Adapting tropical production forests to global climate change: risk perceptions and actions

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SUMMARY

As sustainable forest management is threatened by climate change, adaptation measures may be needed to maintain the productive capacity of tropical forests. Yet the extent to which foresters across the tropics implement adaptation actions in anticipation to climate change impacts remains largely unexplored. In this paper, an assessment of the perceptions of climate risks and the implementation of adaptation actions by forest managers and decision makers dealing with natural and planted tropical forests destined for production purposes is presented. An electronic questionnaire was disseminated globally during 2009, and 152 responses were received from Africa, the Americas, and Asia and the Pacific. Respondents perceived that natural and planted forests are at risk from being affected by climate change. However, they seemed ambivalent when asked if investing in adaptation was currently justified. The results of this survey provide initial insights into how climate considerations are being anticipated in tropical forest management and planning yet further examination at the national and local levels is warranted on how foresters, including those from the tropics, perceive climate change risks and handle current uncertainties in order to take action. The fact that climate change ranked below other threats to forests such as commercial agriculture and unplanned logging nevertheless suggests that long-term forest planning and management is not perceived by respondents as viable given other major drivers of forest loss and degradation.

Keywords: risk perception, adaptive capacity, tropical forests, mitigation, adaptation

Adaptation des forêts tropicales de production au changement climatique mondial: perceptions des risques et actions

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La gestion durable des forêts étant menacée par le changement climatique, des mesures d'adaptation peuvent être nécessaires pour queles forêts tropicales conservent leurs capacités de production. Pourtant, la mesure dans laquelle les forestiers des régions tropicales mettent en œuvre des actions d'adaptation pour anticiper les conséquences du changement climatique n'est pratiquement pas étudiée. Cet article présente une analyse des perceptions relatives aux risques climatiques ainsi que de la mise en œuvre des actions d'adaptation par les gérants des forêts et les décideurs intervenant sur les forêts tropicales naturelles et plantées destinées à la production. En 2009, un questionnaire électronique diffusé dans le monde a permis de recevoir 152 réponses provenant d'Afrique, des Amériques et d'Asie-Pacifique. Les répondants ont estimé que les forêts naturelles et plantées étaient en danger du fait du changement climatique. Toutefois, ils ont été ambivalents lorsqu'on leur a demandé sil'investissement dans des mesures d'adaptation était justifié à l'heure actuelle. Les résultats de cette enquête fournissent un premier aperçu de la manière dont les considérations climatiques sont prises en compte dans la gestion et la planification relatives aux forêts tropicales, mais il est nécessaire d'examiner plus avant, aux niveaux local et national,la manière dont les forestiers, notamment dans les régions tropicales, perçoivent les risques posés par le changement climatique et gèrent les incertitudes actuelles pour pouvoir entreprendre des actions. Le fait que le changement climatique soit considéré comme moins important que d'autres menaces pour les forêts, telles que l'agriculture commerciale et l'exploitation non planifiée, suggère néanmoins que la planification et la gestion à long terme des forêts ne sont pas considérées comme viables par les répondants, compte tenu des autres grands facteurs de perte et de dégradation des forêts existants.

Percepciones de riesgo y la adaptación al cambio climático en bosques tropicales de producción

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A medida que el manejo forestal se ve afectado por el cambio climático, puede ser necesaria la adaptación de medidas para mantener la capacidad productiva de los bosques. Aún así, no se sabe a ciencia cierta hasta que punto los forestales a lo largo de la región tropical implementan acciones de adaptación que buscan anticiparse a los efectos del cambio climático. En este artículo se presenta una evaluación de las percepciones de los riesgos climáticos y de la implementación de acciones de adaptación por parte de administradores forestales y personas implicadas en la toma de decisiones referentes a los bosques tropicales naturales y plantaciones forestales con fines de producción. Se distribuyó un cuestionario electrónico a nivel mundial durante el año 2009 y se recibieron 152 respuestas provenientes de África, Norte, Centro y Suramérica, y Asia y el Pacífico. Los encuestados revelaron que los bosques naturales y las plantaciones forestales se encuentran en riesgo de ser afectados por el cambio climático. Sin embargo, parece haber una posición ambivalente respecto a la pregunta sobre si la inversión en la adaptación se justifica en la actualidad. Los resultados de esta encuesta proveen de elementos para comprender de forma preliminar la manera en que los aspectos climáticos son considerados con en el manejo del bosque tropical. Sin embargo se justifica un análisis adicional a nivel nacional y local sobre la forma en que los forestales, incluidos los de la región tropical, perciben los riesgos del cambio climático y abordan la incertidumbre con miras a la toma de acción. El hecho de que el cambio climático se ubicó por debajo de otras amenazas al bosque, tales como la agricultura comercial y la tala carente de planeación, sugiere que el planeamiento y el manejo forestal a largo plazo no se percibe como viable por parte de los encuestados dada la presencia de otros impulsores de pérdida y degradación del bosque.

