An introduction to the impacts of climate change and vulnerability of forests

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Tropical Forests and Climate Change Adaptation ("TroFCCA")
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The function and structure of forest ecosystems is partly determined by the surrounding climatic conditions. Rainfall patters and mean temperatures define the type of forest ecosystem present in an area. For this reason, changes in climate are likely to affect forests which also implies changes in the provision of important goods and services to society. This paper presents a short introduction to this topic.

1. Introduction

Climate change and climate variability are likely to cause disruptions in the climate system, such as modifications to the precipitation regimes and to the frequency and intensity of extreme events (typhoons and hurricanes). Whether these changes lead to positive or negative consequences will depend on the geographical, environmental, social and economic conditions of the affected area. For example, a rainfall increase could be beneficial in areas where water is scarce, but not in areas affected by floods.

Several factors determine the degree to which a system affected by climate change including:

- *The magnitude* of the change: impacts are usually greater if changes are greater
- *The probability* that a change occurs
- *The rate of change*: the faster a change, the greater the impact
- *The duration of the change:* the longer a change lasts, the greater the impacts will
- *The characteristics of the system*: its tolerance and capacity to adapt

A great deal of attention has been lately devoted to study the characteristics of the system, that is, those internal features by which it can overcome impacts. The climate change jargon refers to them as "**adaptive capacity**", which refers to the capacity of a system to generate internal adjustments in order to adapt to changes in climate. **Adaptations** are all adjustments in response to climate change; it can be **autonomous**, if the adjustments are generated automatically; or **planned**, if such adjustments have been generated through a conscious process. For example, plants react autonomously to an increase or decrease in temperature by decreasing or increasing transpiration, respectively. Planned adaptation is, in turn, a decision to change to drought resistant crops.

The degree in which a system is susceptible to, or incapable to overcome, the impacts of climate change is referred to as **vulnerability**. It is determined by the exposure to impacts, and the sensitivity of the system and its adaptive capacity (Metzger *et al*. 2006):

$$V = f(E, S, AC)$$

Where:
V is the vulnerability
E is the exposure
S is the sensitivity of the system
AC is the adaptive capacity, both autonomous and planned

This suggests that increasing the adaptive capacity of a system (e.g. through planned adaptation) decreases its vulnerability.

2. Climate change and its impacts

Our day to day life, including daily behaviors and economic activities, has evolved under relatively stable climatic conditions. Natural ecosystems have, likewise, evolved and become adapted to specific rainfall and temperature patterns that define their structure and function. For example, the structure and function of tropical rain forests have resulted from abundant rain and high

temperatures, while those of boreal forests have been determined by seasonality.

This means that changes in the climatic conditions are likely to produce changes in the structure and function of ecosystems. Those changes are also likely to result in negative impacts and costs as they may imply changes in ecosystem goods and services. Moreover, direct negative costs are also expected from the increase in extreme events, as already witnessed in several areas of the planet. The following bullets summarize sectorial impacts of climate change contained in the IPCC's third assessment report (IPCC 2001b):

- *Hydrology and water resources*: Expected changes in rainfall can severely affect the hydrology of the planet. Models forecast that runoff flows and groundwater recharge will be reduced in many regions, especially in areas already affected by droughts. This problem will be compounded by an increase in water demand caused by population growth. On the other hand, floods are likely to increase in regions already affected by heavy rainfall.
- *Agriculture*: Agricultural productivity responses will be linked to changes in rainfall regimes and temperature. It is expected that production yield will increase in temperate countries, while the opposite may occur in the tropics.
- *Ecosystems*: Changes in climate variables will cause modifications in the structure and functioning of most ecosystems. Scientists have particularly pointed to the migration of systems to the temperate regions as temperature and rain favours this process.
- *Human settlements*: Climate change will affect human settlements directly through the increase in frequency and intensity of natural disasters as well as sea level rise; and indirectly by affecting their economic sectors, or through impacts on health and population dynamics.
- *Health*: Effects on health are expected to result from the direct impacts of temperature increase, particularly related to heat waves, and from increasing temperatures that favour the transmission of viral and bacterial diseases.

In the specific case of forest ecosystems, changes in different climate variables result in adjustments at different levels. A detailed compilation of these is summarised in Table 1.

