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A Nicaraguan case study

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Development of a prioritization tool for climate change adaptation measures in the forestry sector

A Nicaraguan case study

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Content

Abstract

Developing countries are predicted to have to face most of the impacts from climate change. Adversely, their mitigation potential is comparably lower than that of developed countries. Consequently, adaptation to the adverse effects of climate change is of great importance to them.

Though, as developing countries frequently face limited financial resources for adaptation, the selection of respective measures and their ranking for implementation are critical processes to achieve the most from the invested means. There is a need for decision-makers, at the governmental and non-governmental level, to have tools for the selection and prioritization of adaptation measures that can address their financial resources and socio-economic conditions. Also, such an instrument has to be easy to apply and adaptable to local conditions.

Among sectors, forestry belongs to the most vulnerable; it offers great potential for mitigation as well for adaptation. Therefore, this study proposes a prioritization tool for adaptation measures in the forestry sector, taking into account its unique environmental, socio-economic and institutional aspects. Conceptually, the work is organized around three main steps: (i) the identification of potential adaptation measures, (ii) a catalog of criteria and indicators for the evaluation of those measures and (iii) a Multi-Criteria Analysis for the prioritization of the identified and evaluated measures. As a main method the Analytical Hierarchy Process (AHP) is used as the basis for the development of the prioritization tool.

The Bosawas Biosphere Reserve in Nicaragua is used as an empirical basis for this study. In the process, four different adaptation measures have been evaluated according to a list of criteria and indicators taking into account the conditions found in the study area. These were then prioritized using the AHP method. As a result, a ranking among the adaptation measures according to the adaptation needs of the biosphere reserve was obtained. “Conservation, reforestation and natural regeneration” resulted as the first choice among the adaptation measure for that case.

Keywords: methodology, prioritization tool, Multi-Criteria Analysis, climate change adaptation, forestry sector, Nicaragua.

Acknowledgements

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1. Introduction

The IPCC, in its Climate Change 2013 report, states that there is no doubt that climate change affects the global system and that natural and human systems are disturbed. It further states that the certainty about anthropogenic influence has increased. It is affirmed that "it is extremely likely (95-100% probability) that human influence has been the dominant cause of the observed warming since the mid-20th century" (IPCC, 2013, p. 12). As part of the natural system, forests are impacted by climate change as well.

Forests are important CO2 sinks. Tropical forests, for example, store about a quarter of all terrestrial carbon, but –on the other hand- deforestation is mentioned as the second cause of global greenhouse gas emissions, representing 18% of the global emissions with a rate of 130,000 km^2 per year of forest destruction (Mitchell, et al., 2009).

Some of the climate change impacts that have been identified for the sector are: extreme weather events, expansion of forest in the high-latitude areas, migration of species and dieback of forest species and types (Sedjo, 2009). In economic terms, Eliasch (2008) estimates that if no action is taken the cost of climate change caused by deforestation, on a global scale, could reach up to $1 trillion a year by the year 2100. On the other hand, the benefits of reducing deforestation could amount up to $3.7 trillion over the long term. Nevertheless, on the regional or national level, there is not much information regarding the costs of adaptation for the forestry sector.

Adaptation and mitigation are two complementary approaches to cope with climate change impacts (Davoudi, 2009). Though, as adaptation has been seen as "an unnecessary luxury rather than as an integral part of development policy" (Chambwera, 2010, p. 29), mitigation has been the one, for which a greater number of mechanisms and policies have been developed (Guariguata, et al., 2008). The 4th Assessment Report of the IPCC already affirmed that "adaptation will be necessary to address impacts resulting from climate change that is already unavoidable due to past emissions" (Mimura, et al., 2014, p. 873).

In recent years adaptation has gained more attention and has been enhanced with the Cancun Agreements, which affirm that "adaptation must be addressed with the same priority as mitigation and requires appropriate institutional arrangements to enhance adaptation action and support" (UNFCCC, 2011, p.3). This has been reinforced by the Paris Agreement, approved by the parties under the UNFCCC at the COP 21.

In relation to climate change and the forestry sector, the work has focused mainly on mitigation (e.g. REDD+ initiatives, CDM, etc.). The forest's adaptation potential to contribute in decreasing the vulnerability of rural areas in developing countries is high, however vastly underexploited.

Even though, at regional and local level, funding mechanisms and projects regarding climate change adaptation for the different sectors are currently being implemented, countries face different challenges during the planning process for climate change adaptation projects. Among the main challenges, a lack of tools which help prioritize among available adaptation measures, especially when financial resources are limited, is highlighted (IPCC, 2007b). Furthermore, the IPCC in its last report affirms that “knowledge of impacts and vulnerabilities does not necessarily lead to the most cost-effective and efficient adaptation policy decisions” (Mimura, et al., 2014, p. 872).

As a contribution to close the gap in knowledge, this piece of work develops a tool for the prioritization for climate change adaptation measures in the forestry sector. A biosphere reserve in Nicaragua is used as an empirical basis. Nicaragua serves the demands of an empirical example due to the following reasons: as the developing country with the largest forest resources in Central America, it also comprises a high vulnerability to the effects of climate change. With respect to habitat change, the climate-related changes put Nicaragua among the most vulnerable countries, ranking its vulnerabilities from acute to severe (DARA, 2012).

Due to the availability of information related to climate change scenarios and considering the suggestions of governmental representatives, the Bosawas Biosphere Reserve, located in the north of Nicaragua, was selected as a case study area. Bosawas is the largest non-intervened protected area in Central America (Buss, 2011), has 3.5% of the world’s biodiversity within its territories, active presence of indigenous communities, and represents an important provision of environmental services and products (MARENA-SETAB-GTZ, 2009). Results of recent studies, considering Holdridge life zones, show that up to 70% of the ecosystems on the reserve could suffer changes by year 2035 (Centro Alexander von Humboldt, 2013).

Considering this potential scenario, it is clear that the implementation of measures in order to adapt to the predicted changes is essential for the Nicaraguan forestry sector, especially in Bosawas. Taking into account the limited financial resources, the prioritization of the potential measures to be implemented becomes a core step in the planning process.

Therefore, this document presents an easy to apply tool for the prioritization of climate change adaptation measures which could be adapted to regions or countries with similar contexts as they are found in Nicaragua. The tool will enable decision making through a criteria and indicators catalog for prioritizing different forest management strategies, considering the multiple aspects of climate change adaptation.

This work has been developed by the Climate Service Center – Germany (GERICS) under the project “Economic instruments for adaptation” which aimed to support adaptation planning processes including social environmental multi-criteria tools, cost benefits analysis as well as participation processes to enable bottom-up decisions.

1.1. Objectives

1.1.1. General objective

In order to address the aforementioned intentions, the general objective of this work is:

- The development of an easy to apply and transferable prioritization tool, which includes ecological, economic, social, and institutional dimensions of development for the forestry sector in Nicaragua, and that could be used by all public actors responsible for the implementation of policies and measures for the adaptation to climate change.

1.1.2. Specific objectives

The specific objectives of this work are:

- Identification of a portfolio of measures for adaptation to climate change in the forestry sector.
- Creation of a list of standard criteria and indicators to analyze the measures to climate change adaptation.
- Development of a tool to prioritize the adaptation measures for the forestry sector including the socio-economic and environmental aspects.

1.2. Overview of document structure

This work has been organized according to the objectives previously laid out. The general structure of the developed tool has been constructed within the “Economic instruments for adaptation” project, which aimed at supporting adaptation planning processes, including social environmental multi-criteria tools, cost -benefits analysis, as well as participation processes, to enable bottom-up decisions.

Chapter 1 introduces the intention of the work and lays out its objectives. Chapter 2 presents a general overview of the information related to climate change adaptation and forests, including a list of adaptation measures identified for the sector

Chapter 3 presents general information about planning for climate change adaptation, as well as a review about methods for the prioritization of climate change adaptation measures. The chapter also introduces the conceptual framework for the prioritization of adaptation measures, which serves the general development path for the aspired tool. The Analytic Hierarchy Process (AHP) as the chosen Multi-Criteria Analysis for the development of the tools is described.

In Chapter 4 the Bosawas Biosphere Reserve, which is the case study area for this work, is described. Chapter V lays out the four different adaptation measures identified as alternatives to be implemented in the case study. The evaluation of those four measures is integrated.

The core part of this work is presented in Chapters 5, 6 and 7, which present the results in relation to the specific objectives of this research: identification of adaptation measures for the case study area; description of the developed tool, which includes the criteria, sub criteria and indicators to be used for the evaluation of the measures and finally, how to use the tool in order to obtain the prioritization of the adaptation measures for the forestry sector of Nicaragua.

Chapters 8 and 9 present the discussion and conclusions of the study, where the main remarks and recommendations are made.

2. Adaptation in the forestry sector

There are two main approaches to face climate change which can be used for the forestry sector: adaptation and mitigation. This work will focus on these two approaches, even if new approaches have been developed in order to face climate change.

The IPCC (2014, p. 172), defines adaptation as "the process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects".

Concerning adaptation strategies, Mimura et al., (2014, p. 873) define them as "a general plan of action for addressing the impacts of climate variability and extremes... which include a mix of policies and measures that have the overarching objective of reducing vulnerability to climate change impacts".

Mimura et al., (2014) stress that one of the key features related to decision making and in turn related to adaptation, is the uncertainty under which the process is developed. However, Roberts et al. (2009) point out that, despite uncertainty related to future effects and impacts of climate change, actions have to be implemented in order to reduce the vulnerability of natural and socioeconomic systems to climate change (which increases resilience[1]).

The IPCC (2007b) identifies three categories of adaptation: autonomous, anticipated and planned. The first refers to ongoing responses to changes in climatic conditions such as risk management or production-enhancement activities (not conscious responses); the second, when adaptation is implemented before impacts are even observed; and the last is focused on the increase in adaptive capacity in the long-term.

For the forestry sector in particular, different adaptation measures are mentioned in the literature. Some of them are presented in Table 1.

[1] Resilience: "The capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation" (IPCC, 2007b).

Table 1 Adaptation measures in the forestry sector
Source: Own elaboration

Measure	Reference
On natural ecosystems	
Managing land use (including deforestation), fire and other disturbances, and non-climatic stressors	Field, et al., 2014
Reduction and management of other stresses on species and ecosystems (human induced)	Fischlin et al., 2007; Innes et al., 2009
Conservation of natural ecosystems (including monitoring activities and community management)	Fischlin et al., 2007; Gebhardt et al.,2011; Smith et al., 1996; Innes et al., 2009; Field, et al., 2014
Establishment or expansion of protected areas	Fischlin et al., 2007; Hannah & Salm, 2005
Maintaining viable and widely dispersed populations of individual species	Fischlin et al., 2007
Restoration of degraded habitats or creation of new habitats (high costs)	Fischlin et al., 2007; Innes et al., 2009
Protection of forest against fires and plagues	Laurent, 2003; Gebhardt et al.,2011
Financial incentives for sustainable forest management	Roberts et al., 2009
Establishment of biological corridors	Brooks and Adger, 2004; Smith et al., 1996; Innes et al., 2009
Adaptation of water management policies	Gebhardt et al.,2011
On planted forests	
Changes in management intensity	Easterling et al., 2007; Innes et al., 2009
Mix of hardwood/softwood species	Easterling et al., 2007; Gebhardt et al.,2011
Changes in timber growth, planting and harvesting patterns	Easterling et al., 2007; Roberts et al., 2009; Smith et al., 1996
Changes on rotation periods	Easterling et al., 2007; Gebhardt et al,2011
Landscape planning to minimize fire and insect damage	Easterling et al., 2007
Use of better adapted species	Easterling et al., 2007; Laurent, 2003; Gebhardt et al.,2011; Innes et al., 2009
Captive breeding for reintroduction	Fischlin et al., 2007; Smith et al., 1996
Measures to reduce material inputs and maintenance of soil fertility	Gebhardt et al.,2011
On natural and planted forests	
Strengthening climate change-related research and monitoring	Gebhardt et al.,2011; Innes et al., 2009
Use of mixed strategies	Smith et al., 1996
Ensure the proper functioning of community governance and equitable sharing of benefits among individual families	Innes et al., 2009
Economic diversification of forest based communities	Innes et al., 2009
Practice low intensity forestry and prevent conversion to plantations	Innes et al., 2009
Inclusion of risk management in management rules and forest plans and development of enhanced capacity for risk management	Innes et al., 2009
Maintenance of genetic diversity, assisted species migration and dispersal, manipulation of disturbance regimes	Field, et al., 2014

3. Planning for climate change adaptation

Due to the different and multiple levels and dimensions of climate change, adaptation to this phenomenon is a complex process. To determine which alternative is better to be implemented with a limited budget, capacities, etc., a selection and prioritization process is a key step concerning adaptation planning (Noble, et al., 2014).

Related to the process to formulate and implement national adaptation plans, the UNFCCC (2015) identifies the prioritization of climate change adaptation as part of implementation strategies.

Considering that decision making is done under uncertainty, two types of tools have been identified in order to inform the process: top-down and bottom up. The first one refers mostly to downscaling of simulated climate scenarios; the second is driven by the different stakeholders who identify their own impacts and vulnerabilities and incorporate adaptive options for the appropriate sector or community. However, noting the challenges and complexity of adaptation, it is clear that “no single tool suits all circumstances” (Mimura, et al., 2014, p. 883). Nowadays this is one of the biggest challenges that governments, NGOs, practitioners and communities face around the world when contemplating adaptation to climate change (IPCC, 2007b).

Noble et al., (2014, p. 850) identify some aspects that have to be considered when selecting adaptation options, amongst them:

- Effectiveness in reducing vulnerability and increasing resilience
- Efficiency (increase benefits and reduce costs)
- Stakeholder participation, engagement and support
- Legitimacy and social acceptability
- Designed for an appropriate scope and time frame
- Resources available

Noble et al. (2014) also emphasize two main features when defining the adaptation options: time scale and climate scenario. These two components make the decision making process a dynamic process, which –as mentioned before- depends on different contexts, each with different levels of complexity.

In order to select a method to be used during the decision-making process for the prioritization of adaptation measures, it is important that the method is not too complex, and therefore robust and flexible. At the same time, the method has to be rigorous in practice and feasible in application (Nkem, et al., 2008).

Following some examples of guidelines or tools developed for the prioritization of adaptation measures, the following are presented:

- CLIMACT Prio. Developed by the Institute for Housing and Urban Development Studies (IHS) (Nasra, et al., 2010). This tool uses a Multi-Criteria Analysis and largely focuses on adaptation in the housing or urban sector.
- TroFCCA framework and approach for "Prioritization for Adaptation in Tropical Forest Ecosystems" (Nkem, et al., 2008). Here, four case studies are presented: West Africa, (Burkina Faso), Central America (Nicaragua, Honduras, and Costa Rica), and Southeast Asia (Indonesia).
- The UNDP Adaptation Policy Framework for Climate Change (UNDP, 2004). This framework presents a roadmap for the development of adaptation policies, including the different phases of the process in the different sectors: water, natural ecosystems, agriculture, etc.
- Structured decision-making approach to climate change adaptation in the forest sector (Ohlson, et al., 2005), which presents a general framework, and key principles to be taken into account. The evaluation of adaptation measures is done by using a qualitative matrix which considers trade-offs between strategies and objectives.

Recently, in the Latin American region, some efforts have been made at the governmental level, such as the "Methodology for the prioritization of adaptation measures to climate change", developed by the Environmental Secretary of Mexico, with support from GIZ (2015).

Other countries, such as Colombia, are developing a national system related to indicators of climate change adaptation which are key components during decision-making.

3.1. Conceptual framework for the prioritization of adaptation measures

The development of the tool for the prioritization of adaptation measures, in line with the general objective of this study, is conceptualized around the development path (Figure 1) for a prioritization tool, presented in Máñez & Cerdá (2014) considering the IPCC guidelines (Carter, et al., 1994). The developed tool contributed to the "Economic instruments for adaptation project" of the Climate Service Center (GERICS).

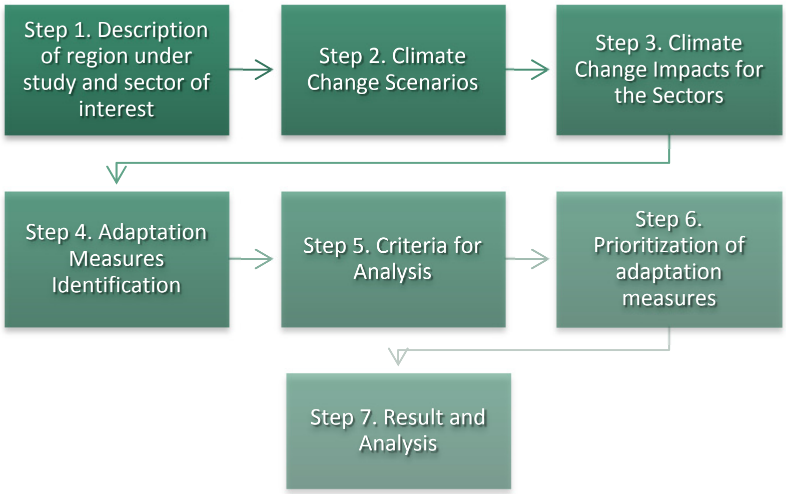

Figure 1 The concept: General structure of a prioritization tool
Source: Máñez & Cerdá, 2014

The structure comprises seven steps. The first three include the description of the area under study (Step 1), respective climate change scenarios (Step 2) and their impacts on the sector of interest (Step 3). All these steps are based on information collection. The information related to these three steps is presented in section IV as part of the case study area description.

The next steps represent the core of this work and are those related to, and developed according to, the specific objectives of this research. Here, the development concept makes use of the Analytical Hierarchy Process (AHP), being a MCA method: identification of adaptation measures (Step 4), definition of criteria for analysis (Step 5), prioritization of adaptation measures (Step 6) and results and analysis according to the developed prioritization tool (Step 7). In the last step (7), the measures to be implemented are chosen, using the outcome of the prioritization tool as a guideline for decision-making. Steps four to seven are presented in the results chapter of this piece of work. In the following, a description of each step and the approaches used for the development of this study are given.

Step 1: Description of the study area

Before starting to work on the prioritization of the adaptation measures, the bio-physical and socio-economic characteristics of the region under study have to be known. This step serves as the basis for the implementation of the prioritization tool.