INTRODUCTION

The ability to achieve sustainable forest management objectives is usually threatened by risks and uncertainties resulting from social, economic and institutional factors (Nasi and Frost 2009, Sayer and Elliot 2005). Tropical forests are experiencing both the direct and indirect impacts of global climatic change (Lewis *et al.* 2004, 2009, Malhi and Wright 2004), thus adding additional uncertainty on how the flow of forest products may be influenced (Kirilenko and Sedjo 2007, Locatelli *et al.* 2008). At the same time, tropical forests are critical in mitigating the impacts of global climate change because of their significant role in carbon sequestration (Canadell and Raupach 2008). Thus, the productive role of tropical forests and the global ecosystem service of climate change mitigation may be compromised if their adaptive capacity is not maintained or strengthened both at the forest-stand level and at landscape scales (Guariguata *et al.* 2008, Killeen and Solórzano 2008, Malhi *et al.* 2008, Millar *et al.* 2007). The synergies between mitigation and adaptation become particularly relevant for incentive-based conservation of global carbon stocks via reduced deforestation and forest degradation (REDD+, Angelsen 2009) to effectively contribute to the long-term maintenance of tropical forest cover (Locatelli *et al.* 2011).

However, the extent to which specific actions are being taken to maintain the adaptive capacity of tropical forests remains limited, particularly in production forests (Guariguata *et al.* 2008, Reyer *et al.* 2009). The area of natural tropical forest under management plans in ITTO (International Tropical Timber Organization) countries is currently estimated at 183 million hectares, about 24% of the estimated area of the natural tropical permanent forest state (Blaser *et al*. 2011). This includes vast portions of the Amazon (Schulze *et al.* 2008) and Congo basins (Laporte *et al.* 2007). Moreover, the importance of tree plantations as providers of timber is expected to increase over time (Easterling *et al.* 2007, FAO 2010). Yet lack of attention to climate change considerations in tropical forestry seems widespread. One possible reason is the high level of scientific uncertainty associated with climate projections and their expected impacts on forest ecosystems at both regional and local scales; particularly across the tropics (Fischlin *et al.* 2009). In addition, actions on climate change adaptation depend on cognitive factors, socio-economic characteristics and individual position in decision-making or policy processes (McDaniels *et al.* 1995, Stedman 2004). Perceptions of climate change risk at the local level are particularly influenced by personal values, beliefs and experiences (Adger *et al.* 2007, Blennow and Sallnäs 2002, Lorenzoni and Pidgeon 2006, Lorenzoni *et al.* 2007). In other words, decision making related to climate change adaptation may not only depend on the amount and scope of scientific knowledge available, but also on individual attitudes to risk, policy and institutional barriers (Patt and Schröter 2008).

Adaptation to climate change aims at reducing vulnerability, i.e. the "degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes" (IPCC 2001). Vulnerability is a function of exposure, sensitivity, and adaptive capacity of the system in question. Assessing the perceptions of decision makers about forest vulnerability, and also how the risks associated with climate change are managed by those involved in forest management, can provide important lessons for the design and implementation of adaptive responses and policies. While surveys to assess these perceptions have been carried out for temperate and boreal forests (e.g. Blennow and Persson 2009, Lindner *et al.* 2008, Williamson *et al.* 2005), little seems to have been reported from across the tropics.

This paper presents an assessment of the perceptions of climate risk by tropical forest managers and decision makers dealing with natural (selectively logged on a polycyclic basis) and planted forests (logged on a monocyclic basis) destined for timber production purposes. The extent to which specific actions to enhance the adaptive capacity of tropical production forests to climate change are being incorporated is described, and some issues constraining individuals to take action are identified. Specifically, the paper responds to the following research questions: is climate change perceived as a threat for production forests and integrated into forest management in the tropics? What impacts of climate change have been observed or are expected? What adaptation practices are known and implemented? What are the obstacles to forest adaptation and the role of institutions in facilitating adaptation? Do perceptions and knowledge influence the implementation of adaptation practices by forest managers?

MATERIALS AND METHODS

In April 2009, an electronic survey was launched in English, Spanish and French, and disseminated through three electronic lists of global outreach: members of the International Society of Tropical Foresters and those subscribed to "Forest-L" (hosted by the International Institute of Sustainable Development) and "CLIM-Fo" (hosted by the Forestry Department of the Food and Agricultural Organization of the United Nations, FAO). Electronic lists of national forestry associations were identified on the internet or through personal or professional contacts. Individual messages were further circulated to national focal points from tropical countries who attended the 2007 and 2008 annual sessions of the FAO Regional Forestry Commissions and to national correspondents of tropical countries of the 2010 FAO Forest Resources Assessment (information available on the FAO website). A reminder was sent three months after the initial launch. The survey was closed in mid-September 2009, after no responses were received over three consecutive weeks.

The survey consisted of five sections and included open-ended questions, categorical answers, and statements for ranking on a 1 to 7 scale (from 1 "strongly disagree" to 7 "strongly agree"). Some statements were adapted from Williamson *et al.* (2005). In the first section, "Perceptions on climate change risks and impacts on forests", respondents were first asked to rate their agreement with nine statements about climate change, its impacts, the capacity of production forests to cope with climate change, the scientific certainty of impacts, and the need for adaptation actions (Table 1). Then, they were asked to rank six current threats to the productivity capacity of production forests, including climate change (Table 2). Respondents were further asked to name the changes they had observed, if any, and whether these changes were due to climate change or perceived normal climate variability. Finally, they were asked to name the changes they expected.

