with sustainable management. After that, if good planning and management of bamboo forest is evidenced by CARs, farmers can receive incentives such as the reduction of taxes and technical assistance. This instrument is an important mechanism that could be useful for developing payments or incentives schemes focussed on farmers who do good practices. In this case, institutions would be in charge not only of control but also of managing mechanisms to distribute benefits to farmers.

On the other hand, planning of guadua forest is also other result which has contributed to the definition of suitable area for establishing guadua plantations and Units Forest Management (UFM). According to Camargo et al. (2007a), about 124000 ha have a high suitability for establishing guadua plantations. It was determined after the evaluation of 25 biophysical and socioeconomic variables. It means high possibilities of land use changing toward guadua plantations with possibilities for commercial outputs in a relative short time (eight years) and additionally for obtaining incentives associated for example to ecological restoration and carbon sequestration.

The UFM represents a set of conditions joined to a territory where guadua forests, farmers, market of products from guadua forests and the adequate infrastructure to do that, are combined. In the coffee region were estimated about 87000 ha associated to UFM of high productivity or with the better conditions for promoting alternatives associated to the management of forests (Camargo et al 2007a). UNF also have been useful to develop initiatives of forest management by groups of farmers with small (but closed) patches of guadua bamboo forests. As a consequence, costs of management and technical assistance as well as labours are considerably reduced. Therefore contributions for increasing the feasibility of obtaining benefits from forest even for farmers with small patches are now reachable and are significant for improving the organization of farmers, which is also convenient for development schemes for the distribution of benefits.

4. Discussion

The capability for carbon sequestration of 109±54 t ha^{-1} in average as well as the institutional and political development are remarkable and might contribute for easing REDD+ project implementation. Soil with about 544±125 t ha^{-1} at 0,5 m of depth is an important part of carbon pools and should be seen with more interest as an significant carbon sink. The proportion of soil carbon in regard to biomass carbon, has been defined as higher by different authors, ie. Lal et al. (1995) suggests that soil carbon can be three times higher to than in living organisms, which is consistent with results presented here.

Aspects related to monitoring carbon and strategies for mainstreaming REDD+ initiatives as a priority within territorial, economical sectors and institutional planning process must be strengthened. Different approaches for bamboo inventory and carbon monitoring should be consolidated and standardised and additionally must be promoted to be included in a national strategy for carbon estimation led in Colombia by Ideam.

The implemented model for forest planning is useful to define land suitability for commercial guadua plantations and also UFM. Nowadays, government institutions can lead the planning of guadua stands based on this model. Besides, consolidation of UFM is an alternative against drawbacks related to fragmented pattern of guadua bamboo forests and also for avoiding their degradation.

5. Acknowledgements

The authors wish to thank to COLCIENCIAS for financing the Projects: “Tecnología para definir la madurez del culmo de *Guadua angustifolia* Kunth una contribución al desarrollo forestal del eje cafetero colombiano" (Contract No. 442-1-2008), this project has provided relevant information for this work. Also thanks go to the Technological University of Pereira for financing and supporting the development of this investigation. Finally, we want to express our gratitude to the owners of farms for permitting us to work in their properties.

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Is there a relationship between climate factors and genetic diversity in Picea chihuahuana Martínez?

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Abstract

Also known as prickly spruce, the Chihuahua spruce (*Picea chihuahuana* Martínez) is the most common of the Mexican spruces. Up to now, more than 38 stands have been reported in the Sierra Madre Occidental within the states of Durango and Chihuahua. Temperatures are likely to impose strong directional selection in many plant populations, which must therefore adapt if they are to survive. Within populations, microgeographic genetic differentiation of individuals with respect to climate suggests that populations may adapt to certain temperatures through changes in gene structure. This adaptation could also apply to Chihuahua spruce because of its large south-north and temperature range. In this study we identified adaptive genetic differentiation linked to five populations of *Picea chihuahuana* M. that display different levels of temperature using population genomics, new correlative approaches and randomization permutation methods. DNA data were obtained by amplified fragment length polymorphism (AFLP) technology. On the basis of the results of the present study, we conclude that in the studied populations an evolutionary response to climate factor temperature is detectable and causes a loss of genetic diversity in warmer locations. Therefore, these populations may exhibit lower stability because of their lower adaptive capacity which could be already reflected in its current lower stem numbers.

Keywords: Sierra Madre Occidental, AFLP, adaptation, selection, temperature.

1. Introduction

Spruce (*Picea* A. Dietr.) is a predominantly boreal or temperate conifer genus which includes between 31 and 50 species depending on the classification system used (e.g. Wright 1955; Schmidt 1989; Farjon 2001). Three endemic and rare spruce species occur in small relict populations between altitudes of 2,200 and 3,500 m above sea level in the montane forests of Mexico (Ledig *et al*. 2000; Farjon 2001). Also known as prickly spruce, Chihuahua spruce (*Picea chihuahuana* Martínez) is the most common of the Mexican spruces. More than 38 stands have been reported in the Sierra Madre Occidental in the states of Durango and Chihuahua (Narváez et al. 1983; Ledig et al. 2000; Jaramillo-Correa et al. 2006). The species spans a north–south range of 687 km. The populations are found in three clusters, each separated by about 300 km. In total, there are about 43,000 individuals, including mature trees and natural regeneration (Ledig *et al*. 2000). Because of its low occurrence, *P. chihuahuana* is included in the lists of threatened species prepared by the International Union for the Conservation of Nature and Natural Resources (IUCN) and the Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias (INIFAP) (Sánchez-Córdoba & Narváez-Flores 1990).

Temperatures are likely to impose strong directional selection on many plant populations, which must therefore adapt if they are to survive. Within populations, microgeographic genetic differentiation of individuals with respect to climate suggests that populations may adapt to certain temperatures through changes in gene structure (Jump 2006). This adaptation could also apply to Chihuahua spruce because of its large south-north and temperature range. There are evidences that *P. chihuahuana* M. is more tolerant to higher temperatures when compared to other spruces, including *P. mexicana* and *P. martinezii* in Mexico. In growth chamber experiments, *P. chihuahuana* was able to survive under temperatures that would normally kill the other species (Ledig *et al*., unpublished).

Several studies have shown that the genetic structure of individual species and particular ontogenetic stages may be associated with physical conditions related to location, such as habitats and climate zones (Bergmann 1978), soil moisture (Stutz & Mitton 1988), oxygen concentration (Zangerl & Bazzaz 1984), moisture and temperature (Lumaret 1984; Guse *et al.* 1988; Kelly *et al.* 2003; Jump *et al.* 2006), and species composition (Wehenkel *et al.* 2007), diversity (Wehenkel *et al.* 2006, 2010) and succession (Wehenkel *et al.* 2011).

In this study we identified adaptive genetic differentiation linked to five populations of *Picea chihuahuana* M. that display different levels of temperature using population genomics, using new correlative approaches and randomization permutation methods (Wehenkel et al. 2010).

2. Material & Methods

2.1. Study sites and populations studied

Branches were collected separately from 254 individuals of *Picea chihuahuana* M. distributed in the five populations a) Paraje Piedra rayada, b) Quebrada de los Durán (Arroyo del Indio Ignacio), c) La pista, d) Arroyo del infierno, and e) San José de Causas covering most of the latitudinal range of the species in Durango State, Mexico (Figure 1). Ledig *et al.* 2000 already described the demographic and ecological parameters of the first four populations. The average annual temperature (T) was taken from climate stations in the vicinity (<17km) of the populations over a 15-***year*** period from ***1970 to 1985.*** The average annual temperature of population (T_p) was estimated by means of the saturated adiabatic lapse rate (0.65K per 100m altitude).

2.2. AFLP data

DNA data were obtained by amplified fragment length polymorphism (AFLP) technology. AFLP fingerprints were generated by use of the modified protocol described by Vos *et al*. (1995). The total genomic DNA of each sample was digested simultaneously with two restriction enzymes, EcoRI and MseI. The double-stranded EcoRI and MseI adaptors were ligated to the ends of the restriction fragments to produce template DNA for polymerase chain reaction (PCR) amplification, which includes two successive steps. The preselective amplification amplified the restricted DNA fragments with the primer combination E01/M03. The selective amplification was carried out using a fluorescent-labeled primer pair (FAM-E35/M63). All PCR reactions were conducted in a Peltier Thermal Cycler (PTC-200 version 4.0, MJ Research). The amplified restriction products were resolved electrophoretically on an ABI Genetic Analyzer 3100 together with the internal size standard GeneScan 500 ROX (fluorescent dye ROX) from Applied Biosystems. The size of the AFLP fragments was determined with the software packages GeneScan 3.7 and Genotyper 3.7 (Applied Biosystems).

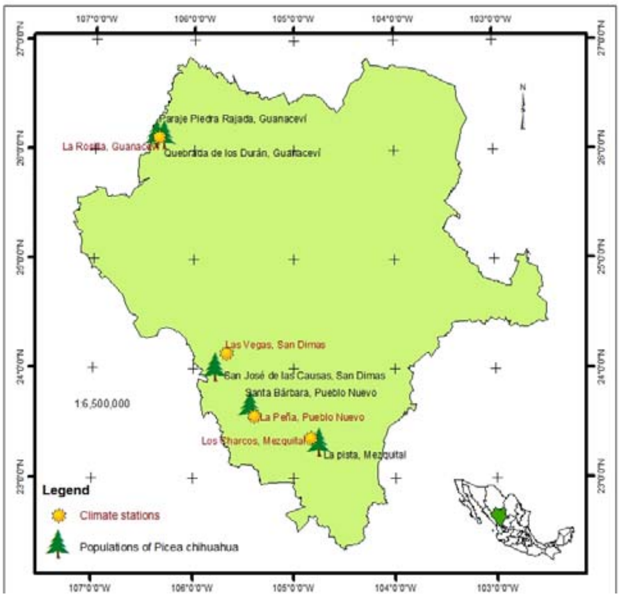

Figure 3. Locations of the five populations of Chihuahua spruce and the four meteorological stations in the vicinity of the stands.

Table 1. Locations of the five populations of Chihuahua spruce (tree number > 2m tall by Ledig et al. 2000) and of the climatic stations in the vicinity (<17km) of the populations, the Average annual temperature of the station (T) and Estimated average annual temperature of population (T_p) over a 15-year period from 1970 to 1985.

Population			***Climate station***		
Location	Geographical coordinates; altitude	Estimated annual average temp (T_p)	*Location*	Geograph. Grid coordinates; altitude	Mean annual temperature (T) and precipitation
La pista, Mezquital 919 trees	*23°19' 4.52"N, 104°44'42.6" W; 2685m*	6.82°C	*Charcos, Mezquital*	*23°22'10"N, 104°50'00" W; 2433m*	8.5°C 567mm
Santa Barbara, Pueblo Nuevo 148 trees	*23°39'50"N,* 105°26'08"W 2725m*	7.57°C	*Santa Barbara, Pueblo Nuevo*	*23°34'15"N, 105°23'40" W; 2765m*	7.3°C 1366mm
San José de las Causas, San Dimas 120 trees	*24°01'05"N, 105°47'06"W 2480m*	3.20°C	*Las Vegas, San Dimas*	*24°08'30"N, 105°40'00" W; 2230m*	4.5°C 810mm
Paraje Pie-dra rayada, *Guanaceví* 3564 trees	*26°08'48"N, 106°22'53"W ;* 2600m	*3.48°C*	*La Rosilla, Guanaceví*	*26°13'30"N, 106°36'70" W; 2816m*	*2.1°C 701mm*
Quebrada de los Durán, *Guanaceví* 2628 trees	*26°07'15"N, 106°24'17"W 2570m*	3.68°C	*La Rosilla, Guanaceví*	*26°13'30"N, 106°36'70" W; 2816m*	*2.1°C 701mm*

***** Geographical coordinates in Ledig *et al.* (2000) are incorrect.

Assuming that each detected (presence) band corresponds to a dominant genotype ((1,0)-, (0,1)- or (1,1)-genotype) of a gene locus (Kelly *et al.* 2003, Jump *et al.* 2006), the dominant and recessive genotype ((0,0)-genotype (absence band)) frequencies at each locus were calculated on the basis of the Chihuahua spruce collections from the five populations (Table 1).

2.3. Genetic structure measures

The genotype diversity at each gene locus ($v_{2g,}$) and the mean genotype diversity over all loci ($v_{2,mg}$) were calculated by the so-called Hill numbers, Hill´s family or diversity profile v_a, where a is a real number ranging from zero to infinity (Hill 1973; Gregorius 1978).

Considered as a function of a, v_a describes a diversity profile for each frequency distribution. The most illustrative values of the subscript a in such a diversity profile are: (i) a = 0, where the diversity is equivalent to the *total* number of variants; (ii) a = 2 as the *effective* number used in most genetic studies, and (iii) $a = \infty$, where only the most frequent variant determines the diversity. In the present study, the diversity profiles are represented by the *effective* number (v_2), as inherent in Simpson diversity ($D = \sum p_i^2$) (Gregorius 1978).

2.4. Covariation of T and T_p with $v2g$

The relationship between average annual temperature (T) and estimated average annual temperature of population (T_p) and genotype diversity ($v_{2g,}$) per gene locus as well as the mean genotype diversity over all loci ($v_{2,mg}$) was measured by the covariation (C) described by Gregorius *et al.* (2007). By definition, two ordinal variables X and Y show entire covariation if one variable consistently increases or consistently decreases as the other variable increases or decreases respectively. There thus exists a strictly monotonic relationship between the two variables. Because of the special mathematical structures of *effective* number (v_2) described by Hill (1973), it is meaningful to look for methods of detecting types of covariation that are monotonous but not necessarily linear. The covariation C varies between -1 and +1, where C = 1 refers to an entirely positive covariation and C = -1 to a strictly negative covariation. If its denominator is zero, C is undefined (Gregorius *et al.* 2007). Formally,

$$C = \frac{\sum_{i<j}(X_i - X_j)\cdot(Y_i - Y_j)}{\sum_{i<j}|(X_i - X_j)\cdot(Y_i - Y_j)|} \qquad [1]$$

In order to test the possibility that the observed degrees of covariation C[T x v2g] and C[Tp x v2g] are produced solely by random events rather than directed forces, a one-sided permutation test was performed, in which a reference distribution was obtained by calculating all possible values of the test statistic under rearrangements of the labels on the observed data. The percentages of imitated C greater than or equal to the respective observed C (P-values) were computed for a sufficient number of permutations (here 10,000)

2.5. Testing differential selection in Picea chihuahuana M.

Patterns of genetic differentiation can be created by gene flow, random drift, selection and mutation (Gregorius *et al.* 2007). The testing differential selection were based on randomly chosen reassignments (Manly 1997) of individuals over collectives of Chihuahua spruce and computing, for each reassignment, the genotype differentiation δ among populations and its components D_j (Gregorius and Roberds 1986) at each locus. This yielded a distribution of imitated δ´s. This distribution was compared with the observed value of δ. The percentages of imitated δ greater than or equal to the respective observed δ (P-values) were calculated (here 5,000). If the observed δ is larger than 97.5 % of imitated δ´s *(i.e. $P < 0.025$*; two-sided permutation test*)*, this implies non-randomly acting diversifying forces (differential selection or non-recurrent mutation) as causes of the genetic differentiation among collectives. Non-recurrent mutation is likely to produce high degrees of genetic diversity, which therefore distinguish it from differential selection (see more in Gregorius *et al.* 2007 and Wehenkel *et al.* 2010).

2.6. Testing effects of small population size in Picea chihuahuana L

Because effects of small population size influence the whole genome in equal measure (Jacquard 1974) these impacts are only important for AFLP when the relationship between average annual temperature and genotype diversity per gene locus has the same statistically significant trend at the majority of AFLP loci. Therefore, we calculated the relative frequency of all AFLP loci which have this statistically significant relationship ($P(Z \geq C)<0.05$) and significantly large differentiation δ among the five populations ($P(Z \geq \delta)<0.0001$). In addition, we measured the relationship between average annual temperature (T) and mean genotype diversity per gene locus (ν2,mg). If the relative frequency is low (e.g. <1%) and the C[T x ν2,mg] is not statistically significant ($P(Z \geq C)<0.05$) then effects of small population size are probably negligible.

3. Results

The AFLP primer combination produced 319 variable bands of 75-500 base pairs across all 254 individuals. Subsequently, the 319 bands were found to correspond to 319 gene loci. A statistically significant and negative covariation (C) between average annual temperature (T) and genotype diversity (ν2g) per gene locus (C[T xν2g]) was only found at 0.9% of AFLP loci (the gene loci 218 ($P(Z \geq C) = 0.016$), 348 ($P(Z \geq C) = 0.016$), and 402 ($P(Z \geq C) = 0.049$)). The negative covariation (C) of average annual temperature (T), with mean genotype diversities over all loci (v2,mg) was not statistically significant ($P(Z \geq C) = 0.145$). At three gene loci, the differentiations δ among the five populations amounted to 0.467, 0.318, and 0.237 and were highly statistically significant with $P(Z \geq \delta)$ values of 0.0001). A statistically significant C[Tp xν2g] was only detected at the gene locus 402 ($P(Z \geq C) = 0.049$). The genotype diversity at loci 218, 348, and 402 is relatively large in populations with low temperatures but shows decreased or drastically decreased values in the other populations with higher temperatures (Figure 2).

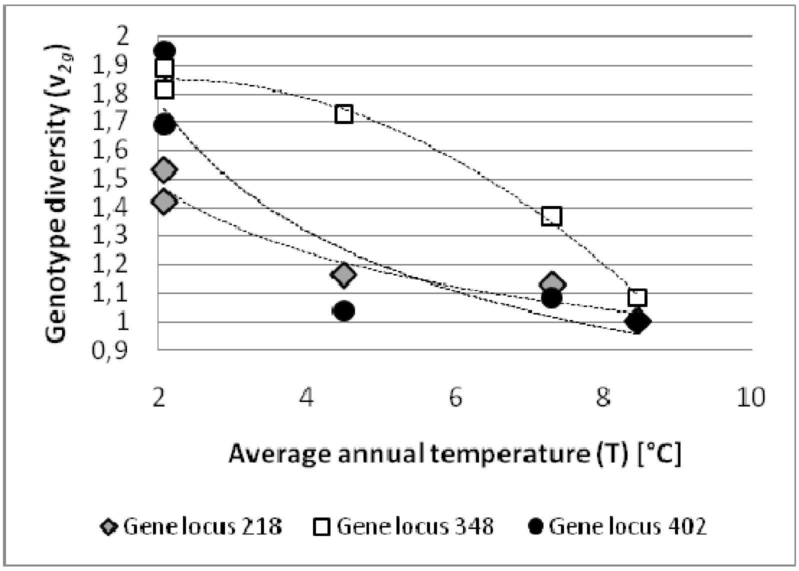

Figure 2. Significant relationships between mean annual temperature (*T*) and genotype diversity (ν_{2g}) at gene loci 218, 348, and 402.

4. Discussion

Because a non-recurrent mutation is only conceivable at AFLP in collaboration with counteracted selection (otherwise the mutated allele is doomed to extinction and the gene locus is without variation) and the relationship between average annual temperature and genotype diversity is significantly large (Wehenkel *et al.* 2010) at loci 218, 348, and 402, we assume that differential selection related to temperature caused the genotype differences at these loci. A small population size cannot be the chief cause for genotype differentiation at these three gene loci because the relative frequency of temperature-linked AFLP loci is low and the $C[T \times v_{2,mg}]$ is not statistically significant. Maybe the gene locus 402 is related to loci of cpDNA, because there is a significant relationship between the recessive genotype of 402 and *T* and Jaramillo-Correa *et al.* (2006) determined that the northern populations of *P. chihuahuana* M. bore higher cpDNA diversity as well as a higher frequency of a certain chlorotype than the central and southern stands.

Efforts should be made to determine what phenotypic differences exist between those individuals possessing and lacking the allels at the three loci and to determine the genes that cause this difference. Additionally, it is important to analyze whether this pattern of adaptive genetic differentiation can be produced experimentally in other species. For this purpose, ongoing long-term climatic manipulation experiments represent a unique resource (Jump et al. 2006).

On the basis of the results of the present study, we conclude that in the studied population an evolutionary response to climate factor temperature is detectable and causes a loss of genetic diversity in warmer locations. Therefore, these populations may exhibit lower stability because of its lower adaptive capacity (Gregorius 2001) which could be already reflected in its current lower tree numbers (see Table 1).

5. Acknowledgements

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Species-specific abundance, tree diversity and its relationship to climate factors in mixed and uneven-aged forests of Durango, Mexico

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Abstract

This paper explores relationships between the major climate variables (precipitation and temperature) and physiographic variables (altitude above sea level) with tree species-specific abundance, and tree species diversity in the mixed and uneven-aged forests of the Sierra Madre Occidental in Durango, Mexico. The relative abundance of *Pinus engelmanni* Carr. was significantly correlated with precipitation, while *Quercus sideroxyla* Humb. & Bonpl. do so with altitude. Species number, Margalef, and Shannon indices showed a significant increase with precipitation. Altitude was also significantly correlated to Shannon index. Results of this study may be useful for planning further work on the impacts of climate change on species-specific abundance, and diversity of tree species in forests of Durango.

Key words: Species distribution; temperature; precipitation; altitude.

1. Introduction

The interaction between vegetation data and climatic factors has become a research focus in fields of geography and ecology. The results have shown that the distribution of species (biogeography) is largely determined by climate, as is the distribution of ecosystems and plant vegetation zones (biomes) (Wilson 1992; Pyŝek 1993). The study of the relationship between the species abundance and climatic factors at the macro-scale provide insights into the ecological processes that determine the abundance and distribution of species (Brown 1995). A species that is abundant at the local scale also tends to occur in more sites (Gaston 1996). This pattern is consistent across scales and taxa suggesting that similar processes might regulate local and regional abundances of species (Davidar et al. 2008). However, since environmental conditions and species abundance change over regions, this relationship may not apply at smaller scales. A species that is well adapted locally might not necessarily be abundant in sites where different environmental conditions prevail (see Gaston & Kunin 1997). Climate change may shift local species-specific abundance. Thus, looking at relationships between species-specific abundance and climatic factors it is an important aspect for planning species adaptation programs.

In tropical Asian forests, large-scale patterns of tree species distributions and diversity were correlated with climate (Davidar et al. 2005; Baltzer et al. 2008). A similar process might exist in Mexican uneven and mixed temperate forests at the regional scale. The knowledge of these traits is needed for biodiversity conservation planning, since they may allow predicting tree responses to environmental changes, if we are able to understand their adaptive limitations to each factor, as well as interactions and feedbacks (Kirschbaum 2000). Finding important traits is also needed for gene conservation. Given the high degree of genetic diversity within tree species, there is a wide range in physiological traits that may allow tree species to adapt relatively quickly to climate change (Hamrick 2004; Aitken et al. 2008). If good relationships can be found between the observed geographic abundance of a tree species and the local climate characterized by a combination of variables, then it should in principle be possible to project future potential distributions of the same climate zone, and hence future potential distributions of the species or communities which are correlated with it.

This paper explores the relationships between the major climate variables (precipitation and temperature), and physiographic variables (altitude above sea level) with tree species abundance and diversity in the area of influence of the Sierra Madre Occidental in Durango, Mexico, and tested the null hypotheses that local tree diversity and species-specific abundance were not associated with environmental factors.

2. Materials & Methods

2.1. Study area

The pine-oak forests cover 16% of the Mexican territory, comprising 31.8 million hectares in total (FAO 1998: 30.1 million ha), and occur throughout the major mountain ranges of the Sierra Madre Occidental, the Sierra Madre Oriental, the Sierra Madre del Sur and the Transvolcanic Belt (Rzedowski 2006). 80% of the forest area is owned and managed by about 8,000 rural communities known as Ejidos and Comunidades who manage their land with some level of governmental control (Thoms & Betters 1998).

The study was conducted in the Sierra Madre Occidental within Durango State (within the geographical coordinates 26° 48' - 22° 19' N and 102° 28' - 107° 11' W). Regarding the extent and economic value of its forest resources, the State of Durango is the most important Mexican State. It occupies first rank in pine growing stock (27.7%), annual yield of coniferous roundwood (25.7%) and other roundwood yields (37.6%) nationwide (SRNyMA, 2006). The timber resources in the State of Durango are estimated to amount to about one-quarter of the national resources of Mexico. Of the total surface area of Durango (12.27 Million ha), about 4.9 Million ha are covered by forests.

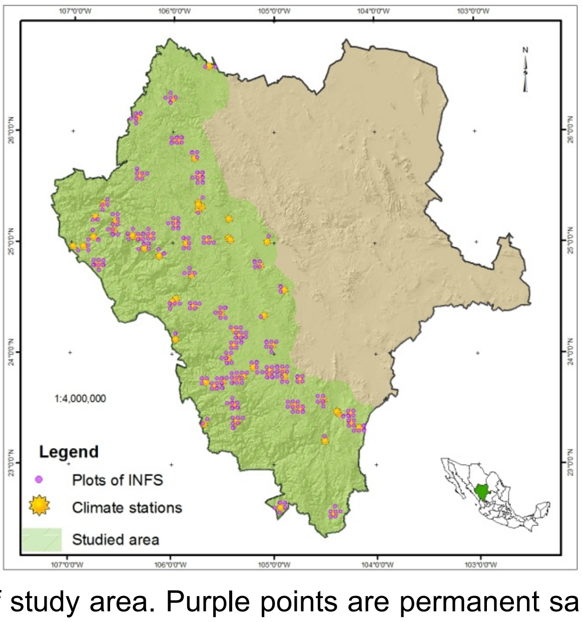

Figure 1. Location of study area. Purple points are permanent sampling clusters taken from the Mexican National Forest Inventory, while the yellow ones correspond to meteorological stations.

The predominant forest types are pine-oak stands, often mixed with *Pseudotsuga*, *Arbutus*, and *Juniperus*, among other tree species (Corral-Rivas 2006, Wehenkel et al. 2010). The study covers about 5 millions hectares of uneven-aged pine-oak forests. The altitudes above sea level fluctuate between 1,400 and 3,000 meters. A temperate climate prevails with rains in summer, annual average precipitation of 800-1,400 mm, and annual average temperature of 12 - 22°C (García 1989). Figure 1 shows the location of the study area in the national context. The species of greater commercial value, considering the technological characteristics of the wood and the distribution range as well as their harvested timber volume, are the following pine species, listed in order of importance: *Pinus cooperi* Blanco, *P. durangensis* Martínez, *P. arizonica* Engelm, *P. leiophylla* Schl et Cham, *P. engelmannii* Carr, *P. cooperi* var ornelasi, *P. teocote* et Cham, and *P. herrerae* Martínez. Other pine species of less commercial value, distribution and abundance are *P. ayacahuite* Ehrenb, *P. lumholtzii* Rob et Fern, *P. douglasiana* Martínez, *P. michoacana cornuta* Martínez, *P. oocarpa* Schiede. In addition some oak species and other coniferous and hardwood species, including the genera *Arbutus*, *Juniperus*, *Pseudotsuga*, *Abies* and *Picea* are also found in the study area.

2.2. Data sources

Vegetation data were taken from 246 permanent sample clusters of the Mexican National Forest Inventory that was conducted in 2004 by the National Forestry Commission. A cluster was integrated by four circular plots of 400 m^2 in size each, and was established on a regular five kilometer grid on the study area (Figure 2).

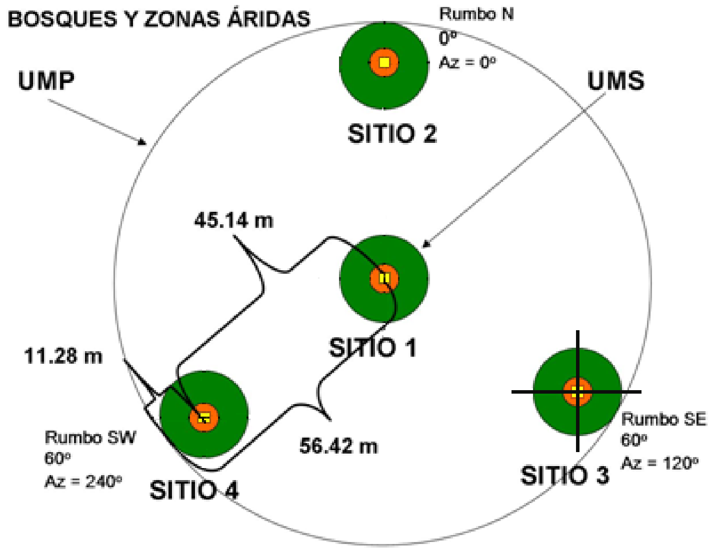

Figure 2. Distribution of sampling plots within a cluster of the Mexican National Forest Inventory (CONAFOR 2004).

Mean annual temperature, annual amount of precipitation, and altitude above sea level were assigned to each cluster from records of 55 weather stations of the National Meteorological System considering a period of 30 years from 1970 to 2000. A radius of 7 km was considered for linking climatic factors with vegetation, that is, a cluster must be located within this radius in order to be related to the climatic information. Table 1 summarizes the main characteristics of the vegetation data used in the analysis. Regarding tree diversity, there were 13 tree species in average within the influence area of a meteorological station, Shannon index ranged from 0.13 to 6.68.88 with a mean value of 1.87, while Margalef index showed a similar trend with values that varied from 0.20 to 4.20 with a mean value of 2.15.

Table 1. Summary statistics of the sample vegetation used to test the hypotheses

Species	Variable	N	Minimun	Mean	Maximum
Pinus arizonica	Temperature (°C)	19	2.01	8.40	19.21
Pinus chihuahuana		12	2.98	7.44	12.28
Pinus durangensis		24	3.69	8.05	20.80
Pinus engelmannii		20	3.79	8.35	20.80
Pinus lumholtzii		21	3.79	8.40	19.21
Quercus sideroxyla		33	2.01	7.55	17.79
Pinus teocote		30	2.98	7.61	19.21
Pinus arizonica	Precipitation (mm)	19	455.77	760.63	1,232.47
Pinus chihuahuana		12	554.03	846.11	1,484.03
Pinus durangensis		24	378.81	978.44	1,572.09
Pinus engelmannii		20	458.02	979.55	1,572.09
Pinus lumholtzii		21	378.81	967.74	1,572.09
Quercus sideroxyla		33	378.81	929.06	1,572.09
Pinus teocote		30	458.02	878.96	1,572.09
Pinus arizonica	Altitude (m)	19	1,640.00	2,212.13	2,500.00
Pinus chihuahuana		12	1,980.00	2,310.90	2,570.00
Pinus durangensis		24	1,150.00	2,151.76	2,600.00
Pinus engelmannii		20	1,360.00	2,205.40	2,600.00
Pinus lumholtzii		21	1,580.00	2,254.64	2,570.00
Quercus sideroxyla		33	1,150.00	2,212.04	2,600.00
Pinus teocote		30	1,150.00	2,223.39	2,600.00
Pinus arizonica	Relative Frequency	19	0.00	0.12	0.56
Pinus chihuahuana		12	0.00	0.05	0.13
Pinus durangensis		24	0.00	0.11	0.36
Pinus engelmannii		20	0.00	0.06	0.40
Pinus lumholtzii		21	0.00	0.07	0.24
Quercus sideroxyla		33	0.00	0.10	0.49
Pinus teocote		30	0.00	0.10	0.46

2.3. Statical analysis

The species-specific relative frequency and the species diversity were estimated at the station level. In this study tree diversity was expressed by the number of species, and the Shannon and Margalef indices, respectively (formulae 1 and 2).

$$Mg = (S - 1) \cdot ln_{10} (N) \quad (1)$$

$$H' = -\sum P_i \cdot ln_{10} (P_j) \quad (2)$$

where S = species number recorded in meteorological station i; N = total tree number in station i; P_j = relative frequency of species j in meteorological station i.