The scope of the required information will depend on the characteristics of the study or intervention area (from national to local level).

Step 2: Incorporating climate change scenarios

Here, available information regarding climate change scenarios for the case study area, such as weather forecasts (short term), seasonal climate forecasts (medium term), and historical climate records as well as climate change projections (for long-term information) are collected and examined. The information does not consider human interference, such as human-related drivers of forest degradation or deforestation.

In the case of their existence, or whether they can be developed, it is preferable to use different climate change scenarios dealing with the specific case study area. Regional and national scenarios, developed by nationally or internationally recognized institutions, can be used in order to identify the overall trend in climate conditions of the area under study if no specific information is available.

Step 3: Integrating climate change impacts for the sector

Once the description of the sector is achieved and the scenarios for climate change projections are known, information related to the analysis of the current, short and long-term impacts from climate change on the sector of interest have to be compiled. Therefore, three categories of impacts have to be considered: spatial extent of impacts, impact on ecosystem function, and productivity of ecosystems.

This step allows decision-makers and practitioners to improve their knowledge with respect to the need for adaptation measures.

Step 4: Identification of adaptation measures

This step refers to the compilation of adaptation measures for the sector of interest, based on the specific features of the area under examination (or areas with similar bio-physical and socio-economic conditions). The information can be obtained through literature reviews, interviews and workshops with different stakeholders and key actors.

After the compilation of all measures, a short-list of feasible measures that could be implemented in the area has to be developed. The definition of the short-list of adaptation measures has to be performed by experts of the sector. Those are the measures, which will later be evaluated by the use of the developed prioritization tool.

It should be noted that for the selection of measures, the distinction between adaptation and mitigation measures is not always straightforward. Since adaptation in natural ecosystems is “an autonomous process” (Ohlson, et al., 2005) it is difficult to identify measures, which would only work towards adaptation. Mitigation measures can also represent a potential for adaptation. Therefore, some of the measures presented in this study can also be classified as mitigation actions. This is why, for the development of this study, the synergy between both approaches was considered additionally in the selection of measures.

Step 5: Definition of criteria for analysis

According to Saaty (2008), in the case for climate change adaptation, once the magnitude of climate change impacts and the need for adaptation and the stakeholders are known and identified, the next step is the identification of the key criteria and their indicators. This will help identify the best alternative, taking into account the available resources.

When talking about ecosystems, land management and climate change adaptation, it is clear that many different aspects have to be considered in order to achieve a more holistic understanding (Schmoldt et al., 2001; Brooks & Adger, 2004; Ohlson et al., 2005; CARE, 2010; UNEP, 2011). Therefore, a catalog or list of criteria, sub-criteria and indicators considering the mentioned aspects has to be developed.

Related to forest management, as framed in adaptive management, there are four criteria that can be considered: dealing with spatial and temporal scale, dimensions of uncertainty, the evaluation of costs and benefits, as well as institutional and stakeholder support (Innes, et al., 2009).

According to Harley et al. (2008, p. 10), adaptation indicators can be defined as "process-based" and "outcome-based" indicators. The indicators should be "precise, robust, transparent and objective” also "simple, clear and easy to understand" (Harley et al., 2008, p. 9) are also mentioned.

Harley et al. (2008) remark as challenges for the definition of indicators for adaptation to climate change: the long timescales, the mix of hazards and opportunities and the absence of agreed definitions of acceptable performance in adaptation. Field, et al., (2014) referred to the complexity of metrics for adaptation, affirming that the most useful indicators are those that not only refer to the process and implementation, but also to the outcomes.

After the problem has been defined and the alternatives for adaptation measures are identified, a list of criteria and indicators has to be developed. The definition of the criteria is done according to the literature related to the sector, including generic criteria defined at national and international levels. The options for adaptation are then evaluated according to their performance, regarding the defined criteria and indicators, using the pairwise comparison method as proposed by Saaty (1990).

The criteria and indicators proposed in this work can be classified as outcome oriented, since they support the decision-making process in the definition of the alternatives with respect to their effectiveness towards the defined set of objectives for adaptation.

The selection has to be made by the use of literature review and workshops (if feasible). The selection process has to consider information regarding planning frameworks, climate change and the forestry sector, and the well-being of forest communities. Suggestions expressed by governmental officers, practitioners and academics interviewed during the information collection process have to be taken into consideration.

When available, it is important to consider information regarding the defined criteria and indicators. For example, post-evaluation reports of measures already implemented in areas with similar conditions can be used as an orientation for the own evaluation process.

Step 6: Prioritization of adaptation measures

According to the criteria defined in the previous step, a method for prioritization has to be used in order to identify a ranking among the selected measures, considering their effectiveness in meeting the objectives of adaptation. In the case of this work, the selected method is a Multi-Criteria Analysis (MCA) using the Analytic Hierarchy Process (AHP) based on Saaty (1990, 2008) which is described in section 3.2.1. Among the advantages of the AHP are:

Since the use of that method comprises the assignment of numeric values to the judgments on a single criterion, the outcomes of the consultations are achieved in a transparent manner. The use of this method can help to avoid biases (Nkem, et al., 2008).

Further the use of AHP has a great value when there is a lack of scientific knowledge since it allows for the use of locally available expertise. Judgment is achieved through a relative numerical ranking which makes the method more feasible (Ishizaka & Labib, 2011).

The expert judgment is mentioned not only as the most demanding phase in terms of inputs (Mendoza & Prabhu, 2000), but also as a very useful and rapid assessment when dealing with impacts and adaptation to climate change (Carter, et al., 1994). AHP has proven to be consistent with other MCA methods (Tavana, et al., 1996).

Step 7: Summary and presentation of results

This is the last step, which summarizes the results obtained from the prioritization process. A ranking of the measures is presented and serves as a guideline for the decision-making for implementation.

3.2. Methods for prioritization: Multi-Criteria Analysis (MCA)

The UNFCCC Secretariat (2005) provides different tools for making choices regarding adaptation to climate change. These are: policy exercise, cost-benefit analysis, cost-effectiveness tool for environmental assessment and management, adaptation decision matrix, screening of adaptation options, and Multi-Criteria Analysis (MCA). A brief overview of some of the most used methods in this field is presented in Annex 11.1, including the description highlights, the advantages and disadvantages of each of them, considering the objectives described in section 1.1. Considering this information, the Multi-Criteria Analysis (MCA) was selected as the basis for the development of the prioritization tool.

The Multi-Criteria Analysis (MCA) is described as "any structured approach used to determine overall preferences among alternative options, where the options accomplish several objectives" (UNFCCC Secretariat, 2005). Thus, the term MCA encompasses several methods of its kind. The methods are classified as those, which give clear recommendations for actions by comparing and ranking different outcomes or alternatives (UNEP, 2011; Heuson et al., 2012). It has been used for the evaluation of climate change policies (de Bruin, et al., 2009), by the scientific community as well as by practitioners in the field of adaptation (Ishizaka &Labib, 2011).

In order to prioritize climate change adaptation measures, different dimensions, such as the technical, financial, social and environmental feasibility have to be taken into account (CARE, 2010). Therefore the inclusion of a great number of climate change dimensions in a MCA method ensures transparency and accountability (UNEP, 2011). The MCA methods can be used when monetary values cannot be assigned to significant environmental and social impacts. Instead, MCA uses attributes or indicators; these do not have to be defined in monetary terms, but are often based on a quantitative analysis (UNFCCC Secretariat, 2005; Nasra et al., 2010; UNEP, 2011; Heuson et al, 2012).

Compared with cost-benefits analysis, Multi-Criteria Analysis tools can lead to more complete assessments, as well as minimizing the chances of making mistakes that lead to maladaptive assessment. This is due to MCA including more than just the economic advantage of the options (Magrin, 2015).

Another advantage of the MCA method is its participative character, where different stakeholders, experts and/or practitioners –with different knowledge, experience, and backgrounds- can participate in the weighting process (Nasra, et al., 2010), which is very important when addressing the challenges of adaptation (Noble, et al., 2014).

The main critics regarding MCA are related to the role of judgment during the process, which can be subjective (UNDP, 2004; Saaty, 2008). Through the use of MCA methods, quantitative results and their reproducibility can be obtained (Nasra, et al., 2010). The authors consider that these two aspects are important for the development of an effective prioritization tool.

3.2.1. Analytic Hierarchy Process as a Multi-Criteria Analysis

Among the multi-criteria decision-making tools, the Analytic Hierarchy Process (AHP), developed by Saaty (1980, 2008), has proven to be useful for different sectors and objectives (e.g. selection, evaluation, decision-making, benefit and cost analysis, etc.) (Vaidya & Kumar, 2006). This method is based on weighting or scaling and has been extensively used for environmental issues (Greening & Bernow, 2004; Ishizaka & Labib, 2011). Mendoza & Prabhu (2000) mention that, compared with the ranking and rating methods, the AHP is the one which provides more information when evaluating different indicators.

The general steps of a MCA using AHP are presented in Figure 2. Each step is explained thereafter.

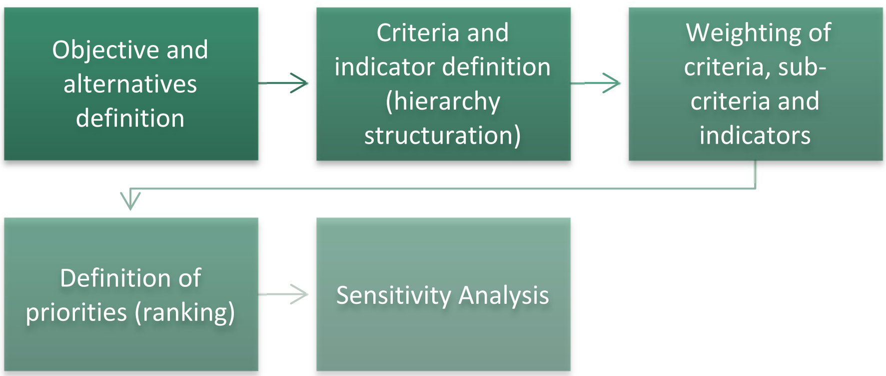

Figure 2 MCA steps

Source: Own elaboration based on Carter et al., 1994; Greening & Bernow, 2004; Saaty, 2008; Nasra et al., 2010; Nairobi Work Programme -UNFCCC, 2011

Objective and alternatives definition

The definition of objectives and alternatives is mentioned as a very important step in any decision-making process since it determines the range of information and the kind of knowledge related to the problem and the objectives of adaptation. Likewise, the alternatives that need to be evaluated are identified in this step. In some cases (e.g. political processes), the alternatives are already given, for example those that are integrated in plans, policies, etc. It is important that the number of alternatives is adequate (not too few so a real decision can be made, not too many so the process is not too complex) (Proctor & Drechsler, 2003).

Criteria and indicators definition

According to Saaty (2008), the consequent step is the identification of the key criteria and their indicators, which will help identify the best alternative, taking into account the available resources. This last task is mentioned as the most creative one (Saaty, 1990).

When using the Analytical Hierarchy Process (AHP), criteria and indicators should be presented in a hierarchical way (from overall goal to criteria, sub-criteria and alternatives). That hierarchy will be considered during the evaluation (Saaty, 1990). Usually, alternatives are presented in the lowest level (Saaty, 2008). The maximum number of criteria to work within different groups and levels ranges between seven and twelve (Proctor & Drechsler, 2003).

The criteria and indicators have to be specific, complete (as such that they can cover all aspects of the decision-making problem), non-redundant (preventing double counting), clearly verifiable, directly relevant to the problem and decomposable in smaller units (Proctor & Drechsler, 2003; Harley et al., 2008, Heuson et al., 2012).

Weighting of criteria and indicators

After the definition of the list of criteria, sub-criteria and indicators is compiled, a weighting process of the criteria and indicators is conducted by the use of the Analytical Hierarchy Process (AHP). According to Saaty (2008), the weighting process can be performed by pairwise comparison matrices among criteria, sub-criteria and indicators. The pairwise comparison matrix is a non-compensatory method which through aggregation allows for the definition of the priorities in each level (Greening & Bernow, 2004; Saaty, 2008). The comparison is made using the Saaty scale or the fundamental scale of absolute numbers, as shown in Table 2.

Table 2 Fundamental scale of absolute numbers
Source: Saaty, 2008

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favor one activity over another
5	Strong importance	Experience and judgment strongly favor one activity over another
7	Very strong or demonstrated importance	An activity is favored very strongly over another; its dominance demonstrated in practice
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
Reciprocals of above	If activity *i* has one of the above non-zero numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i	A reasonable assumption
1.1-1.9	If the activities are very close	May be difficult to assign the best value but when compared with other contrasting activities the size of the small numbers would not be too noticeable, yet they can still indicate the relative importance of the activities
1	Intermediate values	When compromise is needed

Once the criteria and indicators are compared, the results are normalized in order to obtain the relative weights for each criterion (global and local priority) (Saaty, 1990; 2008).

Definition of priorities (ranking)

The prioritization is done according to the results of the weighting process. Every alternative is assessed against each criterion, taking into consideration the global and local priorities obtained through the weighting process (Nasra, et al., 2010). The alternatives are then ranked according to their priorities. The highest weight corresponds to the highest priority.

Sensitivity analysis

An advantage of the AHP is it allows confirming the consistency of the judgments through a sensitive analysis. An inconsistency ratio less than 0.1 is considered as reasonably consistent. In some cases, inconsistency ratios higher than 0.1 (but not much higher) are also accepted (Ishizaka & Labib, 2011). In general, when a ratio over 0.1 is obtained, the judgment (comparison) has to be checked.

Using the values obtained through the prioritization process, the consistency ratio (CR) can be calculated. Following, the steps for the calculation of the CR are presented.

a. The values of every column in the pairwise comparison matrix have to be multiplied by their priority.
b. The values obtained in the previous step are summed.
c. The sum of every row is divided by its priority
d. The consistency index (CI) is calculated. The equation for the calculation of the consistency index is as follows:

$$CI = \frac{\lambda \max - n}{n - 1}$$

Where n is the dimension of the matrix or number of alternatives; λmax is the maximal Eigenvalue. λmax is the average obtained from the values obtained in step 3.

The consistency ratio is given by:

$$CR = \frac{CI}{RI}$$

Where: RI is the random index (see Table 3). The value to be used depends on the dimension of the matrix being evaluated.

If CR is less than 10% (0.10), then the judgments presented in the matrix can be considered as acceptably consistent (Ishizaka & Labib, 2011).

Table 3 Saaty Random indices (RI)
Source: Ishizaka & Labib, 2011

n	3	4	5	6	7	8	9	10
RI	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

4. Case Study Area description

Because the developed tool is based on the characteristics of Bosawas Biosphere Reserve, the description of the area is presented in this chapter. The information related to the general biophysical and socio-economic conditions, as well as relevant information on the forestry sector characterization of Nicaragua and the specific conditions within the Bosawas Biosphere Reserve, which is the case study area of this work, is presented here.

Nicaragua is located in Central America, between the latitudes 13 00 N, 85 00 W, bordered by Honduras to the north, Costa Rica to the south, to Caribbean Sea to the east, and the Pacific Ocean to the west. The country has a territorial extension of about 130,000 km^2, of which around 7% are lakes and rivers (Gobierno de Nicaragua, 2012b).

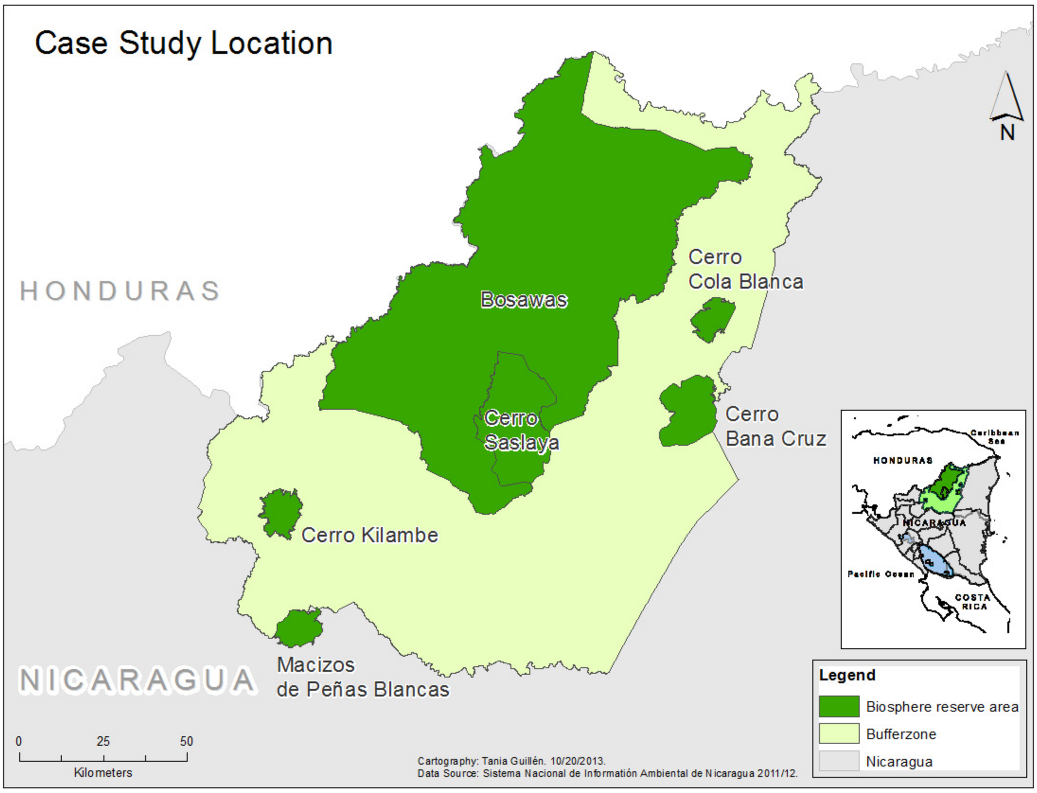

Figure 3 Location of Bosawas Biosphere Reserve
Source: Own elaboration

Bosawas is a Biosphere Reserve located in the central-north of Nicaragua. It comprises around 20,065 km^2 of the country's territory (approx. 14% of the total area) (Figure 3). In the study area the altitude varies from 30 to 1,800 m.a.s.l. and includes eight different types of ecosystems. Within its territories Bosawas comprises six different protected areas (MARENA-SETAB-GTZ, 2009).