In the second section, "Information availability and knowledge on adaptation practices", respondents were asked whether they were aware of any published studies in their countries that suggest that climate change is harming production forests and the forest sector. They were further asked to rate their agreement with statements related to the availability of information about climate change impacts and management practices to help production forests adapt to climate change (Table 3). Respondents were also asked whether they knew about adaptation practices for natural and planted production forests and, with an open-ended question, they were further asked to name up to three of these practices.

In the third section, "Implemented adaptation practices", respondents involved in the management of production forests were asked whether they had implemented specific adaptation practices from a proposed list of eight practices for natural forests and five for planted forests, and to rank the responses on a 1 to 7 scale (1 "not implemented", 7 "frequently implemented"). The proposed practices are broadly considered critical for enhancing or maintaining the adaptive capacity of forests in the face of climate change and were adapted from Guariguata *et al.* (2008), Ogden and Innes (2007) and Spittlehouse (2005). Respondents were also asked whether these practices were implemented in business-as-usual management, without a climate change adaptation perspective, or in anticipation of expected climate change impacts.

In the fourth section, "Obstacles to adaptation", respondents were asked to rate their agreement with six statements related to obstacles to the implementation of adaptation practices (Table 4). They were further asked whether the adaptation practices they had proposed in the third section conflicted with current management and whether activities outside or adjacent to the forest being managed diminished the effectiveness of implemented adaptation practices. In the fifth section, "Institutional factors", respondents were asked whether institutional or policy strategies in their countries of work facilitated the implementation of adaptation practices in production forests and whether national guidelines were available for forest adaptation. They were also asked to rate six statements on the role of institutions and policies in the countries for facilitating the implementation of forest adaptation (Table 5; statements adapted from Guariguata *et al.* 2008). The final section of the survey gathered information on respondents' professional profiles, years of experience in tropical forestry, and countries in which they had the most experience. Provision of personal information (name, email address and institutional affiliation) was optional and anonymity was guaranteed.

The level of agreement on the proposed statements was analysed by linearly transforming the responses from 1 to 7 into a –1 to 1 scale for facilitating interpretation (where –1 means "strong disagreement", 0 "no agreement or disagreement", and +1 "strong agreement"). Statistical t-tests were applied to assess whether the mean agreement level was significantly different from 0 ($P<0.05$) and Kruskall-Wallis tests ($P<0.05$) applied for testing differences among groups of respondents. The groups were defined by the experience of the respondents, their professional role (policy maker, researcher, or forest manager) and their involvement in the management of natural or planted production forests (either "yes" or "no").

For analysing the extent of implementation of forest adaptation practices (third section), the number of respondents was counted, for each proposed practice, in the following four categories: (1) low degree of adoption (implementation <4; 1 means "not implemented" and 7 means "frequently implemented") and no plans to adopt; (2) low degree of adoption and plans to adopt; (3) high degree of adoption (implementation >4) as part of business as usual; and (4) high degree of adoption specifically for adaptation to climate change.

For respondents involved directly or indirectly in the management of production forests, the influence of perception and knowledge factors on the implementation of adaptation practices was analysed separately for natural and planted forests. For identifying the perception and knowledge factors that are most likely to influence the implementation of a given adaptation practice, hierarchical partitioning (HP) was applied (Chevan and Sutherland 1991). Because of multicollinearity among factors, working with a single regression may fail to identify the explanatory power of the factors (MacNally 2000). With HP, all 2^k multiple-regression models are analysed (k being the number of factors) and the explanatory power of a given factor calculated as the mean improvement of the goodness of fit (e.g. R^2) caused by adding this variable to the models. The statistical significance of the explanatory power was assessed with a randomization approach with 1000 permutations of the data (MacNally 2002). Only significant factors ($P<0.05$) are reported.

RESULTS

A total of 170 responses was gathered during the five-month period over which the questionnaire was available online. Eighteen of these were eliminated as they were incomplete. Taking into account that the survey was sent directly to at least 2000 individual addresses, the response rate is estimated at about 8%. However, this response rate is at best only indicative as many people were contacted through snowballing and via international mailing lists whose compositions were unknown. Consequently and unfortunately, there is no information on the entire sample population. Like in any convenience sampling, no reliable statement can be made about whether the sample is representative of the whole population (i.e. the population of stakeholders with internet connection and enough interest in and time for answering the survey). Thus, the results presented in this study should be considered as exploratory (Couper 2000).

The final sample of 152 respondents was distributed according the countries of work as follows: tropical Africa, 26% (24 countries); tropical Americas, 40% (22 countries); tropical Asia and the Pacific, 29% (15 countries); and multiple continents (5%). The following countries counted more than one respondent (in alphabetical order for each region). Africa: Cameroon, Congo, Democratic Republic of Congo, Ghana, Ethiopia, Nigeria and Togo; the Americas: Bolivia, Brazil, Colombia, Costa Rica, Ecuador, Peru and Venezuela; and Asia and the Pacific: Australia, Bangladesh, India, Indonesia, Philippines and Thailand. Sixty-one per cent of respondents described themselves as researchers (n=93), while 20% and 19% identified themselves as forest managers (n=30) and policy makers (n=29), respectively. More than half of the respondents were involved in the management of production forests: 24 in the management of natural forests (16%), 14 of planted forests (9%), and 45 of both types (30%). In contrast, 69 respondents (45%) were not involved in forest management. The median number of years of work experience in forestry was 10 (range 1–40).