We used partial correlation and regression analyses to assess the relationship between local species-specific abundance, diversity of tree species and climate factors at the station level. The PROC CORR and PROC MODEL procedures of SAS/STAT® (SAS Institute Inc. 2004) were performed for the statistical analyses.

3. Results

3.1 Species-specific abundance

Table 2 shows the correlation between species-specific abundance to climate factors. Findings show that there were only three significant relationships. The relative abundance of *Pinus engelmanni* showed a significant decrease with precipitation (p<0.05), *Quercus sideroxyla* was negatively significantly correlated to altitude, and pines in general were highly significant correlated with altitude. Both the relative abundance of *Pinus engelmannii* and *Quercus sideroxyla* did tend to decrease with precipitation and altitude, respectively, while the abundance of pines had a tendency to increase with altitude. The relative frequency of *Pinus arizonica* and *Pinus chihuahuana* did tend to decrease with the temperature; these relationships, however, were not significant (r=-0,338, and r=-0,451, respectively). The relative abundance of *Pinus arizonica*, *Pinus chihuahuana, Pinus durangensis, Pinus lumholtzii,* and *Pinus teocote* did not reveal any significant relationship to studied climate and physiographic variables.

Table 2. Correlation between species-specific relative frequency and climate factors.

Species	N	Temperature	Precipitation	Altitude
Pinus arizonica	19	-0,338	-0,152	0,122
Pinus chihuahuana	12	-0,451	0,185	0,079
Pinus durangensis	24	0,018	0,178	0,111
Pinus engelmannii	20	0,122	-0,479*	-0,399
Pinus lumholtzii	21	-0,038	-0,129	-0,016
Quercus sideroxyla	33	0,035	0,114	-0,446*
Pinus teocote	30	0,125	-0,048	-0,201
Pinus spp	49	-0.303*	- 0.108	0.462**

*Indicates a significant correlation (p<0.05), ** indicates a highly significant correlation p<0.01.

As an example the Figure 3 shows the trend among the relative frequency of pines with altitude.

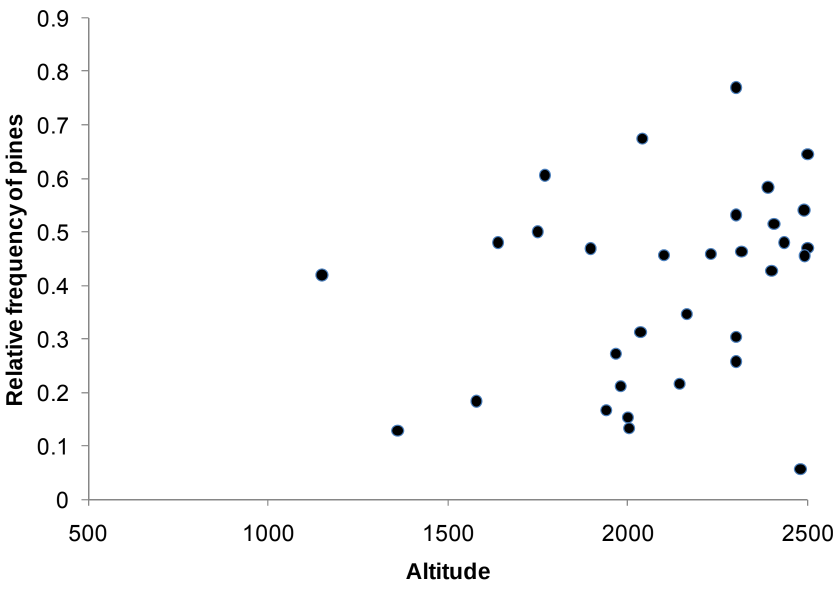

Figure 3. Relation of the relative frequency of pines to altitude in the studied meteorological stations.

3.2 Tree diversity

Table 3 shows the correlation between tree diversity to climate factors. Results show that tree diversity is in accordance with climate and physiographic studied variables. Species number, Margalef, and Shannon indices showed a significant increase with precipitation. Altitude was also significantly correlated to Shannon index. Temperature was, however, not in accordance with species diversity.

Table 3. Correlation between tree diversity and climate and physiographic factors.

Climate factor	Diversity measure		
	Shannon	Margalef	Species number
Temperature	- 0.085	0.025	- 0.113
Precipitation	0.322*	0.383**	0.400**
Altitude	0.322*	0.318*	0.422**

*Indicates a significant correlation (p<0.05), ** indicates a highly significant correlation p<0.01.

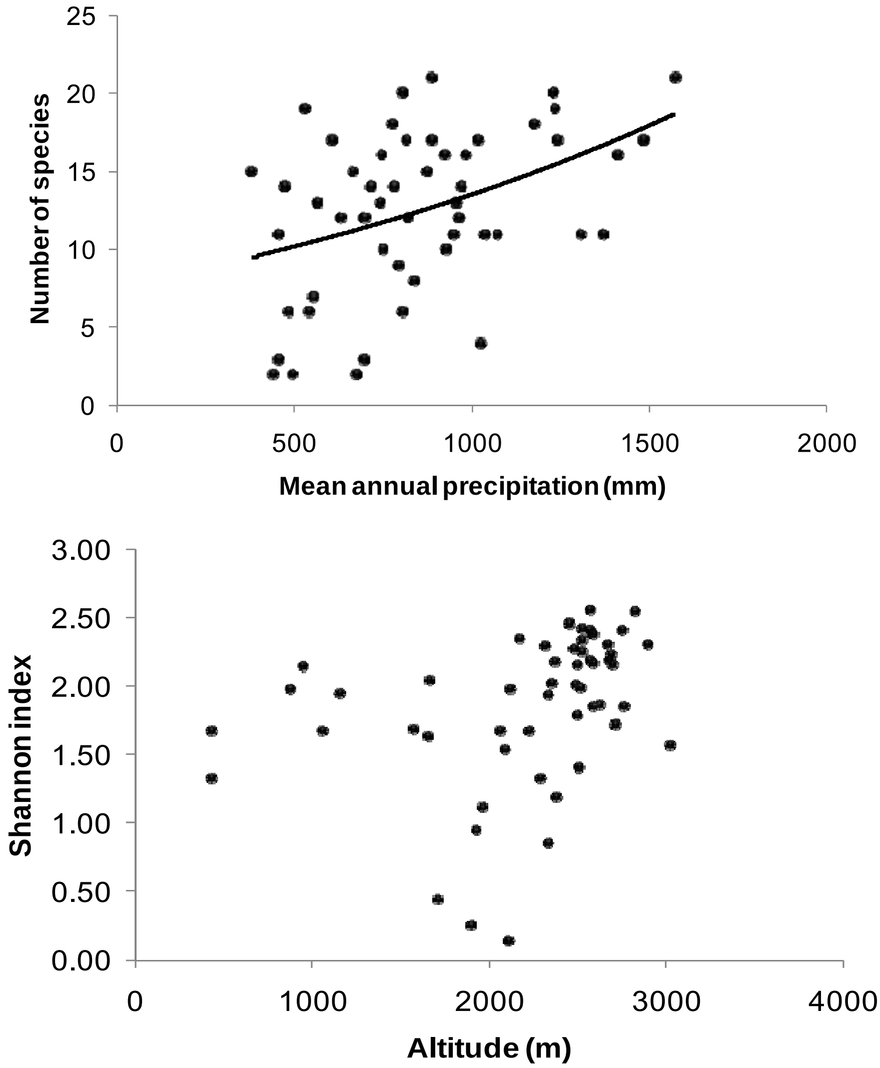

Figure 4. Relation of the number of species to precipitation (left), and the Shannon index to altitude (right).

Figure 4 shows the tendency of the relationships of the number of species to precipitation, and the Shannon index to altitude, left and right, respectively. An exponential model $Species\ number = \exp(a - bprecipitation)$ was fitted to the number of species-precipitation scatter plot, obtaining a R^2=0.19, *RMSE*=4.6, a= 2.03719, and b= 0.000566. Both parameters were significantly different of cero (<0.0001), indicating the possibility of predicting species number from precipitation records. However, more data is needed for modeling. To predict tree responses to environmental changes, we need to understand their interactions and feedbacks (Kirschbaum 2000).

4. Discussion

According to Person's correlation, some significant relationships between the major climate (precipitation and temperature), and physiographic (altitude above sea level) variables with species-specific abundance and tree diversity exist within the mixed and uneven-aged forest of Durango, Mexico. The relative abundance of *Pinus engelmannii* significantly decreases with precipitation, while *Quercus sideroxyla* do so with altitude. The abundance of pines significantly increases with altitude. *Pinus engelmannii* tends to be more drought-resistant than other studied species (González et al. 2007). *Quercus sideroxyla* seems to be more abundant at low elevations, while pines are better placed at high elevations. The former may be a more generalist species and will have a greater chance to survival under climate change (Davidar et al. 2008). On the other hand, our study showed that tree species diversity significantly increases with precipitation and altitude, indicating that these factors contribute to provide good habitat diversity, since species number is also a function of habitat heterogeneity (Van der Maarel 1988). Pyŝek (1993) found similar trends in Europe. Tree species distributions and diversity were also correlated with environmental factors in tropical Asian forests but in a large-scale pattern analysis (Davidar et al. 2005; Baltzer et al. 2008). Climate change that result in unpredictable local weather conditions could adversely affect rare species distribution particularly narrow ranging endemics restricted to particular temperature and rainfall seasonality regimes. Therefore conservation action should focus on identifying species that could be more vulnerable to change in climatic conditions (Davidar et al. 2008).

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Effects of fire severity on regeneration of Pinus pseudostrobus and Quercus spp. in the Sierra Madre Oriental, Mexico

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Abstract

We asked to what extend post-fire regeneration of *Pinus pseodostrobus* in mixed pine oak forest is related to fire severity. To answer this question the regeneration of mixed-pine oak forest 10 months after a wildfire was studied in the Sierra Madre Oriental, Mexico. Three fire severity classes were defined based on the degree of consumption of the pine canopy: low (canopy retaining >20% of green leaves), moderate (>80% of leaves of the canopy trees are scorched) and high (canopy with >80% of the leaves consumed). An important finding of this study is that there are different regeneration strategies with respect to different fire severities. The results showed that completely burned (high severity) sites are densely colonized by oak resprouts (1.4 m^{2-1}), whereas the number of seedlings is low. Sites that were affected by fire to a lesser extent, i.e. the moderate severity zones, have a higher abundance of pine seedlings (3.1 m^{2-1}) and a small percentage of vegetative regeneration.

Keywords: fire severity; *Pinus pseodostrobus*, establishment, post-fire regeneration, Sierra Madre Oriental, seedling

1. Introduction

The regeneration of mixed pine-oak forest after fire has been studied without the influences of fire (Enckelmann 1990). However, due to fuel heterogeneity and topography, wind and microclimatic changes during a fire, both the intensity and severity of fires are quite variable throughout the landscape and produce heterogeneous post-fire environments. Thus fires contain areas with different fire intensities and different fire severity, usually in a complex mosaic. Despite the importance of fire in the Sierra Madre Oriental (González-Tagle et al. 2008) the different post-fire regeneration of patches with different degrees of consumption has not been yet been addressed.

The present study aims to address to what extent the regeneration of *Pinus pseudostrobus* and establishment of *Quercus* spp., two dominant species in the Sierra Madre Oriental, are related to a simple qualitative measure of fire severity.

In the present work three fire severities were classify according to the degree of consumption of the canopy after a crown fire. This measure of severity, which is related to flame height, provides information on fire severity at the canopy level. To what extent fire severity at canopy level is related to fire severity at ground level remains unknown (Pausas et al. 2002). However, one can hypothesise the post-fire *P. pseudostrobus* regeneration and *Quercus* spp. establishment may be related to fire severity (as defined above) because: a) different canopy consumption may create post-fire litter inputs from the scorched canopy; and b) different fire severities may produce different changes in soil nutrient availability.

2. Material & Methods

2.1. Study area

The study was carried out on The Parque Nacional Cumbres situated in the Northern Sierra Madre Oriental, in the Mexican state of Nuevo León. The vegetation types in the Sierra Madre Oriental range from submontane bush land (matorral) in the lower sections, to oak forest in the middle and mixed pine-oak or pure pine forests at the highest elevations between 1000 and 3500 m above sea level. The dominant tree species of pine-oak forests in the Sierra de Madre Oriental are *P. pseudostrobus, P. teocote, Quercus canbyi, Q. rysophylla, Q. polymorpha* as well as *Prunus* and *Juniperus* species (Müller-Using 1994). These forests have important ecological and social functions; they prevent erosion, protect the water resources, produce timber and provide an environment for recreation (González Tagle et al. 2008).

The climate in 'Cumbres de Monterrey' is dry and warm with a mean annual air temperature of 22.3° C. The mean annual precipitation is 602 mm with the highest rainfalls in the hot months May and September. The main soil type is litosol (González Tagle et al. 2008). The particular study sites were chosen in a part of the park close to the municipality of Santiago (Sierra de Santiago) (Figure 1), because they have been affected by fire in April 2008, leaving a mosaic of mixed pine-oak forest with different degrees of consumption.

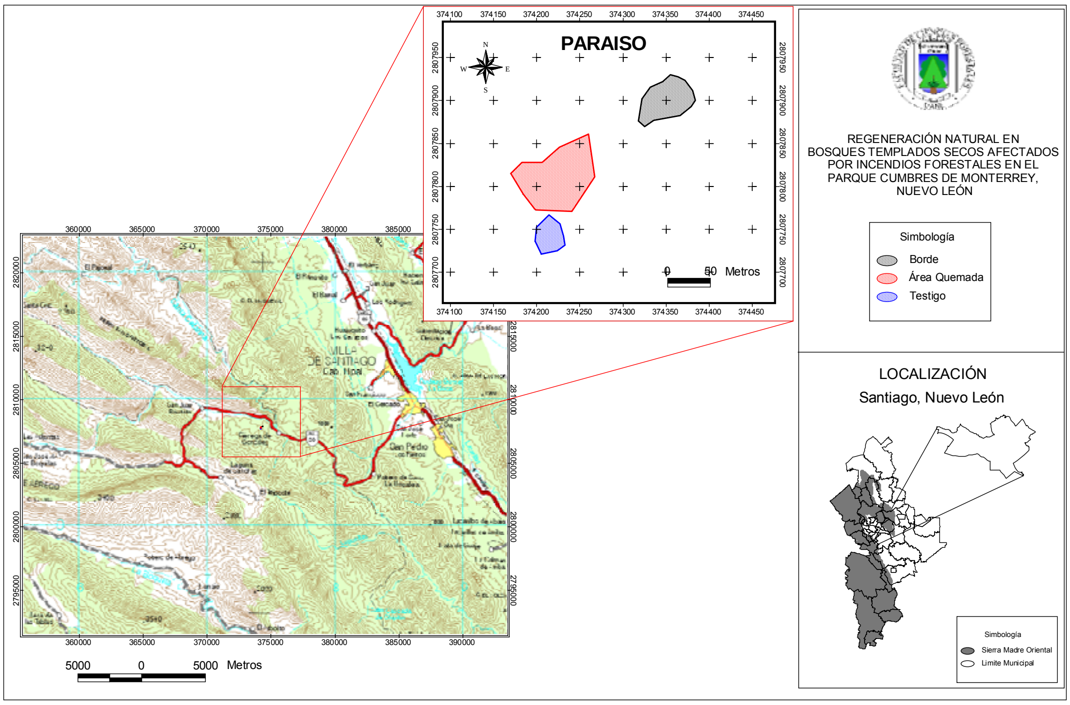

Figure 4. Parque Cumbres de Monterrey, Nuevo Leon; the study area is enclosed in red.

2.2. Sampling

After the 2008 fire, three different fire severity classes were differentiated according to pine canopy damage: low, moderate and high (see Table 1 for detailed definition).

Three forest stands were selected in the 'Parque Nacional Cumbres de Monterrey' (PCM), namely Genovevo (G), Bautista (B) and Paraíso (P) (Table 2). The stands are situated at different altitudes of the national park. Each forest stand was divided in three fire severity according to Table 1. Stands size ranged 0.1 to 0.5 ha depending in the site constrictions (continuity of canopy, size and shape of the stands, homogeneity of conditions).

Table 2. Fire severity classes judged from *Pinus pseudostrobus* canopy damage; description and post-fire mortality of pines. In all three classes, the forest floor litter layer was consumed.

Fire severity classes	Description	Post-fire mortality
Low	Light fire, canopy trees retain> 20% of green leaves (top of the canopy). Trees remain mainly green after fire	No
Moderate	Most leaves (>80%) of canopy trees are scorched (dead) but no consumed. Green leaves may occur at the top (<5%). Trees are mainly brown (retained scorched leaves) after fire.	Yes
High	Severe fire; canopy trees with >80% of the leaves consumed and the rest (if any) scorched (top). No green leaves left.	Yes

Table 2. Site characteristics of the study sites

Site	Altitude (m a.s.l.)	Exposition	Slope (°)	Forest type
Genovevo	1 154			
High		South West	40	pine-oak
Moderate		West	20	pine-oak
Low		South	20	pine-oak
Bautista	1 360			
High		West	30	pine-oak
Moderate		South West	20	pine
Low		West	30	pine-oak
Paraíso	1 417			
High		East	30	pine-oak
Moderate		South East	40	pine-oak
Low		East	30	pine-oak

In all observation units, lines between 30 – 100 m lengths were established in order to assess the regeneration of pines and oaks. Along the lines, 1 x 1 m quadrants were constructed alternating on both sites with a distance of 2 meters between them. In addition to the parameters and the species identification, the regeneration type was determined:

- Vegetative (v): all woody plants < 10 mm diameter and 130 cm height derived from vegetative mechanisms (e.g. resprouting).
- Seedlings (s): woody plants < 10 cm height.

In total, measurements in 50 quadrants per stand were conducted including all regeneration of pine seedlings with height as well as oak regeneration.

A complete inventory of all three stands was conducted, as the size of the stands was quite small und the tree density rather low. Diameter at breast height was measured in all trees on each stand and in all the adjacent trees whose projected canopy area fell within the plot. Seedling emergence was sampled in early spring 2009. Additionally, soil samples of all zones in the stands were analyzed regarding post-fire changes in soil-and water properties. Furthermore, the coordinates, the aspect, the slope and the elevation of all nine locations were determined.

3. Results

3.1. Soil

Most of the sites showed an average pH value of 7 or higher (Table 3), which indicates a neutral or alkaline soil reaction. Soils in Paraíso high, Paraíso low and Genovevo moderate were slightly more acidic (mean 6.2). Electrical conductivity of the soil was high in all sites (mean= 137.5).

Table 3. Soil properties of the study sites at the Sierra Madre Oriental

Site	pH	Texture	Phosphorus (mg L^{-1})	Organic C (%)	Organic material (%)	Electrical conductivity (µS cm^{-1})
Bautista						
High	7.4	Silty-clay	3.1	3.1	5.4	121.9
Moderate	7.5	Silty-clay loam	9.4	3.8	6.5	142.9
Low	7.5	Silty-clay loam	1.1	1.2	2.0	94.9
Genovevo						
High	7.4	Loam	21.8	3.6	6.2	170.9
Moderate	6.3	Silty-clay loam	10.8	5.4	5.8	127.0
Low	7.2	Silty-clay	8.4	3.4	9.4	134.4
Paraíso						
High	7.3	Loam	11.9	5.9	10.2	218.8
Moderate	6.0	Silty-clay loam	4.9	3.2	4.5	137.2
Low	6.2	Silt loam	3.2	3.5	6.0	86.7

The amount of organic material and organic carbon was high in all stands; only in Bautista low it was slightly lower. Soil texture in the moderate sites was silty clay loam. In the high severity zones the amount of sand was higher, resulting in the texture being classified as loam. The main difference in soil properties among the nine stands was in soluble phosphorus. Genovevo moderate and Paraíso high severity showed an adequate amount of disposable phosphorus, whereas it was low in Genovevo low severity and Bautista moderate and even deficient in Paraíso moderate, Paraíso high, Bautista low and Bautista high severity. The value of Genovevo high severity differed highly from the other sites with a value of soluble phosphorus of 21.83 mg L-1. Soil charcoal fragments and remnants of ashes were found in all stands.

3.2. Stand structure

All parameters that were analyzed in order to characterize the structure of the adult stand were only assessed in the moderate- and low severities of the three locations, as less than 5% of the canopy trees survived in the high severity zones. The basal area in the low severity zones in all stands ranged between 16.8 m2 ha-1 in Genovevo and 30.2 m2 ha-1 in Paraíso. For the moderate severity stands, the basal area ranged from 5.3 m2 ha-1 in Genovevo to 11.0 m2 ha-1 in Bautista (Table 4).

The stand density ranged in the low severity from 182.2 ind/ha-1 in Genovevo to 819.3 ind/ha 1 in Bautista stand. Contrary to this, the stand density was rather low in the moderate severity ranged from 73.4 ind/ha-1 in Genovevo to 183.8 ind/ha-1 in Bautista (Table 4).

Table 4. Summary of the results (standard deviations in brackets) found in plots under low and moderate fire severity classes. * Significant differences between fire severities (p<0.05.)

Stand	Variable	Fire severity classes		
		Low	Moderate	High
Bau-tista				
	Basal area (m^2 ha^{-1})	19.8*	11.0	
	Density (N/ ha^{-1})	810.3*	183.8	
	Seedling density (m^2) 10 month post/fire	0.9 (1.1)	3.1 (2.5)*	0.9 (1.2)
	Vegetative density (m^2) 10 month post/fire	0.4 (1.4)	1.7 (2.9)	2.5 (2.6)*
Geno-vevo				
	Basal area (m^2 ha^{-1})	16.8*	5.3	
	Density (N/ ha^{-1})	182.2*	73.4	
	Seedling density (m^2) 10 month post/fire	0.4 (0.6)	0.6 (0.8)*	0.4 (0.9)
	Vegetative density (m^2) 10 month post/fire	0.6 (1.1)	0.2 (0.5)	0.2 (1.1)
Para-iso				
	Basal area (m^2 ha^{-1})	30.2*	7.9	
	Density (N/ ha^{-1})	454.1*	138.8	
	Seedling density (m^2) 10 month post/fire	0.6 (1.1)	0.7 (1.0)	0.3 (0.4)*
	Vegetative density (m^2) 10 month post/fire	0.7 (1.4)	0.1 (2.9)	1.5 (2.1)*

3.3. Regeneration

Regeneration was most abundant in the burned zones of all stands, the high number being generated by the high amount of vegetative oak shoots. Contrary to that, the transition zones of all stands contained the highest numbers of *Pinus* seedlings and less vegetative regeneration (Figure 1). Young pine seedlings were scarce in the control sites, but regeneration of the category n (>10 cm height), meaning pines that are approximately between 1 and 4 years old, made up for this.

As the data was not normally distributed, non-parametric tests had to be conducted. The Kruskal-Wallis-test showed that within the treatment zones in Bautista there was a significant difference (p = 0.001) in the abundance of pine seedlings between moderate and high and between moderate and low. No difference was found between high and low. With respect to oak regeneration, all zones differed significantly from each other. The situation was different in Genovevo and Paraíso, with no significant difference in *Pinus* seedling abundance between the treatment zones. In Paraíso, however, significant differences showed in the abundance of oak regeneration between high and moderate and between high and low. No significance was found between moderate and low.

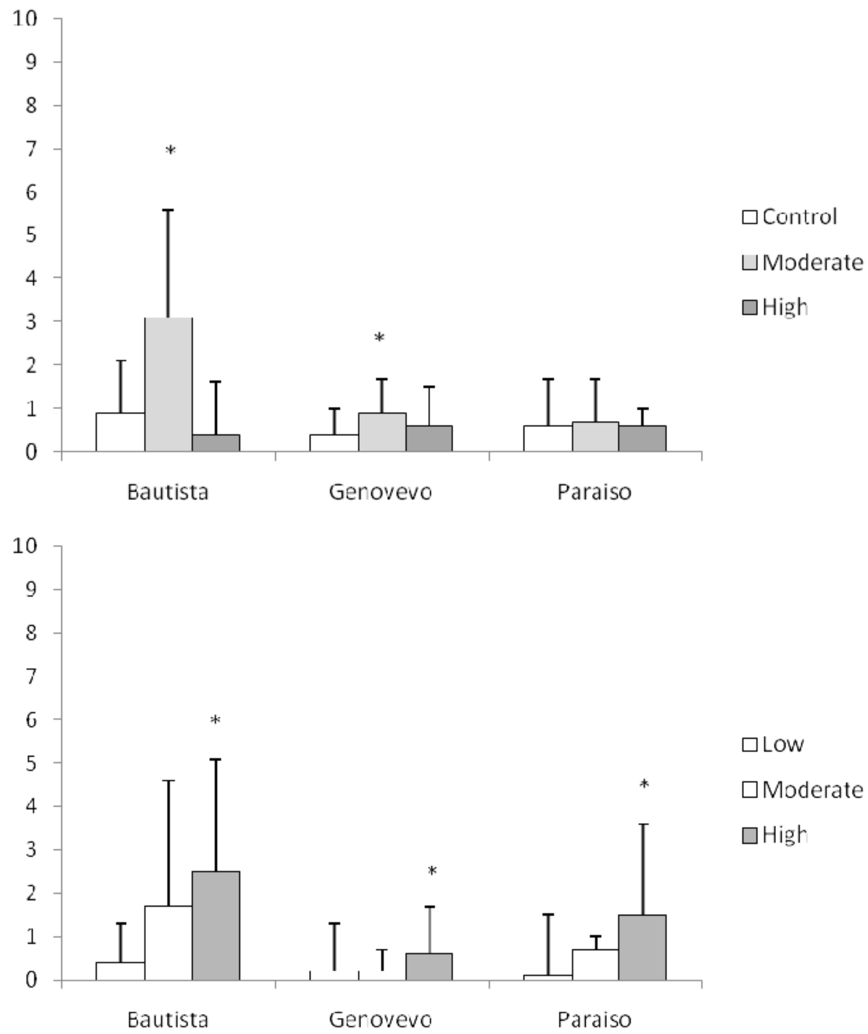

Figure 1. (above) Seedling density (individuals/m-^{2}) and (below) vegetative regeneration (resprouting oaks) 10 months after fire in the Sierra Madre Oriental.

4. Discussion

4.1. Site factors

Beside anthropogenic factors such as livestock-grazing, litter dumping and recreational behavior, numerous other site factors influence the success of post-fire regeneration, such as climate, soil, altitude and slope.

When evaluating the soil conditions (Table 3) in the different sites, it can be observed that the pH-value is highest in the high severity zones (7.4), with the exception of Bautista, where the pH is high in all zones (7.5).The alkaline soil reaction in the high severity zones can be explained by the high amount of fresh and fertile ashes. This is in accordance with Choosing et al. (1999), who found that soil pH in the first 5 centimeters of the soil increases significantly shortly after fire, hence improving the soil quality temporarily. Other studies, however, argue that post-fire charcoal remnants do not have any effect on the soil's chemical reaction.

All sites show a very high electrical conductivity with an average of 120.5 µS cm-1 (Table 3). A study on post-fire soil conditions in Turkey, conducted by Ekinci (2006), showed similar results. Ekinci (2008) compared soil properties of burned and unburned forest stands and found out that the values for electrical conductivity are higher in the burned stands. Even though values in his study are generally higher (576.7 µS cm-1) this applies as well for the stands in PCM. The highest value is 218.7 µS cm-1, and except for Bautista the values are higher in the burned zones. Eknici (2008) explains this by the release of ash and charcoal after the fire. These materials release basic cations such as Ca2+ which increase electrical conductivity as well as the pH value.

Ekinci (2008) also found that the amount of organic carbon was lower in burned sites than in unburned ones. This does not apply for the organic carbon content in the stands in PCM. The reason that no such tendency can be observed could be that the amount of organic carbon in the sampled soils of PCM is comparably low. Values in Ekincis (2008) study ranged around 7%, whereas in PCM they ranged around 3.5 %. Changes in already low organic carbon levels might not be very demonstrative.

Values for available phosphorus only range from adequate to deficient (8.2 mg L-1). But soils with low phosphorus levels appear to be best suitable for *P. pseudostrobus* growth (CONABIO 2009).

Soil texture in the transition zones is classified as silty clay loam and ranges between silty clay and loam in all other zones (Table 2). Eckelmann (1990), who studied the regeneration of pines in the Sierra Madre Oriental, found the same soil textures in stands with *P. pseudostrobus*. Ketterings et al. (2000) and studied soil texture changes after slash-and-burn fires in Indonesia. According to their results, the percentage of clay and silt decrease significantly after fire whereas the percentage of sand increased. This tendency can only be observed to a small degree in the stands in PCM, where the amount of sand is slightly higher in the burned- than in the other zones. In Paraíso, for example, the amount of sand in the soil texture is 11.6% in the transition zone and 38.6% in the burned zone.

Soil water content was not measured in this study, but according to the soil texture, it is likely that water availability is adequate. Due to its optimal pore size, loam or silt is considered the soil texture with the best water availability (Scheffer and Schachtschabel, 2006). However, it must be kept in mind, that the climate in PCM is semi-arid which can lead to drought stress.

4.2. Regeneration

Regeneration recorded in each site proved to be quite variable depending on the severity of the fire and different additional site factors. The species composition and seedling abundance in regeneration of fire-affected stands appeared to be influenced by various environmental factors besides fire. Different species as well as different regeneration strategies were favored in sites of different fire severity and different site conditions.

Mean seedling density ranged between 0.3 and 3.1 N m2 -1 (Table 4 and Figure 1). Fernández et al. (2007) found slightly higher numbers (average = 3.5 N m2 -1) when studying post-fire recruitment of *Pinus pinaste*r in northwestern Spain. Regarding the regeneration of *P. pseudostrobus* with respect to different fire severity, the abundance was highest in the moderate severity zones. Regeneration of oaks, however, was highest in the high severity zones. This difference might be due to the fact that most of the oaks derived vegetatively and resprouting is triggered by disturbances such as fire.

The low severity sites were established in order to have an impression of the regeneration structure and composition with low fire impact. The species composition was more balanced, and in most cases with a dominance of pines over oaks. The numbers of regeneration was smaller than in the moderate severity zones and partly also smaller than in the high severity zones. The difference was made up by a rather small number of seedlings and a higher number of young plants with a height > 10 cm. As there has not been any prior study on post-fire regeneration in PCM, it cannot be said whether the small number derived from high mortality of the regeneration. An investigation on post-fire regeneration variability of *Pinus halepensis* in the Iberian

Peninsula in Spain by Pausas et al. (2004) showed that regeneration density 8 months after fire was very low (average = 1.24 N m2 -1, lowest density: 0.006 N m2 -1). This was explained by inter- and intra-specific competition over the years on the one hand, and by slope, aspect and water availability on the other hand.

The moderate severity zone seems to present the best environment for the establishment of seedlings. Reasons for that could be that the ashes from the fire still fertilize the soil; many gaps are present leading to a high light availability without much competition. Pausas et al. (2003) conducted a study on seedling establishment after fire in *P. halepensis* woodlands in the Iberian Peninsula in Spain. The seedling density ranged from 0.1 to 1.43 N m2 -1, which is even lower than the seedling numbers assessed in PCM. They defined three fire severity classes depending on the consumption of the canopy. Seedling mortality was lower in high severity classes, which was explained by the increased fertility of the soil. The results suggested that there is no clear relationship between seedling density and fire severity which also applies in this study.