4.1. Biophysical conditions

Climate

Bosawas is located on the Caribbean slope, where the dry season only takes three months (February to April), with a mean annual precipitation between 1,800 and 2,800 mm. The mean annual temperature is 26.5ºC with a maximum of 35.5ºC in May and a minimum of 16.1ºC in January. The climate is classified as tropical rainforest and tropical savannah, according to the Köppen classification (MARENA-SETAB-GTZ, 2009).

Ecosystems and land uses

Bosawas is the largest non-intervened protected area in Central America (Buss, 2011), and represents a convergence zone of fauna and flora from North and South America. Within its boundaries different land uses, ecosystems and Holdridge life zones have been identified (Figure 4). The identified life zones are: humid pre-montane forest (bh-PM: bh-PM), humid tropical forest (bh-T), very humid pre-montane forest (bmh-PM), very humid tropical forest (bmh-T), dry pre-montane forest (bs-PM) and tropical dry forest (bs-T).

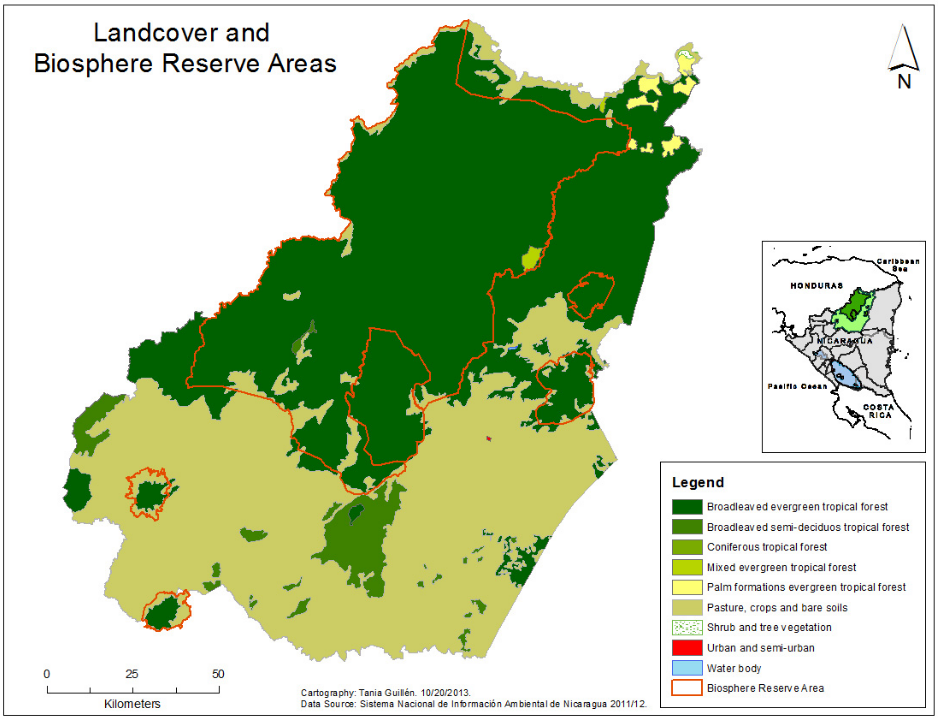

Figure 4 Land-cover of Bosawas Biosphere Reserve
Source: Own elaboration

As well as at the national level, Bosawas has ecologically suffered from land use changes in the last decades, mainly from forests to pasture lands. The region is mentioned as part of the old and the new agricultural frontier which reflects the pressure on the reserve (Ruiz & Marín, 2005). Between 2005 and 2010 the region has lost on average around 43,000 ha of forest cover each year (López M. , 2012). For Bosawas an annual rate of change (TAC) of 4.6 for the closed broadleaved forest and 6.3 open broadleaved forests has been reported. The increase on the TAC index for the open broadleaved forests could be the result of the decline of the closed broadleaved forest (MARENA-SINIA, 2011).

Bosawas represents 3.5% of the world biodiversity (MARENA-SETAB-GTZ, 2009). Across 71% of the territory, Bosawas has a Natural Capital Index (NCI) higher than 50% and only 8% lower than 20%. The NCI values show the high value of remaining biodiversity in the reserve (MARENA-SINIA, 2011). Within its territories, Bosawas has various endemic species of flora and fauna and its ecological integrity is classified as very good (Pérez, et al., 2010).

In Nicaragua there have been initiatives to evaluate the environmental services offered by protected areas, where the most valuable services are: water storage, biodiversity and carbon sequestration. MARENA-SINAP (2011) calculates the potential economic value of those services for systems of protected areas, which present similar ecosystems but only represent 1% of Bosawas total extension, at approximately USD 8,500,000.

4.2. Forestry sector characterization

In Nicaragua, forests are considered as a direct source of resources, mainly for rural and indigenous communities whom are highly dependent on them (Gobierno de Nicaragua, 2012b). In the rural areas, forestry is among the most important economic activities. The most important forestry products are the wood-based products, such as wood and firewood (Gutiérrez, 2004; Global Witness, 2007).

Nicaragua is characterized as a timber export country. INAFOR (2009) states that broadleaved forests alone have a volume of 464,4 million m^3 of wood representing the most important wood source of the country. Nonetheless, in the year 2000 the forestry sector only represented 0.3% of national GDP and 1% of primary sector production, which shows the incipient state of the forestry industry in Nicaragua. Most of commercialized wood (76%) is extracted from natural forests (INAFOR-MAGFOR, 2009). INAFOR (2009) estimates the value of Nicaraguan forests (all species included) at USD 9,8 billion.

Mentioned as threats to forests are: uncertainty of land tenure, fires, natural hazards, illegal logging (around 60% of total authorized cuts), rural poverty, fauna and flora extinction and climate change (Guevara, 2004; Global Witness, 2007).

Forest industry

Besides the great potential for forestry activities, planted forests and the forestry industry make up only 2% of forests in Nicaragua, as well as 3% of added value of national industry (INAFOR-MAGFOR, 2009). There are records of plantation and reforestation initiatives since the 1970s, which were mainly meant for energy generation. The first plantations were established using foreigner species such as Neem (*Azadirachta* spec.) and *Eucalyptus* spec., but latest plantations are using native species such as mahogany (*Swietenia* spec.), cedar (*Cedrelaodorata*) and ceiba (*Ceibapentandra*) (Guevara, 2004).

The forestry sector in Nicaragua, contrary to its great potential, does not represent a main economic sector due to the lack of industry to give added value. The national industry takes charge mainly of the primary transformation (sawmilling) (Guevara, 2004).

Guevara (2004) reports that the secondary and tertiary transformation is undertaken by small and medium size enterprises (2 to 20 workers), which are mainly located in urban or semi-urban areas, but rarely in rural areas. By the year 2006, approx. 6,000 people were employed in the forestry industry (Romero, Pérez, Gallozzi, & Lorío, 2010). The wood processed by these enterprises is mainly extracted from broadleaved forests (76%).

By the year 2009, the North Atlantic Autonomous Region (RAAN) –where most of the broadleaved forests are found- was the region with the most industries related to the forestry sector (32). However, official statistics related to incomes due to wood extraction don't show the economic importance of the activity in the region, which reflects the illegal timber extraction in the region. Estimations show losses in the range of USD 30 to 60 million in taxes for the state of Nicaragua due to illegal logging (Guevara, 2014).

Further problems of the forestry sector in Nicaragua, alongside illegal extraction, are amongst others: technological obsolescence, high levels of waste (only 50% of round wood is converted into sawn timber), low use of waste, and low industrialization of small diameters (Guevara, 2004).

Use of forest-based products

As firewood is the main wood-based product used as source of energy at domestic level, its extraction is a driver of forest degradation. By the year 2009, the permits given to extract firewood and to produce charcoal reached 11,738 metric tons (INIDE, 2009). According to estimations presented in Guevara (2004), by the year 2020, firewood and charcoal consumption will be approx. 6 million m^3 and 35,000 metric tons respectively. For the case of round wood and sawn timber, the production has decreased in the last decades from 900,000 m^3 in 1980 to 210,000 by the year 2000; and increased from 60,000 m^3 in the 1990s to 100,000 m^3 by the year 2000 respectively.

Regarding non-wood base products there is not enough information, even if it is well known that these products are used especially for handicrafts. However the volume does not represent an important flux. Products as pulp, cardboard and paper are mainly imported into the country (Guevara, 2004).

4.3. Socio-economic aspects

Bosawas has approx. 146,000 inhabitants, of which 36,000 are living in the core area, 80,000 in the buffer zone and 30,000 in its transition zone (MARENA-SETAB-GTZ, 2009). Within the territories of Bosawas there are approximately 36,000 indigenous inhabitants grouped in seven different indigenous communities (Mayagnas and Miskito people).

A high percentage of the indigenous territories are listed in one of the forest categories (MARENA-SINIA, 2011). Indigenous communities represent an important aspect for sustainable forest management in Bosawas, confirmed by the deforestation rates, which show a big difference between indigenous and “mestizos” (not indigenous communities, mainly represented by small farmers) inhabitants. By the year 2002, the deforestation rate in areas inhabited by indigenous communities and “mestizos” was 0.15 and 2.15 ha/ inhabitant respectively (MARENA, 2012a).

Indigenous communities are highly dependent on natural resources for their subsistence. Their main activities include agriculture for subsistence farming, hunting, fishing, domestic animals breeding, and in some cases medium scale mining (MARENA-SETAB-GTZ, 2009) .

Related to levels of poverty, many authors agree that areas where most of the forests are located are also the areas with highest levels of poverty in the country (Romero et al., 2010; Guevara, 2004). As an example of the economic conditions of indigenous communities of Bosawas, MARENA-SETAB-GTZ (2009) mentions an income of USD 70 per year per person, which is generated mainly from the commercialization of a part of their basic grain cultivations. Most of the Bosawas territories have a poverty index higher than 70%.

In respect to forest ownership Bosawas comprises communal land, state land and private property. Indigenous community territories, who own 25% of the country’s territory, represent 49% of forest lands. On the other hand, private ownerships, which represent 55% of the national territory, only represent 35% of forest lands (INAFOR, 2009). Contrarily, López

(2012) affirms that even when indigenous communities are the land and forest owners, they have little power regarding decisions that are made concerning their territories.

Regarding employment in the forestry sector, the information presented in the following paragraphs refers to the information found on the national scale. INAFOR-MAGFOR (2009), based on INAFOR's statistics, reported 31,621 people were employed directly or indirectly in the forestry sector, most of them in the Bosawas buffer zone. This statistic shows an increase of 196% regarding what was reported in the year 1996 in Guevara (2004). These are low numbers considering the sector potential. The number of workers in the forestry sector, by that time, was 2,414. From the total amount of workers, almost 80% were unqualified with only empirical knowledge.

4.4. Institutional aspects

Nicaragua has signed various international conventions, such as the Convention on Biological Biodiversity (CBD); the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES); and the United Nations Framework Convention on Climate Change (UNFCCC) (Global Witness, 2007).

Principle 11 of the Rio Declaration on Environment and Development (United Nations Conference on Environment and Development, 1992), points out the need for effective environmental legislation and also mentions standards for environmental management (United Nations, 1999). The Forest Principles, also developed as part of the UNCED, are presented as the basis for certification in the forestry sector (United Nations, 1999). Nicaragua, by the year 2002, officialized its own forest criteria and indicators for sustainability (MARENA, 2002).

The institutional aspects of the Nicaraguan forestry sector are established in Law 462 "Ley de Conservación, Fomento y Desarrollo Sostenible del Sector Forestal"[2] (Asamblea Nacional de Nicaragua, 2003) and Law 217 "Ley General del Medio Ambiente y Recursos Naturales"[3] (Asamblea General de Nicaragua, 2008). One of the main aspects was the creation of incentives for sustainable forest management.

Mentioned as actions for sustainable development of the country in the National Development Plan (Gobierno de Nicaragua, 2012a) are amongst others: forestry development, including natural regeneration, reforestation, and community forestry; protection of natural resources, and adaptation to climate change.

[2] Law of Conservation, Development and Sustainable Development of the Forest Sector
[3] General Law on Environment and Natural Resources

According to Law 290[4], the main institutions related to forest management are:

- Ministry of Agriculture and Forestry (MAGFOR): responsible for policies and regulations for the forestry sector;
- National Forestry Institute (INAFOR): decentralized entity under the Ministry of Agriculture and Forestry and in charge of the compliance and control of the sustainable management of forest resources;
- Ministry of Environment and Natural Resources (MARENA): responsible for the management of protected areas;
- Municipalities: responsible for the Municipal Protected Forest Areas.

The country already has planning tools regarding environmental management and climate change adaptation (MARENA, 2011), such as:

- National Strategy on Environment and Climate Change, which regarding forests mentions: national plans against forest fires and forest sanitation to avoid pests. Among the ones that are planned to be implemented are: environmental education, reinforcement of the protected areas protection mechanisms, regeneration and management of primary and secondary forests (for reestablishment of ecosystems and water harvesting), and restoration and conservation of biological corridors.
- Action Plans for Protected Area Management;
- Local Plans for Adaptation to Climate Change;
- "Plan for Adaptation to Vulnerability and Climate Change in the Agricultural, Forestry and Fishing Sector in Nicaragua", which presents the strategic framework and measures to be taken for the mentioned sectors.

Further important aspects to take into account considering Bosawas is the fact that its borders comprise territories under different political-institutional arrangements. Territories included are situated in three different political departments (Jinotega, Nueva Segovia, and Matagalpa) and one autonomous region (North Atlantic Autonomous Region – RAAN in its Spanish acronym). Also, Bosawas comprises 12 indigenous territories which together represent approx. 68% of the core area. Each territory has its own authorities (MARENA-SETAB-GTZ, 2009).

Regarding the institutional arrangements, according to the legislation, Bosawas is under the administration of MARENA through the Bosawas Technical Secretariat (SETAB). There is

[4] Law for Organization, Jurisdiction and Procedures of the Executive

also a National Commission for Bosawas, which is integrated by central government institutions, the North Atlantic Autonomous Regional Council, municipalities and indigenous territorial government representatives (MARENA-SETAB-GTZ, 2009). Regarding the effectivity of management of the area, the Gap Analysis report mentions that Bosawas has "regular" management effectivity (Pérez, et al., 2010).

4.5. Climate change scenarios and impacts

For the Central American region, the IPCC has projected an increase in temperature from 1.2ºC to 3ºC by year 2100 (using the RCP4.5 scenario). Projections regarding precipitation indicate a decrease in the region (Christensen, et al., 2013). The region shows a high climatic variability and occurrence of extreme climate-related events (CEPAL, 2010).

Climatic variability has been observed in Nicaragua, including extreme weather events such as droughts, tropical storms, heavy precipitations, and cold fronts (PNUD , 2013).

Only the information regarding scenarios presented in CEPAL (2010) is summarized here, where the baseline scenario is based on records from the period 1950-2000. CEPAL (2010) used the scenarios A2 and B2 from the IPCC, because those are the ones which better adapt to the regional type of development. In Table 4 the results of CEPAL (2010) regarding changes on temperature and rainfall patterns in Nicaragua for five different reference years are presented:

Table 4 Changes on average temperature and rainfall patterns for Nicaragua according to scenarios A2 and B2

Source: Own elaboration based on CEPAL, 2010

Scenarios	2020	2030	2050	2070	2100
	Temperature (ºC)				
A2	0.73	0.87	1.90	2.73	4.30
B2	0.57	0.90	1.37	1.80	2.43
	Rainfall Patterns (%)				
A2	-0.60	4.87	-17.93	-17.73	-34.87
B2	5.3	-6.57	-7.31	-6.17	-17.43

According to CEPAL (2010), using the B2 and A2 climate change scenarios (including land-use changes), a regional biodiversity reduction of 18% and 36% by 2050, will occur respectively. In both scenarios, Nicaragua is presented as the country with the highest reduction of the Biodiversity Potential Index (50.63% for B2 and 70.63% for A2 scenario). A connection between forest fires, precipitation and temperature has been identified in Nicaragua (MARENA, 2001; Rodríguez et al., 2001). Rodríguez et al. (2001, p. 14) identify the connection as follows: “the less rainy periods, the higher the likelihood of fires”, and “the higher the temperature the higher the combustion”.

For the case study area there is no specific information related to the different climatic scenarios for the end of the century. However the Humboldt Center, the National Institute of Territorial Studies (INETER), and the Meteorological Institute in Cuba (INSMET) have developed an experiment related to the sensitivity of the life zones classification of Holdridge in Bosawas. The experiment was realized for the period 2012 to 2035, using eight climatic variables, a resolution of 25x25m, a moderate scenario, and the PRECIS Q4 model. In order to present the changes of the life zones, six different periods are used.

Figure 5 shows the results of the experiment, where a drastic change of Bosawas ecosystems can be clearly observed. From the present humid forest in year 2012, a change of approx. 70% to dry tropical forest by year 2035 is expected, where most of the change occurs between the last two periods. Those results match the projected impacts identified by CEPAL (2010) and IPCC (2007b), which observe significant increases in temperatures and changes in rainfall patterns by year 2030.