***Table 1**: An example of adjustments of forest ecosystems at different levels as the results of changes on climate variables.*

Climate factor	Cell level	Organism level	Species level	Ecosystem level
CO_2 increase	Photosynthetic rate increase	Growth rate increase	Decreased seed mortality	Biomass production increase
	Stomatal conductance reduction	Water use efficiency increase	Increased recruitment	Alteration in species competitiveness
		Seed production increase	Period for individuals to reach maturity	Changes in species composition
			Changes in individual density?	
Temperature increase	Photosynthesis increase or decrease	Primary production positive or negative changes	Regeneration rate changes	Alterations in species competitiveness
	Photosynthetic period can increase	Seed production changes	Possible increase in tree mortaility	Species' composition changes
	Transpiration increase		Negative consequences for species sensitive to temperature changes	Soil mineralization increase
Rainfall regime changes	Growth rate decrease	Seed mortality rate increase		Alteration in species competitiveness
			Increase of mature individuals' mortality rate	Species composition changes

Source: Meer, Kramek and Wjik, 2001.

Scholes and Linder (1998), provide an overview of major processes that will be affected by the above impacts. These include:

- Changes in the location of areas suitable for the growth of certain species (shift or disappearance of some productive systems);
- Increases or decreases in the production of timber and non-wood forest product (NWFP) production per unit area;
- Changes in the types and incidence of pests and diseases affecting tree and plant species;
- Altered ecosystem functions (biochemical cycles);
- Increased or decreased nutrient retention;
- Changes in species' reproductive cycles;
- Changes in the value of a system as a tourist attraction.

3. Vulnerability: foregone goods and services from forests

As stated above, vulnerability is the degree to which a system is likely to be affected by climate change. TroFCCA's approach to vulnerability links the impacts of climate change to the goods and services from forests. That is, vulnerability is assessed from the perspective of a society that depends (or is benefiting from) those goods and services, on the basis of the degree to which the provision of goods and services will be affected by climate change.

Society benefits from the presence of forests in many different ways. Directly, several communities depend on the exploitation of fuelwood, timber, and other products like resins and honey. Indirectly by the provision of services like the protection of biodiversity, the regulation of the water and carbon cycles (under specific circumstances) and the protection of soil (also under specific geomorphological circumstances). A typology of such goods and services from forests is presented in Box 1.

Forests are not used in the same way, as this depends on societal needs and cultural values. For example, while in Costa Rica tourism plays an important role in how people value forests, in Borneo the value relates more to their role as providers of timber and food (e.g. meat). The impacts described in section 2 are likely to affect the quantity or quality of the goods and services from which society benefits. Decreased forest goods and services imply negative impacts on society that are, for the most part, direct. On the other hand, social variables such as population dynamics may be indirectly affected by decreases in forest goods and services. For example, if a community lives off the exploitation of resins and honey, alternatives for revenue and employment generation could be affected by the decreased quantity or quality of these resources as a consequence of climate change.

Box 1. Uses of forest ecosystems

- *Direct use:* Forest goods and services for direct consumption. For example, timber and NWFPs, recreation and scientific research.
- *Indirect use:* Environmental services. For example, water cycle regulation, biodiversity protection and carbon sinks.
- *Passive use:* The importance of conserving forest ecosystems so that future generations can benefit from them.
- *Use options:* All those uses not yet exploited or discovered that may acquire value in the future.

Source: Secretariat of the Convention on Biological Diversity (2001).

TroFCCA will start by identifying the importance of forests from a national and local perspective in terms of their goods and services. The next step will be to analyse the specific features of national forests from which goods and services derive, looking to understand the ecological processes that determine the provision of goods and services. The next step would be to understand the relationship between the ecological processes and the climate variables. In other words, what ecological processes are determined and affected by changes in temperature, rain and the presence of extreme events. Figure 1 illustrates this approach.

4. Adaptation

The likely negative impacts of climate change identified in section 3 highlight the need for planned action. Autonomous adaptation should be triggered by the presence of a stress, but this is no a guarantee that the internal adjustments will help the system overcome the impacts or that they will lessen the effects of climate change on society. Furthermore, in some cases, non-planned adjustments at the individual level could worsen the costs in the longer term, usually referred to as **maladaptation**. An example would be when a farmer deforests marginal land to increase yield, leading to further land degradation and less yield in the long run.