The only clear relationship with respect to abundance of pine seedlings was found between site and seedling density. The non parametrical analysis of variance proved that Bautista moderate severity was significantly different from all other sites.

Bautista was the stand with the highest number of regeneration altogether (475 individuals). The number of pine seedlings was highest in Bautista transition and that of oaks was highest in Bautista burned. It seems that the dominance of *P. pseudostrobus* was the major positive influence on the success of seedling establishment in Bautista. Shatford et al. (2007) state that successful seedling establishment after fire not only depends on fire severity and different site factors but also largely on the distance from an available seed source. Daskalakou and Thanos (2004) investigated post-fire seedling recruitment of *P. halepensis* in the Mediterranean. Their results suggested that seedling establishment depends exclusively on the canopy seed bank together with the prevailing meteorological conditions.

Completely burned sites seemed to enhance the effect and success of resprouting. Pausas (2002) investigated post-fire seedling establishment of P. halepensis in the Mediterranean. He suggests that high-severity fire seems to favor seeder species due to an improved nutrient availability, whereas low-severity favors sprouting. This is explained by the higher mortality of resprouts compared to seedlings during high-severity fire. Ceccon et al. (2006), who studied regeneration in dry forests gives a similar statement. She found that the number of resprouts is reduced with a higher frequency and severity of fires. Highly intense fires favor the establishment of seedlings. Barton (2005) states that surface fires favor pines because they have a higher canopy-survival. But resprouting allows oaks to rebound during inter-fire periods. Gould and Kennard (2002), however, argue that despite the higher mortality of resprouts, post-fire forest composition will include a high proportion of vegetative regeneration. The reason is that more resprouts are found in higher size classes which indicate a higher chance of surviving.

Vegetative regeneration is more common in dry ecosystems such as the pine-oak forests of the Sierra Madre Oriental. Kennard (2001) found that a high percentage of tree species regenerate by sprouting in arid regions. This is mainly due to the fact that a greater part of the biomass of dryland plants is invested in the root system, as the water and nutrient availability is limited. Contrary to the success of vegetative regeneration mechanisms, seedlings are less competitive due to their susceptibility to drought. Furthermore, as stated by Ramírez-Marcial (2006), seedlings of conifers grow less efficiently those that of angiosperms, at least during the initial phase of development. A study by Himmelsbach et al. (2006) on the drought resistance of mixed pine-oak forests in Mexico revealed that *P. pseudostrobus* is less competitive than *Quercus* spp. on arid sites.

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Global climate change: from the scientific evidence to the international policy actions and their effects on forests

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Abstract

The following paper has been compiled in an effort to illustrate the mechanisms, both climatic and political, which lie behind the current global climate change crisis. Drawing on a myriad of sources, focus has been placed on identifying the causes behind this phenomenon and the scientific research which has made the idea of a warming climate so inescapable for the human race.

Detailed explanations and assessments of the agencies involved in combating this change in climate, and the policies they have attempted to implement, are also examined. The establishment and development of international bodies tasked with halting this disaster, such as the IPCC, UNFCCC and COP, is charted. These organisations are then examined with respect to their effectiveness and ability to achieve the goals set by not only themselves, but the international community at large.

The history and effectiveness of the policies which are currently dictating environmental action across the world are discussed. In conjunction, the mechanisms employed by these bodies, such as joint implementation and the clean development mechanism, are examined.

Forests play an important role in the climate change, because they can be sinks and sources of greenhouse gases (GHG). Healthy growing forests are a sink of CO_2, while deforestation and degradation activities lead to the emission of GHGs into the atmosphere. Nearly 17.4 % of global anthropogenic GHGs in the year 2004 came from forestry (IPCC 2007). So a decrease in GHG emissions from forests can contribute to achieving the goal of mitigating the increase of the global average temperature (Rotter et al. 2000). To strengthen the role of forests, the REDD mechanism (Reduced Emissions from Deforestation and Degradation) could be key, however the most important elements will be determined by what the participants of the United Nations Framework Convention on Climate Change (UNFCCC) can agree and implement.

1. Introduction

Mankind has influenced the global climate to such an extent that it has become necessary to issue sweeping global legislation in order to preserve it. The seriousness of the situation is reflected in the ever-increasing severity and extent of the measures sought in an effort to curb the increasing temperature rise in our atmosphere. Various bodies have been founded over the years since climate change became a legitimate political issue and over time these organizations have determined the factors that have caused, and in many cases are continuing to cause, global warming.

These groups are constantly evolving to meet the challenges of climatic anomalies which have not been experienced in recorded history and have earned the support of most of the nations of the earth in their ventures. Such a task involving the very atmosphere that maintains life on this planet cannot be solved by any one nation and the very real threat that a changing climate poses to the earth has served to galvanise governments into taking action on an international level. Legislation formed at vast meetings such as the Conference of the Parties in many cases goes on to form the basis for the establishment of groups dedicated to combating climate change and monitoring its effects.

The proceedings and policies produced by these meetings are often guided by scientific research, and in order for this research to be trustworthy, a myriad of science-based organisations strive to use the most up-to-date technology to get the most unadulterated results. The findings of these bodies are then brought to the fore and debated amongst the international community in a bid to find a solution to the current global climate crisis. One such finding of this vein of research has shown the potential for forests to play a major role in mitigating climate change. The extent to which forests can act as ‘carbon sinks’ and offset the emissions from human industry is still an issue, but it is surely such knowledge that will prove the future building block of international policies.

2. Materials and Methods

This study was based on official documents of the UNFCCC, on published papers regarding climate change and the policies relating to it as well as documents from the Food and Agricultural Organisation (FAO) and the Centre for International Forestry Research (CIFOR). Additional information was gleaned from articles sourced from ScienceDirect as well as material which had been disseminated to the authors by lecturers at the Georg-August-Universität, Göttingen. Arguably the most invaluable resource was attendance of the Forest Day 4 in Cancun where the authors were able to engage with leaders in the various fields upon which this paper touches.

Upon conferral over the literature the authors debated the merits and flaws of each piece and received guidance from their supervisor, Sabina Rebeiro, as to which material was most appropriate and best merited inclusion. Several draft papers were prepared and critiqued before the final piece was decided upon. This was then reviewed by two external parties before being submitted.

3. Results

3.1. The greenhouse effect

Despite its potentially harmful effects, the greenhouse effect is an entirely natural and life-sustaining phenomenon that is responsible for keeping the Earth warm. Figure 1 illustrates how the greenhouse effect occurs.

Roughly two-thirds of the solar energy which penetrates the Earth’s atmosphere is absorbed by the surface and the atmosphere, with the remaining third being reflected back into space (Zemp 2008). In an attempt to reach a state of equilibrium, radiation emitted by the land and oceans is absorbed by the atmosphere, including clouds, and reflected back to Earth (Lindzen 1997).

Water vapour, carbon dioxide (CO_2), methane (CH_4), ozone (O_3), and nitrous oxide (N_2O) are all greenhouse gases (GHGs) naturally present in the atmosphere The intensification of the concentration of these gases in the atmosphere, especially CO_2, has been steadily increasing over the past 50 years and over the course of the 20th century (World Bank 2010). Among these gases, the CO_2 is noteworthy due to the high emission volume. This is clear in figure 2 which shows the longest record of direct measurements of CO_2 concentration in the atmosphere.

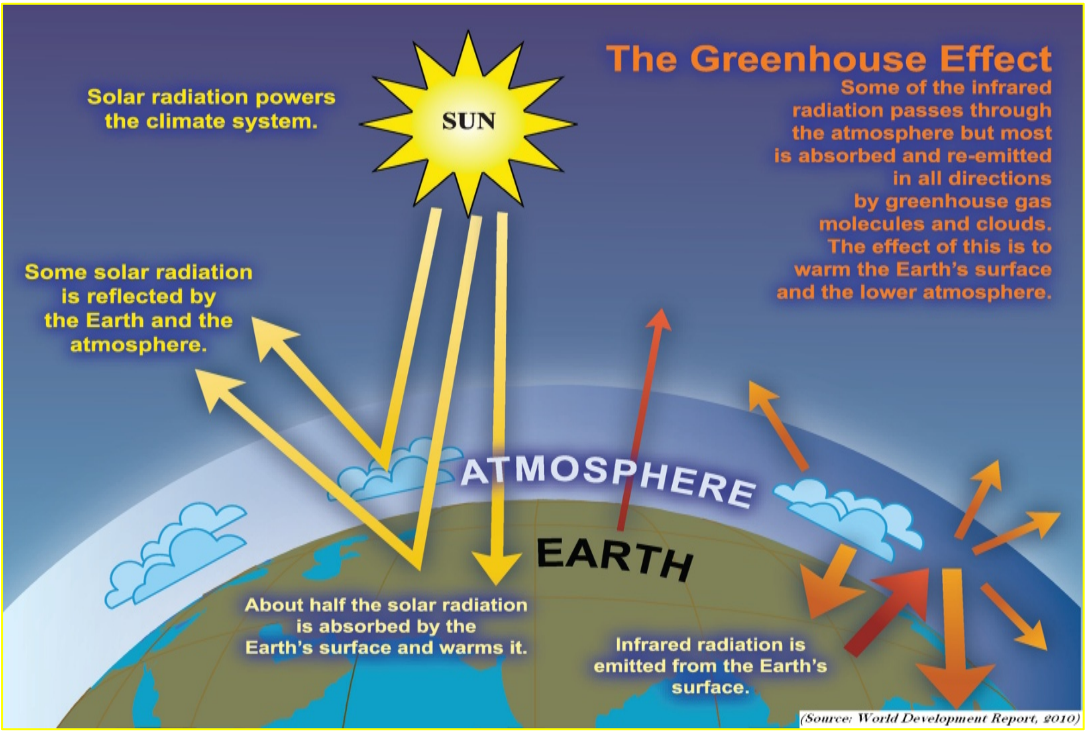


Figure 1. The greenhouse effect.

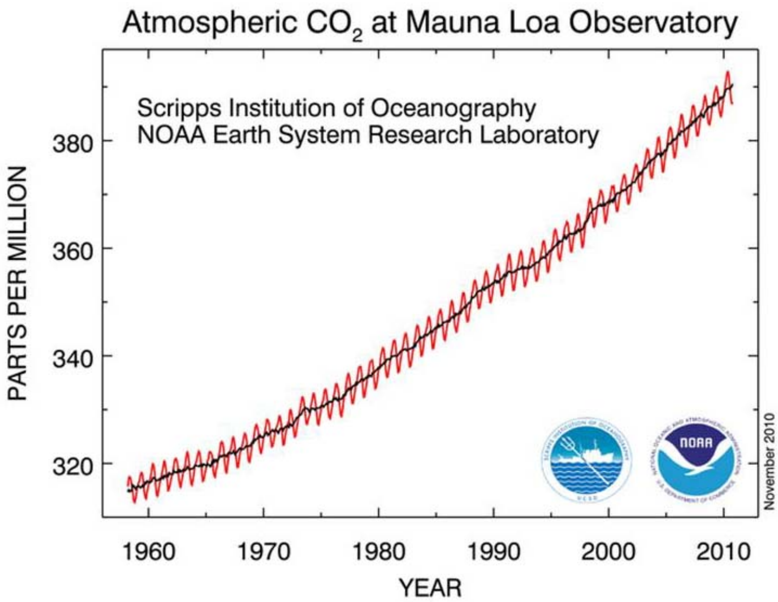


Figure 2. Increase of CO_2 concentration in the last 50 years.

This increase of concentration of greenhouse gases in the atmosphere can be in large part attributed to the burning of carbon-based fossil fuels and, to a lesser extent, deforestation and changes in land use.

3.2. Impacts of climate change

Numerous scientific studies, such as those carried out under the auspices of the IPCC Working Papers, have shown that sectors vital to sustainable development in terms of human health, ecological systems, and socioeconomic sectors (e.g., hydrology and water resources, food and fibre production, coastal systems, and human settlements), are sensitive to changes in climate (IPCC 2007). The fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC) showed incontrovertible evidence that the integrity of regional climates and ecosystems, both terrestrial and aquatic, are being negatively affected by the global rise in temperatures (IPCC 2007). The majority of the earths regions are likely to be adversely affected by rising temperatures, sea level and rainfall. Climate change is an additionally harmful factor which is putting increased pressure on the Earth's already strained environment and resources.

Environmental systems can be expected to be further degraded as climate change intensifies, with the impacts being most apparent on a socio-economic scale where the reality of how detrimental an increase in global temperatures will be is most illustratively manifested. Sufficient amounts of food, water and clean air may be hard to procure and even produce while employment becomes a severe problem and diseases become more prevalent and widespread (UNCCD 2001). The severity of the impact of these factors on a country can be extrapolated from the size of the country's population combined with its level of development and ability to adapt to climate change. Figure 3 illustrates the result of continuing along a "business as usual" line. Every region of the planet will be severely affected within the next 40 years.

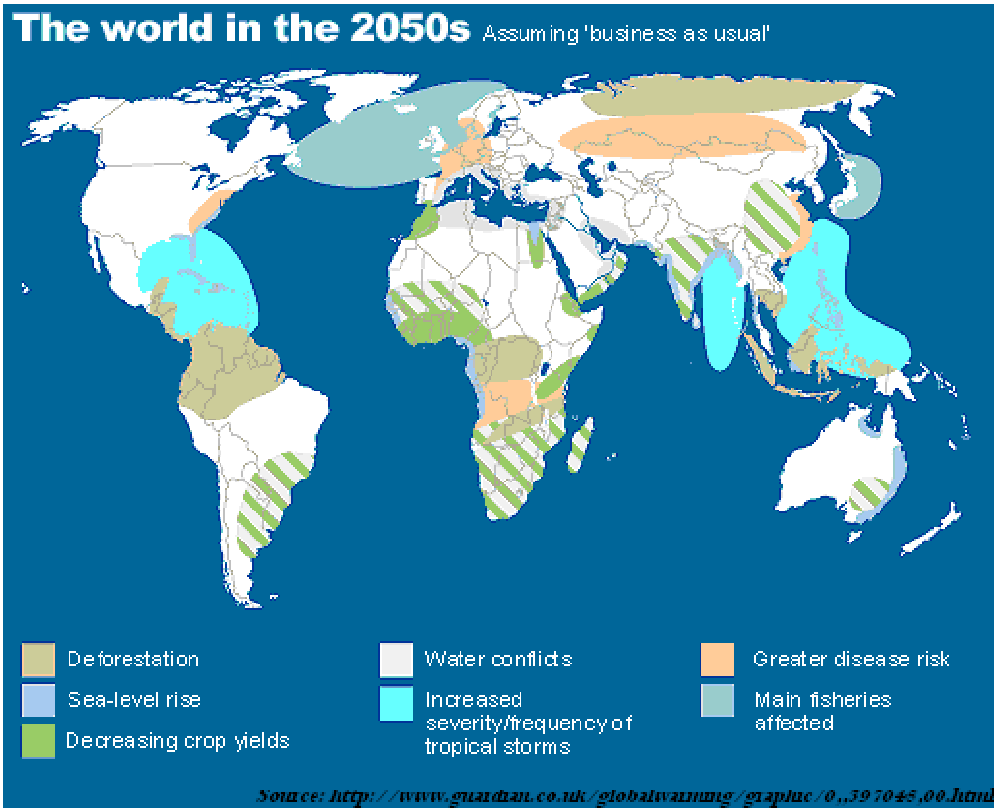


Figure 3. The world in 2050 assuming "business as usual".

The IPCC has produced a series of Assessment Reports, Special Reports, Technical Papers, and methodologies aimed at examining how projected changes in climate could interact with other environmental changes such as the loss of biodiversity, the degradation of large tracts of land an the depletion of water resources and the ozone layer. The content of such reports is increasingly urgent and they serve to dissuade governments from a course of (in)action which would lead to the above scenario.

3.3 Bodies and actors involved in the climate change negotiations

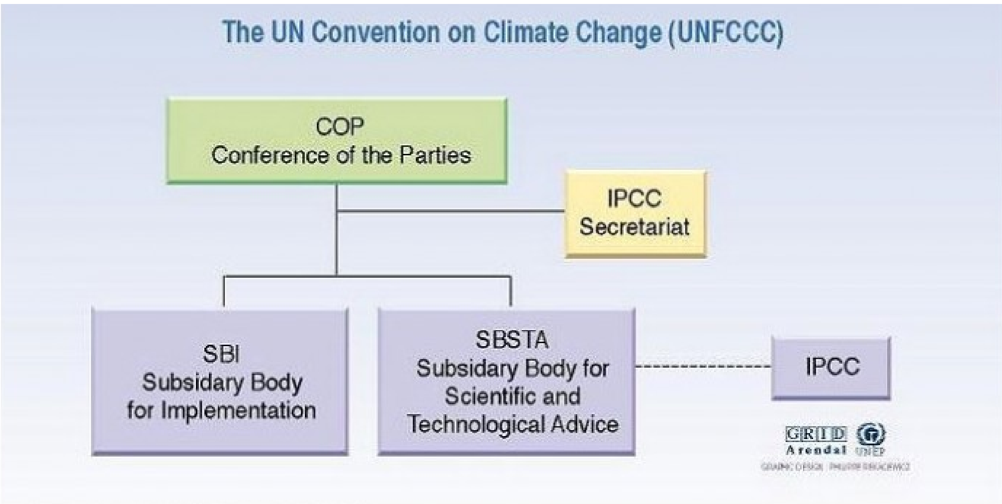
Climate change negotiations at an international level started in the early 80s due to advances in the myriad of fields related to this subject. Since then, many bodies were created to deal with the different aspects involved in these negotiations.

The IPCC was created in 1988 by the World Meteorological Organization (WMO) and the United Nations Environment Program (UNEP). The idea behind the IPCC was to provide a platform which would allow the dissemination of climate-related material succinctly and directly to governments by the United Nations. As such, world leaders could be kept abreast of what was happening to the climate and what effect their actions or inaction was having.

Aside from its Comprehensive Assessment Reports, the IPCC has produced several Special Reports on various topics which are deemed pertinent in relation to the Earth's Climate. The first IPCC report highlighted for the first time the severity of the situation regarding climatic change and showed the impacts that a rise in global temperatures under the intensified influence of GHGs could have. The findings of this report essentially spurred governments to create the United Nations Framework Convention on Climate Change (UNFCCC or FCCC), while the second paved the way for the Kyoto Protocol. In 2007, the IPCC was honoured for its work, and in particular the fourth of its reports: "Climate Change 2007", with the Nobel Peace Prize.

The UNFCCC is an international treaty that aims to stabilize the greenhouse gases concentration in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Agreed at the Rio de Janeiro United Nations Conference on Environment and Development (UNCED) in June 1992, the treaty's has as principle the common but differentiated responsibilities. Thus, the parties were divided in Annex I (developed countries and the ones that are in a transition to a market economy) and Non-Annex I (developing countries).

Following the establishment of the text for the Framework Convention by an Intergovernmental Negotiating Committee, the UNFCCC was opened for signature on May 9, 1992. 194 countries, referred to as "Parties" in this context, agreed to sign-up to the UNFCCC which then entered into force in March, 1994.



Source: United Nations framework convention on climate change (UNFCCC).

Figure 4. UNFCCC bodies.

An intrinsic element of the UNFCCC was the establishment of a national greenhouse gas inventory as a means of monitoring greenhouse gas (GHG) emissions and any increase/decrease which they might exhibit. This GHG 'balance sheet' is maintained by regular reports from the signatories which are submitted to the UNFCCC. The treaty originally set no restrictions on the levels of GHG emissions for the subscribed countries, nor did it set out any punitive measures for an excessive production of these gases.

The UNFCCC has different bodies and actors that are represented by the different political institutions created to deal with issues related to the climate change negotiations and countries involved in this process. The main convention bodies are presented in Figure 4.

3.4. Subsidiary Bodies

Under the UNFCCC, two permanent subsidiary bodies were established with the aim of keeping the secretariat informed on global issues relating to climate change, namely the Subsidiary Body for Implementation (SBI) and the Subsidiary Body for Scientific and Technological Advice (SBSTA). These arms of the UNFCCC are composed of experts in the various fields relating to climate change and its associated disciplines and they often collaborate with representatives of the signatory states. The SBSTA and the SBI traditionally convene on a biannual basis, meeting in conjunction with the COP with a second meeting being held at the seat of the secretariat in Bonn.

The role of the SBI is primarily the resolution of any problems relating to the implementation of directives issued by the UNFCCC. The body is also tasked with assessing and examining the information regarding emission inventories tendered by the signatories in order to establish the efficacy of the Convention and its policies. If the SBI feels that the resources it provides could be better utilised, the UNFCCC has the capacity to offer guidance to any sector through a highly-skilled team specialising in the afflicted area.

In relation to the financial aid given to non-Annex I parties, the SBI is instrumental in determining whether the current level of funding is sufficient, or the party in question should receive a higher/lower amount via the Global Environmental Facility (GEF). The body also examines how appropriately the money is being used which helps to inform it in its other capacity of advising the COP on financial matters such as its budget.

Broadly speaking, the SBSTA operates in a dual capacity of scientific and technological advisor to the COP. It is on the forefront of environmentally-friendly technological advances and part of its mandate is to identify the methods and technology which show the greatest potential to combat climate change. Improvements spearheaded by the SBSTA in the area of data capture and processing allow for the optimal assessment of emission inventories executed by the parties, which in turn informs the UNFCCC of the efficacy of its methods. By collaborating with international organisations such as the IPCC, the SBSTA maintains a flow of knowledge between like-minded institutions to ensure that any important advances are discovered and examined to assess their potential in assuaging climate change.

The adaptation and vulnerability of specific areas is also investigated by the SBSTA. Activities in the Land Use, Land-Use Change and Forestry (LULUCF) sector are looking promising as means of offsetting or reducing emissions, either through the efficient management and protection of forests or by active tree planting, but these capabilities are much discussed and the subject of further in-depth research by the SBSTA and its global network of associates.

3.5. Conferences of the Parties

Since the establishment of the UNFCCC, the associated parties have convened on an annually basis in meetings known as Conferences of the Parties (COP). These gatherings of representatives from all of the signatory members are aimed at assessing the extent of the global changes and the effectiveness of the measures which have thus far been implemented in an effort to curb its effects.

The first COP took place in Berlin in 1995. Since then sixteen COPs occurred (Table 1), in which some had important outcomes, while at others only minor issues were discussed. In this paper we will focus mainly on the most important decisions taken at the last fifteen COPs. Since 2005 the COP have met in conjunction with the Meeting of the Parties (COP/MOP). The COP/MOP is a meeting of the countries or parties that signed the Kyoto Protocol. The non-Kyoto Protocol signatories can attend these meetings in an observational capacity.

Table 1. Year and place of the Conference of the Parties

Conference of the Parties	
1995	COP 1, Berlin, Germany
1996	COP 2, Geneva, Switzerland
1997	COP 3, Kyoto, Japan
1998	COP 4, Buenos Aires, Argentina
1999	COP 5, Bonn, Germany
2000	COP 6, The Hague, Netherlands
2001	COP 6.5, Bonn, Germany
2001	COP 7, Marrakech, Morocco
2002	COP 8, New Delhi, India
2003	COP 9, Milan, Italy
2004	COP 10, Buenos Aires, Argentina
2005	COP 11 and COP/MOP 1, Montreal, Canada
2006	COP 12 and COP /MOP 2, Nairobi, Kenya
2007	COP 13 and COP /MOP 3, Bali, Indonesia
2008	COP 14 and COP /MOP 4, Poznan, Poland
2009	COP 15 and COP /MOP 5, Copenhagen, Denmark
2010	COP 16 and COP /MOP 6, Cancun, Mexico

3.5.1. A brief overview of the most important decisions taken at some of the COPs:

- 1997 – COP 3, Kyoto, Japan - The Kyoto Protocol on Climate Change
  The Kyoto Protocol outlined obligations for a reduction of the greenhouse gas emissions of Annex I countries. Legally binding reductions in greenhouse gas emissions were decide upon at an average of 5.0% below 1990 levels, set to be attained between the years 2008–2012. Four major items were discussed and decided upon in Kyoto, namely Flexible Mechanisms of Joint Implementation (JI) and the Clean Development Mechanism (CDM), Carbon Sinks, Compliance and Financing. It was agreed that credit for Carbon Sinks would be granted for broad activities that absorb carbon from the atmosphere or store it. In what concerns financing, broad outlines of consequences for failing to meet emission-reduction targets were outlined (though these were not ratified until 2007). Finally, three new funds were established with the aim of providing assistance for needs associated with climate change.
- 2000 – COP 6, The Hague, Netherlands
  The United States proposed to use forests and agricultural lands as carbon "sinks" to produce carbon credits to be used towards satisfying a major proportion of the U.S. reduction in emissions. COP 6 was ultimately suspended without agreement on the proviso that negotiations would resume at a later date.
- 2001 – COP 6.5, Bonn, Germany (Resumed from the suspended negotiations of The Hague, 2000)
  The U.S. delegation declined to participate in the negotiations related to the Kyoto Protocol and instead was merely an "observer".
- 2001 – COP 7, Marrakech, Morocco
  Most of the operational details of the Buenos Aires Plan of Action were finalised, thereby setting the stage for nations to ratify the Kyoto Protocol. Operational rules established for international emissions trading among signatories of the Protocol, for the CDM and for joint implementation. The consequences for failing to meet emissions targets were expounded but were postponed by the parties of the Protocol as, once ratified, these consequences would be legally binding.

Accounting procedures for the flexibility mechanisms were put in place. The means of reviewing the adequacy of commitments with regards to the future commitments by developing countries was tentatively suggested for COP 8.

- 2005 – COP 11 and COP/MOP 1, Montreal, Canada
  The first Meeting of the Parties (COP/MOP 1) of the Kyoto protocol happened this year. The Montreal Action Plan agreement was reached at the end of the conference with the aim of extending the Kyoto Protocol beyond 2012 and to negotiate greater cuts in greenhouse-gas emissions. The mechanism for Reducing Emissions from Deforestation and Degradation (REDD) in developing countries was proposed.
- 2006 – COP 12 and COP /MOP 2, Nairobi, Kenya
  Giant strides were made in increasing support for developing countries and for making improvements to the clean development mechanism. A five-year plan of work to support climate change adaptation by developing countries was decide upon. An agreement on the procedures and modalities for the Adaptation Fund was reached.
- 2007 – COP 13 and COP/MOP 3, Bali, Indonesia
  An agreement for a timeline and structured negotiations post-2012 (the end of the first commitment period of the Kyoto Protocol) was established. An Ad Hoc Working Group on Long-term Cooperative Action under the Convention (AWG-LCA) was also put in place. The Bali Action Plan (Decision 1/CP.13) was adopted.
- 2009 – COP 15 and COP/MOP 5, Copenhagen, Denmark
  Foundations were laid for a post-Kyoto agreement. A 13-paragraph 'political accord' was negotiated. The accord represented a collective commitment by developed countries to combat emissions through new and innovative means including forestry and investments through international institutions. Longer-term options on climate financing mentioned in the accord were to be the subject of discussion within the UN Secretary General's High Level Advisory Group on Climate Financing, with a specific focus on identifying new, innovative and additional sources of financing to meet the goal set by industrialized countries of "$100 billion a year by 2020".
- 2010 – COP 16 and COP/MOP 6, Cancun, Mexico
  The decisions adopted in Cancun contain many elements of relevance to the private sector, including a call for low-carbon development strategies and NAMA's. It was also decided that the future role of market based mechanisms under the Convention should be decided at the next COP in Durban, South Africa, in 2011. It was agreed that, in order to help meet emission reduction objectives, project-based mechanisms under the Protocol should continue to be available, a strategy which is aimed at increasing confidence in the much-abused carbon markets.

In short, the conference in Cancun anchored important elements of the Copenhagen Accord in formal decisions and outlined concrete steps to work out the details on a number of elements of the future framework. A new Green Climate Fund was established, as were bodies on technology and adaptation. By far the most impressive achievement was the launching of a work programme on REDD plus, the content of which will be subsequently dealt with below.

3.6. Forests

Forests play an important role in human life as they provide different ecosystem services (Figure 5). Forests produce O_2 through photosynthesis, which is essential to sustaining life on the planet. They also contribute to the production and maintenance of drinking water sources as well as providing a high diversity of flora and fauna which are hugely important for the maintenance of the planets biodiversity. In the context of climate change, the carbon sequestration and carbon stock of forest biomass is the most important ecosystem service provided by forests (Scholz 2008). The forestry sector can help to lessen climate change by acting as a sink for CO_2 (Binkley et al. 2002).

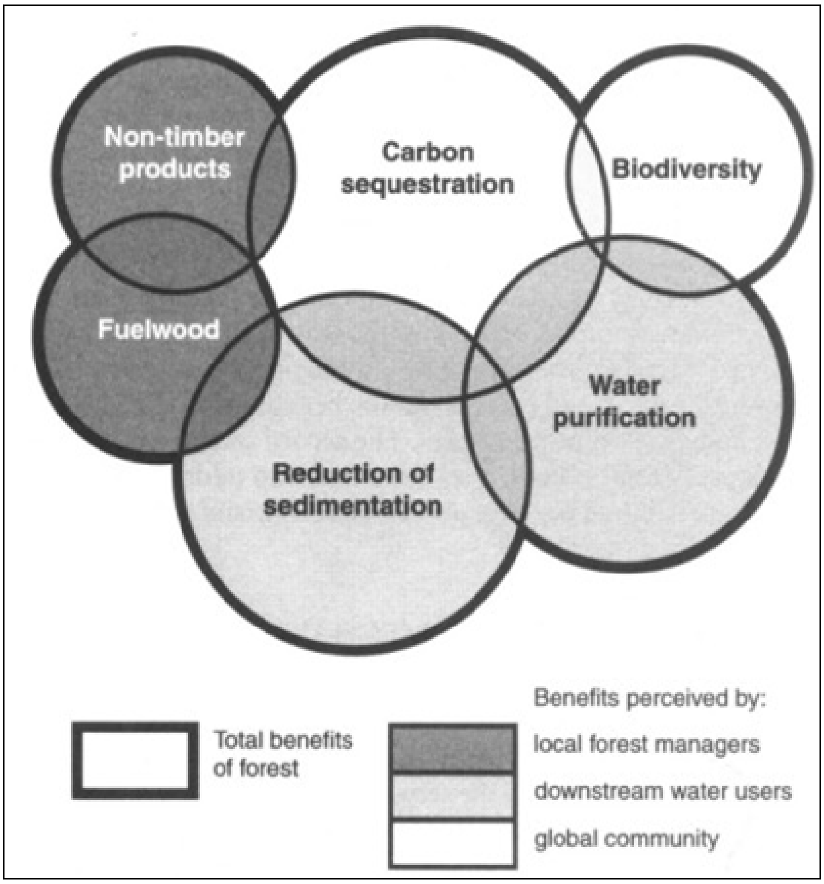


Figure 5. Forest ecosystem services and their beneficiaries (Source: Pagiola et al. 2002)

However, despite the importance of forests, they have being systematically deforested (Skutsch & McCall 2010). Figure 2 shows the average annual change of forest cover in the world.

The figure above shows in red the areas where forest cover decreases, in green where forest cover increases an in grey the areas where the change rate is below 0.5 %. The areas with greatest loss in forest cover can be found in Brazil and Indonesia, while China possesses the highest reforestation rate as desert encroachment drives the country`s afforestation efforts (China 2002). As the Chinese government has many reforestation activities in place, the country does not support the REDD mechanism because it would not generate any economical advantage.

Estimates from the Global Forest Resources Assessment (FAO 2010) show that the forests of the world store approximately 289 gigatonnes (Gt) of carbon in their biomass. However, due to a reduction in the global forest area, especially in Brazil and Indonesia, the carbon stored in forest biomass decreased by an estimated 0.5 Gt annually during the period 2005–2010.