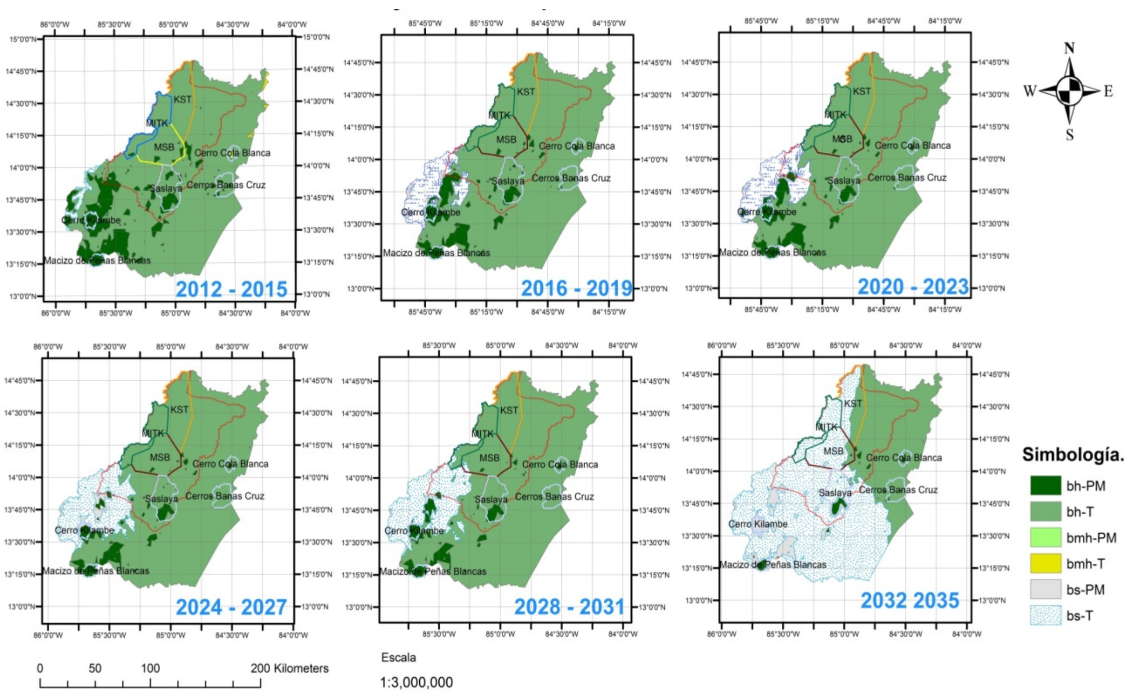

Figure 5 Sensitivity of Holdridge life zones to climate change in Bosawas[5]
Source: Centro Alexander von Humboldt, 2013

[5] bh-PM: humid pre-montane forest; bh-T: humid tropical forest; bmh-PM: very humid pre-montane forest; bmh-T: very humid tropical forest; bs-PM: dry pre-montane forest; bs-T: tropical dry forest

4.6. Ecosystem's vulnerability

However, as a vulnerable country in regard to climate change effects and climate-related extreme events, the natural resources are under high risk (Kronik & Verner, 2010; DARA, 2012; Harmeling & Eckstein, 2013). In this context, the advance of the agricultural frontier is mentioned as an indirect result of the impact of hurricanes and storms in Nicaragua (Kronik & Verner, 2010).

Among the most vulnerable sectors to climate change, biodiversity is mentioned, together with water, hydroelectric power, health and agriculture (CCAD, 2010). In Central America a loss of habitats due to forest fires is expected, as well as increasing droughts and floods which could lead to the spread of invasive species and disease vectors. Among the impacts on natural ecosystems in Central America, which could be presented in Bosawas, are: substitution of humid ecosystems for dry ecosystems and expansion of very dry tropical forests (CEPAL, 2010).

According to statistics presented by DARA in its "Climate Vulnerability Monitor" (2012) regarding habitat change, Nicaragua presents a vulnerabilities rating between acute and severe. The aspects taken into account are: biodiversity, desertification, heating & cooling, labor productivity, sea-level rise, and water supply. Regarding environmental disasters, the country's vulnerability ranges from acute to high, taking into consideration vulnerability to droughts, flood-landslides, storms, and wildfires (in which the country is presented as a hotspot, ranged as number 3). Even when wildfires are sometimes caused by humans, they can also be influenced by dry climates. They also lead to forest and soil degradation (PNUD , 2013).

Estimations for Nicaragua based on different scenarios show that up to 70% of the life zones could change under changing climatic conditions (Mendoza, Chévez, & González, 2001). This is confirmed by the results presented by Centro Alexander von Humboldt (2013).

Because most of the territory in the case study area is located between 200 and 1000 m.a.s.l., the vulnerability of ecosystems is high. This is because the potential for migration of species to areas where they can develop (in similar conditions) is limited (CEPAL, 2010; Mendoza, Chévez, & González, 2001). Based on the characteristics mentioned in Smith et al. (1996) (for example: forest/species with limited geographic range, species with limited seed/migration capabilities, regions where estimates changes in climate are relatively large) it can be affirmed that the ecosystems of Bosawas are very sensitive to climate change. The pressures, due to favorable climatic conditions for agricultural activities, also have to be mentioned (Eitzinger, Sonder, & Schmidt, 2012).

Even when there is little evidence about changes in tropical cyclone activity at the global scale (IPCC, 2013), hurricanes represent a high risk for the North-Caribbean area of Nicaragua where Bosawas is located (MAGFOR, 2013). Among the most relevant events which impacted Nicaraguan forests are: Hurricane Joane (1988), Hurricane Mitch (1998) and Hurricane Félix (2007). The last one, impacted directly the Bosawas area. It was reported that Hurricane Felix affected up to 607,000 ha of forest, mainly broadleaved forest (574,000 ha). It is estimated that around 264,000 ha of primary forests were converted to secondary forests. By year 2009, 45 licenses were approved for the extraction of around 158,460 m3 of rounded wood within the area affected by Hurricane Felix (INIDE, 2009).

5. Identified adaptation measures

The description and the summary of four different measures for adaptation to climate change is presented here, which according to the conceptual framework described in section 3.1 is the fourth step when selecting the adaptation measures to be implemented.

Due to the lack of detailed information regarding already implemented adaptation measures and those in the planning or implementation phase in the case study area, the authors also selected measures that are part of projects implemented by the Government of Nicaragua in other areas of the country. The implementation of those measures is already considered as part of the program's Plan for Protection and Management of Bosawas (MARENA, 2012a) and those related to natural resources management.

The information presented in this chapter served as the basis for the evaluation of the measures, conducted using the prioritization tool developed.

5.1. Measure A: Rehabilitation of ecosystems through the establishment of agroforestry systems

The establishment of agroforestry systems is mentioned as part of the strategy for sustainable management of the land and recovery of forest cover of the Adaptation Plan for Vulnerability and Climate Change in the Agricultural, Forestry and Fishing Sectors of Nicaragua (MAGFOR, 2013), and is also considered in the Strategy against Climate Change of the North Atlantic Autonomous Region (CRAAN, 2011). This measure has been implemented in buffer zones of different protected areas and is part of the program for sustainable production and productive diversification of the Plan for Protection and Management of Bosawas (MARENA, 2012a).

The agroforestry or silvopastoral practices have been established as alternative to cattle and monoculture production systems in many regions as a way to at least recover parts of the loss of forest cover. Usually these measures include: planting high densities of trees and shrubs in pastures, cut and carry systems, and the use of fast-growing trees for fencing and wind screens (Pagiola, Rios, & Arcenas, 2008). Mentioned as benefits of these practices are: on-site benefits, biodiversity benefits, carbon sequestration and hydrological benefits (Pagiola, et al., 2007). Agroforestry systems could be used as a transitional system in order to recover or restore vegetation cover, taking into account the soil potential and traditional uses.

In Bosawas, one specific project "Local and regional environmental management for the management of natural resources and the provision of environmental services in Bosawas

Biosphere Reserve" (Gobierno de Nicaragua-PNUD, 2008) included this measure in order to recover vegetation which was affected by Hurricane Felix in 2007.

Evaluation of Measure A:

Even when there are two different activity clusters related to "ecosystems restoration", the establishment or enhancement of agroforestry systems are the only activities mentioned in relation to restoration.

The establishment of 434 ha of agroforestry systems and the reforestation of 34 ha are reported as results of the project. The reforested area reported only represents 8% of the total restored plant cover area. The establishment and development of the agroforestry systems, and the positive impacts on the biodiversity are mentioned as highly valuable products, but in the final evaluation of the project planting of traditional crops, such as beans, rice and vegetables (tubercles and musaceous plants) are also mentioned. The inclusion of traditional crops (implemented by the Mayagna and Miskito communities) is positive, as these consider rotation cycles which lead to less impact on soil, water and biodiversity resources.

Cacao cultivation is mentioned as one non-traditional crop that was supported through the project. This crop can be combined with agroforestry practices, supporting the conservation and restoration goals of the activity. López & Vijil (2012) mention the need of monitoring activities in order to ensure the positive economic and environmental effects in the medium-long term.

After the finalization of the project, the report stated that agroforestry systems contributed to the recovery of lost forest cover in the buffer zone of Bosawas, which was affected by Hurricane Felix. If the reported ecosystem restoration is equal to reforested area, the authors consider the results as very limited, taking into account the area of natural ecosystems affected by Hurricane Felix.

Within the frame of the project, the establishment of communal committees at the watershed and municipal level was considered which can be positively evaluated in terms of enhancement of local mechanisms for governance, water supply, and sustainable management of natural resources.

In the final evaluation of the project the previous type of land use of the areas affected by Hurricane Felix are not mentioned. For example, it does not state whether the intervened areas were still natural forests or already used as agroforestry systems. This aspect has to be clear when evaluating the measures taken to ensure maintaining the areas with natural ecosystems, and to not encourage land-uses changes.

Considering the results of previous national experiences, it can be said that the establishment of agroforestry systems has shown positive results in terms of enhancement and diversification of rural family's incomes. The benefits for communities in which agroforestry systems have been applied, compared with communities where these systems have not been established, have been calculated up to $183.8 per ha, which reflects an increase in the total value of production. Other positive externalities of agroforestry systems, such as the environmental externalities, have not yet been calculated in monetary terms, but are expected to be significant (Bravo-Ureta, 2012).

5.2. Measure B: Conservation, reforestation and natural regeneration

These measures are part of the program for rehabilitation, management and conservation of natural resources and biodiversity within the Protection and Management Plan of Bosawas (MARENA, 2012a).

The description of this measure is based on the "Environmental and Water Management" component of the "Integrated Management of Watersheds, Water Supply and Sanitation" Project (PIMCHAS) (Schumacher, 2011). The project included activities for institution strengthening, environmental and water management, and health and sanitation. Activities related to the environmental and water management component which could be considered for adaptation to climate change are described here.

The activities of the environmental and water management component were planned to be implemented in the environmental and social sensitivity areas, which are defined as areas that comprise natural and cultural features which are important for ecosystems and human activities. Risk management was included in the project, but as part of the institutional strengthening component.

Evaluation of Measure B:

The identification and mapping of sensitive areas is mentioned as the biggest success of the component and the establishment of practices for production diversification. When the mid-term evaluation of the project was developed, they reported the recovery of 410 ha of riverine forest, representing up to 60% of identified areas for intervention. The activities helped to protect the rivers through the reduction of sediments. Wood and fruit trees were used for reforestation activities, as well as benches to protect water sources from cattle.

By the year 2010, 1,539 ha under protection were also counted, which included reforested areas and natural regeneration through the intervention of the project. This helped to protect 150 sources of water. The involvement of different local organizations is mentioned as very important for the success of the activities. Monitoring in the medium and long term is needed in order to know the real impact of the activities.

Environmental awareness activities were also considered in this component of the project, having involved around 5,000 people by the year 2010. The establishment of "bio-energetic" forests was also considered as part of the component, counting 96 households participating in this activity. 428 producers were also implementing these kinds of practices by the end of the project.

5.3. Measure C: Establishment of forestry management systems

The establishment of forestry systems is part of the Plan for Protection and Management of Bosawas (MARENA, 2012a), through the programs for rehabilitation, management and conservation of natural resources, biodiversity, sustainable production and production diversification.

As well as the establishment of forestry systems, an increase of forest areas through the establishment of forestry systems has been promoted and enhanced in order to achieve sustainable management and recover lost forest cover and degraded land in Nicaragua. An example is the "Social, Environmental and Forestry National Program" (POSAF II), which was implemented from 2002 to 2008. The Environmental Program for Risk Management to Disasters and Climate Change (PAGRICC) is presented as a continuation of the activities implemented by POSAF.

The description of this measure is based on the Component 1 named "sustainable management of the natural resources at the farm level" of the POSAF. The other two components were focused on infrastructure at the local level in order to prevent and mitigate natural disaster, enhancement and capacity building on natural resources management. The description of the component of interest of this work is based on the post-evaluation of the project which was carried out in 2012 (Bravo-Ureta, 2012).

The Component 1 was the one that had most monetary assignation, in approx. USD 20 million of a total amount of USD 38 million. The intervention area was approx. 69,800 ha, located within five political departments of the Pacific and Central Regions: Estelí, Matagalpa, Jinotega, Carazo and Nueva Segovia.

The activities of this component were oriented to the productive conversion of private farms through the implementation of practices previously selected by the project, such as: agroforestry systems, which include forest with annual crops and silvopastoral systems; and forestry systems, which consist of forest management and reforestation. As agroforestry systems were already presented as part of the first adaptation measure to be evaluated, in this part of the work only the activities referring to the forestry sub-system of the POSAF are presented.

Evaluation of Measure C:

The maximum monetary amount of the support packages, in the case of the forestry system, which included technical assistance, vegetative material and other kind of materials, was of up to USD 1,600 per beneficiary.

For the case of the forestry systems plantations, the management of natural regeneration, and forest management were included. Practices included for the sub-systems were, amongst others: preparation and implementation of a forestry management plan, silviculture techniques (such as thinning, rounds, etc.), establishment of forest plantations, and support to natural regeneration. To select the beneficiaries of each system, the soil potential was considered as well.

In the final project evaluation, the beneficiaries mentioned the following positive effects: reduction of poverty, increase in value of their farms, decrease in vulnerability of the communities living downstream, and enhancement of the municipalities.

As part of post-evaluation of the project, beneficiaries were asked about changes during the last 10 years on temperature, precipitation, floods, droughts, and landslides. It is also mentioned in the evaluation report that farmers adopted the practices promoted by the POSAF for the long-term. The beneficiaries were asked about the level of satisfaction regarding the support given by the POSAF. Most of them (92%) were among very satisfied and satisfied.

As a result of the measure implementation, 13,477 farmers (small, medium, and large scale) were beneficiaries of approx. 14,430 support packages (money, assistance and/or materials) for the implementation of forestry systems.

The economic benefits of implanting the forest management system, compared to areas without intervention of the program, have been calculated at up to USD 14,141,462, representing an increase in value of the farm at approx. USD 210 per ha. The benefits were calculated without taking into consideration environmental services, including, for example, carbon sequestration. According Juárez (2008) the CO_2 sequestration of regenerated systems in areas of the POSAF program amounts to 105 tons per ha. The forestry sub-system is the one with highest increases in value of the farms per ha (compared with agro-forestry systems and mixed systems). The total economic benefit (for the entire program) was USD 22.9 million for the period of 2011-2012. Spillover effects of the program are suggested as considerable, considering the restoration of environmental services, environmental education, disaster prevention activities, and enhancement of governance, among others which were part of the program.

5.4. Summary of selected adaptation measures

Table 5 presents a summary of the selected adaptation measures to be evaluated using the criteria and indicators, through the Analytic Hierarchy process proposed in this work.

Table 5 Summary of selected adaptation measures to be evaluated

Source: Own elaboration

Measure	A: Rehabilitation of ecosystems though the establishment of agroforestry systems	B: Conservation, reforestation and natural regeneration	C: Establishment of forestry management systems
Objectives	To recover vegetation cover affected by Hurricane Félix in the buffer zone of Bosawas through proper integral agroforestry systems	To promote and implement conservation of natural resources in environmental and social sensitivity areas	To increase of forest cover in critical areas in order to address the deficit of forest products To improve the income of rural families
Budget	USD 258,700	USD 2,400,000	USD 4,604,400
Implementation period	2008 - 2011	2007 – 2011	2002 – 2008
Activities	– Participatory identification of areas to be restored – Implementation and monitoring of restoration activities – Evaluation of agroforestry systems viable in selected watersheds – Implementation of plant nursery of perennial and semi-perennial crops – Enhancement of the improvement, diversification and agroforestry resources management (implemented with approx. 200 families) – Enhancement of cacao plantation within agroforestry systems	– Identification and mapping of areas with high environmental and social sensitivity – Implementation of conservation and rehabilitation of natural resources – Establishment of a network of local promoters (trained in monitoring and evaluation activities)	– Establishment of forest management systems – Reforestation and natural regeneration management – Forest plantation
Stakeholders	UN Agencies: WFP and UNIDO National institutions: MAGFOR, the Regional Government (GRAAN), municipalities Others: UNAG and PCAC.	National institutions: MARENA, CIRA-UNAN, municipalities Others: communal organizations, and different communities in seventeen municipalities of five different political departments: Estelí, León, Jinotega, Madriz and Matagalpa.	National institutions: MARENA Others: 13,477 farmers (small, medium, and large scale)

6. Building up the prioritization tool

To fulfil the objectives of this work as they are stated in section 1.1, a research approach was developed related to the development of a prioritization tool, considering the features of the forestry sector in Nicaragua. The following chapter introduces the research approach used and describes the developed prioritization tool.

6.1. The approach used

The development of the prioritization tool is achieved by the application of the development path introduced in section 3.1, to the case of the forestry sector in Nicaragua.

Thus, for the research approach, the concept for the development of the prioritization tool is adjusted according to the sectoral and geographical focuses stated in the objectives (Figure 6). Bosawas Biosphere Reserve was chosen as a case study area for this work on the basis of suggestion from the side of government representatives, and due to the availability of information regarding climate change impacts in that area (Centro Alexander von Humboldt, 2013).

Further, this work focuses on steps four to seven of the conceptual framework (see section 3.1), namely the identification of adaptation measures, the definition of criteria for analysis and the prioritization of adaptation measures.

In the study, the forestry sector is considered not only as a commercial activity related to forests, but as extended to the management of natural resources in forests. Therefore, goods and services from ecosystems are taken into account, as well as socio-economic aspects of forest management. Also, the measures presented in this work are considered as planned adaptation measures, because they intend to actively intervene in the natural conditions.

In the following, the approach is explained with respect to the three specific objectives of this study, as they are part of the conceptual framework explained in section 3.1.

Regarding the **identification of potential adaptation measures**, since adaptation in natural ecosystems is “an autonomous process”, it is difficult to identify measures, which exclusively work for adaptation. Therefore, the authors also consider measures which make use of the synergy between mitigation and adaptation to climate change as well as approaches that can be related to resource management, such as agroforestry systems and watershed management approaches, which have a direct or indirect impact on the forestry sector.