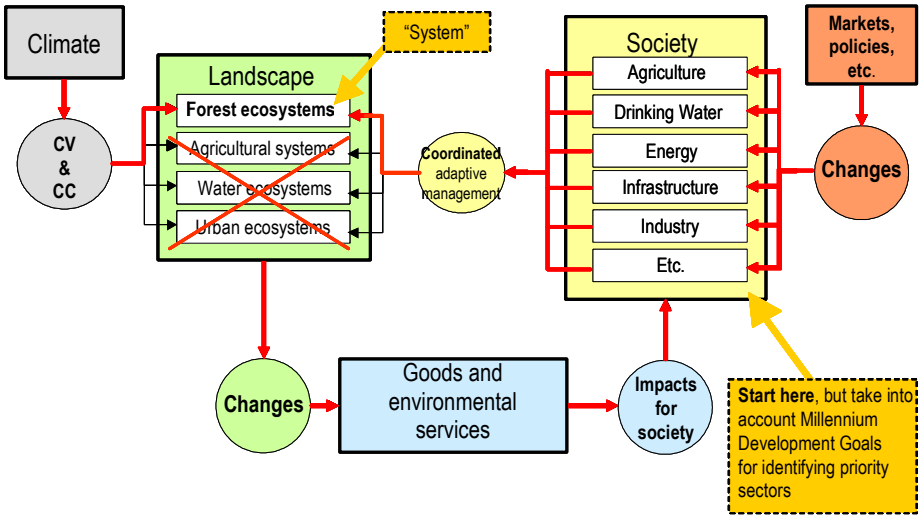

***Figure 1**: General approach of TroFCCA.*

Policies and institutions play a fundamental role within adaptation strategies by establishing national goals and providing society with the necessary elements to take action. Such elements include, primarily, capacity building and financial support. From an institutional point of view, adaptation could either be addressed as a separate topic (i.e. the creation of institutions for adaptation) or by its mainstreaming into the existing institutionality. Latest developments in adaptation policy have highlighted the benefits of the second option, given the crosscutting nature of vulnerability to climate change. They have also noted that the national development policy should be the starting point for this exercise.

Adaptation is here understood as planned adaptation and includes all strategies and actions that are intended to help society to overcome the future negative impacts and costs of climate change. Such actions and strategies should seek to decrease the vulnerability of the society. The IPCC presents a set of objectives for adaptation actions which include (IPCC, 2001c):

- *Accepting the costs*, or, in other words, not to take action. Such decision entirely depends on factors as the expected magnitude of the impact, the adaptation capacity of the system and the potential implementation costs for any action (e.g. whether the costs of adaptation would be higher than their benefit);
- *Sharing and/or compensating for losses*, which refers to the distribution of the costs caused by climate change impacts or to compensate for them. Such options include the transfer of payments to compensate affected people. Resources may come either from public funds of through taxing people that are not affected;
- *Preventing the impacts or modifying the circumstances*, which refers to all measures that aim at avoiding or diminishing specific negative consequences of climate-induced hazards. An example of such actions includes the reforestation of an area to serve as a buffer for hurricanes;
- *Searching for alternatives*, which implies a total or partial change in a specific activity or system that is already, or is likely to be, affected by climate change. An example includes a change to the use of drought resistant crops;
- *Changing location*, required where the consequences of climate change are extreme and that the affected system be moved from one place to another. Such strategy is used for systems located in high risk areas;
- *Research*, which helps in the understanding the causes of climate change, in analysing the impacts of climate change on national and local systems, and in planning appropriate and cost-effective measures to increase the adaptation capacity;
- *Education, awareness creation and dissemination*, intended to disseminate information and create awareness about the importance of adaptation. Education further builds the capacity of local people and enables them to undertake adaptation actions.

Adaptive forest management is a concept that links adaptation and forest management. It was developed in the 1980s as a management approach to deal with cases where present and future changes to natural resources are uncertain

(Walters, 1986). It can be defined as a management approach that acknowledges the lack of unequivocal and definitive knowledge about the ways in which forest ecosystems work, and the uncertainty that dominates interactions with them (Borrini-Feyerabend, 2000).

Robledo and Forner (2005) illustrate the application of adaptive forest management to climate change impacts. In spite of the unpredictability with regards to climate change, forest managers must make decisions and implement plans that are based on assumptions for longer time spans than in other forms of natural resource management, such as agriculture or fishery. Such decisions include which tree species to use for a plantation or silviculture intervention. According to Sit and Taylor (1998), the key characteristics of adaptive management include:

- Acknowledgement of uncertainty about what policy or practice is "best" for the particular management issue;
- Thoughtful selection of the policies or practices to be applied;
- Careful implementation of a plan of action designed to reveal critical knowledge;
- Monitoring of key response indicators;
- Analysis of the outcome in terms of the original objectives;
- Incorporation of the results into future decisions.

Policies and adaptation actions, including the role of adaptive forest management, will be addressed by TroFCCA through national and regional workshops. The staff of the project, together with governments and national experts, will discuss suitable adaptation action on the basis of the studies on vulnerability.

5. References

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