3.7. Forests in the Kyoto Protocol

Despite the importance of forests they were initially marginalised and often excluded in the climate change negotiations. It was not until COP 4 that the Decision 9/CP.4

introduced the guiding policies which were aimed at encompassing land-use, land-use change and forestry under the Kyoto protocol. In the following conferences the issue of forests was again addressed.

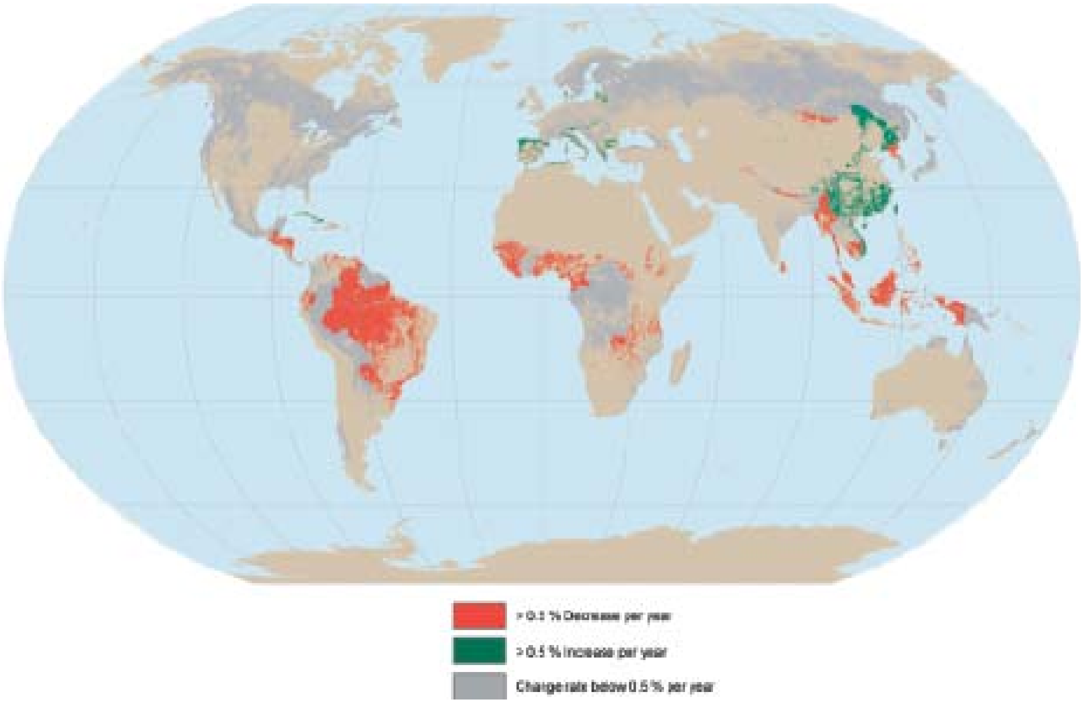


Figure 6. Changes in forest cover in percent per year (Source: IPCC 2010).

In COP 7, with the so called ‘Marrakech Accords’, the definitions and modalities for the inclusion of forest under the Kyoto Protocol were established. (UNFCCC 2010)

In COP 9 the modalities and procedures for afforestation and reforestation project activities and the good practice guidance for LULUCF were agreed upon. In COP 11 the tables of the common reporting format for land use, land-use change and forestry were decided.

The reason for this late inclusion of forests under the Kyoto Protocol is because initially Article 3.3 of the Kyoto protocol, which refers to emissions by sources and removals by sinks resulting from activities in the LULUCF sector, only applied to forestry activities undertaken within an Annex I country. At this time the industry was the key factor as the main undertaking of the Kyoto Protocol was to reduce emissions from industrialised countries. During the course of the climate change negotiations, the role of forests became more important, as it was realised that they offered an inexpensive way for developed countries to reduce their emissions by investing in developing countries.

3.7.1. Definitions

Under the Kyoto Protocol it was necessary that definitions for land use, land use change and forests be established and this was achieved with Decision 11/CP.7. The most important of these definitions are mentioned below.

- “Forest is a minimum area of land of 0.05-1.0 hectares with tree crown cover (or equivalent stocking level) of more than 10-30 per cent with trees with the potential to reach a minimum height of 2-5 metres at maturity in situ. A forest may consist either of closed forest formations where trees of various storeys and undergrowth cover a high proportion of the ground or open forest. Young natural stands and all plantations which have yet to reach a crown density of 10-30 per cent or tree height of 2-5 metres are included under forest, as are areas normally forming part of the forest area which are temporarily without forest cover as a result of human intervention such as harvesting or natural causes but which are expected to revert to forest."

- "Afforestation is the direct human-induced conversion of land that has not been forested for a period of at least 50 years to forested land through planting, seeding and/or the human-induced promotion of natural seed sources."
- "Reforestation is the direct human-induced conversion of non-forested land to forested land through planting, seeding and/or the human-induced promotion of natural seed sources, on land that was forested but that has been converted to non-forested land. For the first commitment period, reforestation activities will be limited to reforestation occurring on those lands that did not contain forest on 31 December 1989."
- "Deforestation is the direct human-induced conversion of forested land to non forested land."
- "Revegetation is a direct human-induced activity to increase carbon stocks on sites through the establishment of vegetation that covers a minimum area of 0.05 hectares and does not meet the definitions of afforestation and reforestation contained here."
- "Forest management is a system of practices for stewardship and use of forest land aimed at fulfilling relevant ecological (including biological diversity), economic and social functions of the forest in a sustainable manner."

The definitions of "forest" and "forest degradation" are controversial as some argue that, from a biodiversity viewpoint, plantations should not be called forest because of their lower biodiversity. To achieve success with REDD there needs to be one globally-accepted definition of what actually constitutes forest degradation. In order to define forest degradation properly it will be important to take into account the full range of biophysical and social conditions under which forests develop and the variety of ways they can be degraded (Sasaki & Putz 2009).

3.7.2. Non permanence of the credits

Forest carbon credits are by their very nature temporary due to the risk that the carbon stock on which they depend goes back to the atmosphere due to fires, pests, insects or storms. "Non permanence" describes the possible net loss of carbon at the project, landscape, regional or national levels. It does not, however, describe the fact that trees in a forest stand die and decompose due to silvicultural treatments in a stand within a forested landscape. A loss in carbon can also be due to human decisions to shape forest land to another land use (Schlamadinger et al. 2007). Therefore the investment in forest projects under the Kyoto Protocol for carbon credits generation is low.

In addition, the quantification and monitoring of the carbon stock in forests is a process full of uncertainties. The methodologies used are very complex and in the case of developing countries this situation is aggravated due to the lack of economic resources to develop reliable forest inventories (4 Forest Day 2010).

Due to the non-permanence of the credits and the complexity associated with the determination of carbon stock, forests are poorly, and often incorrectly, represented in the Kyoto market.

3.7.3. Voluntary market

The voluntary carbon markets are found outside of the compliance market. These markets enable businesses, governments, NGOs, and individuals to offset their emissions by purchasing offsets that were created either through CDM or in the voluntary market. There are currently no established rules and regulations for the voluntary carbon market and this lack of regulation has led to a surge of entrepreneurial businesses establishing themselves in an attempt to tap-in to the lucrative trade in Carbon Credits. The quality of the service provided by these companies can vary wildly.

One positive aspect, however, is that voluntary markets can serve as a testing field for new procedures, methodologies and technologies that may later be included in regulatory schemes. They give space for experimentation and innovation because projects can be implemented with fewer transaction costs than Clean Development Mechanism or other compliance market projects.

For projects that are too small to warrant the administrative burden of CDM or for projects currently not covered under compliance schemes, voluntary markets can be a niche. However, on the voluntary market the lack of quality control has led to the production of some low quality VERs (Verified or Voluntary Emission Reductions).

In order to improve the quality of VERs, some standards have been developed, including: the Gold Standard (GS), the Voluntary Carbon Standard (VCS), the VER+, The Voluntary Offset Standard (VOS), the Chicago Climate Exchange (CCX), the Climate, Community & Biodiversity Standards (CCBS), Plan Vivo System, the ISO 14064-2 and the WRI/WBCSD GHG Protocol for Project Accounting (Kollmuss et al. 2008).

Regarding forestry projects, the voluntary market is not restricted only to afforestation and reforestation. Other practices beside these ones are allowed. Due to this broader scope, the number of forest projects in the voluntary market is much higher than under the Kyoto Protocol. Nevertheless, the price paid for the carbon credits in the voluntary market is lower than in the Kyoto markets.

3.8. RED, REDD, REDD+ and REDD++

The notion of the preservation of existing forests was not mentioned in the original Kyoto Protocol. Instead, the idea, under the acronym of RED "Reducing emissions from deforestation in developing countries and approaches to stimulate action" was first brought to the table at the eleventh COP session in Montreal (December 2005) (UNFCCC 2010).The goal then was to save native forests and to create a possibility for cheap carbon reductions.

At a later date, the RED concept introduced the aspect of degradation and the mechanism was subsequently renamed REDD (Reduced Emissions from Deforestation and Degradation). On COP 13, in Bali, a historical agreement was reached, heartening countries to initiate actions to reduce emissions from deforestation and forest degradation in developing countries (Pelletier et al. 2010).

REDD is an effort to create a financial value for the carbon stored in forests, offering incentives for developing countries to reduce emissions from forested lands and to invest in low-carbon paths to sustainable development (Bosetti & Lubowski 2010). "REDD+" includes the role of conservation, sustainable management of forests and enhancement of forest carbon stocks. With REDD+ a reduction of carbon emissions is possible and it could also encourage new developments aimed at targeting the alleviation of poverty as well as helping to sustain biodiversity and secure vital ecosystem services. Full engagement and respect for the rights of indigenous people and other forest-dependent communities are very important for successful REDD+ projects.

It is important to align REDD+ with national development objectives and ecosystem-based approaches to adaptation. With REDD+, degraded land can be restored, community management of forests can be supported and agricultural drivers of deforestation can be addressed. Because of these realities, the potential of REDD+ to generate additional benefits is widely recognized. These benefits are poverty reduction, biodiversity conservation and synergies with adaptation to climate change.

REDD+ provides a good, effective and cheap opportunity to mitigate climate change. In the future it will be important that the developed countries pay for early REDD+ action and that they support this financial action with technology transfer and capacity building. The economics of REDD are effected by uncertainties in forest C density (Pelletier et al. 2010).

REDD++ includes all of the above-mentioned features of REDD+ but also encompasses agriculture. Agriculture will become a big issue because as the fast growing world population looks to be fed from less and less agricultural land. Maintaining forests to act as buffer zones for climate change is vital to the survival of millions around the world, especially as agricultural areas are increasingly suffering from desertification and increasing settlement. Developing countries can benefit from REDD+ in the form of knowledge and technology transfer, with the possibility of a strengthening of governance by giving the population they govern a higher chance to increase their livelihood.

It will be very important that developing countries can reach the goals in terms of financial aid they need to implement REDD projects. The countries have different backgrounds and goals for forests and these views are always changing: in Indonesia, for example, for a long time the forest was used for wood production but in recent times the focus has switched to conservation.

For the regional politicians it is a great task to promote different strategies for dealing with forests, especially when in many cases this means changing deeply ingrained habits in the population of the country. It will take time until the new way of thinking is accepted and therefore it is important that the developed countries give the developing countries enough time and money to give their people the chance to adapt to the new way of life.

For REDD+, a balance between central oversight and decentralised decision making could prove to be the most important element in its success or failure. Clear tenure and transparent and equitable benefit-sharing arrangements are the most salient requirements which must be met in order to achieve successful implementation.

4. Discussion

Without a concerted effort on a global scale the earth's temperature will rise to a point where worldwide catastrophe, the forerunning symptoms of which are all too obvious already, will be unavoidable. Therefore the best means of mitigating this climatic change is via the implementation of legally-binding legislation which bonds countries in pursuit of a common objective: the reduction of harmful green house gasses and the halting of global warming.

The legislation passed at international and national levels is only as effective as the scientific material upon which it is based and, while COPs offer peerless forums in which to debate and reason-out the necessary policies, such measures cannot succeed without the backing of scientific evidence. The roles of the UNFCCC and IPCC, among others, are vital in supplying this high-quality material which aids significantly in the negotiations and provides the basis from which to build solid protocol.

The RED initiatives (REDD, REDD+ and REDD++) are only in their fledgling stages but they already offer strong hope for the future by not only broadening the scope of methods to deal with climate change, but also by recognising that its impact affects every facet of the planets machinations. They allow for the fact that global warming impacts upon every type of ecosystem and that it can be combated from a variety of different standpoints. Most importantly of all, the REDD initiatives recognise that the climatic problems facing the world's people, forests and agriculture all need to be addressed.

The Kyoto Protocol is arguably the most important document of the last decade in terms of climate-change legislation. If adhered to by the signatory countries, it offers a means to mitigate climate change to a level which the people of the world may be able to adapt to. If it is allowed to fail by not being renewed in Durban in a years' time, there is no ready alternative which could prove as effective. The importance of carbon credits as outlined under the treaty and the central role the forests of the world will play in off-setting the pollution of both developed and developing countries needs to be decided, but the basic tenants of the Protocol, allied to the continuing work of the international scientific and governmental bodies, are the key to combating global warming.

The countries which gathered in Cancun unanimously agreed to move forwards to reach the goal of mitigating the increase of the average global temperature and to reduce the GHG emissions with the overarching aim of protecting the poor and the vulnerable from climate change. The developed countries are willing to front the finance which will hopefully prove sufficient in allowing the developing countries to build their own future in a sustainable way.

The industrialized countries are willing to invest USD$30 billion up to 2012 with the intention to give USD$100 billion more by 2020. An expressed wish of the countries providing these much-needed funds is the establishment of a Green Climate Fund in which both the developing and developed countries are equally represented (UNFCCC 2010).

The USA, currently not a signatory of the Kyoto Protocol, has expressed its intention to contribute financial support and so to join the other countries on some level, but this would still leave them outside the remit of the Protocol. After the senate elections, a ratification of the Protocol by President Obama would seem highly unlikely. The USA is in a worse crisis than when it first decided not to sign and the politicians are seeking to strengthen their economy, something which may prove difficult if Kyoto-imposed emissions targets also have to be met.

The countries decided to strengthen the action to reduce emissions from deforestation and forest degradation in developing countries, therefore REDD is now starched. They want to achieve this with technological and financial support was not mentioned directly, but further steps for the establishment of this mechanism have been given.

The parties want to let a second period of the Kyoto Protocol follow the first without a gap and the talks ended with high optimism as to the reaching of an agreement on the extension of the Protocol in Durban in 2011.

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http://unfccc.int/meetings/cop_11/items/3394.php
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Terrestrial Monitoring Concepts of Forest Carbon under the Framework of REDD

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Abstract

Reducing emissions from deforestation and degradation (REDD) is a mechanism that has been discussed under the United Nations Framework Convention on Climate Change (UNFCCC) and may play a significant role in mitigating climate change. Forest carbon monitoring is a crucial step and prerequisite to estimate potential emissions reduction and uncertainties associated with REDD activities. The concepts and current developments under the UNFCCC for designing forest carbon monitoring systems as well as the IPCC methodologies to estimate forest carbon stocks and changes are presented and discussed.

Keywords: deforestation, carbon stocks changes, REDD, UNFCC, IPCC methodologies.

1. Introduction

According to the Intergovernmental Panel on Climate Change (IPCC) the forestry sector accounts for 17% of the global greenhouse emissions (IPCC 2007). At the UNFCCC the international community recognised the importance of reducing emissions from deforestation and forest degradation and the need to enhance removals of greenhouse gas emissions by forests (UNFCCC 2007; 2009). For these reasons many developing and developed countries are interested in slowing or preventing tropical deforestation under a new scheme, called REDD (Reducing Emission from Deforestation and Forest Degradation), which is a climate change instrument, currently discussed under UNFCCC. Hopefully it will be part of a global commitment after 2012, that aims to reduce emission and can promote co-benefits including biodiversity (UNFCCC 2007; 2009).

The development of REDD initiatives would represent a new economic resource investing in different activities like conservation, sustainable management of forest and enhancement of forest carbon stocks in developing countries (UNFCCC 2007), and could achieve significant greenhouse gas emissions reductions with a low cost and stop the impacts of climate change (Stern 2007; Eliasch 2008; Schmidt 2009).

There are many technical and socio-economic complexities in practice at the national and international levels. Especially the estimation of forest carbon stocks, forest area changes and greenhouse emissions associated, as well as methodologies to develop REDD projects properly (UNFCCF 2009a). This situation is particularly evident in countries rich in forest resources but with poor performance of forest management and with limitations on forest data (Gibbs et al., 2007). For this reason the UNFCCC has encouraged the parties to use the most recent IPCC guidance and guidelines as an approriate basis for estimating forest-related greenhouse gas emissions and removals, forest carbon stocks and forest area changes and to establish national forest monitoring systems (UNFCCC 2009).

In this paper basic approaches toward terrestrial forest carbon estimation and monitoring proposed by the UNFCCC for REDD activities are described. Models and databases that are already available are presented as well as the IPCC methodologies associated to estimate sources and sinks of greenhouse gas emissions and forest area changes. Finally, a case study is presented to illustrate the practical application of the IPCC methodologies.

2. Official definitions under UNFCCC

The UNFCCC have provided definitions, modalities and guidelines for designing emission-reductions forestry projects under Clean Development Mechanism[1] (CDM). However, these are only applicable to afforestation and reforestation[2] activities. The following official definitions are expected to be adapted for the upcoming REDD scheme (UNFCCC 2006, 2006a):

- Forest: "A *minimum area of land of 0.05 - 1.0 hectare with tree crown cover (or equivalent stocking level) of more than 10 - 30 per cent with trees with the potential to reach a minimum height of 2–5 metres at maturity in situ*[3]*".*
- Carbon pools*: "A reservoir. A system which has the capacity to accumulate or release carbon: above-ground biomass, below-ground biomass, litter, dead wood and soil organic carbon".*
- Deforestation: *"The direct human-induced conversion of forested land to non-forested land".*
- *Leakage: "Increase in greenhouse gas emissions by sources which occurs outside the boundary of an afforestation or reforestation project activity under the CDM which is measurable and attributable to the afforestation or reforestation project activity".*
- Baseline net greenhouse gas removals by sinks (Reference emissions levels): *"Sum of the changes in carbon stocks in the carbon pools within the project boundary that would have occurred in the absence of the afforestation or reforestation project activity under the clean development mechanism".*

3. Technical issues for estimating and monitoring carbon stocks and emissions associated relating to REDD under the UNFCCC context

In order to support the development of REDD initiatives in developing countries, the Subsidiary Body for Scientific and Technological Advice (SBSTA[4]) in accordance with

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1 "The **CDM** allows emission-reduction projects in developing countries to earn certified emission reduction (CER) credits, each equivalent to one tonne of CO2. These CERs can be traded and sold, and used by industrialized countries to a meet a part of their emission reduction targets under the Kyoto Protocol" (http://cdm.unfccc.int/about/index.html)

2 "**Afforestation** is the direct human-induced conversion of land that has not been forested for a period of at least 50 years to forested land through planting, seeding and/or the human-induced promotion of natural seed sources". "**Reforestation** is the direct human-induced conversion of non-forested land to forested land through planting, seeding and/or the human-induced promotion of natural seed sources, on land that was forested but that has been converted to non-forested land. For the first commitment period, reforestation activities will be limited to reforestation occurring on those lands that did not contain forest on 31 December 1989". (UNFCCC 2006)

3 It is important to mention that under the CDM rules each Party (country) has had to established the national forest definition using the given ranges.

4 "...The SBSTA's task is to provide the Conference of the Parties (COP) with advice on scientific, technological and methodological matters. Two key areas of work in this regard are promoting the development and transfer of environmentally-friendly technologies, and conducting technical work to improve the guidelines for preparing national communications and

decision 2/CP.13 and for request of the Conference of the Parties (COP), has undertaken work on a REDD programme.

During the development of the programme, the SBSTA organized various workshops and expert meetings in order to share views, provide guidance and reach agreements between the Parties in three main areas: (1) Methodological issues relating to REDD; (2) Reference emissions levels; (3) Elements for building national carbon monitoring systems for REDD.

Methodological issues relating to REDD in developing countries

The relevant remark of this workshop was the recognition that the IPCC guidelines for national greenhouses inventories provide the technical basis for estimating and monitoring emissions reduction from deforestation and forest degradation. Including the use of remote sensing for detecting and monitoring forest area changes, combined with ground-based forest inventory data (UNFCCC 2008).

Additionally, the "REDD Sourcebook" a project undertaking by the Global Observation for Forest and Land Cover Dynamics group was presented. The project aims to complement the IPCC guidelines by identifying difficulties associated with data requirements for estimating greenhouse emissions and removals. Displacement of emissions (leakage) and monitor changes in carbon stocks from forest degradation were identified as the major challenges for developing countries willing to participate in the REDD process. The SBSTA highlighted the need for reaching real global emissions reductions and further consideration to address leakages and forest degradation (UNFCCC 2008).

Reference emissions levels

Based on the experienced of experts, two approaches were presented in order to develop reference emission scenarios: Assessment of historical deforestation rates and expected deforestation rates (modelling). It was stressed that any approach must take into consideration socio economic factors, existing policies and national circumstances. Different disadvantages were indentified such as the difficulty to incorporate policies that a country is implementing or planning to implement, which may affect forest area changes (UNFCC 2009).

Assessments of historical trends in deforestation are limited to data that has been previously collected such as Landsat data for 1980 – 2005. It has been necessary to fill gaps caused by clouds and shadows with other sources like Moderate Resolution Imaging Spectroradiometer (MODIS), furthermore, countries also need access to high resolution imagery and increase technical capacities to carry out national forest assessments and detect logging activities (Olander et al 2008). Expected deforestation approach is based on historic land use change, modelling population growth, determination and quantification of the most important driving forces associated with land use change such as biophysical and socioeconomic factors (Huettner et al 2009; Brown et al 2007).

Models like Forest Area Change (FAC), the Land Use and Carbon Sequestration (LUCS), and the Geographical Modeling (GEOMOD) were tested in Latin America, but each model produced quite different deforestation baselines (Brown et al 2007). The results suggest that a methodology comprising three main steps can achieve a credible expected deforestation rate. First, assessment of historic land-use change and deforestation estimation are made based on a 10 year period, including the identification of the main drivers. Second, areas where deforestation is likely to occur are identified using the key drivers previously identified. Finally, deforestation rates are projected and new potential drivers are incorporated after a period of time in order to

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emission inventories
(http://unfccc.int/essential_background/convention/convention_bodies/items/2629.php)

corroborate the expected deforestation or generate a new projection (Brown et al 2007).

Additionally, the SBSTA has identified the following needs for research and capacity building between the parties in order to determinate reference emission levels: Biomass studies for different forest ecosystems, development of allometric equations (especially below biomass), emissions associated with forest fires and gathering reliable socio-economic data for developing reference emissions levels (UNFCC 2009). The SBSTA also stressed that accurate and transparent estimation of forest carbon changes and emissions associated should be supported by robust measurement and verification systems before a REDD project will be able to generate emission reductions (UNFCC 2009).

Elements for building national carbon monitoring systems for REDD

The design and implementation of a monitoring system was defined as a process in which countries have to make investments in information for the effective implementation of REDD activities. Three main elements were identified to satisfy the requirements of a system to monitor emissions and removals of GHGs: Insertion into a national REDD strategy; systematic and repeated measurements of carbon stocks and estimation and reporting of emissions and removals based on IPCC methodologies.

The development of a national monitoring system for REDD can be structured in five phases: Planning and design, data collection and monitoring, data analysis, reference emissions levels and reporting. Additionally, in order to allow improvements in the monitoring system expertise is needed to quantify report and analyse uncertainties, generating more complete estimations base on the handling of information gaps and sources or error. A summary of the phases and key elements for establish a national monitoring system is presented in table 1 (UNFCCC 2009a).

REDD and outcomes of COP 16

Existing definitions and guidelines might apply for REDD activities (those describe in items 1 - 2) which could speed up the negotiation process focusing the upcoming decisions on financial mechanisms needed for REDD implementation, and enhancing the capacities of developing countries to monitor forest cover and the carbon associated stocks.

The Cancún agreement represents the outcomes of COP 16, according to the draft text of decisions the portfolio of activities that are covered by the REDD mechanism are: “Reducing emissions from deforestation; Reducing emissions from forest degradation; Conservation of forest carbon stocks; Sustainable management of forest; Enhancement of forest carbon stocks...” (UNFCCC 2010). Additionally, the COP requests from developing countries aiming to undertake REDD activities to developed a national REDD strategy, establish national or sub national forest monitoring systems for the monitoring and reporting of the REDD activities, reference emissions levels and perform actions to address displacement of emission (leakage), drivers of deforestation, forest degradation, land tenure rights and forest governance issues (UNFCCC 2010).

4. The IPCC’s Methodologies for National Greenhouse Gas Inventories

Under UNFCCC context each country member has affirmed different commitments in order to contribute to the ultimate objective of the convention which aims to reach a global stabilization in greenhouse gas (GHG) emissions to prevent a future catastrophic climate allowing the adaptation of natural ecosystems and the society to future climate change (UNFCCC 1992).

Table 1. Phases and components for developing a monitoring system (Based on UNFCCC 2009a)

Phase	Component	Capacities required
Planning and design	Monitoring system as a part of national REDD strategy.	UNFCCC process on REDD and understanding IPCC methodologies
Data collection and monitoring	Forest area changes assessment (activity data)	Processing and interpretation of multi date remote sensing imagery for forest area changes. Assessment of drivers of deforestation
	Changes in carbon stocks (emissions factor)	Consolidation of national forest inventories. Estimation and monitoring of carbon stocks changes due to land - use change.
Reference emissions levels	Establish reference emissions levels	Expertise to regularly update and temporal analysis and modelling tools.
Reporting.	National greenhouse gas inventory.	Data infrastructure and information technology to report GHE according to IPCC.

Recognizing the importance of climate change as a global challenge for the entire society, each country has to report (as a commitment) the progress in the implementation of the convention. This means, that both developing and developed countries, must submit regularly detailed information about its anthropogenic GHG emissions following the IPCC guidelines, in other words, countries have to elaborate national greenhouse gas inventories (UNFCCC 1992 – article 4). The IPCC Guidelines for national greenhouse gas inventories were developed by the UNFCCC in order to "assist country Parties in fulfilment of their commitments" and "provide methodologies for estimating national inventories of anthropogenic emissions by sources and removals by sinks of greenhouse gases" (IPCC 2006).

The methods (tier 1 - 3) for estimation GHG emissions and removals in the forestry sector are based on two basic inputs: activity data, which represent the forests area changes and emissions factors, which represent the associated carbon stock changes (IPCC 2006). Under the REDD context activity data is the deforested or degraded area expressed in hectares (ha) and the emission factor is the amount of carbon (biomass) emitted per unit of activity. Forest degradation, sustainable management, conservation and enhancement of forest carbon stocks are covered by the IPCC category of forest land, remain forest land and deforestation by forest converted to others lands (UNFCCC 2009a).

The methodologies are developed to assess changes in biomass (above and below), dead organic matter and soil organic carbon, which are the carbon pools in different land use categories. Any of these pools representing significant emissions or removals is classified as key category and finer detail (tier 3) in the calculations should be made (IPCC 2006). See table 2. Under the Tier 1 the emissions factors are based on default values given by the IPCC and no new data collection is necessary to estimate forest biomass. For example, the average carbon stock for a tropical forest is 300 t d.m/ / ha. And the emissions from deforestation from any tropical country are the result of the rate of deforestation multiplied by the given average, this approach represent a large error ± 70% (IPCC 2006, GOFC 2009).

Table 2. General description of IPCC TIER 1 – 3 (GOFC-GOLD. 2009).

Tier	Details
1	IPCC methods and IPCC default values (no data collection).
2	IPCC methods and country specific data for key factors.
3	Country specific methods or models, repeated measurements of permanent plots to directly measure changes in biomass.

Box 1. Allometric functions for biomass estimation and sources of wood basic density.

1. Lowland tropical rain forest.
In (AB) = -2, 14 + 2, 41 In D (Chave et al 2001). DBH Range ≥ 10 cm; $R^2 = 0.98$
2. Wet forest stands.
BA = ρ × exp (-1,239 + 1,980 In (D) + 0,207(In (D)) ^{2} - (0, 0281In (D)) ^{3}) (Chave et al 2005). DBH Range: 5 -156 cm; $R^2 = 0.98$
BA = 21,297 - (6,953 x D) + (0,740 D^2) (Brown 1997). DBH Range: until 148 cm; $R^2 = 0.97$
3. Tropical mountain systems.
In (BA) = (-2,286 + (2,471 In D) (Del Valle 2003); Range: DBH until 198 cm; $R^2 = 0.97$
Observations
BA: Above biomass; D: DBH (cm); ρ: Basic Wood density (g/m^3).
Sources of wood basic density:
a) Chave et al 2006. Database of wood density for species naturally occurring in Central and South America (2456 Neotropical tree species)
b) IPCC 2006, Chapter 4. Forest Land. Box 4.13 (480 species).

Tier 2 uses default data with country specific data from field measurements. For example, the IPCC average carbon stock for tropical mountains is 60 - 230 t d.m/ha in comparison with 247 ± 40.5 t d.m/ha, estimated from plot measurements in Colombia (Sierra et al 2007). The emissions from an area deforested can be estimated, however, it does not considered forest conditions and it is assumed that all mountain forest in Colombia has the same carbon stock.

Tier 3 is the association of deforestation and degradation with appropriate carbon stocks for estimating emissions. It uses detailed and repeated forest inventories according to forest types and its conditions. Direct measurements of forest biomass and changes, allometric models and specific wood density are also incorporated (IPCC 2006). However, estimations of forest degradation and emissions displacement still represent a major technical challenge under tier 3. The same is true for the assessment of uncertainties in rates of deforestation and biomass estimates to provide accuracy emissions from deforestation and degradation (UNFCCC 2009a). The figure 1 explains the general process for estimating emissions and increments in carbon pools under tier 3, and box 1 gives the allometric models and sources for specific wood density that can be incorporated.