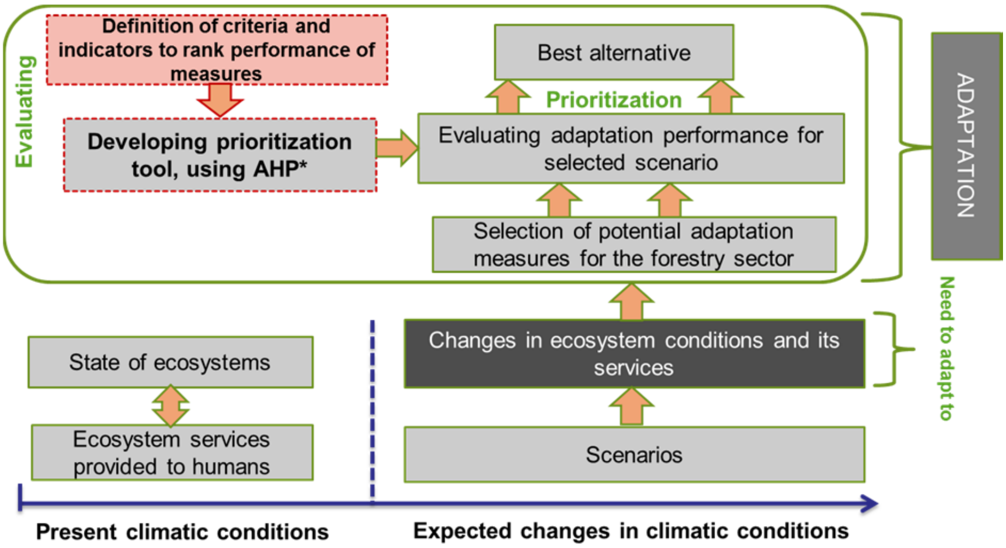

Figure 6 Framework for the evaluation of adaptation measures
Source: Own elaboration

For the creation of the **list of criteria, sub-criteria and indicators,** which allows for the evaluation of each measure, the authors consider the definitions proposed by CIFOR (1999, p. 9). Criteria and sub-criteria are defined as "the intermediate points to which the information provided by the indicators can be integrated and where an interpretable assessment crystallizes". The criteria can be categorized as part of different components on different levels. Indicators are defined as "any variable or component of the forest ecosystem or management system used to infer the status of a particular criterion". For the weighting of the criteria, the authors decided to consider the weights presented in Mendoza & Prabhu (2000) and the suggestions made by governmental and non-governmental representatives during the information gathering process.

For the **development** of the climate change adaptation **prioritization tool,** the authors use a multi-criteria analysis, using the Analytic Hierarchy Process (AHP) developed by Saaty (1990, 2008). The decision was made based on the advantage of being able to have a participative instrument, which allows including non-monetary aspects in the decision-making for climate change adaptation in the forestry sector. Also, the AHP, compared with other MCA methods, gives clear recommendations.

6.2. The developed tool

This sub-chapter describes the structure of the tool developed which, as mentioned before, is focused on the steps four to seven of the conceptual framework presented in section 3.1, namely the identification of adaptation measures, the definition of criteria for analysis and the prioritization of adaptation measures.

In chapter 5, the four different potential adaptation measures which could be implemented in the case study area were already described. Therefore, this sub-chapter presents the proposal of criteria, sub-criteria and indicators –in a hierarchical structure- which will be used in order to prioritize the adaptation measures. The results of the weighting process which lead to the definition of priorities among the proposed tool is also presented.

6.2.1. Proposal of standard list of criteria, sub-criteria and indicators

Presented here is a description of the different indicators selected for use for the evaluation of climate change adaptation measures for the forestry sector. The selected criteria, sub-criteria and indicators are meant to be used by a multidisciplinary group to evaluate the performance of the measures, taking into account the timescales and the baseline of the measure implementation.

It has already been mentioned that when planning for climate change adaptation, different dimensions have to be considered. In order to achieve this requirement, the criteria (**Level 1**) that are considered in this study are:

- Environmental and climate-related
- Economic
- Social
- Institutional criteria
- Financing needs
- Implementation barrier

For the specific case study area of this research, the inclusion of social aspects, such as participation of indigenous/local communities, was very important due to forest location, ownership and national legislation.

The indicators were formulated not only in such a way that they could be a standard and used in different areas, but that they can also be adapted to specific conditions of different areas depending on the quality and availability of the information and expertise of decision-makers or practitioners.

As a result of the analysis for the definition of the criteria, sub-criteria and indicators to be used to evaluate the adaptation measures in the forestry sector, this study presents four levels of hierarchy. The proposed hierarchy is a modification of the hierarchical criteria tree proposed by UNEP (2011).

The criteria and indicators are presented as a hierarchy, as defined in Saaty (2008) where a set of alternatives to be evaluated (**level 4**) through the use of 26 indicators (**level 3**) is proposed. The indicators are comprised within 11 sub-criteria (**level 2**) and 6 different criteria (**level 1**), which are grouped in the only objective of prioritization of the adaptation measures in a hierarchical structure (Figure 7).

A more detailed description of the proposed indicators is presented in the following. The indicators are ranked according to their classification in sub-criteria and criteria, as presented in the hierarchy. The description includes the explanation of the evaluation when comparing the different measures identified for the prioritization process, which can guide the “intensity of importance”, defined according the fundamental scale of absolute numbers from Saaty (2008), presented in Table 2 in section 3.2.1.

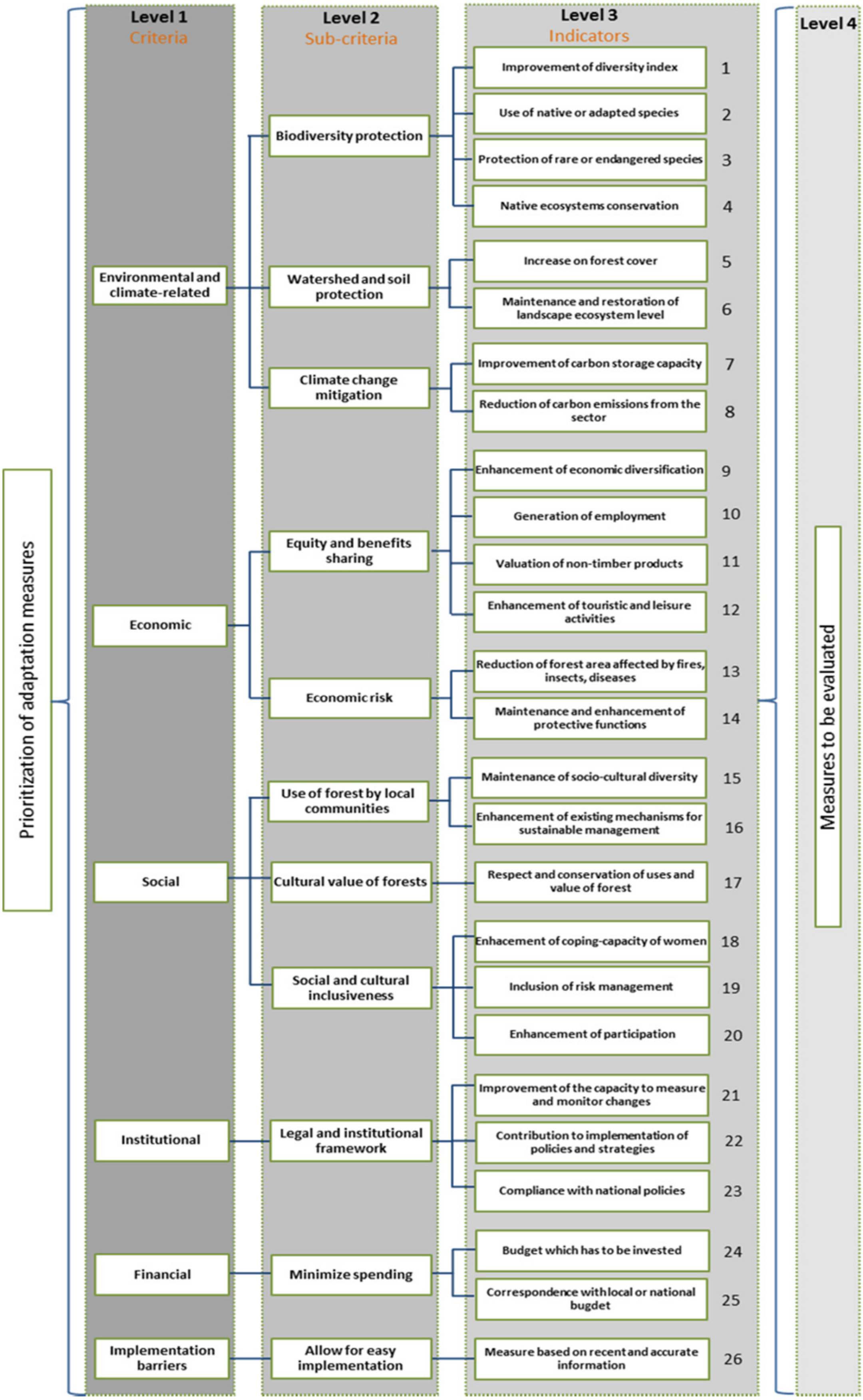

Figure 7 Hierarchical representation of defined criteria and sub-criteria for a prioritization tool for climate change adaptation in the forestry sector
Source: Own elaboration, based on UNEP (2011)

Criterion: Environmental *and Climate-related*

Sub-criterion: Biodiversity Protection

1.	**Indicator**	**Improvement of diversity index (natural capital index)**
Description:		If measure improves the diversity index. Natural Capital Index (NCI) was designed in order to provide information on biodiversity trends at national or territory level. For Nicaragua, it has been developed using two different land use maps (1999-2010), infrastructure map and map of fire spots. The formula to get the NCI is given by 1-ICN= biodiversity loss (MARENA-SINIA, 2011). Besides the environmental benefits, biodiversity can offer economic benefits which in turn benefits and improves resilience of local communities (Laurent, 2003). Therefore, the more the measure improves the diversity index, the more the measure enhances climate change adaptation of the ecosystem and communities.
Explanation of evaluation:		The more the measure improves the diversity index, the higher the score in the fundamental scale.
2.	**Indicator:**	**Use of native or adapted species**
Description:		If proposed measure includes the use of native or adapted species to changing conditions. Normally, native species are able to adapt to changing conditions (in certain range of changes). Adapted species will have higher tolerance to changes in their environment compared to non-native or non-adapted species (Laurent, 2003).
Explanation of evaluation:		The more native or adapted species are used, the higher the score in the fundamental scale.
3.	**Indicator:**	**Protection of rare or endangered species**
Description:		If proposed measure includes protection of rare or endangered species. Safeguarding the largest possible diversity of genetic resources is important to have genetic varieties available which are suitable for a broad range of climatic conditions (GIZ, 2014).
Explanation of evaluation:		The more the measure enhances the protection of rare or endangered species, the higher the score in the fundamental scale.
4.	**Indicator:**	**Native ecosystem conservation as contribution of local fauna and flora to local resilience and adaptability to climate change**
Description:		If proposed measure promotes the conservation of native ecosystems which may increase the resilience and help natural adaptation of the ecosystems to changing climatic conditions. Healthier ecosystems are able to deliver ecosystem services that help people to adapt to climate change (GIZ, 2014). The conservation of native ecosystems can be achieved through the definition of conservation zones or protected areas, as well as minimizing the fragmentation of the natural ecosystems (Fischlin et al., 2007; Innes et al., 2009).
Explanation of evaluation:		The more the measure enhances the protection and conservation of native ecosystems, the higher the score in the fundamental scale.

Sub-criterion: Watershed and soil protection

5.	**Indicator:**	**Increase on forest cover (%)**
Description:		If proposed measure helps to improve forest cover which leads to maintain watershed and soil protection services (filter capacity, water storage potential and soil loss (USLE-based) (Andreu et al., 2012; Innes et al., 2009).
Explanation of evaluation:		The more the measure increases the forest cover, the higher the score in the fundamental scale.
6.	**Indicator:**	**Contribution to maintenance and restoration of landscape ecosystems level**
Description:		If proposed measure contributes to maintenance and restoration of landscape ecosystem level. There is much agreement and evidence that for subtropical and tropical ecosystems, the maintenance and restoration of its ecosystems is an option for climate change adaptation (Innes, et al., 2009).
Explanation of evaluation:		The more the measure contributes to maintenance and restoration of landscape, the higher the score in the fundamental scale.

Sub-criterion: Climate change mitigation

7.	**Indicator:**	**Improvement of carbon storage capacity (%)**
Description:		If adaptation measure helps to improve the storage of carbon per hectare (tonsC/ha). From the tree biomass, it is possible to estimate how much CO_2 is fixed in forest areas and other areas with tree cover. Recover of forest cover enhance carbon sequestration. While transition is taking place, from one age to the next, biomass per hectare increases, meaning that carbon sequestration increases as well (Rudel, et al., 2005). This is seen as a co-benefit of the adaptation measures in the forestry sector.
Explanation of evaluation:		The more the measure improves the carbon storage capacity, the higher the score in the fundamental scale.
8.	**Indicator:**	**Reduction of carbon emissions from the sector (%)**
Description:		If proposed measure helps to reduce emissions from forestry or agricultural sector. A co-benefit of the adaptation measure is the reduction of GHG from land-use changes (Innes, et al., 2009).
Explanation of evaluation:		The more the measures reduce carbon emissions, the higher the score in the fundamental scale.

Criterion: Economic

Sub-criterion: Equity and benefits sharing of economic revenues from forestry sector

9.	**Indicator**	**Enhancement of economic diversification of forest-based communities**
Description:		If proposed measure helps to diversify the economic activities of forest-based communities (for example, through promotion of use or commercialization of non-timber products, dead wood product markets, value added products). Communities depending on a single or very few forest products have less range of responses to climate change, therefore are more vulnerable than those using timber and non-timber products (Innes, et al., 2009).
Explanation of evaluation:		The more the measure improves economic diversification, the higher the score in the fundamental scale.

10. Indicator:	Generation of employment
Description:	If proposed measure enhances generation of employment in forest-based communities (positive trend). Even when there is not much information regarding the incidence of adaptation on the economic conditions, it can be considered that the improvement of the socio-economic conditions of forest-based communities will lead to an increase in their ability to cope with the impacts of climate change (UNDP, 2004).
Explanation of evaluation:	The more the measure helps employment generation, the higher the score in the fundamental scale.
11. Indicator:	**Valuation of non-timber products**
Description:	If proposed measure enhances valuation of non-timber products as direct use of products or services for subsistence, recreational, traditional or cultural purposes. Values can be estimated from the similar goods and services that are exchanged in a market. There is much evidence and agreement that the valuation of non-timber products helps to maintain and enhance multiple tangible socio-economic benefits in forests for the long-term (Innes, et al., 2009).
Explanation of evaluation:	The more the measure enhances the valuation of non-timber products, the higher the score in the fundamental scale.
12. Indicator:	**Enhancement of touristic and leisure activities**
Description:	If proposed measure stimulates, directly or indirectly, touristic and leisure activities. For the Subtropic regions, there is much agreement that the expansion of tourism and recreational services helps to maintain and enhance multiple tangible socio-economic benefits in forests for the long-term (Innes, et al., 2009).
Explanation of evaluation:	The more the measure enhances touristic and leisure activities, the higher the score in the fundamental scale.

Sub-criterion: Economic risk due to hazards, pests, etc.

13. Indicator:	Reduction of area of forest affected by fires, insects, and diseases
Description:	If proposed measure helps to reduce areas affected by fires, insects and diseases which reduce economic losses. According to Innes et al. (2009) the incidence of fires, insects, and diseases on forest ecosystems has direct impacts on the livelihoods and welfare of local people due to the affectation of the ability of ecosystems to provide environmental goods and services.
Explanation of evaluation:	The more the measure helps to reduce areas affected by fires, insects and disease, the higher the score in the fundamental scale.
14 Indicator:	**Maintenance and appropriate enhancement of protective functions of the forests**
	If measure maintains and enhances the protective functions of forest against natural hazards, which reduces economic, social and cultural risks. Forest ecosystems have the ability to overcome harmful impacts of climate change and management of forests is needed in order to guarantee the protective functions at the ecological and socio-economic level (Sakals et al. 2006; Innes et al., 2009).
	The more the measure helps to maintain the protective functions of the forest, the higher the score in the fundamental scale.

Criterion: Social

Sub-criterion: Use of forests by local communities

15.	Indicator	Maintenance of socio-cultural diversity of indigenous and local communities
Description:		If proposed measure enhances or maintains socio-cultural diversity (protect traditional knowledge, innovations, and practices, including their rights to benefit sharing). There is much agreement that the inclusion of socio-cultural diversity in the decision-making process helps maintain and enhance multiple tangible socio-economic benefits in forests for the long-term (Innes, et al., 2009).
Explanation of evaluation:		The more the measure helps or considers socio-cultural diversity, the higher the score in the fundamental scale.
16.	**Indicator:**	**Enhancement of existing mechanisms for sustainable management of the forests through local/indigenous communities**
Description:		If proposed measure makes use of the existing mechanisms for sustainable forest management, taking into account local/indigenous communities. There is evidence and agreement that the local welfare can be enhanced through the promotion of community-based forest management and restoration activities (Innes, et al., 2009).
Explanation of evaluation:		The more the measure helps or considers socio-cultural diversity, the higher the score in the fundamental scale.

Sub-criterion: Cultural value of forests

17.	Indicator:	Respect and conservation of uses and value of forest for local/indigenous communities
Description:		If proposed measure promotes or enhances the uses and values that forests have for local or indigenous people. This indicator refers to the measurement of values and attitudes towards forestry, uses of forests, and other perceptions about forest-related activities. The goal is to comprehend the perceptions and understandings of forestry held by different groups, and what they value about forests. There is much agreement that the integration of local and community knowledge about past and current changes is part of adaptation (Innes, et al., 2009).
Explanation of evaluation:		The more the measure respects and conserves traditional uses and values, the higher the score in the fundamental scale.

Sub-criterion: Socio-cultural inclusiveness

18.	Indicator:	Enhancement of coping-capacity of women
Description:		If measure maintains and enhances the protective functions of forest against natural hazards, which reduces social and cultural risks. Forest ecosystems have the ability to overcome harmful impacts of climate change and management of forests is needed in order to guarantee the protective functions at the ecological and socio-economic level (Sakals et al. 2006; Innes et al., 2009).
Explanation of evaluation:		The more the measure helps to maintain the protective functions of the forest, the higher the score in the fundamental scale.

