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Setting Targets for Costing Ecosystem Adaptation

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Abstract

Countries lack sound estimates of the costs they would need to incur to adapt to climate change. The problem is particularly serious for ecosystems adaptation, where current estimates are scarce and mainly based on the global financial flows needed for conservation. Methodological challenges remain unsolved and new approaches that operate not only on the protected area networks and at a level where policy action can take place are needed. We argue that setting desired targets for ecosystems based on climate impacts rather than designing the interventions based on monetary benefits and costs is a valid approach. Based on this, the aim of this paper is to put together existing efforts to cost ecosystem's adaptation and identify the key points that future developments should take into consideration. The discussion is illustrated with a case study estimating the costs of adaptation in Indian forests. Shortcomings from previous approaches are identified and overcome by including a set of possible adaptation options, identifying areas that are more vulnerable to climate change, quantifying the magnitude of the required adaptation option and identifying both positive and negative impacts. Remaining challenges and policy implications are finally discussed.

Keywords: adaptation costs, natural ecosystems, biodiversity, climate change, India.

Mathematics Subject Classification: 91B32, 91B76

JEL Classification System: Q54, Q23

1. INTRODUCTION

Natural ecosystems and biodiversity in general are increasingly recognized as the basic support for the benefits we obtain from nature (MEA, 2005). This support is being threatened by the changing climate, where biodiversity loss is expected to accelerate in the near future stressed by climate change (Pimm and Raven, 2000; Thomas, 2004), and where a 3°C warming is expected to transform about one fifth of the world's ecosystems, as stated in the last IPCC assessment report (Fischlin *et al*., 2007). The impacts of climate change in biodiversity and ecosystems are characterised by the increasing evidence on the magnitude of the impacts, the irreversibility of biodiversity loss, the difficulty to isolate climate from other anthropogenic causes, and the loss of resilience to climate and other stressors (Parry et al., 2009). All these factors contribute to explain the urgent need as well as the difficulties for planning adaptive actions in biodiversity and ecosystems, as well as to appreciate the problems that may arise when costing these adaptation actions. For developing countries, the prospect is worrying as they are expected to face the greatest and earlier impacts in terms of livelihoods, economic growth and welfare (UNDP, 2007).

The imminent impacts of climate change are shifting priorities in climate policy to adaptation over mitigation. Since any mitigation strategy cannot entirely avoid climate change impacts on ecosystems in the next decades, adaptation actions are needed. Nevertheless mitigation is still necessary in order to reduce future costs of adaptive measures and longer term impacts (IPCC, 2007). Indeed, forests will have to adapt to climate change to be effective in mitigation (Innes et al., 2009). Ecosystems adapt naturally to climate change through autonomous adaptation. Planned adaptation for ecosystems differs in that humans may interfere in ecosystems in order to avoid or reduce climate change impacts. In this paper we are referring to planed adaptation when estimating adaptation costs in ecosystems.

In spite of the imminent impacts expected, countries still lack estimates of the costs they need to incur to adapt to climate change (IPCC, 2007; Boyd, 2010). Information on these costs is essential as costs often act as a barrier against taking adaptation policies. Global assessments of adaptation costs have been published recently, including the World Bank (World Bank, 2009), Stern Review (Stern et al., 2006), Oxfam (2007), or UNFCCC (2007) and Parry et al. (2009). The gap of costing adaptation is larger for natural ecosystems, where current estimates are scarce and at the global level. Agrawala and Frankhauser (2008) review approaches to adaptation and impacts concluding that the knowledge on adaptation costs and impacts for other sectors than coastal protection is very limited. Moreover, there is an emphasis on the OECD countries, with only a few studies for developing countries. From the global estimates, natural ecosystems are mentioned by acknowledging their importance for the resilience to climate change, and only one of these global reports estimates adaptation costs in ecosystems (Parry et al., 2009). However, this study did not include the estimates on the costs of adaptation to natural ecosystems in the final total cost estimates from all the sectors. Last estimates of total global costs of adaptation in the following 20 years, including sectors such as agriculture, infrastructures, health, coastal zones, and water, were calculated in the range of $4 to over $100 billion a year (Parry et al., 2009). This study excluded adaptation costs in ecosystems, as well as the tourism and energy sectors due to the lack of accurate information.