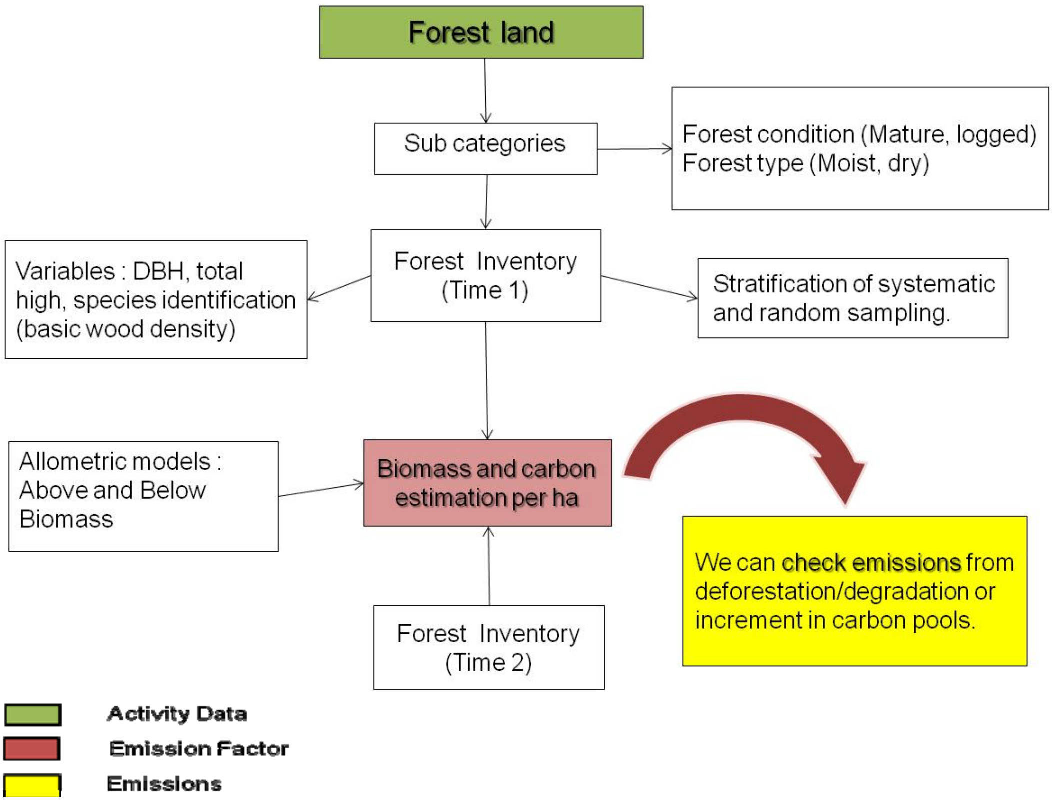

Figure 1. General process for estimating emissions and increments in carbon pools under Tier 3. Source: Author based on IPCC 2006

Case study

A practical application of IPCC Tier 3 approach to estimate emissions from land-use change is presented here. Based on local emissions factors (wood density per tree species) the emissions from deforestation were estimated in two states of Brazil, known as the arc of deforestation, Mato Grosso and Rondonia, where half of the deforestation and emissions of Brazil is localized (Nogueira et al 2007).

Using remote sensing imagery of LANDSAT, Disaster Monitoring Constellation (DMC) and the China-Brazil Earth Resources Satellite program (CBERS), areas greater or equal to 6, 25 ha were identified as deforested area (activity data) and maps of forest land and non-forest land were produced. According to forest types, different vegetation units were identified across the states and samples of wood density were taken from each tree species or genus. From commercial wood inventories biomass was estimated based on wood density in each vegetation unit.

The results suggest that previous emissions in the region were overestimated by 23.4 million tons of CO2 per year due to the use of wood density values from outside the arc of deforestation. The average wood density in the study was estimated in 0.583 g cm-3 for all tree species in comparison with the average 0.69 g cm-3, which was used prior to the field sampling (Nogueira et al 2007). This type of study was not only useful for estimating accuracy emissions but also for effectively changing the reference emission levels in the region and in Brazil.

Conclusions

Forest carbon monitoring under framework of REDD is a requisite for countries aiming to participate in the future forest carbon market. The IPCC methodologies, especially Tier 3 and the outcomes of the SBSTA provide the appropriate guidance to design forest national monitoring systems and estimate forest carbon stocks and changes. The systematic and repeated measurements under the monitoring system establish and verify whether emission reductions took place. Research and investments in the estimation of local emission factors gives more accuracy in the emissions reported and increases credibility of REDD projects in the carbon market. The financial mechanism that enables the implementation of REDD activities at national level is a crucial and unresolved issue under the UNFCCC which requires further developments and major decisions to guarantee the decisive role of forest in mitigating climate change.

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Case Study: Clean Development Mechanism Project in Piura, Peru

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Abstract

Carbon markets have been a large and fast growing sector in recent years. Forestry-based projects have a small share within these markets but with a clear tendency of growth. This is the result of their broadly accepted cost-effectiveness that also brings social and ecological benefits, while the disadvantages of implementing this kind of projects are still what keeps them from taking off. Via a case study from a successful story in Northern Peru we present an overview of different aspects of implementing forestry-based projects for emission offsets. These aspects include ecosystem, social and economical benefits as well as difficulties and disadvantages.

Keywords: carbon market, forest carbon market, offsets, CDM, Jose Tavara.

1 Introduction

Peru has the second largest forested area in Latin America, after Brazil, with 61% of its national territory covered by tropical rainforest (PROFONANPE 2010). Being ranked as the world's sixth for its tropical rainforest extension, Peru is of great interest for forestry-based projects aiming to offset emissions, especially when land use and transformation of forest into agricultural or pasture lands accounts for as much as 47.5% of the net greenhouse gas emissions of the country (Minam 2010). The country's economical stability demonstrated by continuous growth and low inflation rates together with its history of participation in the Kyoto negotiations, and the recently created Ministry of Environment that provides political support for the forestry sector among other environmental policies are the main attractors for inversions.

Despite all of the above mentioned, in 2009 from the 33 projects approved for CDM validation only one was related to forestry (Sabelli 2009). This could reveal the problems of forestry-based carbon projects in relation to other proposals that appear less complicated or more profitable in the short term.

2 Material & Methods

2.1 Case Study Background

2.1.1 Piura Region and Dry forests

Piura is a costal region of Peru located in the north of the country. With as much as 200 km from the Pacific ocean to the Western Slope of the Andes, Piura has the widest coastline of the country. It is characterised by a variable climate due to the encounter of the peruvian and equatorial streams as well as periodic impacts of the El Niño southern oscillation (Regional Government of Piura 2010). Precipitation oscillates between 10 and 1500 mm depending on the location. Temperatures in the dry season reache 35 ºC while in the wet season only 15 ºC. Mainly dominated by deserts at about sea level, some geographical features can be higher than 3800 meters. Within this variety of climatic and geographical conditions, dry deciduous forests are found and local people use them as their main resource.

Dry deciduous forests are seasonal forests that experience wet and dry periods resulting in a variety of plants adapted to dry conditions by morphological, physiological or behavioural mechanisms (Murphy & Lugo 1986). Yet dry deciduous forests are among the most threatened ecosystems in the world and have received very little attention in the past (Pennington 2000; Abou Rajab 2010). In Peru this type of forests occurs in dry valleys on relatively fertile soils that are also favourable to agriculture and cattle ranging.

2.1.2 Land Use

Shortly after Peru's independence in the 19th century, stock farmers maintain their livestock feeding freely from the dry forest. Additionally logging activities were carried out for charcoal production that supplied the industry's demand (Hocquenghen 1998). Increasing demand for exotic timber and parquet lead to overexploitation of economically important species like Hualtaco (*Loxopterygium huasango*); almost extinguishing it from the region.

In modern days dry forests supports local communities that depend directly or indirectly on the forest resources. The vast majority of households rely on the low and irregular income coming from extensive livestock farming. The livestock graze uncontrolled in the forest resources causing visible harm to the lower leaves of trees and shrubs and threatening regeneration. During long lasting drought periods, after all herbs and grasses have gone, livestock will feed from fruits, seed and roots of the woody species which is the only forage available (Abou Rajab 2010).

While subsistence logging is not unsustainable (Ocaña 1986) illegal timber extraction in large volumes for production of parquet, furniture, charcoal and fuel as well as forests fires and urban expansion are the main threads to the forest.

2.1.3 Land Tenure

From 1990 Peru started a process of liberation of land tenure. This process was based on legal mechanisms oriented to bring inversions, allow free transference of properties and finish land adjudication procedures that could create a land market (SPDA 2009). At that time forests were under a special regime so they could not be used for farming; being excluded from the land market.

Further policy changes included forests under the land market but interested parties had to prove direct and continuous economical exploitation of the land in order to get a title for it. The government would only recognise agriculture and livestock farming as economical activities. While land under the "economic exploitation" regime could be owned by individuals or entities; forest resources were common goods and no individual or entity could claim rights on them. This legal framework created an increment of the forest area converted into crops or pastures, so users could secure ownership (Sabelli 2009).

The situation in the dry forest of Piura was not different from the rest of the country and forest started to be cut and burnt not only from the point of immediate economical benefits but also in order to assure the procedure of land ownership.

2.2 The Project Overview

2.2.1 General Description

All information gathered related to planning and implementation of the project was found in the original Project Design Document (PDD) submitted to the CDM- Executive Board. In the mentioned document the aim of the project was described as the reforestation of 8 980,52 ha of degraded land property of the Jose Ignacio Tavara

Pasapera community from the Chulucanas district, Morropón, province of the Piura region in Peru (Figure 1).

Only native woody species are used and while recovering the dry forest ecosystem the project also attempts to improve economical opportunities for locals from activities such as wood extraction and the use of non-timber forest products. More than 200 families participate in the planting and they will benefit from restored ecosystem services and revenues from wood production and carbon offsets (TÜV SÜD Industrie Service GmbH 2009).

The project will generate tCERs over a renewable crediting period of 20 years with an Estimated Annual Emission Reduction of 48 689 t CO_2-e (TÜV SÜD Industrie Service GmbH 2009). Peru serves as host party and was not considered a participant of the project but its approval was requested in order to register the project.

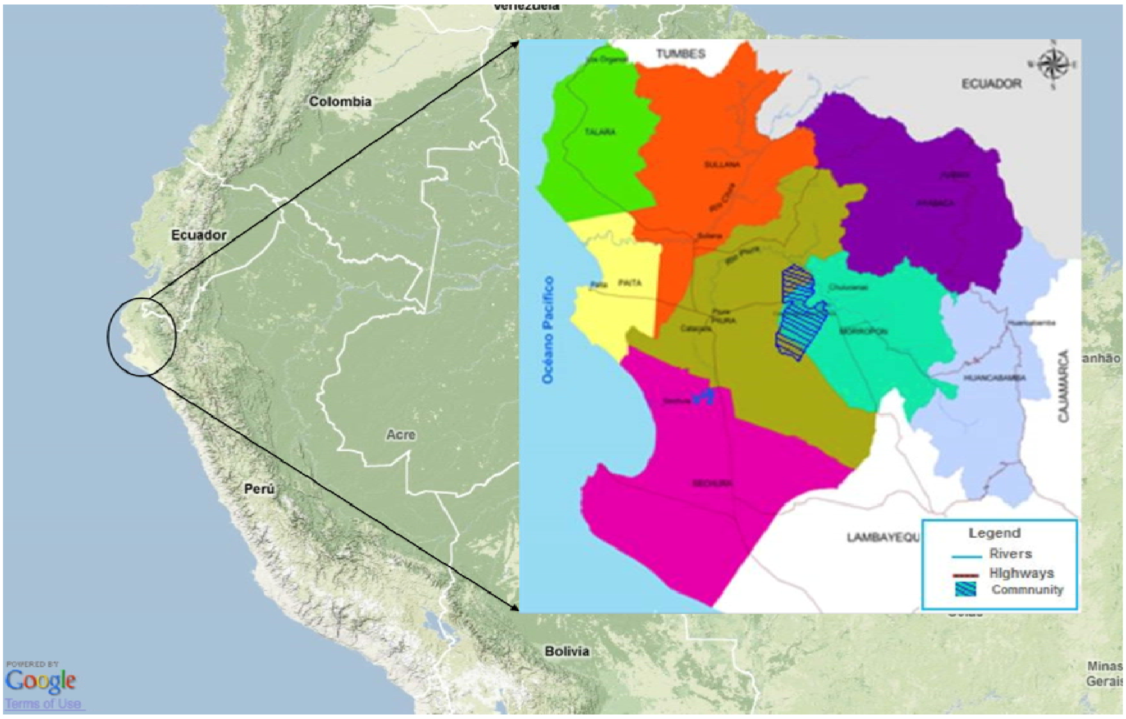

Figure 1. Location of the community Jose Ignacio Tavara Pasapera in Piura, Peru.

The three project participants had different roles and obtained different benefits, this was arranged via an internal agreement. The project participants are as follows:

Private Entity A	Private Entity B	Private Entity C
Comunidad campesina Jose Ignacio Tavara Pasapera, Piura, Peru.	Asociación para la Investigation y el Desarrollo Integral (AIDER), Lima, Peru.	Fondo Nacional del Ambiente (FONAM), Lima, Peru.

- Comunidad Campesina Jose Ignacio Tavara Pasapera, holder of the legal ownership over the land. It will be benefited from timber and ecosystem services. Also co-beneficiary from the 92,5% of CER’s.
- Asociación para la Investigation y el Desarrollo Integral (AIDER), responsible for technical and administrative support. Also co-beneficiary from 2.5% of CER’s.
- Fondo Nacional del Ambiente (FONAM), responsible for backing and advice in the CER’s negotiation. Also co-beneficiary from 5% of CER’s.

2.2.2 Climate and Physical Environment

The climate is considered arid (Picture 1) with an annual mean precipitation of about 300 mm. The rainy season would typically start in January and continue until April, being followed by a dry period of about 8 months. Temperatures may fluctuate between 32 and 18 ºC with and annual mean of 25,7 ºC. This was registered in the 2001 - 2006 period. As Piura is the centre of impact for El Niño events temperature and precipitation can drastically change during El Niño years, generally meaning that temperature and precipitation increase largely and then a severe drought period follows (Abou Rajab 2010).

The project area belongs to the Piura watershed that is originated at 3600 m.a.s.l. on the oriental Andes, at the Huarmaca River. The annual volume of the river depended in former times from rain intensity and El Niño events, but irrigation projects implemented in the 50's and 70's maintain a permanent amount of water all year round diminishing also the effects of floods in the area.

Concerning soils the area is located over eolic plains that come from deposits in the Cenozoic period. Soils are sandy varying between grey and dark grey with low organic matter content. The pH values are in the 6,1 - 6,8 range (CDM - Executive board 2009).

Picture 1. Arid condition at project's site. Photo taken from the PDD final version.

2.2.3 The Ecosystem

The Jose Ignacio Tavara community is located on the Equatorial Dry Forest biogeographic province. These forests are strongly seasonal and have a Net Primary Productivity lower than rainforests because growth only takes place during the wet season. (Pennington 2000). Due to human pressure the project area has a low diversity of flora with tree crown coverage lower than 30% percent* where dominant species are Algarrobo (*Prosopis pallida*), Zapote (*Capparis scabrida*) and Faique (*Acacia macracantha*) also an important association between Overo (Cordia lutea) and Zapote (Capparis scabrida) is commonly seen. Under this type of association Overo provides shelter and good conditions for the growing of *Capparis scabrida*.

Livestock farming, agriculture and wood extraction are common practices not only inside the project area. This unmanaged activities are characterised by lack of knowledge regarding sanitary measures, commercialisation and production technical aspects.

Timber harvesting is legally prohibited in the dry forest, with the exception of fuel wood and Overo sticks, but illegal loggers commonly enter to the forest harvesting Zapote and Algarrobo for charcoal and NTFP's production (CDM - Executive board 2009).

2.3 Project Implementation

2.3.1 Reforestation Model Analysis

The Jose Ignacio Tavara community's land has not been forest at least since 1989 and this was confirmed from the satellite image analysis and testimonies of locals. So baseline the scenario was defined as degraded land with poor natural regeneration due to anthropogenic activities that will continue to suffer from deforestation as it has have for at least two decades (CDM - Executive board 2009).

The projects introduce some planned measures in order to reverse the baseline situation. Initially the area was divided in 5 zones where grazing activities were redistributed and the reforestation programmed. The reforestation process will involve native species such as Algarrobo, Zapote and Overo (Table 1). In the first stage of the project Overo will be used for nursery helping the forest recuperation. The project also uses an irrigation system developed in the area based on a drip mechanism that is fed by a reservoir.

Baseline stocks of greenhouse gas removals were estimated for all vegetation types and resulted in an overall of 125 247 tCO_2. On the other side fertilisation activities will contribute to the project's emissions and they were calculated as 250,02 tCO_2-e for Algarrobo trees and 82,73 tCO_2-e for Zapote trees which is valid for the first 5 years of plantation. Leakage was found not to be significant concerning livestock grazing and wood collection (CDM - Executive board 2009). Wood collection is mainly use for fuel at rather low amounts and can be gathered from already dead trees or branches, other ways of leakage like grazing was contemplate from the beginning of the project design which is why livestock has been regulated through rotation within temporary grazing areas. Although the emissions will mainly come from fossil fuel combustion in the water pump bombs, this is estimated for the first 6 years (Table 2).

Table 1. Plantation program with stands model applied on the 5 zones.

Year (Stratum)	Algarrobo (ha)	Zapote (ha)	Total (ha)
1	1248.92	416.31	1666.23
2	1502.29	500.76	2005.05
3	1775.01	591.67	2369.68
4	1260.36	423.46	1687.82
5	938.81	312.94	1256.75
Total	6735.39	2245.13	8980.52

2.3.2 Investment and Financing

For the investment analysis the scenario in which the project only produce financial benefits from activities different to those generated through the CDM related incomes was considered.

This Internal Rate of Return (IRR) was calculated at 9,41% which is below the Required Rate of Return (RRR) of 11% set by the National System of Public Investment of Peru. Projects within the country will only be approved if the 14% benchmark set by the government is surpassed, which is not the case. This benchmark was used because there is not other specific benchmark established for forestry projects in Peru (TÜV SÜD Industrie Service GmbH 2009).

Table 2. Estimation of anthropogenic GHG Removals by sink.

Year	Estimation of baseline net GHG emission removals by sink (tCO2-e)	Estimation of actual net GHG emission removals by sink (tCO2-e)	Estimation of leakage (tCO2-e)	Estimation of net anthropo-genic GHG e-mission remo-vals by sink (tCO2-e)
1	1 634	70	3	-1 567
2	4 526	743	11	-3 794
3	6 482	2 112	24	- 4 394
4	9 712	5 940	44	-3 816
5	10 451	12 763	60	2 253
6	6 175	22 395	56	16 164
7	6 175	30 937	46	24 716
8	6 175	37 950	34	31 741
9	6 175	42 256	15	36 066
10	6 175	44 404	0	38 228
11	6 175	44 278	0	38 102
12	6 175	43 231	0	37 056
13	6 175	43 139	0	36 964
…	…	…	…	...
Total for 20 years	125 436	625 106	293	499 376

The native species used for reforestation in the project have a long growing cycle and therefore it was calculated that they could not provide revenues for the first 40 years, therefore, revenues were calculated from year 44. This calculation goes far beyond the crediting period of 20 years but corresponds with the total operational lifetime of the project. Table 3 shows the total establishment costs including CDM components.

It has been confirmed that there was no alternative financing available for the project activity and that it has become recently available through the project and its carbon component (TÜV SÜD Industrie Service GmbH 2009). Additionally, without the incentive of the project, reforestation of the area would be impossible.

For purpose of calculation tCER were assume to cost $ 5 per tCO2-e which is accepted according to relevant publications (Ecosystem Marketplace 2010).

Table 3. Establishment Costs with and without CDM costs.

Concept	Total
Fixed Investments	4 204 398,10
Operational Costs	2 492 626,20
CDM Costs	115 400,00
Total Establishment Costs without CDM	6 697 024,30
Total Establishment Costs with CDM	6 812 424,00

3 Discussion

Forestry-based projects for offsetting emissions were thought as the easiest cost-effective instruments to fight against climate change. It is recognised that the share of this type of projects in the voluntary market is growing and at the moment they account for as much as 36% of the total transaction volume (Gorte & Ramsaur 2010). In the first two quarters of 2009 only, the value on the Forest Carbon Market was at 21 million US dollars (Ecosystem Marketplace 2010).

But as attractive as it looks the forestry sector faces some other problems when the time to implement the project arrives. Especially in the voluntary market the broad variety of standards used to evaluate the projects does not follow a general rule and therefore quality may differ much among methods. Tenure rights and transaction costs are issues to be addressed, they are key aspects concerning community-based projects. Some say that an area of about 4000 ha can compensate for the costs of implementing this kind of projects (Sabelli 2009) Thus, securing the rights of ownership over such large areas might be a problem especially in developing countries. Forestry projects must also prove that the actions being carried out by the project are different from business-as-usual. This is an addition to the problem of leakage and permanence.

Forestry-based projects for emission offsets are promising, but further measures must be taken in order to achieve not only environmental but also social benefits.

4 Acknowledgments

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Contribution of remote sensing to REDD

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Abstract

Forests play a key role on climate change. They store a large amount of carbon in our terrestrial ecosystem. Deforestation and forest degradation are two large sources of greenhouse gas emissions in tropical countries. As the Kyoto Protocol expires by the end of 2012 and countries didn't make an agreement on emission reduction during the meetings of Cancun, Reduced Emissions from Deforestation and Degradation (REDD) gives people another hope for reducing emission on a global scale. REDD's success depends on mapping and monitoring of tropical forest carbon stocks and emissions over large geographic areas. Thus, remote sensing technology is widely used to estimate the carbon emission. In this article, the author makes an introduction to the remote sensing technology, listing the features of sensors that are frequently used. Then the author makes a comparison of advantages and limits of these sensors. Based on the features, advantages and limits of such sensors, the author introduces ways of their application in REDD.

Keywords: REDD; baseline; activity; data; remote sensing

1. Introduction

Forests sequester and store huge amounts of carbon, thus they play a key role on the climate's change. When forests are destroyed or degraded, the carbon they stored is released into the atmosphere as carbon dioxide (CO2). Tropical deforestation is estimated to have released 1–2 billion tonnes of carbon per year during the 1990s, roughly 15–25% of annual global greenhouse gas emissions (Malhi and Grace 2000, Fearnside and Laurance 2003, 2004, Houghton 2005). In most tropical countries, deforestation and forest degradation are the largest source of greenhouse gas emissions. In Africa, for example, deforestation takes the part of nearly 70% of total emissions (Food and Agricultural Organization of the United Nations FAO statistical database 2005). Moreover, clearing tropical forests also destroys globally important carbon sinks that are currently sequestering CO2 from the atmosphere and are critical to future climate stabilization (Stephens et al 2007).

Therefore, avoiding deforestation and associated emissions becomes a more and more necessary and important issue nowadays. Against such a background, UNFCCC (The United Nations Framework Convention on Climate Change) is put forward.

UNFCCC is an international environmental treaty which was achieved during the United Nations Conference on Environment and Development (UNCED), informally known as the Earth Summit; it was held in Rio de Janeiro from June 3 to 14, 1992. The objective of the treaty is to stabilize greenhouse gas concentrations in the atmosphere at a safe level. Through this, dangerous anthropogenic interference with the climate system can be prevented.

In the 1997, policies related to deforestation and degradation was excluded from the Kyoto Protocol. After this, the rise in deforestation, particularly in Brazil, resulted in the formation of the Coalition of Rainforest Nations. Papua New Guinea, Costa Rica and other forest nations constitute the participants.

Then the UNFCCC agreed to create a new mechanism, led by forest-rich developing countries, calling for economic incentives contributing to reductions in emissions from deforestation in developing countries(REDD).

REDD provides financial incentives to help developing countries to reduce national deforestation rates and associated carbon emissions. Countries facilitating reductions could sell those carbon credits on the international carbon market. These emissions reductions could mitigate climate change, help conserve biodiversity and protect other ecosystems.

For successful application of REDD, three factors are of great importance: baseline, activity data and emission factor. The baseline approach is critical to the success of a REDD mechanism because it affects the quantity, credibility, and equity of credits generated from efforts to reduce forest carbon emissions (UNFCCC. 2009). The other two determine the emissions (figure1.).

Emissions = Activity Data x Emissions Factors

Figure 5. Formula for emissions

For the baseline evaluation, methods based on data gained from remote sensing technology, the only choice of sensor is the Landsat series. For the emission factor, nowadays there are still no mature methods to directly apply remote sensing technology. Thus, in the article, the author chose to ignore this factor. For the activity data, different sensors to detect land-use change are used to find deforestation and degradation, as well as to evaluate carbon storage.

2. Material & Methods

2.1. Remote sensing based baseline evaluation

2.1.1. The Landsat Program

The Landsat Program is a series of Earth-observing satellite missions jointly managed by NASA and the U.S. Geological Survey. Since 1972, Landsat satellites have collected information about Earth from space. This science, known as remote sensing, has matured with the Landsat Program.

Table 3. Features of Landsat

Name	Lifetime year	Sensor	Repeat Coverage	Radiation width	Bands	Reso-lution
Landsat 1	1972-1998	RBV,MSS	18days	185 km	B:0.45-0.52	30m
Landsat 2	1975-1982	RBV,MSS	18days	185 km	G:0.52–0.60	30m
Landsat 3	1978-1983	RBV,MSS	18days	185 km	R:0.63-0.69	30m
Landsat 4	1982-1992	MSS,TM	16days	185 km	NIR:0.76-0.90	30m
Landsat 5	1984-now	MSS,TM	16days	185 km	SWIR:1.55-1.75	30m
Landsat 6	1993 failed	MSS,ETM	Failed	185 km	TIR:10.4-12.5	60m
Landsat 7	1999-now	TM,ETM+	16days	185 km	SWIR2.08-2.35	30m

Landsat satellites have taken specialized digital photographs of the Earth’s continents and surrounding coastal regions for over three decades, enabling people to study many aspects of our planet and to evaluate the dynamic changes caused by both natural processes and human practices. From table 1, features of Landsat can be gained.

2.1.2. Baseline estimation

There are two different strategies to establish a deforestation baseline: retrospective and prospective approaches. The so-called retrospective baseline methods assume a linear trend by extrapolating deforestation emissions rates from a historical reference period into future commitment periods (Huettner et al. 2009). Due to the high annual variability of carbon emissions from tropical deforestation (Houghton 2005), most scientific analyses recommend using averages over longer past reference periods instead of single reference years.

Prospective baseline methods anticipate the future behavior of land-use change, often by understanding the drivers of past trends, to predict deforestation rates and locations (Brown et al. 2007). Such models are similarly based on historical deforestation data, but specifically project future developments of e.g. demographic, economic and technological variables leading to specific infrastructure, energy and food demands that drive land use change (Verburg et al. 2006).

Considering the complexity of the prospective baseline methods, here we chose only the retrospective methods to introduce how Landsat data is combined into evaluation of baseline (figure 2.).

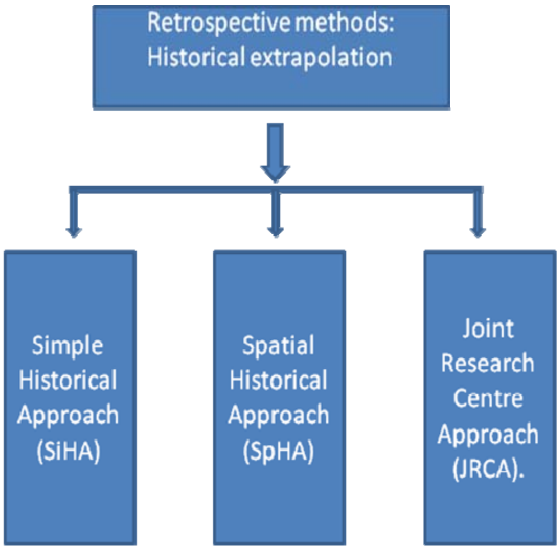


Figure 2. Retrospective methods

Historical baselines are calculated by extrapolating the mean relative rate of deforestation and its associated emissions over a past reference period linearly into the commitment period. In the article, the author chooses three methods. The chosen baseline methods represent the main methodological approaches discussed under the UNFCCC REDD process: Simple Historical Approach (SiHA), Spatial Historical Approach (SpHA) and Joint Research Centre Approach (JRCA) (Huettner et al. 2009).

SiHA: Historical relative deforestation rates are based on existing gross forest cover data from the FAO Forest Resource Assessment for three points in time: 1990, 2000 and 2005. Spatial data is not available to further quantify these rates.

SpHA: Historical relative deforestation rates are based on globally consistent satellite imagery of forest cover for the period 1990 to 2005. These images are taken from at least three points in time to determine forest area changes.

The JRCA approach also suggests calculating the baseline by satellite images from the period 1990 to 2005, but furthermore introduces a method to distinguish intact forest, non-intact forest and non-forest land (www.cifor.cgiar.org/ NR/ rdonlyres/ D0207F59-8D5D-4362-A706-46AEE48619A A/ 0/ JRCProposal.pdf). In this method, a national and global relative baseline rate of forest conversion is built, and then it is compared with actual land-use change in the commitment period. If the national baseline rate is less than half of the global baseline rate in the reference period, then the difference is accounted as avoided forest conversion in the commitment period; however, if the national baseline rate is higher than the global rate, emission reductions occurring below the national baseline in the commitment period are accounted for (Huettner et al. 2009). Deforestation and carbon values are separated according to forest type, forest sub-category and forest conversion type.

The Landsat has following advantages: 1) Since the first Landsat satellite was launched in 1972,data of Landsat series is available from the 1970s, 2) Landsat data can cover nearly the whole earth, it has global scale, 3) Landsat data is freely available from NASA (National Aeronautics and Space Administration. US) or USGS (U.S. Geological Survey), 4) Methods to apply Landsat data tend to be mature. Therefore, for baseline evaluation, the first choice of remote sensors is Landsat.

2.2 Assessment of Activity Data

2.2.1. Deforestation and Degradation

According to UNFCCC, the author here puts the definition of deforestation to be the direct human-induced conversion of forested land to non forested land (UNFCCC 2006). Meanwhile, based on the IPCC (Intergovernmental Panel on Climate Change), forest degradation means direct human-induced long-term loss of forest carbon stocks (IPCC 2006). The differences of the two can be seen in table 2.

Table 2. Differences between Deforestation and Forest Degradation

Deforestation	Forest Degradation
Quick and obvious change from a clearing cut or fire	Slower and subtle change in forest cover
Transformation from forest to non-forest	Hard to be detected due to its continuous characteristics from forest to non-forest
Easy to be detected by remote sensing	Possible to develop into deforestation

2.2.2. Suitable sensors for activity data estimation

Although Landsat are excellent sensors for both land-use change detection and baseline evaluation, most Landsat satellites have run for many years, some have exceeded their designed lifespan.

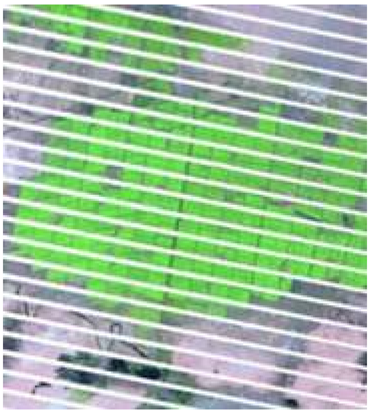


Figure 3. Landsat-7 ETM-SLC failed
http://www.cnic.cas.cn/zcfw/sjfw/gjkxsjjx/dxal_sdb05/201007/t20100729_2915158.html

Therefore, someday, they will stop working. Moreover, in 13th May 2003, a severe error happened to Landsat-7 ETM-SLC (Scan Line Corrector) (Figure 3.), causing great data loss. Besides, Landsat data are very easily interrupted by bad weather (clouds).

What's more, the resolution of Landsat is only 30 meters. That means it can be only used into monitoring areas in large scale with relevant coarse images. This is not enough for detecting forest degradation.

2.2.3. Method used to monitor forest degradation

Here the author lists one method used for monitoring forest degradation.

(1) Identify the anomalies in the primary forest cover by using certain types for remote sensors

(2) Geo-referenced information sent to relevant sectors(government for example) every certain period

(3) Build early deforestation warning system

(4) Control operations (regulations)

(5) Indicator of potential areas where deforestation may happen

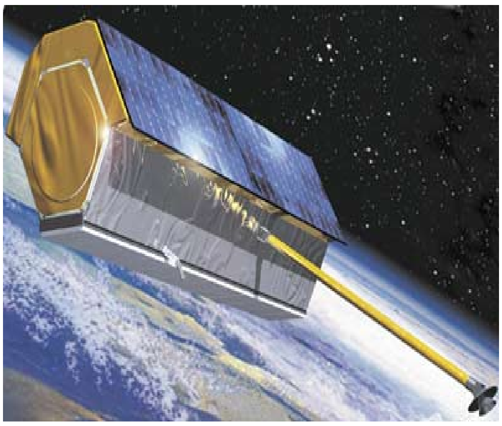
2.2.4. Remote sensors used for monitoring land-use change

Here the author lists three different types of remote sensors.