19. Indicator:	Inclusion of risk management
Description:	If measure takes into account risk management aspects in order to increase capacity for risk management (drought, floods, storms, wildfires, pests, etc.). For tropical areas, there is not much evidence, but agreement that risk management enhances at the long-term multiple tangible socioeconomic benefits in forests (Innes, et al., 2009).
Explanation of evaluation:	The better the measure includes risk management aspects, the higher the score in the fundamental scale.
20. Indicator:	**Enhancement of participation of local/indigenous communities**
Description:	If proposed measure takes into account or enhances participation of local/indigenous communities in forest management activities. There is much evidence and agreement that the enhancement of the participation of local/indigenous communities ensures community governance and equitable sharing of benefits among the community, which further enhances multiple tangible socio-economic benefits in forests for the long-term (Innes, et al., 2009).
Explanation of evaluation:	The more the measure enhances participation of local/indigenous communities, the higher the score in the fundamental scale.

Criterion: Institutional

Sub-criterion: Legal and institutional framework for forest conservation and sustainable management

21. Indicator	Improvement of the capacity to measure and monitor changes in the conservation and sustainable management of forest
Description:	If measure improves or reinforces the monitoring activities for forestry sector. There is much evidence and agreement that in tropical regions, the improvement of monitoring capacities supports the same aim of the legal and institutional framework, namely maintaining and increasing forest areas (Innes, et al., 2009).
Explanation of evaluation:	The more the measure improves the monitoring capacities, the higher the score in the fundamental scale.
22. Indicator:	**Contribution to the implementation of policies and strategies forest / rural sector**
Description:	If measure contributes to the implementation of national, subnational and local policies and strategies. The enforcement and implementation of policies in areas that are affected by illegal logging is considered as an option in order to maintain or increase forest areas (Innes, et al., 2009).
Explanation of evaluation:	The more the measure contributes to the implementation of policies and strategies, the higher the score in the fundamental scale.
23. Indicator:	**Rate of compliance with national policies and forest management laws and regulations**
Description:	If proposed measures comply with the local and national institutional framework. There is much evidence and agreement that in tropical regions, law enforcement contributes to maintain or increase forest areas (Innes, et al., 2009).
Explanation of evaluation:	The more the measure complies with national legal framework, the higher the score in the fundamental scale.

Criterion: Financing needs

Sub-criterion: Minimize spending on technology and other types of spending

24.	Indicator:	Budget which has to be invested in order to implement the measure
Description:		The budget needed to be allocated in order to implement the measure (direct costs of adaptation measure implementation). Financing is presented as one of the bigger barriers for implementation of adaptation measures in the forestry sector. There is a need to estimate costs and benefits of the alternatives to adapt (Roberts, Parrota, & Wreford, 2009).
Explanation of evaluation:		The less the financial resources needed for the implementation of the measure, the higher the score in the fundamental scale.
25.	**Indicator:**	**Correspondence with local or national budget planning**
Description:		If proposed measure complies with local or national budget planning. Information regarding cost and benefits of projects are important for both the project-related decision-making as well as at the politic level. Sometimes this issue turns into a barrier for the implementation of adaptation measures (Roberts et al., 2009; Heuson et al., 2012).
Explanation of evaluation:		The more the measure corresponds to local or national planning, the higher the score in the fundamental scale.

Criterion: Implementation barriers

Sub-criterion: Allow for easy implementation

26.	Indicator:	Measure is based on recent and accurate information
Description:		If measure is based on recent and accurate information. Recent and accurate information helps to determine the need for implementation of adaptation measures, which in the long-term will help to enhance the multiple intangible socio-economic benefits (Innes, et al., 2009).
Explanation of evaluation:		The more the measure is based on recent and accurate information, the higher the score in the fundamental scale.

6.2.2. Weights among criteria, sub-criteria and indicators

In order to obtain a global priority, which represents the prioritization among the different alternatives being evaluated, the Analytic Hierarchy Process (AHP) requires the definition of weights (priorities) across and within the different levels. Therefore, the pairwise comparison has to be developed throughout the different levels which comprise the hierarchy.

For the developed tool, the pairwise comparison was used to obtain the weights among the sub-criteria and indicators. The results of the pairwise comparison and the definition of its weights (priorities) are presented in this section. This serves as a basis for the prioritization and evaluation among the identified adaptation measures; therefore, after obtaining the weights among the criteria, sub-criteria and indicators, the evaluation of the different adaptation measures, has to be performed. A detailed example of the weighting process using the pairwise comparison is presented in the following chapter.

It has to be pointed out that in this section only the results of the prioritization process among the different criteria, sub-criteria and indicators are presented. Also, the weighting process was performed only by the authors –as an empirical exercise-. Normally, however, it should be the result of a participative process, counting on knowledge, expertise and experience of different stakeholders.

The weights among the criteria **(CP)** (level 1) were defined considering the results obtained by Mendoza & Prabhu (2000) as well as through suggestions gathered in the open and semi-structured interviews performed during the development process of the tool (Figure 8). Considering this information, the criteria which has the most weight is “environmental and climate-related”, followed by “social” and “financial needs”.

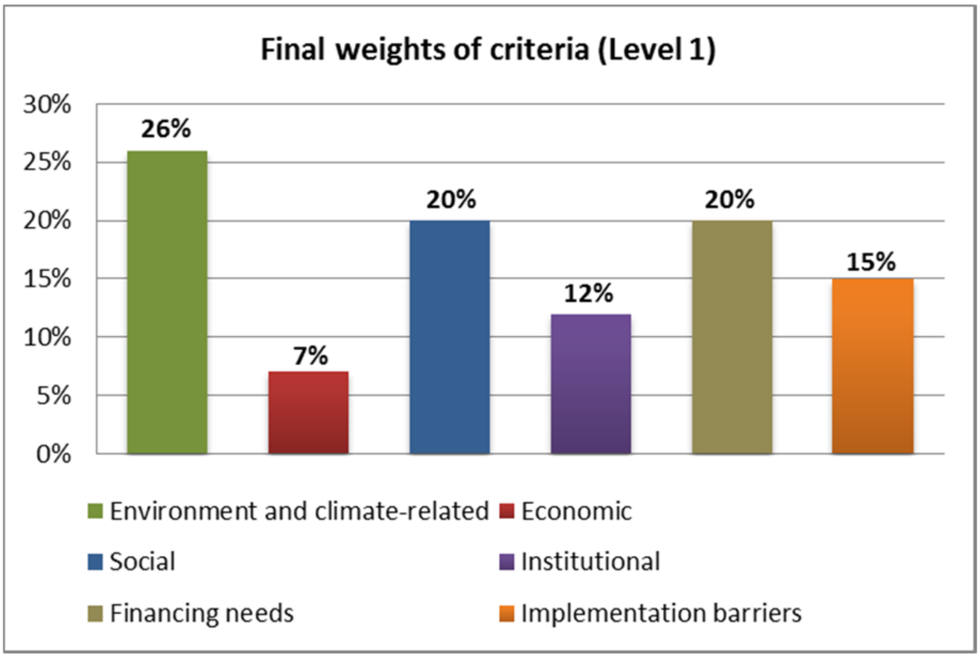

Figure 8 Final weights of criteria (level 1)

The weight of every sub-criteria of the second level **(SP)** was obtained by multiplying its weight (obtained by the pairwise comparison among the sub-criteria grouped in the same criteria) by the importance of its parent criterion or upper level (meaning results of level 1). The weight of every indicator **(IP)** was obtained by multiplying its priority (among all the indicators grouped in the same sub-criterion) by the weight of its parent sub-criteria (results of level 2). The sum of every level priority must equal one.

Table 6 and Figure 9 present the result of the weighting process (using the pairwise comparison) of the sub-criteria (level 2) and indicators (level 3). Due to lack of space Table 6 is divided into two parts where the upper part is followed on the right hand by the lower part.

Table 6 Synthesizing weights (priorities) of criteria, sub-criteria and indicators

Part 1

L1	**Environment and climate-related**								**Economic**					
CP	*0.26*								*0.07*					
L2	**Biodiversity Protection**				**Watershed and soil protection**		**Climate change mitigation**		**Distribution of economic benefits**				**Economic risks reduction**	
	0.14				*0.57*		*0.29*		*0.75*				*0.25*	
SP	*0.036*				*0.148*		*0.075*		*0.053*				*0.018*	
L3[6]	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***	***13***	***14***
	0.111	*0.175*	*0.424*	*0.290*	*0.500*	*0.500*	*0.250*	*0.750*	*0.250*	*0.250*	*0.250*	*0.250*	*0.751*	*0.249*
IP	*0.004*	*0.006*	*0.015*	*0.011*	*0.074*	*0.074*	*0.019*	*0.057*	*0.013*	*0.013*	*0.013*	*0.013*	*0.013*	*0.004*

Part 2

L1	**Social**						**Institutional**			**Financial needs**		**Implementation barriers**	**Sum (level)**
CP	*0.20*						*0.12*			*0.20*		*0.15*	*1,00*
L2	**Use of forests for local communities**		**Cultural values of forests**	**Social and cultural risks**			**Legal and institutional framework**			**Minimize spending**		**Easy implementation**	
	0.44		*0.32*	*0.24*			*1.00*			*1.00*		*1.00*	
SP	*0.088*		*0.064*	*0.048*			*0.120*			*0.200*		*0.150*	*1.00*
L3	***15***	***16***	***17***	***18***	***19***	***20***	***21***	***22***	***23***	***24***	***25***	***26***	
	0.75	*0.25*	*1.00*	*0.45*	*0.23*	*0.32*	*0.14*	*0.43*	*0.43*	*0.50*	*0.50*	*1.00*	
IP	*0.066*	*0.022*	*0.064*	*0.022*	*0.011*	*0.015*	*0.017*	*0.051*	*0.051*	*0.100*	*0.100*	*0.150*	*1.00*

***L1, L2, L3:** Level 1, Level 2 and Level 3
***CP:** Criteria prioritization; **SP:** Sub-criteria prioritization; **IP:** Indicators prioritization

Figure 9 presents the hierarchical structure of the tool, together with the given weights of every criterion, sub-criteria and indicators presented in the previous table. In level 1 (criteria), the global priority of each criterion regarding the final objective (prioritization of the measures) is shown.

In level 2 (sub-criteria) two weights are presented: the weight of that sub-criterion among the sub-criteria grouped in the same criteria (each one of them identified with the same range of colors), and the weight of the sub-criteria among all other sub-criteria presented in the same level (in black square).

[6] Numbers in Level 3 are referred to the number assigned to each indicator (see section 6.2.1)

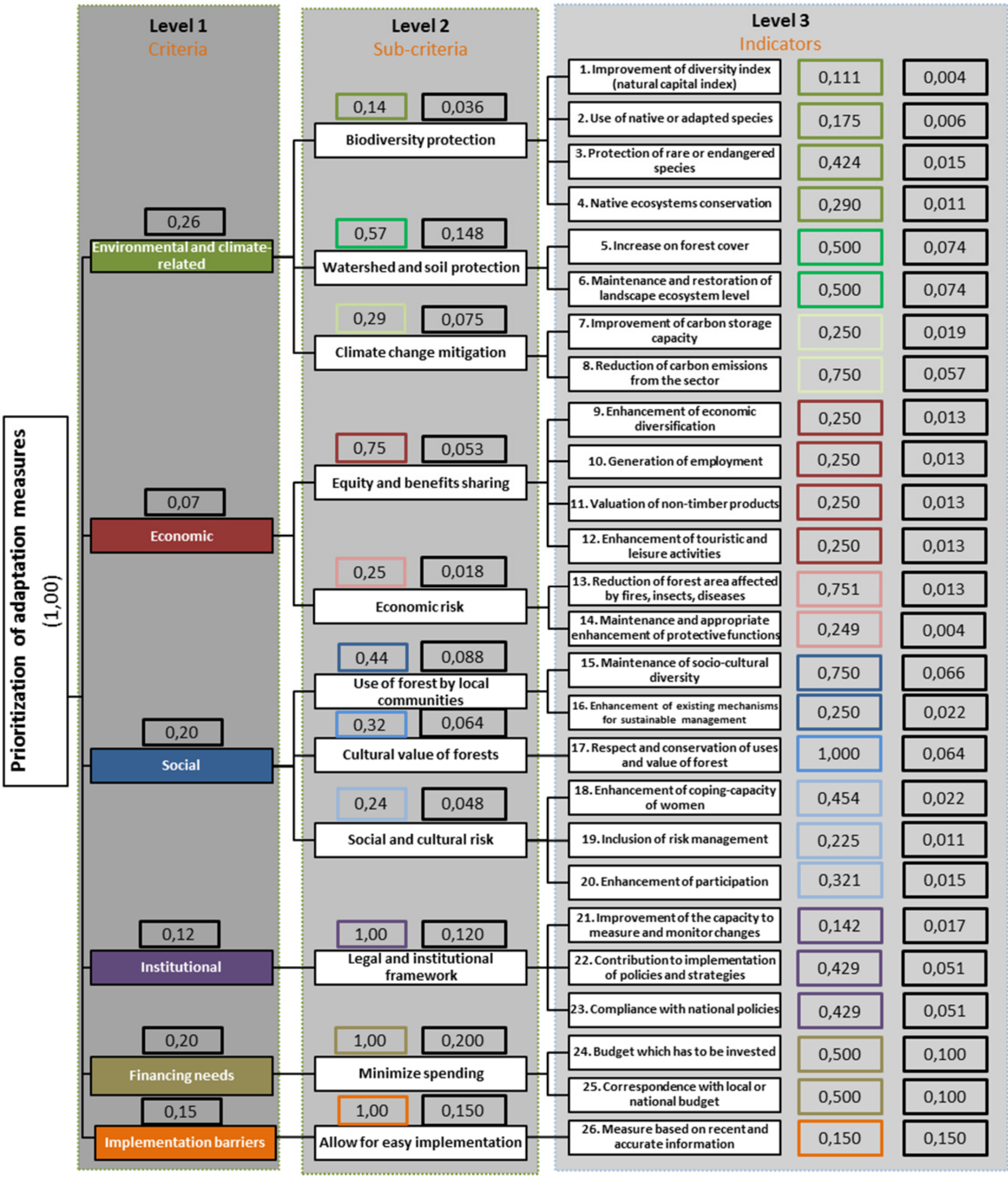

Figure 9 Priorities among criteria, sub-criteria and indicators

In the case of level 3 (indicators) there are also two weights presented: the weight of each indicator among the indicators grouped in the same sub-criteria (identified with the same color), and the weight of the indicator among all indicators (in black square).

For example, the priority (weight, in black square) of the “biodiversity protection” sub-criterion (level 2) among the other sub-criteria grouped within the “environmental and climate-related” criterion was obtained by multiplying 0,14 (weight of the sub-criterion, obtained through the pairwise comparison) by 0,26 (weight of the criterion where it is grouped).

In the case of the indicator “improvement of diversity index”, in level 3, its weight was obtained by multiplying 0,111 (its weight obtained through the pairwise comparison) by 0,04 (weight of the “biodiversity protection” sub-criteria where it is grouped).

Figure 10 and Figure 11, show in a graphical way the results of the weighting process among sub-criteria (level 2) and indicators (level 3). The colors of the sub-criteria and indicators indicate to which criteria they are associated.

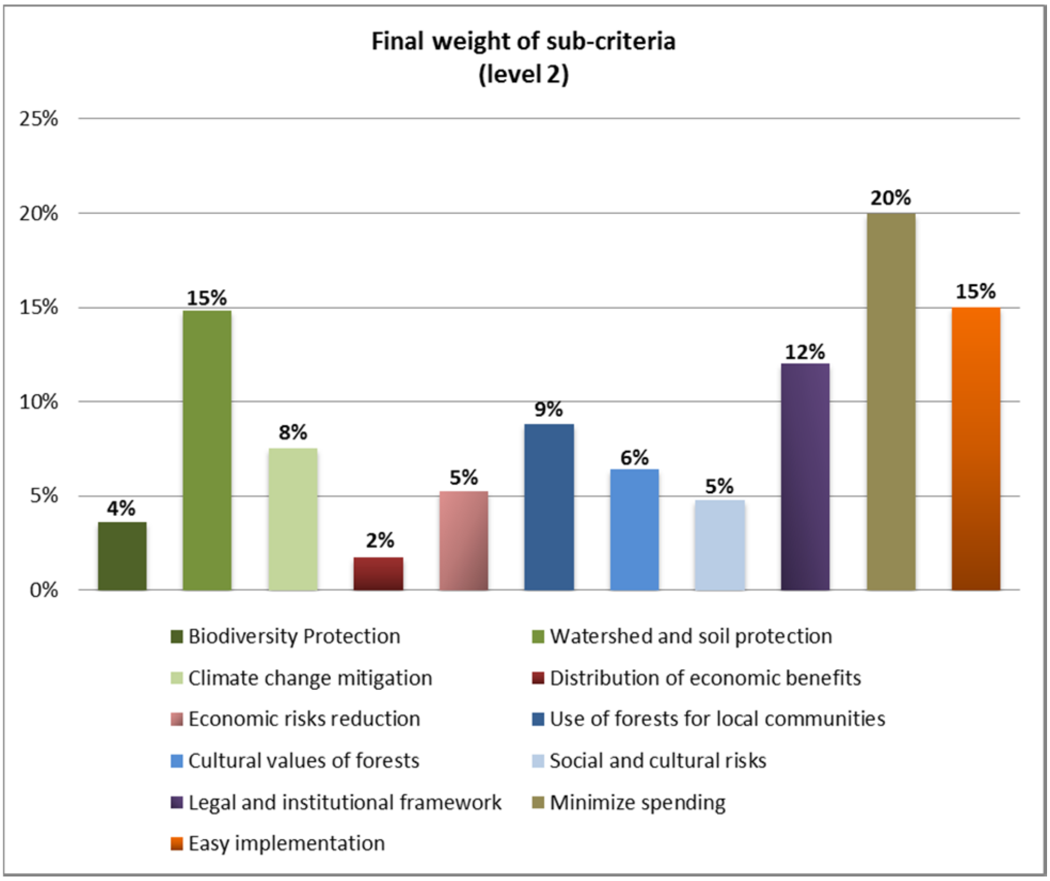

Figure 10 Final weights of sub-criteria (level 2)

Among the sub-criteria (level 2), the sub-criterion of minimizing spending on the implementation of climate change adaptation measures is ranked as the one with the greatest weight (20%).