Perceptions of climate change risk and impacts on forests

Overall, respondents agreed with the statements related to the anthropogenic nature of climate change and the risks it induces on human and forest systems (statements 1–4 in Table 1). Respondents with more than 10 years experience expressed stronger agreement with the statement that climate change is a serious threat to the productive capacity of forests (statement 4, Table 1) than respondents with less experience. However, there was no clear agreement or disagreement on whether scientific certainty is currently sufficient to justify investment in adaptation actions (statement 5, Table 1). This could reflect contrasting views about scientific certainty about climate change and its impacts, or contrasting views about the need to invest in adaptation.

TABLE 1 *Perceptions on climate and its impacts on production forests (sorted from strongest agreement to strongest disagreement).*

No.	Statement	Average value and significance[1]	Differences among groups of respondents[2]
1	Current climate change is driven by human activities	+0.64*	
2	Within 20 years, climate change will diminish the productive capacity of tropical forests.	+0.4*	
3	Climate change presents a serious threat to my personal life	+0.35*	
4	Climate change is a serious threat to forest productive capacity	+0.32*	People with less than 10 years experience < People with more
5	Scientific certainty is sufficient to justify investment in adaptation in production forests	+0.07	
6	There is still plenty of time to implement adaptation in production forests	–0.22*	
7	Planted production forests have capacity to cope with climate change	–0.28*	
8	Natural production forests have capacity to cope with climate change	–0.29*	Researchers < Forest managers < Policy makers
9	Impacts of climate change on forests and their productive capacity are well understood	–0.36*	

[1] Range from -1=strongly disagree to +1=strongly agree; * significantly different from 0 ($P<0.05$).
[2] Kruskall-Wallis test ($P<0.05$); empty cells mean no significant differences among groups.

On average, respondents disagreed with the statement that there is still plenty of time to implement adaptation, acknowledging the urgency to act (statement 6). This shows that the responses to statement 5 reflect contrasting views about scientific certainty on climate change impacts, rather than contrasting views about the need to invest in adaptation—this is confirmed by the fact that, on average, respondents perceived that the impacts of climate change on forests and their productive capacity are not well understood (statement 9). Respondents also perceived that neither natural nor planted production forests currently have the capacity to cope with climate change (statements 7 and 8). Researchers disagreed the most with the statement on natural production forests having the capacity to cope.

Respondents perceived that commercial agriculture, unsustainable logging, and subsistence agriculture were currently the most important threats to the productive capacity of the forests in their countries (Table 2). Climate change appeared as the fourth most important threat.

About 60% of the respondents had observed changes in the forests they work in which they attributed to climate change, while 23% had observed changes that they attributed to natural climate variability (the remaining 17% had not observed any changes). About 89% of the respondents expected forest changes attributable to climate change. For both open-ended questions on observed and expected changes, respondents provided diverse responses in terms of climatic exposure (e.g. changes in precipitation regimes, increase in temperature) or climatic impacts on forests (Figure 1). Regarding climatic exposure, changes were mainly related to precipitation regimes and destructive extreme events such as heavy rains, floods and windstorms. Respondents expected more changes in the future than they had already witnessed. Sea-level rise and consequent increased salinity of soils and water were mentioned less than the other exposure factors, as they are relevant only in coastal areas.

TABLE 2 *Ranks given to selected threats to the productive capacity of forests*

Threat	Mean rank[1]	Differences among groups of respondents[2]
Commercial agriculture	2.95	Higher for forest managers
Unsustainable logging	3.18	
Subsistence agriculture	3.61	
Climate change	3.82	
Infrastructure, urbanization	4.20	Higher for forest managers
Mining, oil or gas	4.59	

[1] 1 = most relevant threat; 7 = least relevant.
[2] Kruskall-Wallis test ($P<0.05$); empty cells mean no significant differences among groups.

The most observed or expected types of impact on forests were changes in biodiversity (change in presence and abundance of plant and animal species, loss of habitat diversity, disruption of species interactions; Figure 1). The second most observed or expected types of impact were related to forest growth, productivity, and regeneration of trees and non-timber forest products, with associated changes in biomass and carbon or even forest dieback. Changes in phenology were the third most often observed impact types. Indirect impacts to policies and people were also mentioned and represented the fifth most often expected impacts. Respondents mentioned that climate-change related policies (e.g., incentives to produce biofuels at the expense of forest cover) can affect forests. They also considered that people whose livelihoods are affected by climate change—for example, if their agriculture is less productive in the future—could encroach on forests and cause deforestation.

Information availability and knowledge on adaptation practices

Forty-nine per cent of the respondents said that they were aware of studies in their countries that suggest that climate change is harming production forests and the forest sector currently and will do so in the future. No statistically significant differences were observed among groups of respondents. Overall, respondents perceived that available information was insufficient for them to understand the impacts of climate change on either natural or planted production forests (statements 1 and 2, Table 3). Similarly, respondents disagreed with the statement that management practices are available to help both natural and planted production forests adapt to climate change (i.e. they considered that such management practices were not available; statements 3 and 4). In particular, the level of disagreement was higher regarding practices for natural production forests than for planted production forests.

Overall, about 47% of the respondents were aware of adaptation practices for natural production forests. Irrespective of their professional groups, respondents involved in the management of natural forests were more aware of practices (62%) than those not involved in forest management. For planted production forests, about 49% of the respondents said they were aware of adaptation practices; no significant differences were observed among groups.