(1) Radar sensors

Through sending out signals (microwave pulses) that penetrate ground cover and clouds, radar sensors gain information about the underlying terrain.

Here we take a German radar sensor-- Terra SAR-X as an example (figure 4.). Firstly, the advanced radar sensor has a very high resolution which could be up to 1 meter. Such data will be very helpful to monitor forest degradation. Secondly, it also has excellent radiometric accuracy up to 6 meters. When radar signals returned from the ground and tops of trees, tree height then can be estimated, which are then converted to forest carbon stock estimates using allometry. Thirdly, its quick site access time can reach 2.5 days max. (2 days at 95% probability) to any point on Earth. Fourthly, by sending radar signals, such sensor is independent of illumination and weather conditions, bringing relatively stable data.



Three different modes

Spotlight mode
10*10 km
1-2 meters resolution

Strip-map mode
30km wide stripes
3 and 6 meters resolution

ScanSAR mode
100 km wide strips
16 meters resolution

Figure 4. Terra SAR-X (www.skyrocket.de)

However, if we want to gain data of a radar sensor (e.g. Terra SAR-X), we need to pay for it. Then the cost will be high. Besides, when we use radar sensors to monitor the mountainous area, the data becomes less accurate.

(2) LIDAR

LIDAR (Light Detection And Ranging) is an active remote sensing technology. Like the similar radar technology, which uses radio waves, LIDAR sensors send out pulses of laser light and measure the return time of the signal, then height and vertical structure of forests can be directly measured.

LIDAR sensors have many advantages, they usually have very high resolution thus they can directly estimate the height and vertical structure of forests to build 3D images (Figure 5.) Finally, forest carbon stocks are estimated by applying allometric height–carbon relationships (Hese et al 2005).

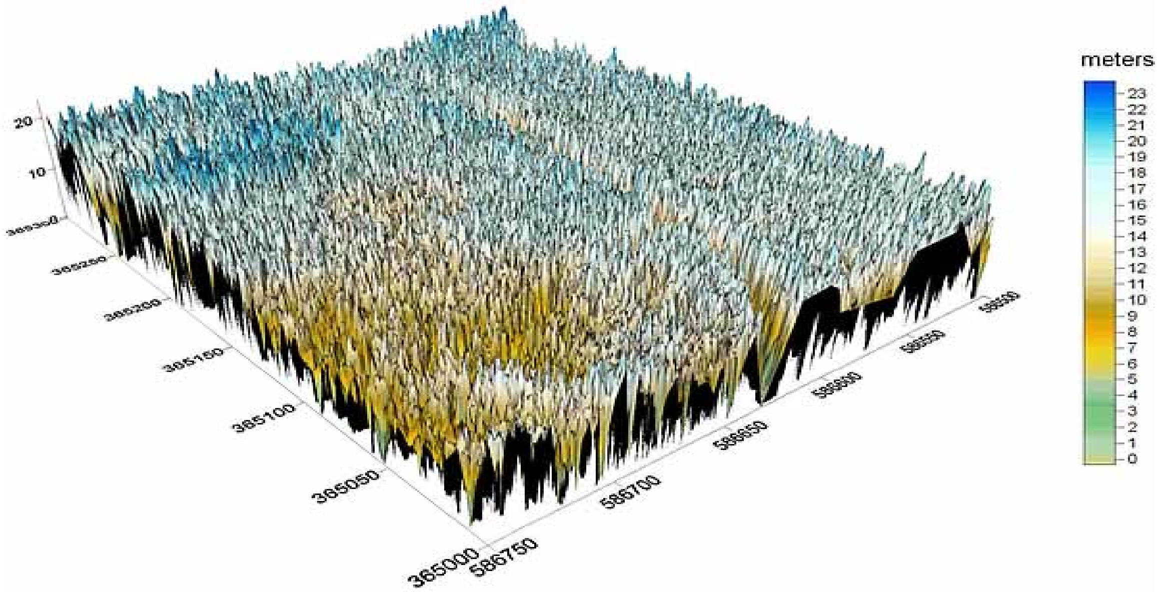


Figure 5. 3D images gained from LIDAR for biomass estimation
www.forestry.gov.uk/forestry/infd-6rukp

However, the cost of LIDAR data is extremely expensive and its coverage scope is limited. Now, it can be only used for monitoring small-area regions.

(3) Optical high resolution sensors

The spatial detail of optical images collected from airborne sensors (up to10 cm pixels) can be used to directly collect measurements of tree height and crown area or diameter. Allometric relationships between ground-based measurements of tree carbon stocks and its crown area with or without tree height can be applied to estimate forest carbon stocks with high certainty (Michael Huettner et al. 2009).

An airplane-mounted system, using dual cameras and collecting imagery that can be viewed in 3D, has been demonstrated to reduce costs of conducting forest inventories, particularly for highly variable, widely spaced inaccessible sites (Brown et al. 2005, Brown and Pearson 2005) and for dense forests (Pearson et al 2005).

However, such sensors' application is quite expensive and the detecting scope is limited.

3. Combined approaches to REDD monitoring

3.1. Linking carbon stocks evaluation and deforestation

For the carbon emissions' evaluation, it is necessary to know deforested area and the amount of carbon these forests stored. Then, through using remote sensing technology, deforestation areas can be detected. Then, if the carbon stocks are collected according to a stratified sampling design it is important that deforestation is estimated for those same strata either through 'wall-to-wall' mapping or by 'targeting sampling' using the same stratified sampling scheme (DeFries et al 2005, 2007, Olander et al 2007). The average carbon stock value for each forest strata can be applied to the satellite-based forest map to estimate national-level forest carbon stocks or to a map of deforestation to estimate national-level forest emissions. Thus, if changes in carbon stocks and emissions happen, it could be monitored from satellite-based observations of deforestation once the broad spatial distribution of carbon stocks is well established (Holly K Gibbs et al 2007).

3.2. Linking carbon stocks and forest degradation

One approach to account for carbon emissions from degradation is to measure forest carbon under different forest conditions as depicted in the stratification matrix (figure 6.). To account for various levels of degradation, sampling schemes could measure carbon across broad forest types (e.g. evergreen broadleaf, seasonally flooded) and condition (e.g. young, logged, fragmented) in each forest stratum.

Forest Condition →

Forest Type ↓

	Mature	Logged	Secondary (young)	Secondary (med. aged)	Burnt
Moist					
Dry					
Seasonal					

Figure 6. Generalized stratification matrix that uses forest type and condition to capture the major variation in forest carbon stocks (Holly K Gibbs et al 2007)

A significant constraint in identifying forests with different conditions is the capacity to map them from space (Achard et al 2006). It will be very challenging to map all types over an entire country. Sensors used to detect deforestation can identify changes in forest area more accurately than the more subtle changes in forest condition due to degradation. Thus, it is unlikely that the current suite of optical sensors can fully identify all types of degradation (Thenkabail et al 2004, Fuller 2006) without innovative methods or coupling satellite imagery with ground-based observations.

4. Discussion

Whether Landsat data could be combined with LIDAR data to achieve a better effect? Yes, it could be.

How Landsat could be used to detect forest degradation in tropical area?

Due to the lower resolution, usually people don't choose Landsat to monitor forest degradation in tropical areas.

5. Conclusions

(1) Landsat is widely used to define baseline.

(2) Applications of different sensors in land use change monitoring are still in development for REDD (especially forest degradation).

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An Overview of Carbon Markets

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Abstract

Emissions through human activities have lead to the global climate change. The Kyoto Protocol, a legally binding agreement under United Nations Framework Convention on Climate Change (UNFCCC) sets a limiting target for industrialized countries in reducing the emission of green house gases (GHGs). In order to meet the target, Kyoto provides three market-based mechanisms: Emission Trading, Clean Development Mechanism and Joint ImplementationI. Carbon marketing has become one of the popular actions to address climate change with the cost efficiency point of view. Carbon commodities are traded in two types of markets: compliance and voluntary markets. Compliance markets are regulated by certain mandatory carbon reduction rules such as Emission Trading under Kyoto and European Union´s Emissions Trading Schemes (EU-ETS). EU-ETS is the largest mandatory multinational company based trading scheme till date. Voluntary carbon markets are not governed by mandatory caps and can generate carbon credits according to demand with smaller in size compare to regulated markets: Chicago Climate Exchange and Over- the-Counter market for example. Though carbon marketing is regarded as the cost efficient means of reducing carbon emissions, there is a lot of criticisms about carbon quality and additionality of projects. In the forestry sector, more than two thirds of forestry offsets are traded on the voluntary market.

Key words: Carbon, trading, market

1. Introduction

The global carbon market has become a cost effective means of taking action against climate change mitigation. Payment is made for buying carbon offsets which is generated by reducing green house gases elsewhere. Carbon trading is done under two kinds of schemes: compliance and voluntary. The compliance market is regulated under cap- and-trade systems such as Kyoto Protocol (KP) and European Union Emission Trading Schemes (EUETs).The offsets in excess of allocated limit or cap can be traded to those who require additional ones in order to meet the targets. The other form is a voluntary market where the offsets are transacted without mandatory regulations as desired by the organizations or by an individual. The size of compliance or regulated markets is much bigger than the voluntary market. The total value of 8,625 $MTCO_2$ traded in the 2009 was 143,897 US $ million and the overall quantity of 94 $MTCO_2$ in case of voluntary market worth 387 US $ million in the same year (Hamilton 2010).

Forestry carbon markets constitute only a small proportion under the Kyoto protocol. But the voluntary market is a fertile grounds for generating forest carbon offsets. 0.2 Mt CO_2 transacted in 2008 by regulated markets is a small fraction as compared to 5.0 Mt CO_2 traded by voluntary market in the same year (Hamilton 2010).

2. Material & Methods

This report is primarily based on secondary sources of data. The information is collected through review of peer reviewed journals, articles, books and related web sites related to Kyoto Mechanisms (CDM, JI, and EU-ETS), compliance and voluntary carbon tools.

3. Results

3.1. Carbon Markets

Carbon credits can be generated either through a cap-and-trade system or project based mechanisms. Compliance markets such as the Kyoto market and EU-ETs perform their transactions on the basis of limits (cap) put on their GHGs emissions. They are driven by mandatory regimes for offsetting carbon on national, regional or international level such as the Kyoto Protocol and European Union´s Emissions Trading Schemes. In contrast, voluntary markets are not legally binding as compliance and can voluntarily offset carbon through projects. It enables business, governments, NGOs and individuals to buy offsets on voluntary basis either through CDM or within voluntary market itself. The market size of the voluntary sector is very small and transacted USD 400-700 million as compared to the compliance sector with 120 billion in 2008. But the voluntary markets are rapidly growing (www.carbonafrica.co.ke).

There are also some compliance programs under cap-and-trade like Regional Greenhouse Gas Initiative (RGGI) and Western Climate Initiative which works from within the Kyoto Protocol. Chicago Climate exchange is a voluntary scheme which regulates under cap and trade (Kollmuss et al. 2008). The tools under compliance and voluntary schemes are presented in table1.

Table 1. Types of Carbon Trading Programs Source: Kollmuss et al. 2008)

Type of Program	Cap-and-Trade	Associated Baseline-and-Credit (offset) Program
Compliance Market	Emission Trading under Kyoto Protocol	CDM & JI
	EU-ETS	CDM & JI
	RGGI	RGGI Offset Program
	Western Climate Initiative	Under development
Voluntary Market	Chicago Climate Exchange (CCX)	CCX Offset Program

3.2. Kyoto Markets

The Kyoto Protocol entered into force on February 16, 2005. The major principle was “common but differentiated responsibilities”, as industrialized countries were more responsible for emission of Green House Gases (GHGs) given the 150 years of their industrial development. The targeted six GHGs are carbon dioxide, methane, nitrous oxide, hydro fluorocarbons, per fluorocarbons, and sulfur hexafluoride. A total of 37 industrialized countries (Annex I countries) and European community under the agreement targeted to reduce the emissions by 5% compared to the level of the year 1990, which is considered as baseline year over the commitment period (2008-2012). Kyoto targets can be fulfilled either by lowering emissions in their own country or implementing projects in other countries. In addition, they can also buy carbon credits from those countries which are already in excess of carbon allowances (http://unfccc.int/kyoto_protocol/items/2830.php).

Three types of flexible mechanisms existed under Kyoto Protocol (**Fig.1**).

- Clean Development Mechanism (CDM)
- Joint Implementation (JI)
- International Emission Trading (IET)

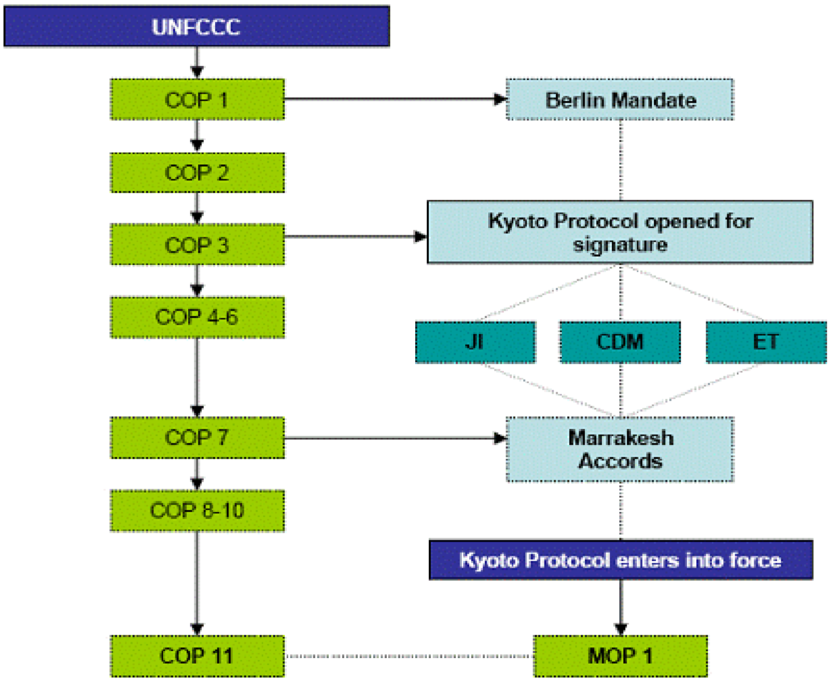

Figure 6. Development of Kyoto mechanisms (Source: Cdmrulebook.org, 2010)

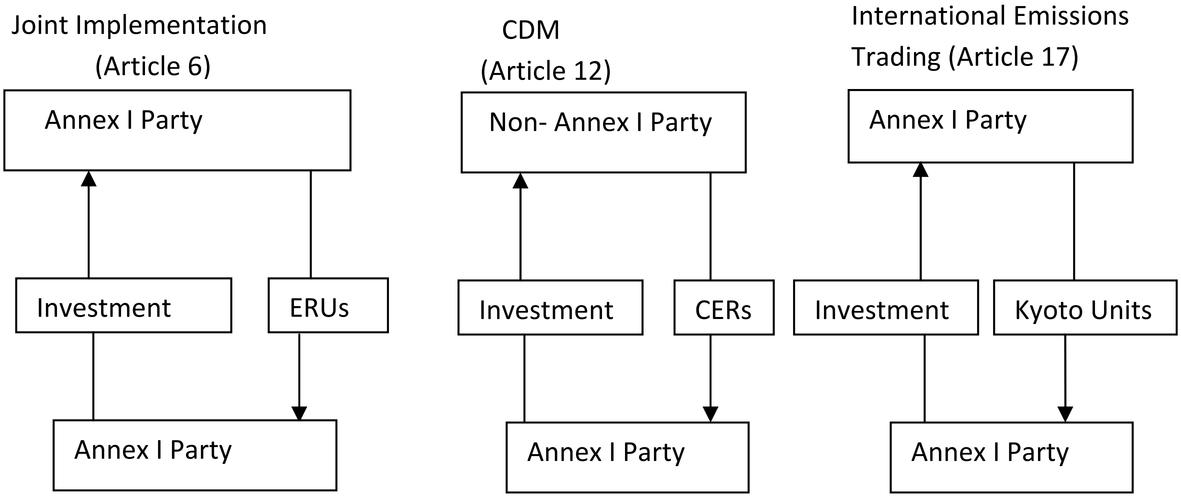

Figure 2. Flexible mechanisms under Kyoto Protocol (Source: www.cdmrulebook.org)

(1) CDM**:** under the article 12 of Kyoto, Annex I countries can implement projects in non-Annex I countries and thereby obtain carbon credits to meet their Kyoto obligations. Such credits are called Certified Emissions Reductions (CERs) (Hepburn 2007).

(2) JI**:** Under the article 6.1 of KP, Annex I parties can implement emission reducing projects in another developed host party where the cost is relatively low. Such projects can then generate Emission Reduction Units (ERUs) which is used to fulfill their Kyoto obligations (Hepburn 2007).

(3) IET**:** under the article 17 of KP, Annex B countries can sell their emission units to the countries which are in need to cover their Kyoto targets. This trading can be

done in the form of CERs, ERUs, Assigned Units (AAUs) and Removal Units (RMUs). So, this is in link with regional and domestic schemes, EU-ETs as an example (Hepburn 2007).

3.3. European Union Emission Trading Schemes (EU-ETs)

One of the multi-national trading scheme in the world, it was introduced in 2005 and was founded as major tool for European countries for helping them to meet their Kyoto targets (http://ec.europa.eu/clima/policies/ets/index_en.htm). It is the biggest market with more than 11,000 installations in the energy and industrial sectors that operates under cap-and-trade mechanism (National government regulates the cap as National Allocation Plans (NAPs) within which companies are bound in emission trading). The commitment period (2005-7) had been a success for Phase I with a steady increment in the transacted volume of carbon. Currently, phase II (2008-12) is on the way which operates in all 27 members of European Union in addition to 3 non-EU countries The EU-ETS linking directive permits to use credits from CDM and JI in phase II) but has recently excluded credits from forestry projects. EU-ETS transacted around 1.6 Gt and a value of €28m followed by the CDM market with total of 947 Mt and €12bn in 2007 shown in FIg.1 (Roine et al. 2008).

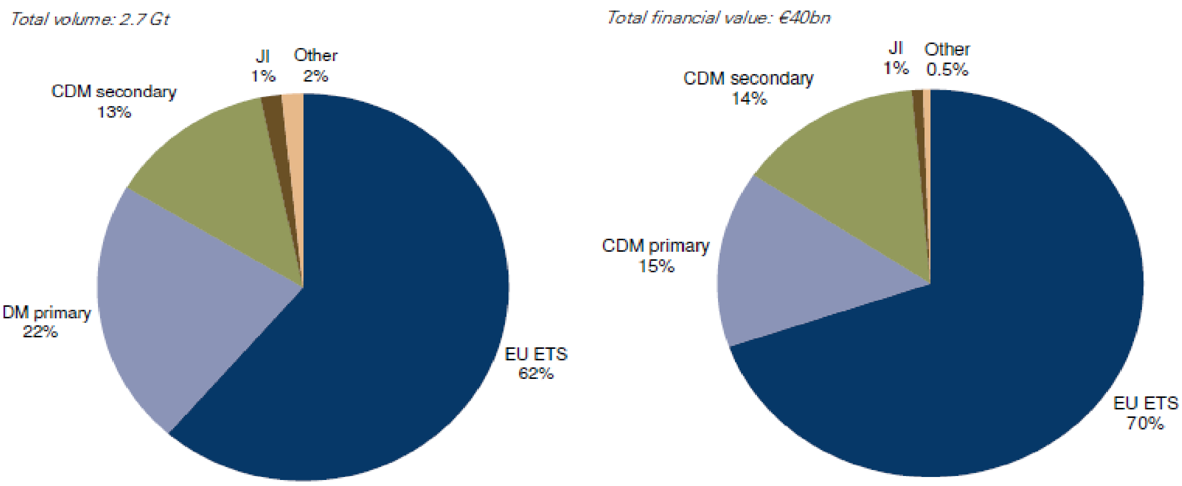

Figure 1. EU-ETs leading ahead in the global market (Source: Roine K. et al. 2008)

3.4. Compliance versus Voluntary

The worldwide marketing of regulated carbon in the year 2009 was estimated to be 8,625 $MtCO_2$ with the increment in value by 7% than that of the previous year. But in the case of the voluntary market, the total traded quantity was 94 $MtCO_2$ in the year 2009 which made a decrement by 47% in the value compared to 2008 (Hamilton et al. 2010).

3.5. Forestry and Carbon Market

Voluntary Carbon Markets play a major role in the forest carbon trade covering 73% of the total offsets. The credits transacted can be within the voluntary market, called Verified Emission Reductions (VERs), or from regulated market credits, called CERs.

Two important parts of the voluntary market are the Chicago Climate Exchange (CCX), which is regulated by cap-and-trade and Over-The-Counter Market which has no binding regulation.

In case of OTC market, credits generally called VERs or carbon offsets transacted 11% in total. Forestry carbon credits are usually obtained from three kinds of projects: Afforestation/Reforestation (A/R), Reducing Emissions from Deforestation and Degradation (REDD), and Improved Forest Management (IFM). A/R projects are leading ahead with the volume of 59% carbon credits followed by REDD with 24% and by IFM with 8% in total (Hamilton et al. 2010).

Table 2. Global carbon market (Source: Hamiltan et al. 2010)

	Volume ($MtCO_2e$)		Value (US$ million)	
Markets	**2008**	**2009**	**2008**	**2009**
Voluntary OTC	57	51	420	326
CCX	69	41	307	50
Other exchanges	0.2	2	2	12
Total Voluntary Markets	**127**	**94**	**728**	**387**
EU ETS	3,093	6,326	100,526	118,474
Primary CDM	404	211	6,511	2,678
Secondary CDM	1,072	1,055	26,277	17,543
Joint Implementation	25	26	367	354
Kyoto [AAU]	23	155	276	2,003
New South Wales	31	34	183	117
RGGI	62	813	241	2,667
Alberta's SGER	3	5	34	61
Total Regulated Markets	**4,713**	**8,625**	**134,415**	**143,897**
Total Global Markets	**4,840**	**8,719**	**135,143**	**144,284**

CCX accepts projects within the US and non-Annex countries under its criteria. Forestry projects undertaken are A/F, IFM and are on the way of taking REDD. Forest projects cover about 14% of credits registered with the steady increment in past two years (Hamilton et al. 2010).

Table 3. Quantity and price of forest carbon market (Source: Hamilton et al. 2010).

Markets	Volume ($MtCO_2$)		Value (million US$)	
	Historical Total	2008	Historical Total	2008
Voluntary OTC	15.3	3.7	129.7	31.5
CCX	2.6	1.3	7.9	5.3
Total Voluntary Markets	**17.9**	**5.0**	**137.6**	**36.8**
New South Wales	1.8	0.2		
CDM A/R	0.5	0.1	2.9	0.3
NZ ETS	0.1		0.7	
Kyoto (AAU)	0.6		8.0	
Total Regulated Markets	**2.9**	**0.2**	**11.6**	**0.3**
Total Global Markets	20.8	5.3	149.2	37.1

The Kyoto markets CDM and JI accept carbon credits from Land-Use, Land Use - change and Forestry (LULUCF) activities. CDM approves A/F projects and can issue either temporary certified emissions (tCERs) or long-term certified emission reductions (ICERs). Under the New Zealand Emissions Trading Schemes, which includes reforestation and avoided deforestation credits. REDD which is still under the process of UNFCCC negotiations has yet to explicitly determine its regulations But efforts are being made to conduct REDD readiness activities: Carbon Partnership Facility (FCPF) which supports developing countries in capacity building process; UN-REDD program that aims to help in developing and implementing national REDD strategies.

The historical total of regulated carbon market worth 11.6 million US Dollar, which is overtaken by the significant value of 137.6 million US Dollar in the voluntary market, is given in table 3.

4. Discussion - Criticisms of Carbon offsetting

Though Carbon trading schemes has been the most cost effective approach in climate change mitigation, there are some criticisms of this marketing:

- There are a number of offsets that come from projects which are non-additional (Schneider 2007).
- Carbon projects do not benefit host community and is a form of carbon colonialism (Eraker 2000).

5. Conclusion

Carbon markets can play a significant role in the mitigation of climate change. The compliance market which is regulated by mandatory rules is bigger in size as compare to the voluntary market. But the voluntary market can still contribute to the reduction of emissions as it makes enables individuals or organizations to purchase carbon offsets. For both types of markets, it is essential to consider the quality of offsets to be maintained by taking into serious account terms of additionality. The voluntary sector specifically has to go along with the carbon standard and show transparency in the market. Forest carbon offsets which are only a fraction in the compliance market, need to be integrated on a broader scale. Its importance to not let emission reduction with low cost efficiency be overwhelmed.

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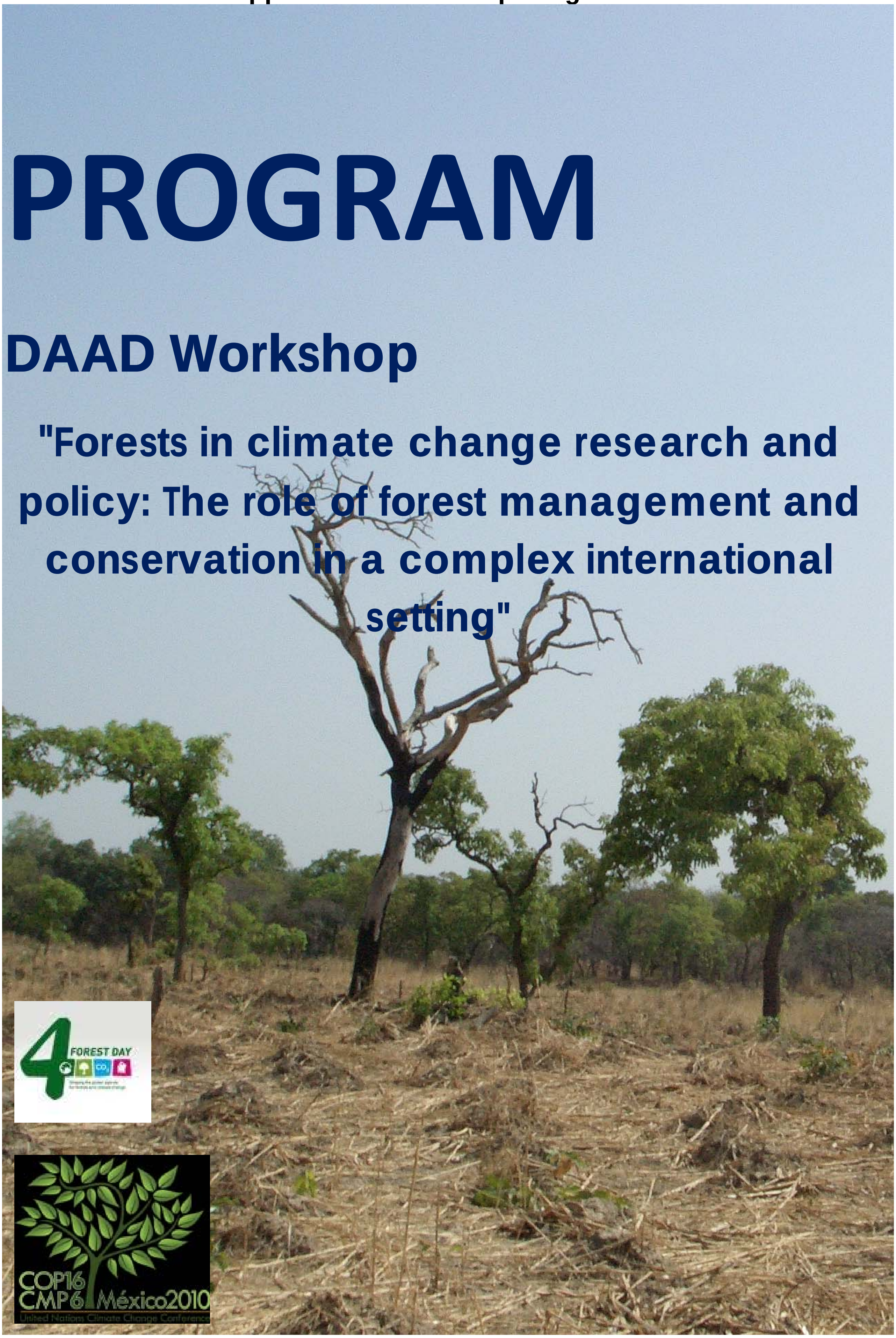
www.carbonafrica.co.ke (Visited on 8th of December, 2010)

http://www.cdmrulebook.org/ (Visited on 12th of December, 2010)

http://unfccc.int/kyoto_protocol/items/2830.php (Visited on 12th of December, 2010)

Appendix 1: Workshop Programme



PROGRAM

DAAD Workshop

"Forests in climate change research and policy: The role of forest management and conservation in a complex international setting"


DAAD
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Program of the DAAD Workshop

"Forests in climate change research and policy: The role of forest management and conservation in a complex international setting"

Organized and implemented
by

Chair of Forest Inventory and Remote Sensing
Faculty of Forest Sciences and Forest Ecology
Georg-August-Universität Göttingen

together with

Facultad Forestal
Universidad Autónoma de Nuevo León
Linares, México

Cancún 02-09. December 2010

Thursday, 2.12.2010		Arrival
All day	Arrival of participants	

Friday, 3.12.2010		DAY ONE
8:00 – 9:00 h	Meeting of Organization panel	
9:00 – 10:00 h	Workshop Opening	- Opening: Christoph Kleinn (Universität Göttingen) - Welcome Address: David Schmidt (German Embassy in Mexico City, tbc) - Information on workshop organization - Introduction of participants - Presentation of workshop programme
10:00 – 10:30 h	**Coffee break**	
		Moderator: Christoph Kleinn
10:30 – 11:00 h	Seminar paper	(How) can silviculture contribute to carbon sequestration? (Achim Dohrenbusch)
11:00 – 11:30 h	Seminar paper	Soils as a sink and source of greenhouse gases – Effects of land-use change (Rainer Brumme)
11:30 – 12:00 h	Seminar paper	Issues of a REDD readiness in Laos (Horst Weyerhaeuser, SIDA, Laos)
12:00 – 13:30 h	**Lunch break**	
		Moderator: Axel Bader
13:30 - 14:00 h	Seminar paper	Estimation of carbon emissions from deforestation and forest degradation in South Central Chile during the period 1994-2007 (UACH, Valdivia, Chile)
14:00 – 14:30 h	Seminar paper	Adaptation and Mitigation Strategies to Global Warming implemented in Buffer Areas in Costa Rica: Case Study La Amistad Biosphere Reserve (UNA, Heredia, Costa Rica)
14:30 – 15:00 h	Seminar paper	Innovative financing strategies for the restoration and conservation of the tropical dry forest in Colombia (UdeA, Medellín, Colombia)
15:00 – 15:30 h	**Coffee break**	
		Moderator: Axel Bader
15:30 – 16:00 h	Seminar paper	Possibilities of guadua bamboo forests in the

		context of REDD+: A case study in the coffee region of Colombia (UTP, Pereira, Colombia)
16:00 – 16:30 h	Seminar paper	A) Is there a relationship between climate factors and genetic structure in *Picea chihuahuana Martinez*? B) Tree species distribution and its relationship to climate factors in forests of Durango (Mexico) (UJED Durango, México)
16:30 – 17:00 h	Seminar paper	Effect of fire severity on tree structure, seedling establishment and soil carbon content in mixed pine-oak forest, northeast Mexico (UANL, Linares, México)

Saturday 4.12.2010 DAY TWO

9:00 - 10:30 h	Workshop	Preparation of visit to FD4
10:30 – 11:00 h	**Coffee break**	
		Moderator: Axel Bader
11:00 – 11:30 h	Seminar paper	Global climate change: from scientific evidence to international policy actions and their effects on forests (Uwe Halbach, Göttingen, Germany)
11:30 - 12:00 h	Seminar paper	Monitoring of forest carbon pools in the UNFCCC frame work (Helmuth Nieves, Göttingen, Germany)
12:00 – 12:30 h	Seminar paper	An overview of carbon trade markets (Lavander Renzoandre De la Peña, Göttingen, Germany)
12:30 – 14:00 h	**Lunch break**	
14:00 – 18:00 h		Visit to Forest Day 4 conference venue, introduction for the students who assist at FD4 **Registration at Forest Day 4**
18:00 h	Presentation	Welcome at conference venue by the FD4 organizers (CIFOR representative).