Apart from global estimates, studies focussing at the local level are also needed since avoiding climate change impacts through adaptation can only be a policy substitute of emissions cut at this level (Callaway, 2004). According to Callaway, adaptation becomes relevant at the local level and loses importance at the global level. Recently, the World Bank has presented the preliminary results from the Economics of Adaptation to Climate Change (EACC), including a section of adaptation costs for forestry and ecosystems services. At this point, they recognize that it is not clear yet how to quantify the impact of climate change on biodiversity and what adaptation measures are effective to preserve it (WB, 2009). Consequently, they estimate the impact on timber production in 2050 and recommend that no planned adaptation is needed as harvest is expected to increase in this period by 6% (WB, 2009). The impacts on ecosystem services provided by natural habitats are not considered, nor are biodiversity and other elements related to wild habitats. Information on the adaptation costs for natural ecosystems are needed as forest ecosystems, for example, can be left out of adaptation planning, as market benefits such as timber are expected to increase. But it is less uncertain how other services related to forests, such as food supply, biodiversity or fire risk will need strengthening adaptation.

The aim of this paper is to discuss the methodological and practical challenges when facing adaptation costs in natural ecosystems. This is a relatively undeveloped field since only a few studies have been conducted. We contribute to the developing methodologies by proposing target based levels on adaptation to climate change impacts on threatened ecosystems, and evaluating the costs of achieving these levels. This paper is structured as follows: section 2 introduces previous studies costing adaptation in natural ecosystems; section 3 discusses the main methodological challenges we have identified; section 4 illustrates the discussion with a case study while section 5 concludes with some future recommendations.

2. REVIEW OF PREVIOUS STUDIES AND ESTIMATIONS

The literature on adaptation costs is scarce and recent, where analyses on the costs of adapting natural ecosystems are less advanced than in other sectors, such as coastal protection or agriculture. Many studies assessing economic impacts of climate change initially estimated the costs of adaptation as if they were valuing the costs of, for example, the infrastructure needed for protection against a given sea level rise. Tol et al. (1998) conducted an early review of climate change impacts on different sectors from which they identified some as adaptation costs, such as coastal protection or defensive interventions against pollution. This approach was criticized for making simple assumptions about adaptation, where most studies failed to compare the benefits of adaptation in terms of damages avoided against the costs of the measures needed to achieve the reduced damages (Tol et al., 1998). The costs of adaptation are relevant if one wants to compare the costs and benefits from adaptation policies. Such a benefit cost approach to determining the appropriate adaptation responses would undoubtedly take a lot of time and resources, as it has to build from the bottom-up. This has not been done to date, but we do have one set of global estimates of the costs that use a different approach. These are provided in the study conducted by the UNFCCC (Berry, 2007), and are based on James et al. (2001). The first step on the calculations was to estimate the costs of meeting the goals of IUCN to achieve its target of protecting natural ecosystems by enhancing global protected areas. This was estimated as requiring an increase in expenditure of $12-21.5 billion per annum (James et al., 2001). Since these costs only cover a proportion of total biodiversity, the full ecosystems adaptation costs need to be scaled up, providing an estimate in the range of $64.5 and $83.5 billion per year (Berry, 2009). The UNFCCC study uses two adaptation scenarios, business as usual and scenario with mitigation. These scenarios do not have an explicit level of adaptation for climate change to be achieved, but they assume that an adequate protected area network would provide at least the first step in arriving at the necessary adaptation to climate change for natural ecosystems. However, this assumption could be as well interpreted as the amount of adaptation deficit in conservation, not necessarily related to climate change adaptation. It may be argued that reaching the IUCN conservation target may not be considered climate adaptation but a development deficit in conservation (WB, 2009). Parry et al. (2009) suggest however that such large development deficit should be included in adaptation, including these costs in their estimations, while the WB study does not.

The figures of James et al. referred to above (US$12-21.5 billion) are based on an increase of 10% in the areas to be protected. Another study was conducted by Blamford et al. (2002), and following a similar approach they calculated the costs of expanding protected areas to cover 15% of the total area of each terrestrial region. They obtain an estimate of $23 billion per year for marine protected areas and $20-28 billion per year for terrestrial protected areas. An earlier study by Lewandroski et al. (1999), had already estimated the costs to regional economies of setting aside land to protect ecosystem diversity, although not necessarily under the threat of climate change. These costs were measured through the value of market goods and services forgone when protecting land. The total annual costs ($1990) of retiring 5, 10 and 15% of the world's land area to protect these resources were $45.5, $93.3 and $143.8 billion, respectively. Table 1 summarizes these studies and compares the range of these global biodiversity and ecosystems adaptation estimates. In all cases it is clear that the links to climate change are tenuous at best.