Respondents named up to 162 specific practices thought to increase the adaptive capacity of natural production forests to cope with climate change impacts and 161 specific practices for planted production forests (Figure 2). For natural production forests, most practices were silvicultural and focused on the stand scale; for example, the management and protection of "seed trees" or the application of reduced-impact logging norms (Putz *et al.* 2008). For planted production forests, the most often cited practices related to selection of species for planting and origin of planting materials, germplasm management (on- and off-site), genetic improvement (including genetically modified organisms), and the maintenance or enhancement of genetic diversity.

FIGURE 1 *Factors of climatic exposure and impacts on forests, as observed or expected by the respondents*

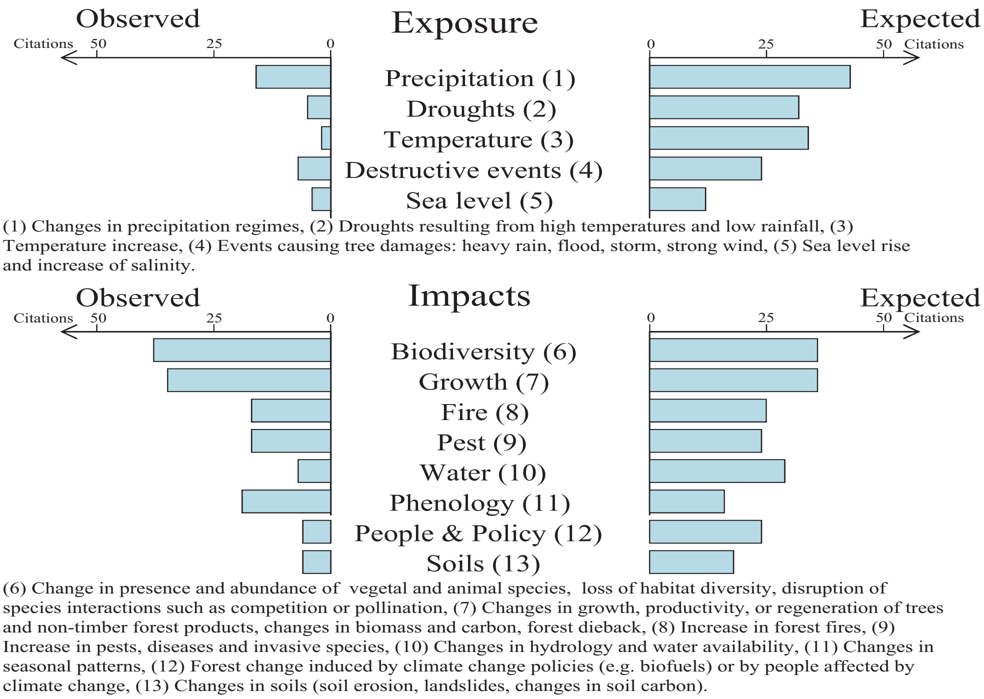


TABLE 3 *Perceptions on information availability and knowledge on adaptation practices for enhancing the adaptive capacity of production forests to climate change*

No.	Statement	Average value and significance[1]
1	There is sufficient information available for understanding the impacts of climate change on natural production forests	–0.32*
2	There is sufficient information available for understanding the impacts of climate change on planted production forests	–0.33*
3	Specific management practices are available to help natural production forests adapt to climate change	–0.33*
4	Specific management practices are available to help planted production forests adapt to climate change	–0.12*

[1] Range from –1=strongly disagree to +1=strongly agree; * significantly different from 0 ($P<0.05$). Differences among groups of respondents were not significant for all statements.

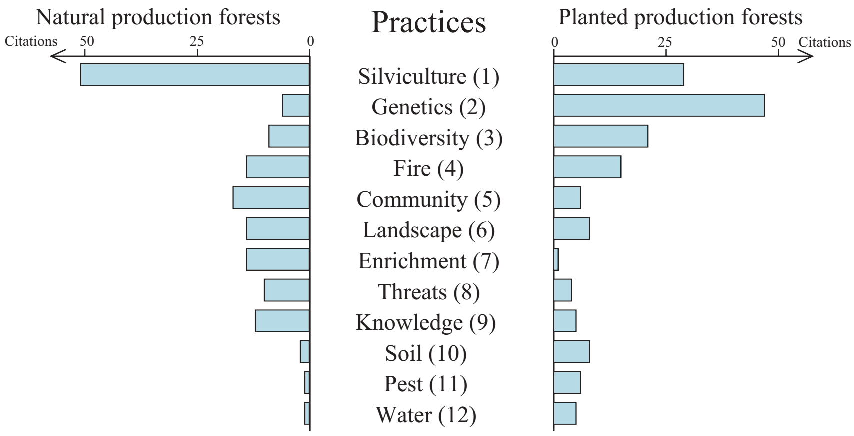
Implemented adaptation practices

Among the 69 respondents involved in the management of natural forests, 59 had adopted at least one practice for adapting forests to climate change. Among the 59 respondents involved in the management of planted forests, 36 had adopted at least one adaptation practice. Although most respondents considered that these practices facilitate the adaptation of production forests to the impacts of climate change, they recognized that very often, these practices were already being implemented as part of routine management (column 3 in Figures 3 and 4).