Sunday 5.12.2010 DAY THREE

07:30		Departure from Sina Suites Hotel
07:45		Foto session
08:00 – 20:00h	**FD4**	**Participation at CIFOR Forest Day 4**

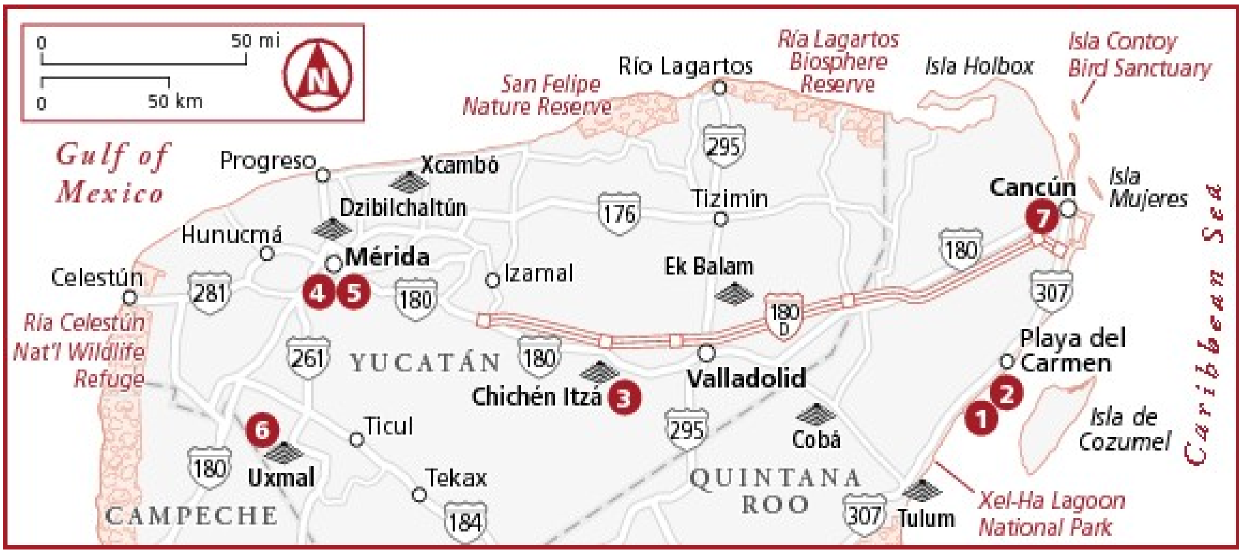
		For directions to the conference centre please see Map attached at the end of Program.

Monday, 6.12.2010 **DAY FOUR**

07:10 – 19:30h	Field trip	Toulum and Xel-Há

Source: Bruno Girini, 2005

Nature park Xel-Há and Tulum, located about 100 and 130 km south of Cancun will be visited by bus, which leaves at the Hotel at 7:10 in the morning, the estimated time of return is 19:30 o`clock. First we will visit the nature park of Xel-Há. The nature park is home to much wildlife; especially bird watching is well possible in the preserved forest. In addition various archaeological sites that were used by the Mayas will be visited. Most archaeological sites are natural caves. Some very large caves collapsed, forming so called cenotes which are home to an exceptional ecosystem. At 14:30 o`clock we will leave Xel-Há to visit the famous Ruins of Tulum, located directly at the coast line. Tulum was habituated in AD 1200-1521. Being built during the time of decline of the Maya civilization. Further, it is assumed that it was a major port town, until it was abandoned 75 years after the Spanish conquest. More about the history of Tulum will be told during the guided tour through its remains.



Source: http://www.frommers.com

Tuesday, 7.12.2010 DAY FIVE

		Moderators: Achim Dohrenbusch and David Morales
09:00 – 10:00 h	Workshop	Wrap-up of FD4 impressions
10:00 – 10:30 h	**Coffee break**	
10:30 – 12:00 h	Workshop	Design of the structure of the proceedings volume and assignation of tasks (i.e. reports on FD4 and on the entire project)
12:00 – 12:30 h	Workshop	Introduction to group work
12:30 – 14:00 h	**Lunch break**	
14:00 – 17:30 h	Workshop	Group work on summary papers / minutes of FD4

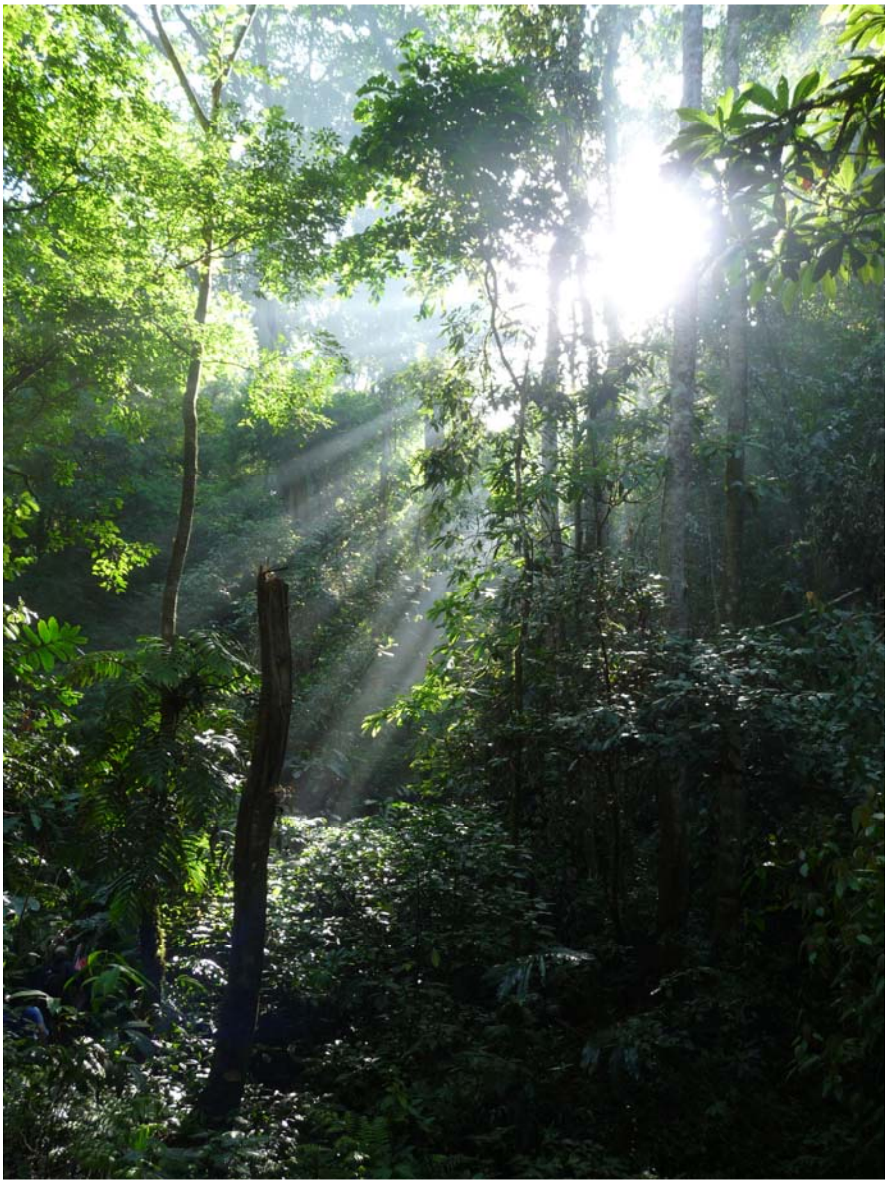
Wednesday, 8.12.2010 DAY SIX

9:00 – 10:30 h	Workshop	ctd. Group work summary papers / minutes of FD4.
10:30 – 11:00 h	**Coffee break**	
11:00 – 12:30 h	Workshop	ctd. Group work summary papers / minutes of FD4.

12:30 – 14:00 h	**Lunch break**	
		Moderators: Achim Dohrenbusch and David Morales
14:00 – 15:00 h	Workshop	Plenary discussion on progress
15:00 – 15:30 h	**Coffee break**	
15:30 – 18:00	Workshop	ctd. Group work summary papers / minutes of FD4.

Thursday, 9.12.2010 DAY SEVEN

		Moderators: Achim Dohrenbusch and David Morales
9:00 – 10:30	Workshop	Final discussion on workshop outputs
10:30 – 11:00 h	**Coffee break**	
		Moderator: David Morales
11:00 – 12:00 h	Workshop	Evaluation and compilation of suggestions
		Moderator: Achim Dohrenbusch
12:00 – 12:30 h	Workshop	Assignation / verification of responsibilities Verification of deadlines
12:30		Workshop Closing
Afternoon		Departure of participants



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ACCOMMODATION and WORKSHOP VENUE

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Tel: +52-998 883-10-17
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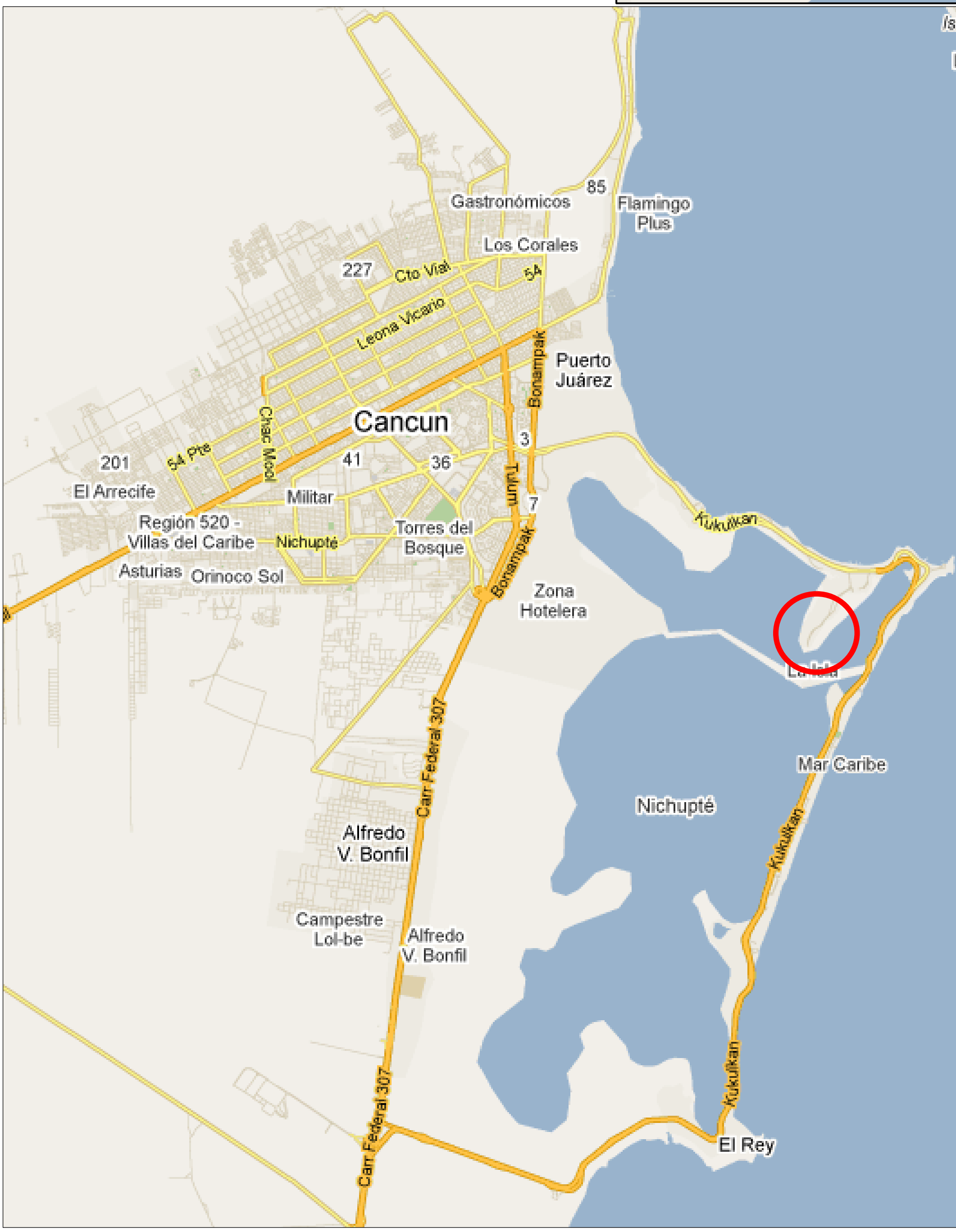
Source: Google maps



FOREST DAY 4 VENUE

Cancun Center, Conventions and Exhibitions

Boulevard Kukulcan KM. 9 1er Piso
Zona Hotelera
77500 Cancún
Quintana Roo, México

Toll free from Mexico: 01 800 881 04 00
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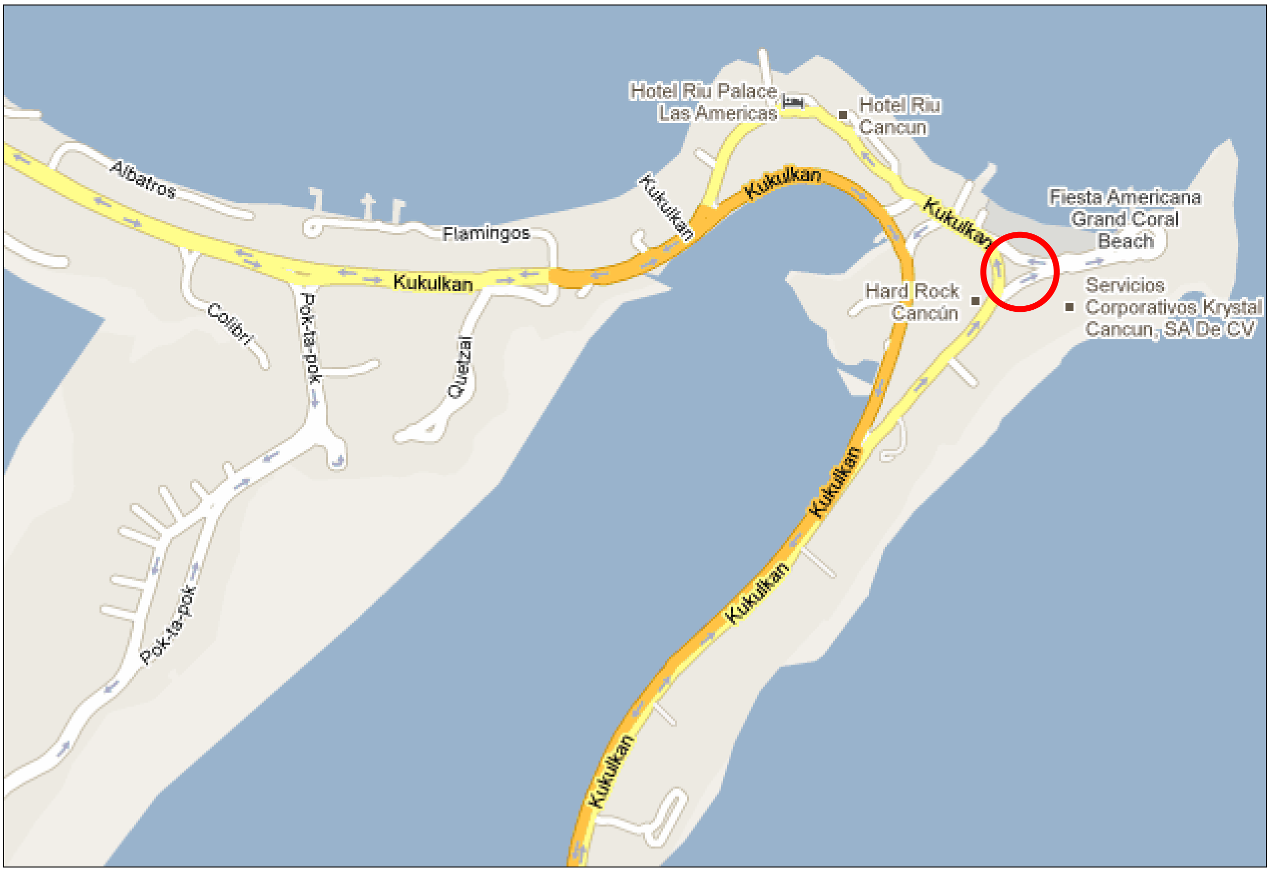

Source: Google maps

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China	Tel: +52 55 5550 0823
Colombia	Tel: +52 55 5525 0277
Costa Rica	Tel: +52 55 5525 7764
Germany	Tel: +52 55 5283 2200
Ireland	Tel: +52 55 5520 5803
Nepal	Tel: +52 55 60-5568
Peru	Tel: +52 55 5259 0239
Vietnam	Tel: +52 55 5540 1632

HOSPITAL IN CANCÚN

Hospital Americano
Retorno Viento 15 Smza. 4
Cancun, Q. Roo. 77500
Tel: (998) 884 6133 or (998) 887 5304

Appendix 2:

Forest Day 4, Programme Summary
<http://www.forestsclimatechange.org/?id=334>

Time	Forest Day 4 Programme				
07.00-09.00	**Registration**				
09.00-10.30	**Opening Plenary**, *Gran Cancún*				
10.30-10.45	Break				
10.45-12.15	**Subplenaries**				
	1. Biodiversity: Synergies in po-licy and practice **Cozumel 2**	2. Adaptation Now: Options for transforming landscapes to build climate change resilience **Cozumel 1**	3. Mitigation: Can REDD+ finance meet both climate change and development objectives? *Gran Cancún*		
12.15-13.00	Lunch				
13.00-14.15	**Global updates on forests and climate change**, *Gran Cancún*				
14.15-14.30	Break				
14.30-16.00	**Parallel Learning Events 1**				
	Moving forward on the governance reform agenda: Illegal logging corruption, and climate change, **Cozumel 2**	Meso-American experiences in protecting community - indigenous peoples' rights over forests, **Xcaret**	Delivering the emission reductions in REDD+: Challenges for MRV, **Cozumel 1**	Promoting synergies between climate change mitigation and adaptation across forest landscapes, **Coba**	Optimising multiple environmental and social benefits of sustainable forest management and REDD-plus, **Isla Mujeres**
16.00-16.15	**Break**				
16.15-17.45	**Parallel Learning Events 2**				
	Mexico's experience in promoting community-based forest enterprises, **Cozumel 2**	REDD+ and forest finance: A 360 degree view on forest finance, **Cozumel 1**	REDD and agricultural drivers of deforestation, **Xcaret**	Land use, land use change and forestry (LULUCF), **Isla Mujeres**	
17.45-18.00	Break				
18.00-18.15	**Google Earth Engine demonstration**				
18.15-19.00	**Closing Plenary**, *Gran Cancún*				
19.00-21.00	**Cocktail reception**				

Appendix 3:

Summary statement of Forest Day 4, CIFOR

From www.forestsclimatechange.org/fileadmin/downloads/fd4/FD4-summary-statement.pdf

Time to act on forestry and climate change

This statement is a summary of Forest Day 4 (FD4) held in parallel to COP16 at the Cancún Center on Sunday 5 December 2010. It highlights issues, quotes and outcomes of the day, and provides some key messages to the UNFCCC on how to move forward in the negotiations.

Time to act on forestry and climate change

FD4 was co-hosted by the Center for International Forestry Research (CIFOR), the Mexican National Forestry Commission (CONAFOR), and members of the Collaborative Partnership on Forests (CPF). It brought together more than 1,500 of the world's leaders and experts, practitioners and policy makers, advocates and investors, indigenous people and, community representatives, and the media to discuss and debate how to accelerate the integration of forests into climate mitigation and adaptation from local to global levels. His Excellency President Felipe Calderón Hinojosa, in his opening speech at FD4, told the plenary "… it's time for all of us to push, and push hard for the full incorporation of REDD+ into a long-term international climate change agreement." In a passionate plea, the Mexican president also stressed, "Either we change our way of life now, or climate change will change it for us."

Keynote speeches by Daniel Nepstad, Director of the International Program at the Amazon Environmental Research Institute and Mirna Cunningham Kain, Chair of the Center for Autonomy and Development of Indigenous Peoples, emphasized the critical needs for both sound forestry and climate change science, and pro-active engagement with indigenous people and forest-dependent communities as the *de facto* and *de jure* custodians of land and forest resources to secure equitable outcomes. UN Under Secretary-General for Economic and Social Affairs Sha Zukang provided an important forward-looking perspective, drawing particpants' attention to the multiple benefits of forests and the International Year of Forests in 2011.

At subsequent subplenary sessions and learning events, FD4 participants shared experiences on a number of existing and promising approaches for integrating forests into strategies to address climate change: aligning REDD+ with national development objectives, ecosystem-based approaches to adaptation, restoring degraded lands, empowering community management of forests, addressing agricultural drivers of deforestation, measuring reduced emissions, and increasing mitigation through forest management in developed countries, and mobilizing additional finance.

Harnessing REDD+ to sustainably manage forests and reduce poverty

The potential of REDD+ to generate additional benefits – including poverty reduction, biodiversity conservation, and synergies with adaptation to climate change – is now widely recognized. Sir Nicholas Stern reaffirmed that "Climate change and poverty reduction are the defining challenges of this century…. The story of how we use REDD+ financing to mitigate climate change must also be a development story." FD4 participants also recognized that such benefits will not be captured automatically. The design and implementation of REDD+ policies, strategies and projects to ensure effectiveness and efficiency, and to safeguard vulnerable ecosystems and the rights and livelihoods of indigenous peoplep and forest-dependent communities, remained the subject of healthy debate throughout FD4. The day also saw the emergence of a robust consensus that the risks of no action on protecting the world's forests are far greater than the risks of moving ahead with less-than-perfect agreements.

REDD+ provides a key and cost-effective opportunity to mitigate climate change

FD4 participants reaffirmed that through REDD+ we may significantly reduce, remove and avoid global emissions at reasonable cost, as long as we take due account of the rights and livelihoods of indigenous people and local communities, biodiversity and ecosystem services, whilst assisting developing forest countries adapt to climate change. Despite some setbacks at the Bonn and Tianjin intersessionals, the current draft REDD+ negotiating text (FCCC/AWGLCA/2010/CRP.2, 4 December 2010) is close to agreement. Half of those polled saw the lack of a global climate agreement as the most significant barrier to scaling up REDD+, along with lack of clarity on carbon rights, weak national monitoring, reporting and verification (MRV) systems, and limited funding.

The rights of indigenous people and forest-dependent communities need to be protected

FD4 participants noted that communities and indigenous people depending on and living in or near forests often believe that REDD+ may result in the usurpation of their rights by outsiders, or in increased hardship due to new limitations on forest use. Throughout the Meso-American region, indigenous people, forestry *ejidos* and community concessions manage significant forest areas based on local knowledge, practices and value systems, which have contributed significantly to forest conservation whilst maintaining their livelihoods. In Mexico, 70 percent of the country's forests are in communally managed community lands. A long history of support has focused on strengthening local governance institutions in communal territories (*ejidos* and *comunidades*) that have enabled communities to take over forest operations and begin building enterprises. The experiences of these communities have allowed some notable examples to begin experimenting with carbon trading. FD4 participants noted that these communities would be more willing to engage with REDD+ initiatives if they were to participate in all aspects of REDD+ design and implementation, if they are granted rights to the carbon in their forests, if they play a central role in the design of local rules, and if REDD+ does not permit more powerful competitors to threaten local interests.

Additional financing is needed to implement REDD+ at scale

The REDD+ financing pledges made to date fall short of estimated funding requirements made by the Stern and Eliasch reviews and the Informal Working Group on Interim Finance. FD4 participants reaffirmed the need for an agreement on a robust and predictable system for mobilizing financial resources from various sources, primarily developed countries. This will be needed to stimulate and pay for early REDD+ action at scale, technology transfers, capacity building and the development of national and sub-national MRV systems, among others. FD4 participants recognized that opportunities exist to catalyze additional public and private finance and investment to support actions addressing the drivers of deforestation.

Biodiversity conservation is a prerequisite for the success of REDD+

FD4 participants noted that the conservation and sustainable use of biodiversity are not merely co-benefits for REDD but also prerequisites for its success. Biodiversity underpins forest resilience, health and productivity, and thus the permanence of forest carbon stocks. Countries such as Ecuador and Mexico harness their rich biodiversity to enhance and stabilize carbon sequestration in forests and other ecosystems, and as vital “green infrastructure” for adaptation. Participants recognized the need to harness such synergies at all levels. The new 2011–2020 Strategic Plan of the Convention on Biological Diversity (CBD), adopted in Nagoya, Japan, could support the aims of the UNFCCC. The Strategic Plan aims to bring 17 percent of land areas under protected area management, to halve the rate of deforestation, to bring all forests under sustainable management, and to restore 15 percent of degraded ecosystems. FD4 recognized that this will provide additional opportunities to secure biodiversity co-benefits, for example through the five-point REDD+ Partnership Work Program 2011–2012. More than 90 percent of FD4 participants polled said that biodiversity safeguards are either “very important” or “essential” for the success of REDD+, and more than 95 percent said that it is important to monitor co-benefits.

REDD+ and agricultural drivers of deforestation

FD4 participants acknowledged that agricultural intensification does not necessarily reduce deforestation. Empirical studies suggest that where demand for agricultural products is elastic or where economies are “open”, deforestation increases as returns to land increase. In contrast, where demand is inelastic or where economies are “closed” intensification can reduce deforestation. FD4 participants proposed several options to increase intensification whilst reducing net annual rates of deforestation including: increasing production efficiencies; promoting multifunctional landscapes; directing REDD+ financing to increase efficiencies in agronomic practices; and shifting extensive production systems to low carbon landscapes.

Promoting synergies between climate change mitigation and adaptation across landscapes

More than 1 billion hectares of forest lands and secondary forests worldwide have been degraded. Integrated landscape management and forest restoration offer the potential to foster synergies between adaptation and mitigation by increasing carbon stocks while at the same time enhancing ecosystem resilience and reducing social and economic vulnerabilities of forest-dependent people. FD4 participants also recognized that integrating mitigation and adaptation at the landscape scale would maximize local co-benefits and contribute to increased capacity to cope with the risks associated with climate change. FD4 participants noted that more research is needed to explore linkages between adaptation and mitigation in forests at different scales.
Two specific challenges – agreement on monitoring, reporting and verification (MRV) systems, and continued improvements in forest governance – were also discussed at FD4. Many difficult questions remain in these areas (for example, reaching a balanced decision on mitigation that will satisfy all Parties from developed and developing countries; how to achieve the progressive shift to low carbon development whilst sustaining economic growth).

Strengthen linkages between national and subnational MRV systems for REDD+

Significant progress in monitoring changes in forest area from deforestation and afforestation means that effective MRV for REDD+ is possible, but challenges remain for monitoring forest degradation and peatland emissions. Carbon monitoring based on national forest inventories presents several cost advantages but such inventories are not always available. FD4 participants reaffirmed the need for significant additional capacity building and technology transfer, including the application of novel technologies. Examples include Google's Earth Engine (demonstrated by Rebecca Moore, Head of Google's Global Outreach Program prior to the Closing Plenary of FD4), Open Data Kit and androids for forest biomass measurements with communities. FD4 participants agreed that more experience is also needed on establishing regional REDD+ baselines and jurisdictional accounting and crediting systems aligned to national MRV systems.

Improve accounting rules for forest management in developed countries

Negotiations underway in UNFCCC to change the greenhouse gas accounting rules under the Kyoto Protocol could have significant implications for the management of temperate and boreal forests, which make up nearly half of the world's forests. Forest Day 4 participants agreed that improved rules are needed. They also felt that more comprehensive accounting on forests would be beneficial both for the climate and for forests. Participants acknowledged that this is a complex and controversial issue, but success in reaching agreement on new rules would help smooth the way for agreement on new emission reduction commitments by developing countries for the second commitment period of the Kyoto Protocol. New rules on forest management could also facilitate development of rules for potential REDD+ reporting.

The success of REDD+ strategies and projects will depend on whether they influence governance reforms or are shaped by existing governance failures

FD4 participants recognized that the ability of developing countries to enhance the role of their forest resources in mitigating climate change is closely linked with their commitment to governance reform. Good performance and effective carbon emissions reductions at national level requires the removal of perverse policy and incentive frameworks, alignment of policies across sectors, capacity and independence of forest agencies, balanced distribution of power across scales and groups and their engagement in decisions and benefits. FD4 participants acknowledged there are huge challenges to reform the embedded structures of past poor governance. Addressing them will negatively affect powerful groups and will shift relationships, powers and benefits. REDD+ could influence these processes in many ways. The legality and legitimacy of REDD+ are likely to depend on a balance between central oversight and decentralized decision making, clear tenure and transparent and equitable benefit-sharing arrangements.

Reinforcing the UNFCCC momentum on forestry and climate change

Forest Day 1 was held at COP13 in Bali when an historic breakthrough on REDD was achieved. Despite the disappointments in Copenhagen, considerable progress was made in 2010 at the International Conference on Major Forest Basins in Paris, and the Oslo Climate and Forest Conference. The establishment of the REDD+ Partnership and the UN Secretary-General's High-Level Advisory Group on Climate Change Financing were followed by new funding pledges including "fast-track" financing. The presentations and discussions during FD4 highlighted a number of negotiating areas that are closer to agreement than others, and complementary efforts that are needed to ensure their success. The former include REDD+, securing co-benefits, protecting rights to forests and carbon, fast-track financing and achieving synergies between adaptation and mitigation. Antonio La Viña, negotiator from the Philippines, characterized the REDD+ text currently under negotiation as "not just good, but very good". All these negotiating areas provide critical opportunities at COP16 to translate decision texts into official agreements and financing by early 2011 to obviate the risks of further delays in mobilizing resources to address climate change in developing countries.

A key challenge of COP16 in Cancún is how existing mitigation and financing pledges made through the Copenhagen Accord can now be transformed into official commitments under the UNFCCC. This may require abandoning the “nothing is agreed until everything is agreed” global climate change architecture approach to ensure that a balanced cluster of decisions can be made in negotiating areas that remain close to agreement. This will ensure that commitments can be translated into actions in 2011.

Appendix 4:

The Cancún Agreement

Selected sections with direct reference to forests, forestry and land use change, from http://unfccc.int/files/meetings/cop_16/application/pdf/cop16_lca.pdf

DRAFT TEXT

version of 10.12.2010 @ 16:00

Note by the President

OBS.: This "Contents" is given here for orientation on the entire text; the page numbers refer to the original text and not to this Proceedings Volume !

This text reflects the current status of the negotiations, incorporating the results of consultations conducted under the auspices of the Ad Hoc Working Group on Long-term Cooperative Action under the Convention and the consultations launched by the President of the sixteenth session of the Conference of the Parties and the sixth session of the Conference of the Parties serving as the Meeting of the Parties to the Kyoto Protocol.