Among the indicators (level 3), the indicator number 26 “measure is based on recent and accurate information”, which is a standalone indicator within the “implementation barrier” criterion, is the one with the highest weight (Figure 11).

In Figure 11, the weight of each indicator among the different criteria can also be observed. For example, in the environmental criteria, the ones with higher weights are “increase of forest cover" (No. 5) and "contribution to maintenance and restoration of landscape ecosystems" (No. 6).

Among the economic-related indicators, the ones with the highest weights are "reduction of area of forest affected by fires, insects and diseases" (No. 14) and "enhance of economic diversification" (No. 10).

In the case of the social-related criteria, the ones with the highest weights are "maintenance of socio-cultural activities" (No. 15) and "respect and conservation of uses of forest for local/indigenous communities" (No. 17).

In the institutional criteria, the indicators "contribution to implementation of policies and strategies" (No. 22) and "rate of compliance with national policies, laws and regulations" (No. 23) are the ones with the highest weights.

In the case of the indicators grouped in the financing needs criteria, both of them have equal weights. There was not enough accurate information related to economic resources allocated to adaptation to climate change.

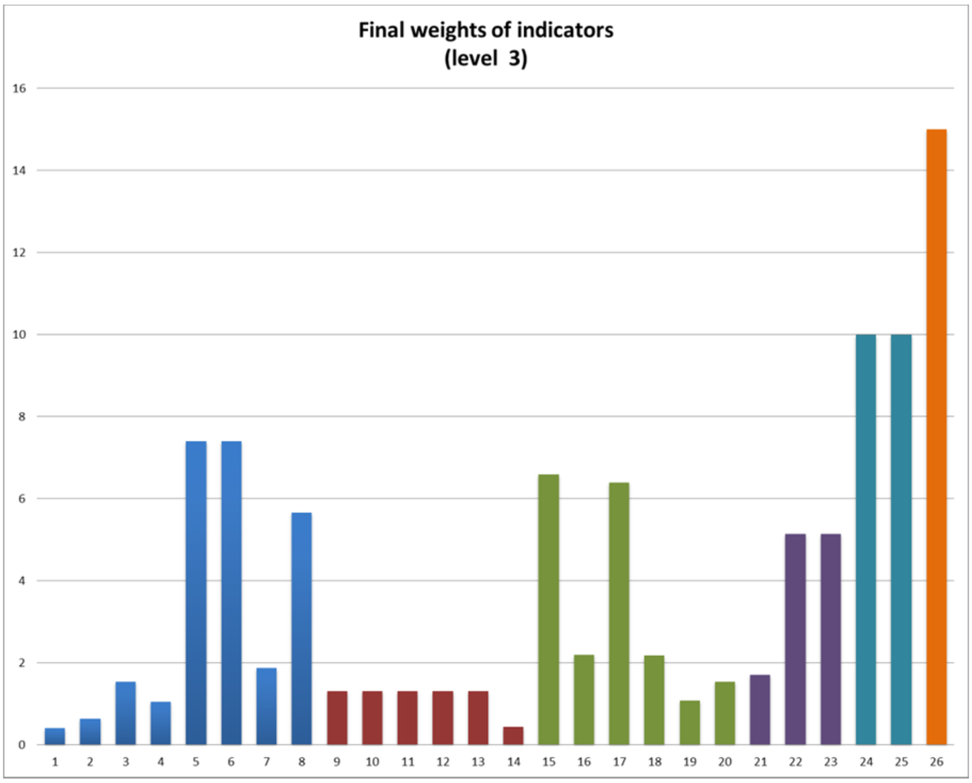

Figure 11 Final weights of indicators (level 3)

7. Using the prioritization tool

A method for prioritization has to be used in order to identify which adaptation measure, from the ones presented in the Annex 11.1, is more suitable to be implemented according to the previously defined criteria and indicators (section 6.2). In this case, the selected method is a Multi-Criteria Analysis (MCA) tool using the Analytic Hierarchy Process (AHP) based on Saaty (1990, 2008), which was described in section 3.2.1.

Therefore, after explaining the structure of the proposed prioritization tool, how the tool can be used, based on the information given for the case study area (chapter 4) and the evaluation of the adaptation measures (chapter 5) is explained in this chapter. The steps presented in the following sections were performed for the weighting process among sub-criteria and indicators of the proposed tool.

7.1. Weighting of the measures using the pairwise comparison

Each potential adaptation measure presented in chapter 5 which, according to the hierarchical structure of the tool presented in Figure 7 is located in level 4, has to be analyzed against each indicator (level 3). Also, each sub-criterion (level 2) and indicator has to be weighted based on their specific level according to the hierarchical structure and to a set of pairwise comparison matrices using the Saaty scale (Table 2).

As previously mentioned, for level 1 the weights were defined based on literature and suggestions collected from interviews with Nicaraguan officers. Therefore, for level 1 the weights are distributed as following: 26% to Environment and Climate-related, 7% to Economic, 20% to Social, 12% to Institutional, 20% to Financing Needs, and 15% to Implementation Barriers.

The empirical example to demonstrate how the prioritization process was carried out for the sub-criteria, indicators and alternative levels using the AHP method is presented in the following. The calculations for the weighting process for all sub-criteria, indicators and alternatives were performed in an Excel spreadsheet.

It is important to mention that in the presentation of the example of the weighting process, as a way to present the empirical exercise –considering the case study-, only the author's judgment is exposed. Although, in order to obtain unbiased results, the weighting process should be performed by specialists and experts in the sector the general objective and specialized information on the area still need to be taken into account.

The example presented in Table 7 presents the pairwise comparison matrix using the levels 4 (alternatives or measures to be evaluated) and 3 (indicators) of the developed prioritization tool presented in Figure 7.

Here, the performance of the four different adaptation measures with respect to the indicator number 1 (improvement of natural capital index) is evaluated. The comparison was developed by the authors using the Saaty scale, employing the range of equal importance to extreme importance presented in Table 2 in section 3.2.1.

In a first step, in order to determine the preferences, the Saaty scale is used, considering the explanation of the evaluation (included in the description of each indicator) and the evaluation of each measure.

Table 7 Example of a pairwise comparison matrix using the Saaty scale, comparing the adaptation measures (A, B and C) with respect to one indicator

Indicator 1: Improvement of natural capital index

Pairwise comparison

A. Rehabilitation of ecosystems through the establishment of agroforestry systems
B. Conservation, reforestation and natural regeneration
C. Establishment of forestry management system

	A	B	C
A	1	1/3	5
B	3	1	7
C	1/5	1/7	1

How to read the pairwise comparison matrix?

In accordance with Saaty (2008), the judgment of the authors presented as an example in Table 7 should be read comparing the performance of the measure indicated on the left column of the table with the measure indicated at the top, with regards to the improvement of the natural capital index (indicator 1).

Using the example, the first step is to compare each measure with itself. For example, measure A (rehabilitation of ecosystems) with measure A. The result of this comparison (same options) is always 1. In the example, these comparisons are framed in the dotted square.

The second step is to compare different measures. Here, a judgement has to be made as to how many times better a measure performs with respect to the other (pairwise comparison). Examples of pairwise comparisons are presented in the red, green and orange squares.

Following the example, when comparing measure B with measure A (see red squares), one has to read that “measure B *has a moderate importance* (value 3 of the fundamental scale) when comparing with measure A". As the value of the comparison between measure B and measure A was 3, it is stipulated that 1/3 is what one needs to use in the measure A to measure B comparison, because according to Saaty (2008, pág. 85) "one always enters the whole number in its appropriate position and automatically enters its reciprocal in the transpose position".

When comparing measure C to measure A (see green squares), one has to read that "measure A *has a strong importance* (value 5 of the fundamental scale) when comparing with measure C". Therefore, its reciprocal number (1/5) is located in the transpose position.

As a summary of the presented pairwise comparison matrix, the judgement of the authors regarding the performance of measure A in relation to the indicator "improvement of natural capital index" should be read as follows: measure B has *a moderate importance* when comparing with measure A; measure A *has a strong importance* when comparing with measure C.

Regarding the performance of measure B: Measure B has a moderate importance regarding measure A; a strong importance regarding measure C.

The pairwise comparison matrix can also be presented in rational numbers, as Table 8 shows. As a next step, the values obtained for every comparison (columns entries) are added together.

Table 8 Pairwise comparison matrix, comparing the adaptation measures with respect to one indicator (rational numbers)

Indicator 1: Improvement of natural capital index

Pairwise comparison		**A**	**B**	**C**
A. Rehabilitation of ecosystems through the establishment of agroforestry systems	**A**	**1,00**	0,33	5,00
B. Conservation, reforestation and natural regeneration	**B**	3,00	**1,00**	7,00
C. Establishment of forestry management system	**C**	0,20	0,14	**1,00**
SUM		**4,20**	**1,48**	**13,00**

7.1.1. Normalization process

After the definition of the importance of a measure, sub-criteria and/or indicators regarding other measures, sub-criteria and/or indicators, a normalization process has to be carried out. The normalized matrix is obtained by using the values presented in the pairwise comparison matrix. As a result of the normalized matrix, the definition of priorities (ranking) is obtained.

Following the example, Table 9 shows how the normalized matrix is obtained. First, each value of every column presented in Table 8 has to be divided by the total sum of its respective column (see blue squares). The sum of each column has to be 1.

Table 9 Calculation of a normalized matrix

Indicator 1: Improvement of natural capital index

Pairwise comparison		A	B	C
A. Rehabilitation of ecosystems through the establishment of agroforestry systems	**A**	$=\frac{1}{4,34}$	$=\frac{0,33}{1,62}$	$=\frac{5}{13,33}$
B. Conservation, reforestation and natural regeneration	**B**	$=\frac{3}{4,34}$	$=\frac{1}{1,62}$	$=\frac{7}{13,33}$
C. Establishment of forestry management system	**C**	$=\frac{0,20}{4,34}$	$=\frac{0,14}{1,62}$	$=\frac{1}{13,33}$
SUM		**1,00**	**1,00**	**1,00**

Table 10 shows the results of the normalization process. After calculating the normalized matrix, the weights can be obtained (priority column). The weights (priority) are obtained via the calculation of the average of every row. The weight (priority) of measure A was calculated as follows:

$$\text{Weight (priority)} = \frac{\boxed{[0,23+0,20+0,38+0,39]}}{4} = 0,30$$

Table 10 Normalized matrix (comparison between measures)

Indicator 1: Improvement of natural capital index

Pairwise comparison		A	B	C	Priority
A. Rehabilitation of ecosystems through the establishment of agroforestry systems	**A**	0,24	0,23	0,38	0,28
B. Conservation, reforestation and natural regeneration	**B**	0,71	0,67	0,54	**0,64**
C. Establishment of forestry management system	**C**	0,05	0,10	0,08	0,08
SUM		**1,00**	**1,00**	**1,00**	**1,00**

How to read the normalized matrix?

According to the values obtained in Table 10 and presented in the “priority” column, the measure that better performs regarding the indicator 1 “improvement of natural capital index” is measure B “conservation, reforestation and natural regeneration”, which obtained the highest value in the rank (0.55). The second measure that better performs is measure A, “rehabilitation of ecosystems through the establishment of agroforestry systems”, which obtained the second highest value (0.30). The measures which obtained the lowest values are measure C “establishment of forestry management systems” (0.10). The rank of the performance of the measures considering the indicator 1 is therefore as follows:

-No. 1: Measure B (0,64)
-No. 2: Measure A (0,28)
-No. 3: Measure C (0,08)

7.1.2. Sensitivity analysis

As mentioned in previous chapters, the AHP allows confirming the consistency of the judgments, through a sensitivity analysis. Table 11 shows the calculations of the consistency ratio, calculated for the example, based on the steps presented in section 3.2.1.

The first step in calculating the consistency ratio is to take every value of every column presented in Table 8 (pairwise comparison matrix) and multiply it by the priority of each option (presented in last column of Table 10). Following the example, the first value (representing the consistency ratio of A/A) presented in Table 11 (blue square) is obtained from the multiplication of 1 (respective value in Table 8) by 0,28, which is the value obtained as the priority of measure, presented in Table 10. The calculation is as follows:

$$CR = 1 * 0{,}28$$
$$\mathbf{CR = 0,28}$$

Table 11 Consistency ratio

	A	B	C	Sum	Eigenvector
A	0,28	0,21	0,37	0,86	3,06
B	0,85	0,64	0,52	2,01	3,12
C	0,06	0,09	0,07	0,22	3,01
Average					**3,07**

After having all the consistency ratio values, the second step is to calculate the Eigenvector of every measure. The Eigenvector is obtained after dividing the sum of every row by the priority of each measure (Table 10). Following the example, the Eigenvector of the measure A is calculated as follows:

$$\text{Eigenvector} = \frac{0{,}86}{0{,}28} = \mathbf{3,07}$$

Once the Eigenvector values are calculated, the Eigenvalue (λmax) is obtained by calculating the average of all Eigenvector values. Therefore, the λmax for the example is **4,21**.

The third step is to calculate the consistency index (CI). The CI for the example is calculated as follows:

$$\text{CI} = \frac{\lambda\,\text{max} - \text{n}}{\text{n} - 1} = \frac{3{,}07 - 3}{3 - 1} = \mathbf{0,03}$$

*Where: ***n*** is given by the dimension of the matrix.

Finally, as a fourth step, the consistency ratio CR of the matrix is calculated. The CR is obtained:

$$\text{CR} = \frac{\text{CI}}{RI} = \frac{0{,}03}{0{,}58} = \mathbf{0,05}$$

*where: RI is given by the Saaty Random indices (Table 3, page 23). As the dimension of the matrix is 4, the RI value is 0,90.

Result of the sensitivity analysis[7]:

As the Consistency Ratio (CR) resulted from the sensitivity analysis is 0.08 which is <0.10, it can be affirmed that the comparison performed as example is acceptably consistent.

7.2. Results: Prioritization of adaptation measures

The steps presented in the previous sections were conducted in order to obtain the prioritization among three of the four different levels of the prioritization tool: sub-criteria

[7] In order to facilitate the process, here are presented some links where the calculations needed for the AHP tool can be performed:
1) http://www.isc.senshu-u.ac.jp/~thc0456/EAHP/AHPweb.html
2) http://bpmsg.com/academic/ahp_calc.php

(level 2) and indicators (level 3) of the developed tool, as well as for the prioritization of the identified adaptation measures (alternatives) (level 4) using the information of the case study area (chapter 5) and the evaluation of the identified alternatives (chapter 6).

Here, the results of the weighting process, which lead to the prioritization of the adaptation measures -making use of the developed tool- , are presented.

7.2.1. Prioritization of the adaptation measures

After obtaining the weights of the criteria, sub-criteria and indicators, the prioritization among the selected alternatives (level 4) was performed. In order to obtain the prioritization of the alternatives, the same procedure for the upper levels of the hierarchy was followed.

First, the pairwise comparison among the alternatives, with respect to their relative preference related to each indicator, was carried out. In this step, the information regarding every measure to be evaluated, related to every indicator, was considered. Here the importance of having the most plausible and accurate information in order to make fair judgments has to be pointed out.

Then, in a second step, the prioritization is given against the twenty six criteria. The prioritization is obtained by multiplying the results of the weight process when comparing every measure against each indicator (level 3) by the weight of the indicators evaluated (level 4). In this step, the prioritization or weight is obtained by the sum of the values of every level.

Figure 12 presents a Radar Graph which allows for the observation of the performance of every measure, pointing out its performance related to each of the 26 proposed indicators. It can be easily observed that measure **B** is the one that performs better in respect to most of the indicators. Measure **C** shows a good performance related to most of the economic indicators, while measure **A** shows a good performance (but not so good as measure **B**) regarding environmental and climate-related indicators.

Table 12, Table 13 and Figure 13 present the final results of the prioritization process of the selected adaptation measures, using the weights of the defined criteria, sub-criteria and indicators. To see the detail of the weight in respect to the indicators, see Annex 11.2.

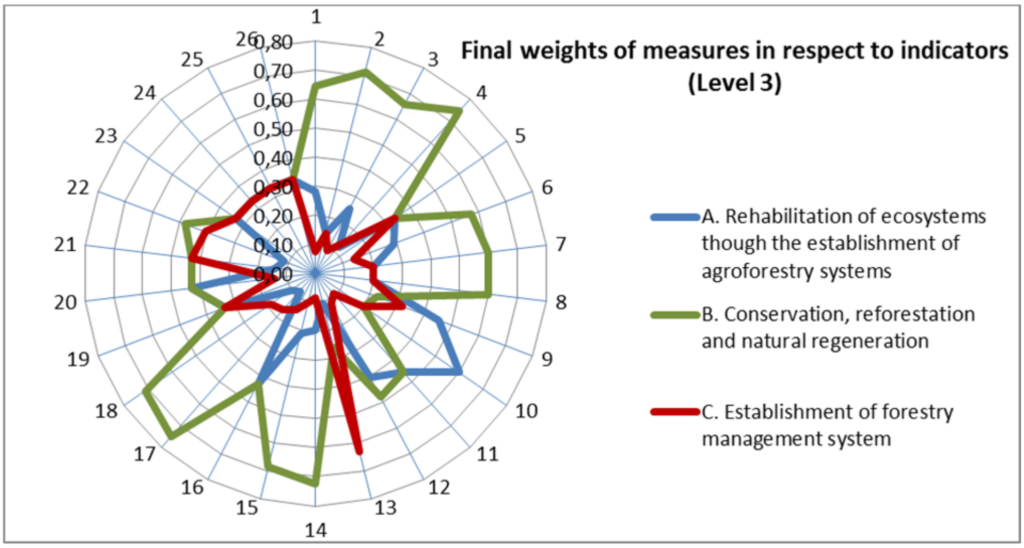

Figure 12 Final weights of measures in respect to indicators

According to the results, the “conservation, reforestation and natural regeneration” measure (measure B) is the one with the highest weight (46%), followed by the “establishment of forestry management systems” (28%), then the “rehabilitation of ecosystems through the establishment of agroforestry systems (26%).