For natural production forests, the most adopted practice mentioned was maximizing regeneration by enrichment planting and by applying minimum-diameter cutting limits (Figure 3). However, this practice is largely business as usual. Minimizing harvesting impacts through the application of reduced-impact logging was the second most adopted practice and the most adopted specifically for adaptation purposes. Pest management had the lowest level of adoption. The second least adopted practice was the maximization of genetic diversity of planted seedlings in enrichment of natural forests, but this practice was often planned for the future.

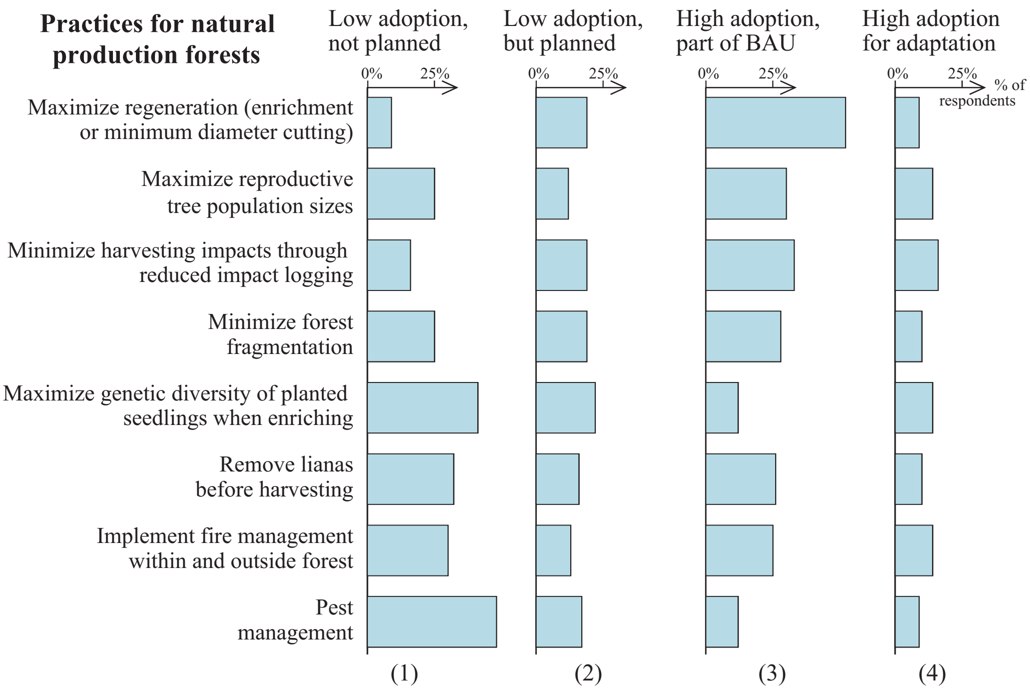
For planted forests, the most adopted adaptation practice was widening buffer strips and fire breaks, either as business as usual or specifically in anticipation of climate impacts (Figure 4). The use of seed sources adapted to expected future conditions was the second most adopted practice. Planting a range of genotypes during each rotation (and letting nature take its course) was the practice with the lowest level of adoption and, when it is adopted, it is never specifically for adaptation but rather part of business as usual.

FIGURE 2 *Practices cited by respondents for increasing the capacity of production forests to adapt to climate change*



(1) Specific silvicultural techniques at the plot scale: spacing trees in plantation, thinning, managing seed trees, harvesting, reduced impact logging, changing rotation length...), (2) Selection of species, germplasm, and origin of planting materials, genetic improvement (including GMO), increase of genetic diversity, off site germplasm conservation, (3) Biodiversity (e.g, native shrubs in understory, enriching with native species, planting diversified and local species, improving nursery techniques for important species), (4) Fire prevention, controlled burning, (5) Participatory approaches, community management, (6) Avoiding fragmentation, creating corridors and buffer areas, conserving forests with high biodiversity in the landscape, (7) Enrichment planting and assisted natural regeneration, (8) Reducing socioeconomic threats by increasing forest protection, developing protected areas, controlling deforestation, or strengthening agriculture in forest surroundings, or improving tenure & governance, (9) Awareness raising, education, training, monitoring, research, (10) Soil conservation and fertilization, (11) Pest control, (12) Water conservation and management (irrigation, drainage).

FIGURE 3 *Adaptation practices for natural production forests: percentage of respondents reporting (1) a low implementation level and no plans to implement, (2) a low implementation level but with plans to implement, (3) a high implementation level as part of business as usual (BAU), (4) a high implementation level specifically for adaptation*



Obstacles to adaptation

Respondents agreed with all the statements related to the obstacles to the implementation of adaptation practices in production forests (Table 4). They perceived that the major obstacle to the implementation of adaptation practices was the lack of financial capacity (statement 1). The second and third obstacles related to the lack of, and access to, information (statements 2 and 3). Forest managers seemed to put more emphasis on lack of access to information as an obstacle, and less on lack of information itself, than other respondent groups.