It has been prepared in direct response to requests from Parties urging the President to present a text that covers all the issues and paints the whole picture of the outcome. As indicated above, it reflects the current status of the efforts of delegations to converge on a balanced outcome.

Contents

Advance unedited version, 10.12.2010 @ 16:00h

Draft decision -/CP.16

Outcome of the work of the Ad Hoc Working Group on long-term Cooperative Action under the Convention

The Conference of the Parties

Recalling its decision 1/CP.13 (the Bali Action Plan), and decision 1/CP.15,

Seeking to secure progress in a balanced manner, in the understanding that, through this decision, not all aspects of the work of the Ad Hoc Working Group on Long-term Cooperative Action under the Convention are concluded, and that nothing in this decision shall prejudge prospects for, or the content of, a legally-binding outcome in the future,

Reaffirming the commitment to enable the full, effective and sustained implementation of the Convention through long-term cooperative action, now, up to and beyond 2012, in order to achieve the ultimate objective of the Convention,

Recalling the principles, provisions and commitments set forth in the Convention, in particular its Articles 3 and 4,

Recognizing that climate change represents an urgent and potentially irreversible threat to human societies and the planet, and thus requires to be urgently addressed by all Parties,

Affirming the legitimate needs of developing country Parties for the achievement of sustained economic growth and the eradication of poverty, so as to be able to deal with climate change,

Noting resolution 10/4 of the United Nations Human Rights Council on .human rights and climate change., which recognizes that the adverse effects of climate change have a range of direct and indirect implications for the effective enjoyment of human rights and that the effects of climate change will be felt most acutely by those segments of the population that are already vulnerable owing to geography, gender, age, indigenous or minority status and disability.

I. A shared vision for long-term cooperative action

1. *Affirms* that climate change is one of the greatest challenges of our time and that all Parties share a vision for long-term cooperative action in order to achieve the objective of the Convention under its Article 2, including through achievement of a global goal, on the basis of equity and in accordance with common but differentiated responsibilities and respective capabilities; this vision is to guide the policies and actions of all Parties, while taking into full consideration the different circumstances of Parties in accordance with the principles and provisions of the Convention; the vision addresses mitigation, adaptation, finance, technology development and transfer, and capacity-building in a balanced, integrated and comprehensive manner to enhance and achieve the full, effective and sustained implementation of the Convention, now, up to and beyond 2012;

2. *Further affirms* that:

(a) Scaled-up overall mitigation efforts that allow for the achievement of desired stabilization levels are necessary, with developed country Parties showing leadership by undertaking ambitious emission reductions and in providing technology, capacity-building and financial resources to developing country Parties, in accordance with the relevant provisions of the Convention;

(b) Adaptation must be addressed with the same priority as mitigation and requires appropriate institutional arrangements to enhance adaptation action and support;

(c) All Parties should cooperate, consistent with the principles of the Convention, through effective mechanisms, enhanced means and appropriate enabling environments, and enhance technology development and the transfer of technologies to developing country Parties to enable action on mitigation and adaptation;

(d) Mobilization and provision of scaled up, new, additional, adequate and predictable financial resources is necessary to address the adaptation and mitigation needs of developing countries;

(e) Capacity-building is essential to enable developing country Parties to participate fully in, and to implement effectively, their commitments under the Convention; and that the goal is to enhance the capacity of developing country Parties in all areas;

3. *Recognizes* that warming of the climate system is unequivocal and that most of the observed increase in global average temperatures since the mid twentieth century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations, as assessed by the Intergovernmental Panel on Climate Change in its Fourth Assessment Report;

4. *Further recognizes* that deep cuts in global greenhouse gas emissions are required according to science, and as documented in the Fourth Assessment Report of the Inter-governmental Panel on Climate Change, with a view to reducing global greenhouse gas emissions so as to hold the increase in global average temperature below 2°C above pre-industrial levels, and that Parties should take urgent action to meet this long-term goal, consistent with science and on the basis of equity; *Also* recognizes the need to consider, in the context of the first review, as referred to in paragraph 138 below, strengthening the long-term global goal on the basis of the best available scientific knowledge, including in relation to a global average temperature rise of 1.5°C;

5. *Agrees*, in the context of the long-term goal and the ultimate objective of the Convention and the Bali Action Plan, to work towards identifying a global goal for substantially reducing global emissions by 2050, and to consider it at its seventeenth session;

6. *Also agrees* that Parties should cooperate in achieving the peaking of global and national greenhouse gas emissions as soon as possible, recognizing that the time frame for peaking will be longer in developing countries, and bearing in mind that social and economic development and poverty eradication are the first and overriding priorities of developing countries and that a low-carbon development strategy is indispensable to sustainable development. In this context, *further agrees* to work towards identifying a timeframe for global peaking of greenhouse gas emissions based on the best available scientific knowledge and equitable access to sustainable development, and to consider it at its seventeenth session;

7. *Recognizes* the need to engage a broad range of stakeholders at global, regional, national and local levels, be they government, including subnational and local government, private business or civil society, including youth and persons with disability, and that gender equality and the effective participation of women and indigenous peoples are important for effective action on all aspects of climate change;

8. *Emphasizes* that Parties should, in all climate change-related actions, fully respect human rights;

9. *Confirms* that Parties, especially developing country Parties that would have to bear a disproportionate or abnormal burden under the long-term cooperative action under the Convention, should be given full consideration;

10. *Realizes* that addressing climate change requires a paradigm shift towards building a low-carbon society that offers substantial opportunities and ensures continued high growth and sustainable development, based on innovative technologies and more sustainable production and

consumption and lifestyles, while ensuring a just transition of the workforce that creates decent work and quality jobs;

II. Enhanced action on adaptation

11. *Agrees* that adaptation is a challenge faced by all Parties, and that enhanced action and international cooperation on adaptation is urgently required to enable and support the implementation of adaptation actions aimed at reducing vulnerability and building resilience in developing country Parties, taking into account the urgent and immediate needs of those developing countries that are particularly vulnerable;

12. *Affirms* that enhanced action on adaptation should be undertaken in accordance with the Convention; follow a country-driven, gender-sensitive, participatory and fully transparent approach, taking into consideration vulnerable groups, communities and ecosystems; and be based on and guided by the best available science and, as appropriate, traditional and indigenous knowledge; with a view to integrating adaptation into relevant social, economic and environmental policies and actions, where appropriate;

13. *Decides* to hereby establish the Cancun Adaptation Framework encompassing the provisions laid out below, with the objective of enhancing action on adaptation, including through international cooperation and coherent consideration of matters relating to adaptation under the Convention;

14. *Invites* all Parties to enhance action on adaptation under the Cancun Adaptation Framework, taking into account their common but differentiated responsibilities and respective capabilities, and specific national and regional development priorities, objectives and circumstances, by undertaking, inter alia, the following:

(a) Planning, prioritizing and implementing adaptation actions, including projects and programmes[5] and actions identified in national and subnational adaptation plans and strategies, national adaptation programmes of action of the least developed countries, national communications, technology needs assessments and other relevant national planning documents;

(b) Impact, vulnerability and adaptation assessments, including assessments of financial needs as well as economic, social and environmental evaluation of adaptation options;

(c) Strengthening institutional capacities and enabling environments for adaptation, including for climate-resilient development and vulnerability reduction;

(d) Building resilience of socio-economic and ecological systems, including through economic diversification and sustainable management of natural resources;

(e) Enhancing climate change related disaster risk reduction strategies, taking into consideration the Hyogo Framework for Action2[6] where appropriate; early warning systems; risk assessment and management; and sharing and transfer mechanisms such as insurance, at local, national, subregional and regional levels, as appropriate;

(f) Measures to enhance understanding, coordination and cooperation with regard to climate change induced displacement, migration and planned relocation, where appropriate, at national, regional and international levels;

(g) Research, development, demonstration, diffusion, deployment and transfer of technologies, practices and processes; and capacity-building for adaptation, with a view to promoting access to technologies, in particular in developing country Parties;

[5] Including in the areas of water resources; health; agriculture and food security; infrastructure; socio-economic activities; terrestrial, freshwater and marine ecosystems; and coastal zones.
[6] <http:/www.unisdr.org/eng/hfa/hfa.htm>

(h) Strengthening data, information and knowledge systems, education and public awareness;

(i) Improving climate-related research and systematic observation for climate data collection, archiving, analysis and modelling in order to provide decision makers at national and regional levels with improved climate-related data and information;

15. *Decides* to hereby establish a process to enable least developed country Parties to formulate and implement national adaptation plans, building upon their experience in preparing and implementing national adaptation programmes of action, as a means of identifying medium and long-term adaptation needs and developing and implementing strategies and programmes to address those needs;

16. *Invites* other developing country Parties to employ the modalities formulated to support the above-mentioned national adaptation plans, in the elaboration of their planning effort referred to in paragraph 14 (a) above;

17. *Requests* the Subsidiary Body for Implementation to elaborate modalities and guidelines for the provisions of paragraphs 15 and 16 above, for adoption by the Conference of the Parties at its seventeenth session;

18. *Requests* developed country Parties to provide developing country Parties, taking into account the needs of those that are particularly vulnerable, with long-term, scaled-up, predictable, new and additional finance, technology, and capacity-building, consistent with relevant provisions, to implement urgent, short-, medium- and long-term adaptation actions, plans, programmes and projects at local, national, subregional and regional levels, in and across different economic and social sectors and ecosystems, as well as to undertake the activities referred to in paragraphs 14.16, above and paragraphs 30, 32 and 33 below;

19. *Acknowledges* the need to strengthen, enhance and better utilize existing institutional arrangements and expertise under the Convention;

20. *Decides* to hereby establish an Adaptation Committee to promote the implementation of enhanced action on adaptation in a coherent manner under the Convention, inter alia, through the following functions:

(a) Providing technical support and guidance to the Parties, respecting the country-driven approach, with a view to facilitating the implementation of adaptation activities, including those listed in paragraphs 14 and 15 of this decision, where appropriate;

(b) Strengthening, consolidating and enhancing the sharing of relevant information, knowledge, experience and good practices, at local, national, regional and international levels, taking into account, as appropriate, traditional knowledge and practices;

(c) Promoting synergy and strengthening engagement with national, regional and international organizations, centres and networks, to enhance the implementation of adaptation actions, in particular in developing country Parties;

(d) Providing information and recommendations, drawing on adaptation good practices, for consideration by the Conference of the Parties when providing guidance on means to incentivize the implementation of adaptation actions, including finance, technology and capacity-building and other ways to enable climate-resilient development and reduce vulnerability, including to the operating entities of the financial mechanism of the Convention, as appropriate;

(e) Considering information communicated by Parties on their monitoring and review of adaptation actions, support provided and received, possible needs and gaps and other relevant information, including information communicated under the Convention, with a view to recommending what further actions may be required, as appropriate;

21. *Invites* Parties to submit to the secretariat, by 21 February 2011, views on the composition of, and modalities and procedures for, the Adaptation Committee, including on proposed linkages with other relevant institutional arrangements;

22. *Requests* the secretariat to compile these submissions into a miscellaneous document to be made available by the fourteenth session of the Ad Hoc Working Group on Long-term Cooperative Action under the Convention, and to prepare a synthesis report based on those submissions by the fourteenth session of the Ad Hoc Working Group on Long-term Cooperative Action under the Convention;

23. *Requests* the Ad Hoc Working Group on Long-term Cooperative Action under the Convention, taking into account the above-mentioned submissions and synthesis report, to elaborate the composition of, and modalities and procedures for, the Adaptation Committee, for adoption by the Conference of the Parties at its seventeenth session;

24. *Requests* the Ad Hoc Working Group on Long-term Cooperative Action under the Convention, in elaborating the above-mentioned modalities and procedures, to define, as appropriate, linkages with other relevant institutional arrangements under and outside the Convention, including at national and regional levels;

25. *Recognizes* the need to strengthen international cooperation and expertise to understand and reduce loss and damage associated with the adverse effects of climate change, including impacts related to extreme weather events and slow onset events[7];

26. *Decides* to hereby establish a work programme in order to consider, including through workshops and expert meetings, as appropriate, approaches to address loss and damage associated with climate change impacts in developing countries that are particularly vulnerable to the adverse effects of climate change;

27. *Requests* the Subsidiary Body for Implementation to agree on activities to be undertaken under the above-mentioned work programme;

28. *Invites* Parties and relevant organizations to submit to the secretariat, by 21 February 2011, views and information on what elements should be included in the work programme, including the following:

(a) Possible development of a climate risk insurance facility to address impacts associated with severe weather events;

(b) Options for risk management and reduction; risk sharing and transfer mechanisms such as insurance, including options for micro-insurance; and resilience building, including through economic diversification;

(c) Approaches for addressing rehabilitation measures associated with slow onset events;

(d) Engagement of stakeholders with relevant specialized expertise;

29. *Requests* the secretariat to compile these submissions into a miscellaneous document and to prepare a synthesis report based on those submissions to be made available for consideration by the Subsidiary Body for Implementation at its thirty-fourth session, and with a view to making recommendations on loss and damage to the Conference of the Parties for its consideration at its eighteenth session;

30. *Invites* Parties to strengthen and, where necessary, establish regional centres and networks, in particular in developing countries, with support from developed country Parties and relevant organizations, as appropriate; and to facilitate and enhance national and regional adaptation actions, in a manner that is country-driven, encourages cooperation and coordination between regional stakeholders and improves the flow of information between the Convention process and national and regional activities;

31. *Notes* that an international centre to enhance adaptation research and coordination could also be established in a developing country;

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[7] Including sea level rise, increasing temperatures, ocean acidification, glacial retreat and related impacts, salinization, land and forest degradation, loss of biodiversity and desertification.

32. *Invites* all Parties to strengthen and, where necessary, establish and/or designate national-level institutional arrangements, with a view to enhancing work on the full range of adaptation actions from planning to implementation;

33. *Decides* that all Parties should use existing channels to provide information, as appropriate, on support provided and received for adaptation actions in developing countries; and on activities undertaken, including, inter alia, progress made, experiences, lessons learned, and challenges and gaps in the delivery of support with a view to ensuring transparency and accountability, and encouraging best practices;

34. *Invites* relevant multilateral, international, regional and national organizations, the public and private sectors, civil society and other relevant stakeholders to undertake and support enhanced action on adaptation at all levels, including under the Cancun Adaptation Framework, as appropriate, in a coherent and integrated manner, building on synergies among activities and processes, and to make available information on the progress made;

35. *Requests* the secretariat to support the implementation of the Cancun Adaptation Framework, including related institutional arrangements under the Convention, in accordance with its mandate and subject to the availability of resources;

III. Enhanced action on mitigation

A. Nationally appropriate mitigation commitments or actions by developed country Parties[8]

Emphasizing the need for deep cuts in global greenhouse gas emissions and early and urgent undertakings to accelerate and enhance the implementation of the Convention by all Parties, on the basis of equity and in accordance with their common but differentiated responsibilities and respective capabilities,

Acknowledging that the largest share of historical global emissions of greenhouse gases originated in developed countries and that, owing to this historical responsibility, developed country Parties must take the lead in combating climate change and the adverse effects thereof,

36. *Takes note* of quantified economy-wide emission reduction targets to be implemented by Parties included in Annex I to the Convention as communicated by them and contained in document FCCC/SB/2010/INF.X[9] (to be issued);

37. *Urges* developed country Parties to increase the ambition of their economy-wide emission reduction targets, with a view to reducing their aggregate anthropogenic emissions of carbon dioxide and other greenhouse gases not controlled by the Montreal Protocol to a level consistent with that recommended by the Fourth Assessment Report of the Intergovernmental Panel on Climate Change;

38. *Requests* the secretariat to organize workshops to clarify the assumptions and the conditions related to the attainment of these targets, including the use of carbon credits from the market-based mechanisms and land use, land-use change and forestry activities, and options and ways to increase their level of ambition;

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[8] Notes from the Chair: In the context of negotiations on item 1 (b) (i) of the Bali Action Pln, Parties have used different terms such as ´all developed countrz Parties´, ´all Annex I Parties´, ´those Annex I Parties that are not Parties of the Kyoto Protocol´, ´all developed country Parties and other Parties that voluntarily wish to take quantified emission reduction or limitation commitments´. Depending on the results of the negotiations, the terms usdin in this context may need to be made consistent.

[9] Parties' communications to the secretariat that are included in the INF document are considered communications under the Convention.

39. *Requests* the secretariat to prepare a technical paper based on Parties. submissions with the aim of facilitating understanding of the assumptions and conditions related to the attainment of their emission reduction targets and comparison of the level of emission reduction efforts;

40. *Decides*, building on existing reporting and review guidelines, processes and experiences, to enhance reporting in the national communications of Parties included in Annex I to the Convention on mitigation targets and on the provision of financial, technological and capacity-building support to developing country Parties as follows:

(a) Developed countries should submit annual greenhouse gas inventories and inventory reports and biennial reports on their progress in achieving emission reductions, including information on mitigation actions to achieve their quantified economy-wide emissions targets and emission reductions achieved, projected emissions and on the provision of financial, technology and capacity-building support to developing country Parties;

(b) Developed countries shall submit supplementary information on the achievement of quantified economy-wide emission reductions;

(c) Developed countries shall improve the reporting of information on the provision of financial, technology and capacity-building support to developing country Parties;

41. *Decides* to enhance the guidelines for the reporting of information in national communications by Parties included in Annex I to the Convention, including the development of common reporting formats, methodologies for finance, and in order to ensure that information provided is complete, comparable, transparent and accurate;

42. *Decides* to enhance guidelines for the review of information in national communications with respect to the following:

(a) Progress made in achieving emission reductions;

(b) Provision of financial, technology and capacity-building support to developing country Parties;

43. *Decides* that developed countries should establish national arrangements for the estimation of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol;

44. *Decides* to establish a process for international assessment of emissions and removals related to quantified economy-wide emissions reductions targets in the Subsidiary Body for Implementation, taking into account national circumstances, in a rigorous, robust and transparent manner, with a view to promoting comparability and building confidence;

45. *Decides* that developed countries should develop low-carbon development strategies or plans;

46. *Decides* on the following work programme for the development of modalities and guidelines described above, building on existing reporting and review guidelines, processes and experiences:

(a) The revision of guidelines, as necessary, on the reporting of national communications, including the biennial report:

(i) The provision of financing, through enhanced common reporting formats, methodologies for finance and tracking of climate-related support;

Parties' communications to the secretariat that are included in the information document are considered communications under the Convention.

(ii) Supplementary information on achievement of quantified economy-wide emission reductions targets;

(iii) Information on national inventory arrangements;

(b) The revision of guidelines for the review of national communications, including the biennial report, annual greenhouse gas inventories and national inventory systems;

(c) The establishment of guidelines for national inventory arrangements;

(d) Modalities and procedures for international assessment and review of emissions and removals related to quantified economy-wide emission reductions targets in accordance with paragraph 44, including the role of land use, land-use change and forestry, and carbon credits from market-based mechanisms, taking into account international experience;

47. *Invites* Parties to submit views on the items in paragraph 46, including with respect to the initial scheduling of the processes described in this section, by 28 March 2011;

B. Nationally appropriate mitigation actions by developing country Parties

Recognizing that developing country Parties are already contributing and will continue to contribute to a global mitigation effort in accordance with the principles and provisions of the Convention, and could enhance their mitigation actions, depending on the provision of finance, technology and capacity-building support provided by developed country Parties,

Reaffirming that social and economic development and poverty eradication are the first and overriding priorities of developing country Parties, and that the share of global emissions originating in developing countries will grow to meet their social and development needs,

48. *Agrees* that developing country Parties will take nationally appropriate mitigation actions in the context of sustainable development, supported and enabled by technology, financing and capacity-building, aimed at achieving a deviation in emissions relative to .business as usual. emissions in 2020;

49. *Takes* note of nationally appropriate mitigation actions to be implemented by non-Annex I Parties as communicated by them and contained in document FCCC/AWGLCA/ /2010/INF.Y[10] (to be issued);

50. *Invites* developing countries that wish to voluntarily inform the Conference of the Parties of their intention to implement nationally appropriate mitigation actions in association with this decision to submit information on those actions to the secretariat;

51. *Requests* the secretariat to organize workshops, to understand the diversity of mitigation actions submitted, underlying assumptions, and any support needed for implementation of these actions, noting different national circumstances and respective capabilities of developing country Parties;

52. *Decides* that, in accordance with Article 4, paragraph 3, of the Convention, developed country Parties shall provide enhanced financial, technological and capacity-building support for the preparation and implementation of nationally appropriate mitigation actions of developing country Parties and for enhanced reporting by these Parties;

53. *Also decides* to set up a registry to record nationally appropriate mitigation actions seeking international support and to facilitate matching of finance, technology and capacity-building support to these actions;

54. *Invites* developing country Parties to submit to the secretariat information on nationally appropriate mitigation actions for which they are seeking support, along with estimated costs and emission reductions, and the anticipated time frame for implementation;

[10] Parties' communications to the secretariat that are included in the INF document are considered communications under the Convention.

55. *Also invites* developed country Parties to submit to the secretariat information on support available and provided for nationally appropriate mitigation action;

56. *Requests* the secretariat to record and regularly update in the registry the information provided by Parties on:

(a) Nationally appropriate mitigation actions seeking international support;

(b) Support available from developed country Parties for these actions;

(c) Support provided for nationally appropriate mitigation actions;

57. *Agrees* to develop modalities for the facilitation of support through the registry referred to in paragraph 53 above, including any functional relationship with the financial mechanism;

58. *Decides* to recognize nationally appropriate mitigation actions of developing countries in a separate section of the registry;

59. *Requests* the secretariat to record, and regularly update, information submitted by Parties, in a separate section of the registry:

(a) Mitigation actions contained in document FCCC/AWGLCA/2010/INF.Y referred to in paragraph 49 above;

(b) Additional mitigation actions submitted in association with paragraph 50 above;

(c) Once support has been provided, internationally supported mitigation actions and associated support;

60. *Decides* to enhance reporting in national communications, including inventories, from Parties not included in Annex I to the Convention (non-Annex I Parties) on mitigation actions and their effects, and support received; with additional flexibility to be given to the least developed country Parties and small island developing states:

(a) The content and frequency of national communications from non-Annex I Parties will not be more onerous than that for Parties included in Annex I to the Convention;

(b) Non-Annex I Parties should submit their national communications to the Conference of the Parties, in accordance with Article 12, paragraph 1, of the Convention every four years or in accordance with any further decisions on frequency by the Conference of the Parties taking into account a differentiated timetable and the prompt provision of financial resources to cover the agreed full costs incurred by non-Annex I Parties in preparing their national communications;

(c) Developing countries, consistent with their capabilities and the level of support provided for reporting, should also submit biennial update reports, containing updates of national greenhouse gas inventories including a national inventory report and information on mitigation actions, needs and support received;

61. *Also decides* that internationally supported mitigation actions will be measured, reported and verified domestically and will be subject to international measurement, reporting and verification in accordance with guidelines to be developed under the Convention;

62. *Further decides* that domestically supported mitigation actions will be measured, reported and verified domestically in accordance with general guidelines to be developed under the Convention;

63. *Decides* to conduct a process for international consultations and analysis of biennial reports in the Subsidiary Body on Implementation, in a manner that is non-intrusive, non-punitive and respectful of national sovereignty; he international consultations and analysis aim to increase transparency of mitigation actions and their effects, through analysis by technical experts in consultation with the Party concerned, and through a facilitative sharing of views, and will result in a summary report;

64. *Also decides* that information considered should include information on mitigation actions, the national greenhouse gas inventory report, including a description, analysis of the impacts and associated methodologies and assumptions, progress in implementation and information on domestic measurement, reporting and verification and support received; discussion about the appropriateness of such domestic policies and measures are not part of the process. Discussions should be intended to provide transparency on information related to unsupported actions;

65. *Encourages* developing countries to develop low-carbon development strategies or plans in the context of sustainable development;

66. *Agrees* on a work programme for the development of modalities and guidelines for: facilitation of support to nationally appropriate mitigation actions through a registry; measurement, reporting and verification of supported actions and corresponding support; biennial reports as part of national communications from non-Annex I Parties; domestic verification of mitigation actions undertaken with domestic resources; and international consultations and analysis;

67. *Invites* Parties to submit views on the items in paragraph 66, including with respect to the initial scheduling of the processes described in this section, by 28 March 2011.

C. Policy approaches and positive incentives on issues relating to reducing emissions from deforestation and forest degradation in developing countries; and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries

Affirming that, in the context of the provision of adequate and predictable support to developing country Parties, Parties should collectively aim to slow, halt and reverse forest cover and carbon loss, according to national circumstances, consistent with the ultimate objective of the Convention, as stated in Article 2,

Also affirming the need to promote broad country participation in all phases described in paragraph 73 below, including through the provision of support that takes into account existing capacities,

68. *Encourages* all Parties to find effective ways to reduce the human pressure on forests that results in greenhouse gas emissions, including actions to address drivers of deforestation;

69. *Affirms* that the implementation of the activities referred to in paragraph 70 below should be carried out in accordance with annex I to this decision, and that the safeguards referred to in paragraph 2 of annex I to this decision should be promoted and supported;

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 forest;

(e) Enhancement of forest carbon stocks;

71. *Requests* developing country Parties aiming to undertake 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 level[11] or, if appropriate, as an interim measure, subnational forest reference emission levels and/or forest reference levels, in accordance with national circumstances, and with provisions contained in decision 4/CP.15, and with any further elaboration of those provisions adopted by the Conference of the Parties;

(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[12], 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;

(d) A system for providing information on how the safeguards referred to in annex I to this decision are being addressed and respected throughout the implementation of the activities referred to in paragraph 70, while respecting sovereignty;

72. *Also requests* developing country Parties, when developing and implementing their national strategies or action plans, to address, inter alia, drivers of deforestation and forest degradation, land tenure issues, forest governance issues, gender considerations and the safeguards identified in paragraph 2 of annex I to this decision, ensuring the full and effective participation of relevant stakeholders, inter alia, indigenous peoples and local communities;

73. *Decides* that the activities undertaken by Parties referred to in paragraph 70 above should be implemented in phases beginning with the development of national strategies or action plans, policies and measures, and capacity-building, followed by the implementation of national policies and measures and national strategies or action plans that could involve further capacity-building, technology development and transfer and results-based demonstration activities, and evolving into results-based actions that should be fully measured, reported and verified;

74. *Recognizes* that the implementation of the activities referred to in paragraph 70 above, including the choice of a starting phase as referred to in paragraph 73 above, depends on the specific national circumstances, capacities and capabilities of each developing country Party and the level of support received;

75. *Requests* the Subsidiary Body for Scientific and Technological Advice to develop a work programme on the matters referred to in annex II to this decision;

76. *Urges* Parties, in particular developed country Parties, to support, through multilateral and bilateral channels, the development of national strategies or action plans, policies and measures and capacity-building, followed by the implementation of national policies and measures, and national strategies or action plans, that could involve further capacity building, technology development and transfer and results-based demonstration activities including consideration of the safeguards referred to in paragraph 2 of annex I to this decision, taking into account the relevant provisions on finance including those relating to reporting on support;

77. *Requests* the Ad Hoc Working Group on Long-term Cooperative Action under the Convention to explore financing options for the full implementation of the results-based actions[13] referred to in paragraph 73 above, and to report on progress made, including

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[11] In accordance with national circumstances, national forest reference emission levels and/or forest reference levels could be a combination of subnational forest reference emissions levels and/or forest reference levels..

[12] Including monitoring and reporting of emissions displacement at the national level, if appropriate, and reporting on how displacement of emissions is being addressed, and on the means to integrate subnational monitoring systems into a national monitoring system.

[13] These actions require national monitoring systems.

any recommendations for draft decisions on this matter, to the Conference of the Parties at its seventeenth session;

78. *Also requests* Parties to ensure coordination of the activities referred to in paragraph 70 above, including of the related support, particularly at the national level;

79. *Invites* relevant international organizations and stakeholders to contribute to the activities referred to in paragraphs 70 and 78 above.

...

Annex I

Guidance and safeguards for policy approaches and positive incentives on issues relating to reducing emissions from deforestation and forest degradation in developing countries; and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries

1. Activities referred to in paragraph 70 of this decision should:

(a) Contribute to the achievement of the objective set out in Article 2 of the Convention;

(b) Contribute to the fulfilment of the commitments set out in Article 4, paragraph 3, of the Convention;

(c) Be country-driven and be considered options available to Parties;

(d) Be consistent with the objective of environmental integrity and take into account the multiple functions of forests and other ecosystems;

(e) Be undertaken in accordance with national development priorities, objectives and circumstances and capabilities and should respect sovereignty;

(f) Be consistent with Parties. national sustainable development needs and goals;

(g) Be implemented in the context of sustainable development and reducing poverty, while responding to climate change;

(h) Be consistent with the adaptation needs of the country;

(i) Be supported by adequate and predictable financial and technology support, including support for capacity-building;

(j) Be results-based;

(k) Promote sustainable management of forests;

2. When undertaking activities referred to in paragraph 70 of this decision, the following safeguards should be promoted and supported:

(a) Actions complement or are consistent with the objectives of national forest programmes and relevant international conventions and agreements;

(b) Transparent and effective national forest governance structures, taking into account national legislation and sovereignty;

(c) Respect for the knowledge and rights of indigenous peoples and members of local communities, by taking into account relevant international obligations, national circumstances and laws, and noting that the United Nations General Assembly has adopted the United Nations Declaration on the Rights of Indigenous Peoples;

(d) The full and effective participation of relevant stakeholders, in particular, indigenous peoples and local communities, in actions referred to in paragraphs 70 and 72 of this decision;

(e) Actions are consistent with the conservation of natural forests and biological diversity, ensuring that actions referred to in paragraph 70 of this decision are not used for the conversion of natural forests, but are instead used to incentivize the protection and conservation of natural forests and their ecosystem services, and to enhance other social and environmental benefits[14];

(f) Actions to address the risks of reversals;

(g) Actions to reduce displacement of emissions.

Annex II

Subsidiary Body for Scientific and Technological Advice work programme on policy approaches and positive incentives on issues relating to reducing emissions from deforestation and forest degradation in developing countries; and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries

In the development of its work programme, the SBSTA is requested to:

(a) Identify land use, land-use change and forestry activities in developing countries, in particular those that are linked to the drivers of deforestation and forest degradation, to identify the associated methodological issues to estimate emissions and removals resulting from these activities, and to assess their potential contribution to the mitigation of climate change, and report on the findings to the Conference of the Parties at its eighteenth session on the outcomes of the work referred to in this paragraph;

(b) Develop modalities relating to paragraphs 71 (b) and (c), and guidance relating to paragraph 71 (d) of this decision, for consideration by the Conference of the Parties at its seventeenth session;

(c) Develop as necessary, modalities for measuring, reporting and verifying anthropogenic forest-related emissions by sources and removals by sinks, forest carbon stocks, forest carbon stock and forest area changes resulting from the implementation of activities referred to in paragraph 70 of this decision, consistent with any guidance for measuring, reporting and verification of nationally appropriate mitigation actions by developing country Parties agreed by the Conference of the Parties, taking into account methodological guidance in accordance with decision 4/CP.15, for consideration by the Conference of the Parties at its seventeenth session;

…

[14] Taking into account the need for sustainable livelihoods of indigenous peoples and local communities and their interdependence on forests in most countries, reflected in the United Nations Declaration on the Rights of Indigenous Peoples, as well as the International Mother Earth Day.

Appendix 5:

Photograph of the Workshop Participants

Photograph taken in front of the Cancún Center, where Forest Day 4 took place.