The above approach, which takes as its point of departure the need to expand protected areas has a number of shortcomings. One is of course that there are other areas where natural ecosystems could be affected by climate change. The second is that the methodology is too top down and a more bottom-up or local approach is warranted (Callaway, 2004). Following this line, we will focus our discussion in this paper on adaptation costs at the regional or country-wide level. At this level, there are a few case studies assessing the costs of specific adaptation options in the case of natural ecosystems. These are adaptation measures such as migration corridors in Kenya (Ferrano and Kiss, 2002), coastal reforestation in Croatia (Pagiola et al., 2004) or conservation of tropical forests in Costa Rica (Ferrano and Kiss, 2000). Another example is a study conducted in the UK estimating the costs for restoration and re-creation of natural habitats under climate change, at annual costs that amount to £2.5 million (US$4 million) under a 2050s high-emissions scenario (Metroeconomica, 2006). These studies are summarized in Table 2. Note that cost estimates in Table 2 vary on the unit of account (US$ per ha, or US$ per has per year) and some costs refer to systems as a whole, without details of the land areas covered.

As observed from the existing case studies, costing adaptation in natural ecosystems has been done either focusing on single isolated interventions, or by looking at the global level using one single adaptation option and without well justified targets. One exception is Busch et al. (2009) study, where authors conducted an approach costing adaptation options in natural habitats in Madagascar. In their approach, they calculated the cost of ensuring minimum acceptable viable areas of stable forest habitat for 72 endemic plant species under different levels of climate change. They based their analysis on the area of natural ecosystem needed for the species to survive, and set the target based on the climate change expected impacts. Specifically, Busch et al. (2009) selected three adaptation strategies guided by an expert workshop: avoiding forest degradation through wood product substitution; avoiding deforestation through agricultural stabilization; and restoring natural forest to achieve a minimum cover. For each plant species, they identified the expected impact of climate change in terms of the area of habitat, setting a minimum area of 10.000 Ha of stable forest as established by the IUCN. The per hectare costs of the adaptation measures was estimated from interviews held with natural forest managers. They obtained that avoiding forest degradation and avoiding deforestation are substantially cheaper adaptation strategies than restoring natural forest once it has been cleared. This paper is an important step forward in assessing ecosystem adaptation costs, but does not provide the total adaptation costs or identifies vulnerable areas, since multi species conservation strategies should need less land allocated to conservation, as compared to a species by species estimation. The case study that we will present here, bases the level of adaptation on the estimated impacts, and sets adaptation targets based on information of the level of impact that is expected.

3. METHODOLOGICAL CHALLENGES

The aim of this section is to identify key methodological challenges where an effort is needed in order to provide accurate estimates of adaptation costs for natural ecosystems. A review on the existing global studies costing adaptation and recent literature on ecosystem adaptation costs has been conducted and the main key points we considered are listed here. Later on, through a case study in India we will illustrate how these challenges can be addressed, while remaining issues will be discussed at the end of the paper regarding the state of the art and the next steps.

3.1 Targets for Adaptation

In most studies approaching adaptation costs, two set of scenarios are compared: a future with no climate change impacts and a future with climate impacts. Adaptation could be elected from various levels, from covering all impacts to covering as much as cost-effective measures allow or even not adapting (WB, 2009). When setting the baseline level, this can be a fixed baseline (today's *status quo*) or a projected baseline (based on the trends without the effect of climate change). The measurement of climate change impacts depends on the chosen or available baseline, while the level of adaptation needed does as well. Under this situation we can set targets for the adaptation needed to reduce the expected impacts. These adaptation actions will have a level of success in achieving the climate impact reduction, leaving residual impacts. Figure 1 represents the magnitude of an impact with time. The above line represents the level of the impact with climate change. The baseline can be set as the current situation (fixed) or as a projected scenario without climate change (projected baseline). Based on the expected impact, an adaptation target is set with the objective of reaching the selected baseline scenario. Therefore, the level of adaptation required is the one that reduces the impact to the chosen scenario. Depending on the success of adaptation, the difference between the reduced impact with adaptation and the baseline will be the residual impact.