About 63% of the respondents thought that the application of forest adaptation practices does not conflict with current

FIGURE 4 *Adaptation practices for planted production forests: percentage of respondents reporting (1) a low implementation level and no plans to implement, (2) a low implementation level but with plans to implement, (3) a high implementation level as part of business as usual (BAU)), (4) a high implementation level specifically for adaptation*

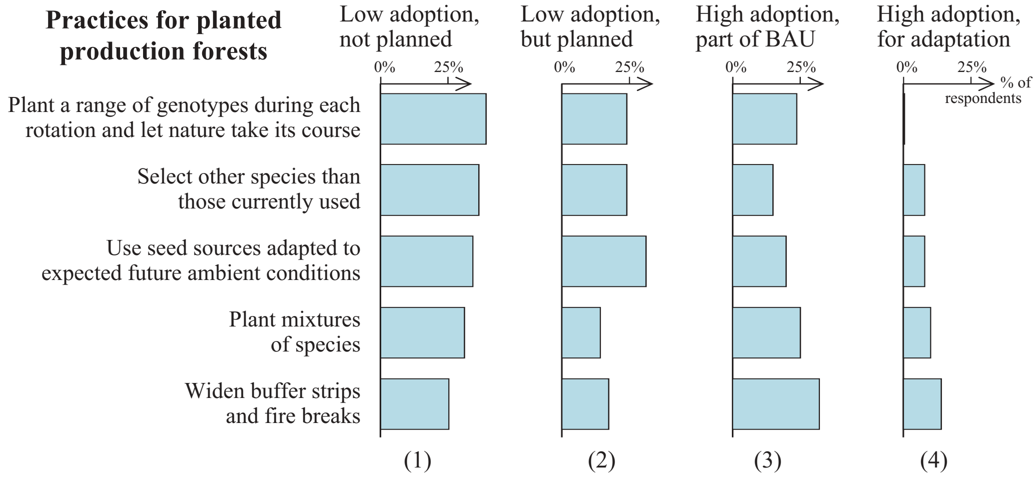


TABLE 4 *Obstacles to the implementation of adaptation practices for production forests*

No.	Statement	Average value and significance[1]	Differences among groups of respondents[2]
1	Lack of financial capacity is an obstacle	0.60*	
2	Lack of information is an obstacle	0.56*	Lower for forest managers
3	Lack of access to information is an obstacle	0.42*	Higher for forest managers
4	Complexity of information is an obstacle	0.41*	
5	Lack of human capacity is an obstacle	0.36*	
6	Uncertainty about climate change impacts is an obstacle	0.36*	

[1] Range from –1=strongly disagree to +1=strongly agree; * significantly different from 0 (P<0.05).
[2] Empty cells mean no significant differences among groups.

management practice. Respondents with more than 10 years of work experience had a significantly higher level of agreement with this statement (80%) than the rest. About 37% of the respondents thought that threats to the forest resulting from activities outside or adjacent to it diminish the effectiveness of any adaptation practice being implemented, while 13% thought the contrary (50% did not know). Policy makers were the most concerned by this issue (52% of positive responses). The most reported threats were fires set outside the forests (24 responses) and deforestation caused by external drivers (urbanization, encroachment, agriculture expansion, mining; 19 responses).

Institutional factors

About 30% of the respondents thought that institutional or policy strategies exist in their countries of work for promoting activities to enhance the capacity of the production forests to adapt to climate change; 36% thought that such strategies do not exist, and 34% did not know. Only 13% of respondents thought that published national guidance was available for guiding the development of adaptation for natural production forests (and 14% for planted production forests), 53% thought that national guidance was not available (48% for planted production forests); the others did not know. Forest managers seemed more aware of the existence of national guidance than other groups, yet the percentage was still low for this group (only 20%).

There was neither agreement nor disagreement with the statements about the way current institutions and policies facilitate the implementation of forest adaptation by defining practical approaches, increasing awareness, promoting good practices for fire management, mainstreaming forest adaptation into national development strategies, and establishing appropriate financial mechanisms (Table 5). Yet respondents disagreed with the statement that institutions and policies promote seed exchange and participatory genetic improvement programmes for smallholders involved in tree planting (statement 6, Table 5).

What drives action?

The implementation of adaptation practices by respondents involved directly or indirectly in the management of production

TABLE 5 *Institutions and policies facilitating the implementation of adaptation practices for production forests*

No.	Statement	Average value and significance[1]	Differences among groups of respondents[2]
1	Institutions and policies define practical approaches for enhancing the adaptive capacity of forests	0.06	
2	Institutions and policies increase awareness about enhancing the adaptive capacity of forests	0.06	
3	Institutions and policies promote good practices for fire management within, and adjacent to, production forests	0.05	
4	Institutions and policies mainstream forest adaptation into national development strategies	0.02	
5	Institutions and policies establish appropriate financial mechanisms for the implementation of practices for forest adaptation	0.00	Higher for project managers
6	Institutions and policies promote seed exchange and participatory genetic improvement programmes for smallholders involved in tree planting	–0.20*	

[1] Range from –1=strongly disagree to +1=strongly agree; * significantly different from 0 ($P<0.05$). [2] Kruskall-Wallis test ($P<0.05$); empty cells mean no significant differences among groups.

forests depended on respondents' perceptions of climate change impacts. For natural forests, implementation was higher if respondents perceived that climate change will diminish forest productive capacity within 20 years. For planted forests, extent of implementation increased if respondents perceived that planted forests have the capacity to cope with climate change. This result seems contradictory, but may be explained by the fact that investing in adaptation is perceived as a way to facilitate natural adaptation processes and would be useless if planted forests had no adaptive capacity.