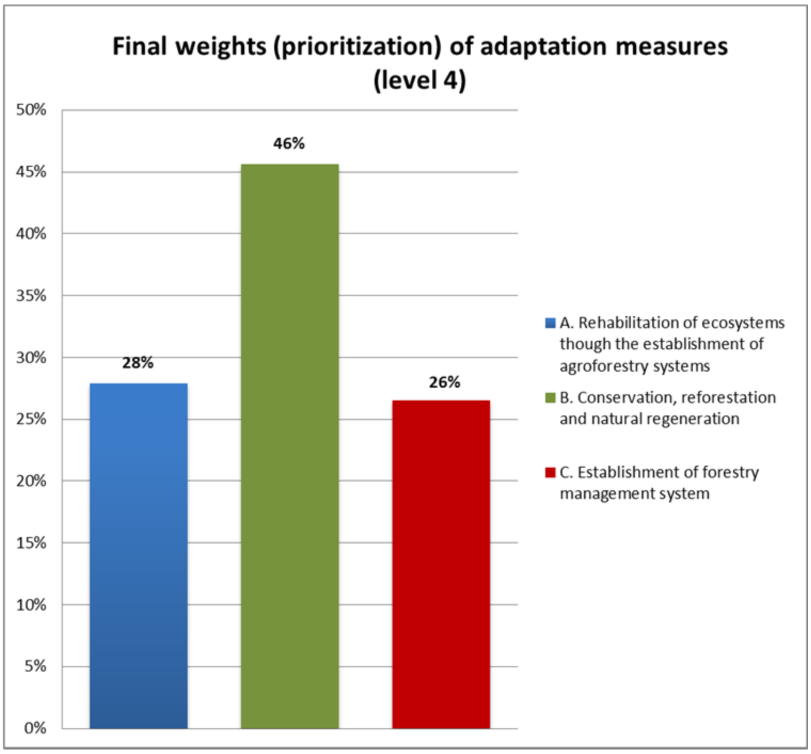

Figure 13 Final weights (prioritization) of adaptation measures

Therefore, the ranking of priorities of the measures considering the different defined criteria, sub-criteria and indicators for the forestry sector in the case study area are presented in Table 12:

Table 12 Ranking of priorities of adaptation measures according to weights

Adaptation Measure		Weight	Ranking
B	Conservation, reforestation and natural regeneration	0.46 (46%)	**1**
A	Rehabilitation of ecosystems though the establishment of agroforestry systems	0.26 (26%)	**3**
C	Establishment of forestry management system	0.28 (28%)	**2**

8. Discussion

In the following, the results obtained in the development process of the tool are discussed with respect to the general and specific objectives laid out in section 1.1.

8.1. Identifying climate change adaptation measures

The identification of the measures was the first step in the prioritization process and represents the first objective of this work. The selected measures were chosen among those suggested by the literature and, more importantly, among those already implemented or in the planning or implementation phase in Nicaragua. All the measures are included as part of local planning instruments.

In the literature related to impacts and adaptation to climate change, three categories of adaptation are listed: autonomous, anticipated and planned adaptation (IPCC, 2007b). For the case study area, consisting of natural ecosystems, the types of identified adaptation are: autonomous and planned.

Regarding planned adaptation, which was of interest in this work, the greatest difficulty during the identification of measures has been the lack of specific information on measures implemented in the case study area. Therefore, measures that are included as part of the Plan for Protection and Management Plan of Bosawas (MARENA, 2012a), but which have not been implemented yet, were considered. At the time of this work, out of the four alternatives presented, only one had been implemented in Bosawas (Measure A). The other three have been implemented or are in the implementation phase in other parts of the country.

It can be noted that, in the documents of project formulation, the measures are not directly identified as adaptation measures for the forestry sector, or even as adaptation measures as such. Most of the alternatives are related to the improvement of watershed management or economic diversification; they are not directly identified as adaptation measures to climate change, which made the process of measurement identification a challenging task. In this respect, the synergy between the approaches for natural resources management was considered (Fischlin et al., 2007; Easterling et al., 2007; Innes et al., 2009; Gebhardt et al., 2011; etc.).

8.2. Definition of criteria, sub-criteria and indicators for evaluation of adaptation measures

The creation of a list of standard criteria and indicators to analyze the measures to climate change adaptation is mentioned as the second specific objective of this work. A set of criteria, sub-criteria and indicators organized as a hierarchy, following Saaty (2008), are a result of this piece of work.

The proposed criteria and indicators intend to include the different aspects of adaptation to climate change for the forestry sector, considering aspects suggested by UN-Habitat (2011), UNEP(2011), and Innes et al. (2009), such as socio-economic aspects, institutional frameworks and local knowledge. Aspects related to sustainable forest management as suggested by Fischlin et al. (2007) were also considered. A special feature of the case study area chosen for the validation of the methodology is the important role of indigenous communities. Therefore, the social aspect of forest use, cultural values, and the distribution of economic benefits, amongst others, had to be included in the list of criteria, sub-criteria and indicators.

The main intension for the list of criteria, sub-criteria and indicators is for it to be used by a group or board of experts and practitioners, applying the AHP method. As the AHP allows doing so, the indicators can be either qualitative or quantitative. Availability of information or expertise is always crucial (Ishizaka & Labib, 2011). The proposed hierarchical structure allows for the adaptation of criteria and indicators, and it is open for comments and reviews by experts and/or practitioners, who will make use of the tool in order to make it applicable in other contexts. Thus, the list provided in this work is not seen to be all-encompassing and comprehensive. It rather provides a first rounding of possible criteria and indicators according to the literature.

For the definition of the list of standard criteria, sub-criteria and indicators, the greatest difficulty was the identification of those criteria and indicators which are related to adaptation in the forestry sector. Widespread presence of that challenge is also mentioned by Saaty (1990) as the most creative task in the AHP process. The most important document related to this specific objective is the “Practical framework for planning pro-development climate policies” provided by UNEP (de Bremond & Engle, 2011).

For the indicators related to financial aspects, the use of complementary economic methods can be suggested. This becomes important since in many cases, adaptation measures are funded by international cooperation agencies. Therefore, the costs, benefits and/or efficiency of implementation can be better analyzed (Vaidya & Kumar, 2006). This is especially important in the light of limited financial resource availability. Those methods can be performed for measures ranked in first places, where the financial aspect is the determinant.

8.3. Prioritization tool

The proposal of a tool for the prioritization of the adaptation measures in the forestry sector was the third and most important objective of this work. To achieve this objective, the authors propose a Multi-Criteria Analysis, using the AHP method in combination with the list of criteria and indicators developed in earlier parts of this work.

For the tool development, this work amended the general concept for the development of such an instrument, which is laid out in the IPCC guidelines (Carter et al., 1994) and in similar proposals for the evaluation of adaptation measures (UNDP, 2004; Nasra et al., 2010; among others).

The innovation proposed in this work is the use of the AHP method in order to include non-monetary criteria in the decision-making process for the selection of adaptation measures in the forestry sector. Furthermore, the tool allows for the inclusion of the judgments, stated by different stakeholders concerned about different aspects related to the adaptation to climate change. This flexibility makes the developed tool a transparent and participative way for stakeholders to decide about the selection, evaluation, ranking and choice of measures.

Evaluation of the measures has to be performed by a board of experts and/or practitioners, in order to achieve a reliable judgment, securing a reliable result. The use of judgments, due to their subjectivity, is the focal point of critics of the AHP (Greening & Bernow, 2004); but Saaty (2008) states even quantitative evaluation can be considered as subjective, depending on the interpretation made. Therefore, carrying out a transparent selection of stakeholders is recommended, including local stakeholders of the area to be affected by the measures. This selection can help validate the results of the prioritization process which can later facilitate the implementation phase.

The calculations for the AHP require a great level of care, mainly when the hierarchy is composed of many levels. Even though the calculations are not complex, the finer intricacies are not to be underestimated and a structured approach is important. The magnitude depends on the number of levels, making up the hierarchically structured decision making process. This difficulty can be overcome by training in order to clarify the steps of the calculations.

The prioritization was used only for the calculation of the weights for the level 2 and 3 and among measures (level 4). The weights for level 1 were assigned, considering literature related to criteria for forest management (Mendoza & Prabhu, 2000).

Referring to the sensitivity analysis, the example (section 7.1) was shown to demonstrate how it can be calculated in order to confirm the consistency of the judgement made.

Prioritization for the case study area

When using the tool, some difficulties mentioned by Ohlson et al. (2005) were experienced: challenges concerning information on the prediction of impacts of climate change upon the sector under study; the lack of information on climate change in the area, and great uncertainties related to the scenarios and impacts for the forestry sector. Another challenging aspect was the absence of any valuation of the expected benefits from implemented measures (except for the case of the Socio-Environmental and Forestry National Program -POSAF II-).

In Nicaragua, even when the planning and policy instruments include many activities related to forest and natural resources management, only few projects were identified which were already implemented or in the implementation phase. This circumstance made the identification and evaluation of the measures a difficult task. This problem can be overcome when using the tool with experts, practitioners and different stakeholders.

During the structuring of the proposed tool it was confirmed that the AHP method allows for the integration of different aspects, either quantitative or qualitative, considering the context for which the tool is proposed (Garro, Osorio, & Díaz, 2010).

Further, regarding the results obtained by the use of the tool, even when the evaluation was not made using different scenarios as originally intended (due to lack of information), it can be affirmed that, having the specific information for the area available, the tool can be used to compare the performance of the measures for the different scenarios. Again, the availability of information is understood as a crucial factor for the evaluation and decision-making process. For the national level, scenarios A2 and B2 can be used. These climate scenarios are the ones mentioned in national communications and other reports for the region, for example by CEPAL (2010) and MARENA (2012).

It has to be mentioned that, for the empirical exercise, the weighting of the indicator related to “budget for measure implementation” and “measure based on recent and accurate information” was carried out using equal values. The weights were given in that way due to lack of information regarding the amount of financial sources for addressing adaptation to climate change. In Nicaragua, most projects related to the management of natural resources and climate change are implemented with limited funds of cooperation agencies.

9. Conclusions and Outlook

Nicaragua has been mentioned amongst the most vulnerable countries to climate change. Scenarios show that its natural resources, including forests, will face changing climatic conditions within the next decades. Those changes, besides the impacts on natural ecosystems, will also affect livelihoods of communities dependent on those resources, such as forest-based communities. In order to face the changing climatic conditions, the government and other institutions are implementing measures to increase the coping-capacities of ecosystems and communities. But with limited financial resources, the selection of the measures to be implemented is a crucial process.

Considering the aspects previously mentioned, the Nicaraguan forestry sector was chosen as the case study, which helped the development of the prioritization tool of climate change adaptation measures based on the characteristics of this sector. The tool comprises important aspects mentioned by government representatives and literature as being essential for planning tools: the inclusion of social, economic and environmental aspects.

The proposed tool for prioritization of adaptation measures fulfils the general objective proposed for this work. The proposed tool follows the general steps included in the guidelines for evaluation of the impacts of climate change, vulnerability and evaluation of adaptation measures. In addition to the guidelines however, the tool presents a specific methodology to prioritize in a transparent way. It also offers a possibility to take the opinions of experts, practitioners and/or stakeholders related to the sector under study into consideration. Even though the results of this work reflect the author's judgment, it is considered to be empirically relevant.

It can be confirmed that the prioritization tool is flexible as its structure allows for adaptations considering different contexts. The adaptation of the tool for prioritization of measures for other sectors is also possible. These adaptations could affect the calculated weights presented in this work; therefore, new calculations would have to be carried out. But, as it has been previously mentioned, the calculations don't represent a high level of complexity. Therefore, the tool is also transferable.

The methodology may present difficulties during the calculation of the weights due to the different hierarchical levels, but the authors consider a short training will be sufficient to transfer the knowledge. Another characteristic of the proposed tool is that it can be complemented by tools or methods more specific to different aspects, such as cost-benefit or cost-efficiency analysis for the financial aspect.

The tool is reliable as long as the results are obtained based on the judgment of experts, practitioners, and even stakeholders, which may also generate greater acceptance of the final results. The consistency of the judgement can also be confirmed through the sensitivity analysis. This characteristic also fits with those mentioned by government representatives.

From the information gathered related to the case study area, it can be affirmed that the government is one of the actors promoting the implementation of adaptation measures, focusing on the enhancement of the capacities of the communities dependent on forest resources.

For the case study area, the “conservation, reforestation and natural regeneration” measure is ranked as number one for its implementation. This measure is more related to the conservation and preservation of natural ecosystems, which in the case study area are associated to indigenous communities who have forest and land ownership. The measure showed to perform best in regard to environmental and climate-related, socio-cultural, and institutional aspects. The selection of this alternative as the prioritized measure confirms Ohlson et al. (2005), who, concerning adaptation in natural ecosystems, claim autonomous responses to be the most appropriate adaptation measures.

More specific and detailed information regarding climatic scenarios is needed to assess the impacts on the forestry sector of Nicaragua for different scenarios, as intended at the outset of this work.

10. References

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11. Annexes

11.1. Overview of methodologies for decision making when planning for adaptation

Source: Own Source based on: Grafakos & Olivotto, 2012; UNFCCC Secretariat, 2015; Nairobi Work Programme - UNFCCC, 2011; UNFCCC, 2013

Methodology	Pros	Cons
Cost-Benefit Analysis The CBA helps to define if an adaptation measure is suitable to be implemented, taking into consideration its benefits and costs usually in monetary terms. It helps to compare options, both with respect to a specific time period and the maximization of benefits **(UNFCCC, 2013)**.	- Possible to compare different categories of benefits or costs with respect to a single value - Solid and widely used - Project and policy specific - Strong and absolute comparability - Intergenerational considerations (discount rate)	- Need of extensive data - Need of trained staff - Time consuming - All benefits have to be measured and expressed in monetary terms - Difficulties in selecting discount rates - Uncertainty in assigning monetary values to nonmarket goods and services
Adaptation Decision Matrix The ADM method focuses on the relative effectiveness and costs of adaptation measures. It is useful when benefit of policies objectives cannot be monetized or a common metric cannot be used. Different scenarios of climate change can be considered **(UNFCCC Secretariat, 2005)**.	- Used when benefits of meeting policy objectives cannot be - easily monetized or expressed in a common metric - Useful to point out relative advantages and disadvantages - of different alternatives	- Subjectivity of scoring process
Cost-Effectiveness Analysis This method focuses on minimizing the costs of the implementation of the measure. Different climate scenarios can be used. It is used when the impacts of policies cannot be monetized and mostly for the evaluation of individual projects. As a result, is obtained a ranking which presents the different measures that have been evaluated, related to their cost-effectiveness **(UNFCCC, 2013)**	- To compare options, both with respect to a specific period of time and considering the maximization of the benefits - Considers non-monetary benefits - Identifies most cost-effective option	- Need of trained staff - Uncertainty in assigning monetary values to nonmarket goods and services - Unable to offer absolute analysis - Time consuming and need of extensive data
Multi-Criteria Analysis Describes any structured approach used to determine overall preferences among alternative options, where the options accomplish several objectives **(UNFCCC Secretariat, 2005).**	- Allows selecting adaptation measure when having various objectives and wide range of criteria - Considers monetized and non-monetized costs - Generates stakeholders acceptance (transparency) - Intergenerational consideration (range of criteria used, stakeholders inclusion)	- Difficulties when assigning weights - Scoring and ranking is subjective - Relative comparability -

11.2. Prioritization of adaptation measures against indicators

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	P
A	0,0011	0,0009	0,0039	0,0013	0,0247	0,0212	0,0038	0,0113	0,0060	0,0079	0,0060	0,0053	0,0014	0,0008	0,0139	0,0094	0,0052	0,0022	0,0036	0,0066	0,0024	0,0059	0,0171	0,0333	0,0333	0,0500	0.28
B	0,0026	0,0045	0,0102	0,0079	0,0247	0,0425	0,0113	0,0339	0,0030	0,0026	0,0060	0,0063	0,0034	0,0032	0,0453	0,0094	0,0481	0,0155	0,0036	0,0066	0,0073	0,0247	0,0171	0,0333	0,0333	0,0500	0.46
C	0,0003	0,0009	0,0014	0,0014	0,0247	0,0104	0,0038	0,0113	0,0042	0,0026	0,0012	0,0015	0,0083	0,0004	0,0067	0,0031	0,0107	0,0041	0,0036	0,0022	0,0073	0,0209	0,0171	0,0333	0,0333	0,0500	0.26

A: Rehabilitation of ecosystems though the establishment of agroforestry systems

B: Conservation, reforestation and natural regeneration

C: Establishment of forestry management system

12. Glossary

Adaptation capacity: is the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences (IPCC, 2007b).

Adaptive management cycle: Developed in the late 1970s to support decision-making under uncertainty for natural resource management (Hollin, 1978 cited in (Pelling, 2011)). Often is explained as the spread of successful innovations from individuals to become common practice (Pelling, 2011).

Afforestation: occurs when forest cover expands through the planting of trees on lands without trees.

Criteria: the intermediate points to which the information provided by the indicators can be integrated and where an interpretable assessment crystallizes. The criteria can be categorized as part of different components in different levels.

Deforestation: takes place when people clear land of tress and regrowth does not occur (Rudel, et al., 2005)

Ecosystem approach: is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way. Application of the ecosystem approach will help to reach a balance of the three objectives of the Convention. It is based on the application of appropriate scientific methodologies focused on levels of biological organization which encompass the essential processes, functions and interactions among organisms and their environment. It recognizes that humans, with their cultural diversity, are an integral component of ecosystems (Convention on Biological Diversity).

Forestation: refers to a general process in which forest cover increases.

Indicators: any variable or component of the forest ecosystem or management system used to infer the status of a particular criterion.

Reforestation: occurs when forest spontaneously regenerate on previously forested lands.

Resilience: is popularly understood as the degree of elasticity in a system, its ability to rebound or bounce back after experiencing some stress or shock. It is indicated by the degree of flexibility and persistence of particular functions (Pelling, 2011).

Vulnerability: is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity (IPCC, 2007c).

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