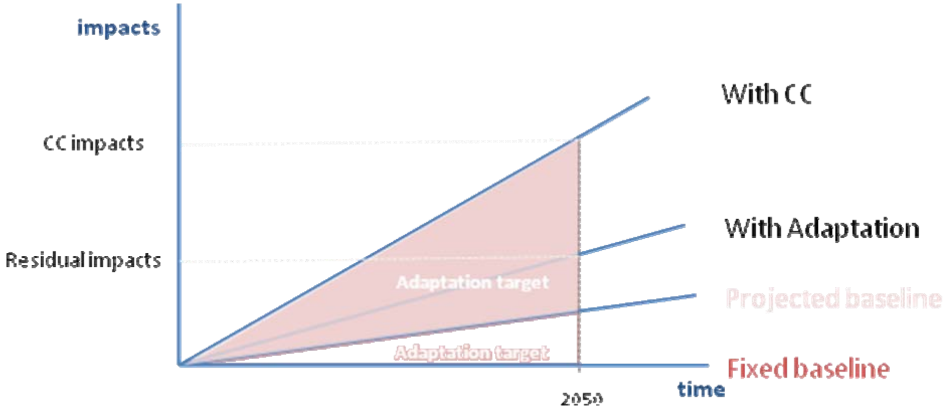

Figure 1. Setting targets for adaptation (Source: adapted from Parry and Carter, 1998).

Due to the lack of data on the success of a given adaptation plan, the appropriate adaptation level can be taken as the one that equals the current situation with a future scenario with no change (all the area in the graph). Based on this, the amount of adaptation can be identified from the magnitude of the expected impact. The idea is to set targets to recover “without climate change” situations in the future, based on projected impacts. For a review on adaptation and mitigation options in relation to the potential impacts on biodiversity see Paterson *et al*. (2008). One example would be the risk of climate change to forests, where a magnitude of forest loss could be identified, and where the adaptation target would be on recovering that forest from being lost. In this line, the concept of “conservation triage” as a means of prioritizing some targets in the face of climate change is emerging in conservation policy concerning climate change (Hagerman et al., 2010). When evaluating adaptation costs, setting targets based on climate impacts and vulnerability can be the preferable approach under a precautionary perspective. Target based approaches contrast to cost benefit analysis (CBA), marginal costs and benefits for a policy are compared. In the case of ecosystems and climate adaptation, information about the economic benefits from conservation is relatively poor, both due to the gap in knowledge on the effectiveness of adaptation measures and the lack of understanding and knowledge on the benefits derived from ecosystems and how these benefits may be impacted by climate change. In this context, a CBA analysis would suffer from incomplete information on benefits from ecosystems. Basing adaptation on environmental goals or targets in vulnerable areas overcomes such critiques. On the other hand, it is also true that a target based approach has its limitations, and it is important to be aware of the level of efficiency of implementing adaptation policies in all vulnerable areas, given a certain amount of limited economic resources.

3.2 Effectiveness of Adaptation

Effectiveness is understood in this context as a measure of the success of adaptation in avoiding the impacts of climate change. If impacts can be quantified, then effectiveness would be the rule that gives us the magnitude of adaptation to be implemented. How many adaptation units are required to avoid the impact to happen or reduce it to the minimum? Effectiveness becomes especially relevant in the case of natural ecosystems. Parry et al. (2009) stated in the UNFCCC report that the main reason why only few studies look at the adaptation costs in natural ecosystems is due to the inexistence of effectiveness measures on the adaptation actions. Until more information is available in effectiveness, we propose the targets approach as an upper bound based on trying to avoid all the impact. There is of course only a probability that the adaptation measures will achieve the reduction in losses due to climate change. Thus the adaptation costs will have a US$ value as well as a probability associated with them: the higher the required probability of success the higher the dollar cost. To date no studies have looked at this trade-off. When possible, cost effective analysis could help to identify the most desirable adaptation options from the set of potential measures.

Success on adaptation depends on both the spatial and the temporal scales. Effectiveness of a given adaptation option can be perverse as provoking externalities at other spatial or temporal scales (Adger et al., 2005). The effects of a specific adaptation measure in other sectors and places should be considered to avoid this problem. Also, effectiveness depends on the future state of climate and therefore on the uncertainty regarding climate impacts. Flexible adaptation options are therefore preferred. All this complexity derives into the difficulty of assessing the effectiveness of adaptation measures, as it depends on the sequence and interactions of different options over time (Adger et al., 2005). As an alternative approach, recent studies defend adaptive management as a way of adapting to climate change (Roberts et al., 2009). Adaptive management can be understood as a process where different measures are implemented on natural ecosystems and processes are monitored and re-planned in other to improve efficiency (Colfer, 2005). However, this is a long learning process where information about the success and effectiveness of adaptive management can only be seen in the mid-term.