The knowledge of the respondents and their perception on information availability influenced the implementation of adaptation: for both natural and planted production forests, implementation increased if respondents were aware of management practices for adapting forests to climate change or if they perceived that practices were available. Another influencing factor was the perception of conflict between adaptation and forest management: respondents who perceived that adaptation of forests does not conflict with conventional management practices were more likely to implement adaptation.

DISCUSSION

The purpose of this work was to assess the perceptions of forest managers, experts and policy makers about climate change risk to tropical production forests, the extent to which specific measures are already being taken to adapt, and the obstacles that appear to constrain action on adaptation. The results provide preliminary insights into how climate considerations are being anticipated in tropical forest management and planning. Overall, respondents perceived that natural and planted forests are at risk from climate change and that their adaptive capacity is, at present, insufficient. Overall, however, respondents seemed ambivalent when asked if investing in adaptation was currently justified. Scientific uncertainty may be playing a role here, even though a large number of the respondents were able to mention specific climate impacts, either projected or already apparent. These results are similar to those of Colombo (2006) and Williamson *et al.* (2005) from perception risk assessments by forestry experts across Canada, where production forests are facing massive, climate-driven mortality (Kurz *et al.* 2008) and where forest planning apparently fails to proactively incorporate climate adaptation considerations (Ogden and Innes 2008). Further examination at the national and local levels is warranted on how foresters, including those from the tropics, perceive climate change risks and handle current uncertainties in order to take action.

A reported lack of willingness of survey respondents to invest in forest adaptation may also reflect a disconnection between value judgments and existing scientific knowledge (Dessai *et al.* 2004). This further suggests that successful action to adapt to climate change will not only depend on the availability of scientific information, but also on the beliefs and socio-cultural contexts of individuals (Davidson *et al.* 2003, Lowe and Lorenzoni 2007). A study in Mozambique (Patt and Schröter 2008) found, for example, that farmers and policy makers disagreed about the relative seriousness of climate risks. The long-term experience of farmers made them perceive climate change as less of a risk compared to other non-climate events affecting their daily lives (see also Tucker *et al.* 2010). Policy makers, however, perceived climate risk as more pervasive and more likely to occur. Given the overall low level of national measures indicated by respondents (Table 5), little incentive to invest in adaptation may be justifiable even if climate risks are perceived high. As discussed by Lorenzoni and Pidgeon (2006), individuals are more likely to take action if they perceive government and institutional capabilities adequate to manage climate risks.

Overall, the findings from this pilot survey suggest some implications for the management of tropical forests in the context of a changing climate. First, a better understanding of perceptions of risk in the tropical forestry sector can help to improve policy development as much as the amount of scientific information that managers or decision makers may get on the topic. This is because it is becoming increasingly obvious that the success of a given adaptation policy will depend on gauging the perceptions of different segments of society of how climate change may place them at greater or lesser risk (Grothmann and Patt 2005, Leiserowitz 2006) instead of applying uniform prescriptions. Second, education and access to information on climate impacts and adaptation measures may have to be improved. Notably, broad disagreement was observed among respondents when asked if enough practical guidance was available for enhancing the adaptive capacity of tropical production forests to climate change. The view that sustainable forest management may not need substantial modification from existing good practice in order to reduce the vulnerability of the forest to climate change impacts (Guariguata *et al.* 2008, Innes *et al.* 2009, Noss 2001, Spittlehouse 2005) may need clearer articulation and effective dissemination. At the same time, curricular advancement may also be warranted in order to overcome the perceived pan-tropical scarcity of forestry professionals able to scientifically manage risk and uncertainties (Sayer and Elliot 2005, Temu *et al.* 2008). This may be particularly crucial in areas with reportedly high vulnerability of forestry systems to climate change and other disturbances such as wildfires and fragmentation (Füssel 2009, Scholze *et al.* 2006).

Another implication relates to the design of mitigation initiatives aimed at increasing forest cover and reducing deforestation and forest degradation in tropical countries (REDD+; Angelsen 2009). The REDD+ mechanism is, in essence, performance-based sustainable forest management (Seymour and Angelsen 2009). Unless adaptation considerations are integrated into these initiatives, climate change impacts may jeopardize the ability of the forest to sequester carbon. For example, Reyer *et al.* (2009) surveyed the approved methodologies for afforestation and reforestation under the Kyoto Protocol and found that there was neither any formulation referring to the impacts of climate change on the project's viability nor any direct measures related to climate change adaptation. Clearly, the success of any REDD+ initiative will depend not only on the application of sound forestry practice but also on the consideration of socio-economic and governance issues (Agrawal *et al.* 2008). To the extent that forest agencies and managers are aware that a minimum set of adaptation measures needed to maintain the mitigation potential of tropical forests is already embedded in the objectives of sustainable forest management, progress can be made.

However, the fact that climate change ranked below other threats to forests such as commercial agriculture and unplanned logging suggests that long-term forest planning and management is not perceived by respondents as viable (or else as a priority) given other major drivers of forest loss and degradation. This calls for further attention by researchers, managers and decision makers on explicitly linking the application of good forestry practice and the control of degradation or deforestation drivers both inside and outside the forest (Putz and Nasi 2009). To this end, the integration between mitigation and adaptation strategies will need firm insertion into national forest policy making (Locatelli *et al.* 2011, Millar *et al.* 2007).

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