3.3 Natural Ecosystems and Ecosystem Services

Assessing adaptation costs for enhancing ecosystem services could be of key importance as ecosystem-based adaptation is gaining attention (Zaunberger et al., 2008). Ecosystem-based adaptation can be defined as the use of sustainable ecosystem management to support societal adaptation (CBD 2009). The main goals of this adaptation strategy are the conservation of biodiversity to allowing ecosystems to resist to climate and provide services, and the preservation of natural ecosystems that can provide cost-effective protection against climate change. One example would be wetland restoration, which can benefit biodiversity as well as provide defense against floods or sea level rise. The novelty of ecosystem-based approaches entails a lack of information and data on the benefits, costs and effectiveness of these approaches. This makes it difficult to undertake cost-benefit analysis and other assessments which are often required for funding and policy decisions. From the economic perspective, when measuring costs for ecosystem adaptation, one has to face the disparity between costing adaptation in natural ecosystems as purely associated with the existence of current and future ecosystems and their component biodiversity, or whether ecosystem services are included in the benefits from adaptation (Berry, 2009). The Millennium Ecosystem Assessment establishes a framework for valuation of these services that could be adapted to the climate change arena. However, if considering ecosystem services in adaptation the issue of double counting could easily arise and will constitute a major problem. Therefore we approach adaptation costs based on the impacts on habitats and species, rather than on the services provided by them.

3.4 Autonomous vs. Planned Adaptation

Costing adaptation for natural ecosystems is based on the premise that autonomous adaptation will be insufficient (Fischlin et al. (2007), and thus human planned adaptation is necessary to avoid the projected negative impacts on biodiversity. However, ecosystems are expected to adapt at least in part to climate changes and including these changes on the economic analysis remains a challenge. Planned adaptation should ideally identify the scope for human intervention taking into account ecosystems natural adaptation.

3.5 Adaptation Options in Natural Ecosystems

A number of existing estimates for adaptation costs are based on enlarging the protected area system (Berry, 2009). However, climate change will require nature conservation efforts beyond the current protected areas approach (Stern, 2006). Heller and Zavaleta (2009) review in a recent work the literature addressing biodiversity management and adaptation in the face of climate change. From 113 papers, they identify 524 recommendations that are ranked depending on the frequency of appearance. General conclusions from the analysis are that 33% of the recommendations address biodiversity conservation in conjunction with ecosystem services. Among the three first measures ranked are: the increase in habitat connectivity, the integration of climate change into planning exercises and the mitigation of other threats to ecosystems (Heller and Zavaleta, 2009). In the case of species conservation, adaptation should operate at the landscape level allowing for species migration, while for natural ecosystems these species component should act as criterion for identifying vulnerable areas in which to focus adaptive planning. It would be desirable that future approaches on costing adaptation consider adaptation options other than those within the protected area system.

3.6 No Regrets Actions

Callaway (2004) defines *no regrets actions* as ones that are taken for reasons other than avoiding climate change damages, but which nevertheless softens the impacts of climate change as they occur. A review on existing adaptation policies for forests conducted by Roberts et al. (2009) highlights that existing adaptation policies often serve for multiple proposes and are not only introduced to fight climate change. At the same time, non-climate oriented policies could serve as well as adaptation strategies. Looking at the non-regret actions is an alternative methodology for allocating costs to adaptation oriented policies. Particularly in developing countries, there are many potential actions related to development goals that can be still effective to reduce vulnerability to climate change.

There are cases where climate impacts are projected in the long term and the impacts expected in 2030 or 2050 are unknown. This problem is very common in natural ecosystems where the impact can be negative in the long term while positive in the short term (e.g. increase in productivity due to the fertilization effect -DEFRA, 2005-). In the next section and for our case study we will also illustrate adaptation costs based on no regrets actions.

3.7 Considering Biodiversity

In the face of climate change, maintaining biodiversity is required to ensure the supply of ecosystem services for human wellbeing. However, the relationship between biodiversity and ecosystem services is complex and currently still not well understood (TEEB, 2010). Based on biodiversity indicators, those ecosystems with higher indices should be favored as adaptation goals. The most species can be protected more cheaply under climate change by focusing resources on avoiding forest degradation and deforestation now, through the creation of substitute sources of wood products and agricultural commodities. Previous studies costing adaptation in different sectors such as coastal zones, fisheries of forestry have focused on economic benefits from existing markets, excluding both the externalities that these production may cause on biodiversity as well as the non-market benefits that can arise from these assets (WB, 2009; Sedjo, 2010). Setting targets for biodiversity encompasses many challenges as interactions occur between species and habitat composition. To avoid this problem, we may consider focusing on habitats or ecosystems in order to identify the adaptation targets, and include biodiversity in the analysis as criteria for vulnerability to climate change of these habitats.

4. PRACTICAL CHALLENGES: CASE STUDY

In many developing countries with tropical forests, adaptation to climate change is restricted due to a lack of financial resources (Roberts et al., 2009). Adaptation options in these areas are many times focused on reducing human induced impacts on forests. At the same time, the lack of information on the costs of climate oriented adaptation policies can act as a barrier towards adaptation. In this section we draw from the results of a earlier investigation (Markandya and Mishra, 2010) to illustrate the main difficulties in costing adaptation in a developing country, with India as our case of study.

India covers 1.8% of the world's forest area, where these forests are home and support to around 100 million people (REDD, 2009), supply 40% of the country's energy needs and contain a great diversity of habitats and species (CBD, 2009). The case study presented here estimates the costs of adaptation for Indian forests. Based on a detailed methodology presented in Markandya and Mishra (2010), targets for adaptation are calculated while adaptation options are identified based on the magnitude of climate change impacts and the vulnerability of the forest types to climate change. The adaptation costs will be estimated based on the required action to meet these targets. Methodological steps are shown in figure 2.

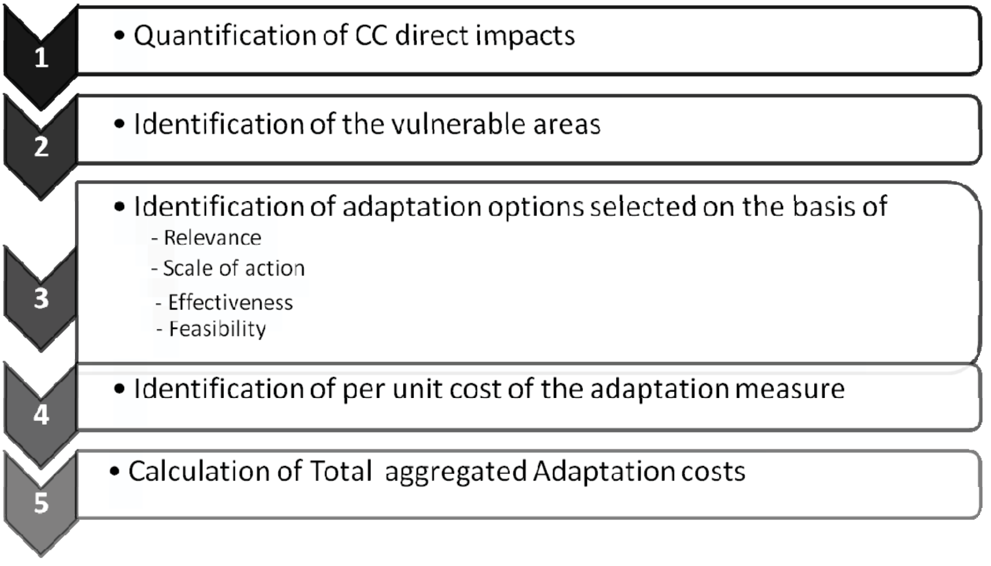

Figure 2. Methodological steps for costing adaptation in natural ecosystems (Source: adapted from Markandya and Mishra, 2010).

The main impact affecting forests in India was identified from Ravindranath et al. (2006). Based on both climate and vegetation models, they obtain shifts in forest distribution under the B2 scenario for 2085, taking place in 68% of the current area. As no estimations are available on future Indian forest distribution without climate change, we base our adaptation costs on a fixed scenario, as explained in section 3. The distribution of this impact on forests varies in space, where a shift towards wetter forests types are expected in the North East region and drier forest types are expected in the North West region (Ravindranath et al., 2006). Adaptation targets are set based on the expected impacts of climate change on forests, and are measured as the hectares of forests being shifted, compared to the current scenario. However, as not all forest shifting may need adaptation strategies, vulnerable areas were identified using three different criteria: a) whether climate change is decreasing the forest net primary productivity[i]; b) whether climate change is decreasing biodiversity richness[ii] in the forest; and c) whether the change is towards a higher fire vulnerability forest[iii]. This way we focus planned adaptation where conservation biologists identify it is needed. Based on this, the targets for adaptation were set from shifts in forest types deriving into lower primary productivity, lower biodiversity richness, or higher forest fire risk, obtaining that total vulnerable forest area amounts to 6.2 million hectares[iv]. This vulnerable area supposes 9.7% of total forests land in India, and allows us to focus the attention of adaptation in a reduced forest area. Additionally, by setting our three criteria, we have considered biodiversity, productivity and fire risk in our adaptation target strategy.

An exploration of the adaptation options potentially applicable to Indian forests was conducted by means of a literature review of recent recommendations from the scientific literature (Heller and Zavaleta, 2009), international organizations such as the Food and Agriculture Organization (FAO, 2008), or Indian national programs such as the National Adaptation Plan (Government of India, 2008). From these options, expert opinion was followed as to select the best set of adaptation options that may be applied to each shift in forest type (Ojea et al., 2009). From these, unitary costs were obtained from a review of current programs being developed in India. Table 3 summarizes the set of adaptation options that are considered and their cost. Note that the costs for these measures have been divided in capital and recurrent costs, and have been converted to 2009 US$[v].

The timeframe for adaptation policies usually focuses on the next 20 or 30 years, but projections of impacts are often provided in the longer run, as in the present case study. Sound knowledge on impacts is needed for target setting. Therefore, the costs estimated in this study may be seen as the costs of adapting to long term impacts. Also in practice, these adaptation options will take place in the future. However, prior actions are needed to initiate the preparatory work. In order to estimate adaptation costs in India, we will follow two different approaches. First, we will estimate adaptation costs based on these long term impacts and assuming we will start adapting from now. Second, we will apply a no regrets actions approach in order to derive adaptation costs for the shorter term.

4.1 Adaptation costs based on long-term impacts (2010-2085)

This first approach will be based on the impacts identified for 2085 and where the adaptation target is 6.2 million hectares of vulnerable forest, as derived from Ravindranath et al. (2006). While the target is to be accomplished in the long run, actions will be needed much earlier since forests take a long time to adjust (Leemans et al., 2004). We take the assumption that we have to start adapting from now on to these impacts (Ravindrannath et al., 2006). Therefore, unitary costs for adaptation actions (table 3) are calculated for the 2010-2085 period at an interest rate of 5%. Based on these, and given the range of possible adaptation options, two scenarios were settled to calculate the costs: one with the minimum action required as a lower bound and, a second scenario with all the desirable adaptation options[vi]. Based on these two scenarios, and taking into account the impacts time frame (2010-2085), total costs for forest adaptation to climate in India were calculated as $1.15 billion for the lower bound scenario and $2.56 billion for the upper bound estimate. This is the cost of addressing the expected change in forest ecosystems to 2085. This approach may be seen as the costs of adapting to long term impacts (2075-2085). How to implement these adaptation options from now on is out of the scope of this paper and timeline options could be discussed on a policy context.

4.2 Adaptation costs based on no regrets actions (2010-2030)

As opposed from longer term impacts, where adaptation has to be planed from now on in order to avoid or decrease the expected impacts, short term impacts can be easily addressed by reinforcing existing actions and programs that have climate co-benefits. These actions are known as non-regret actions and are used here to provide an approximation to adaptation costs in Indian forests in the shorter term (2030). Since 2030 impacts in Indian forests are highly uncertain, we identify current and forthcoming forest policies that will contribute in adapting forests to climate change. Examples of no regrets policies for forests are to initiate forest fire management strategies, or to promote mixed species forestry to reduce vulnerability (Ravindrannath et al., 2006). Based on judgments of forest experts, from a review of last 10th Five Year Plan and current 11th Five Year Plan from the Working Group on Forests (Government of India, 2007) we have identified those policies that are more suitable for climate adaptation. From the 16 different schemes of the 10th and 11th Plans, the selected policies are: The National Afforestation Program (NAP) scheme; the Integrated Forest Protection (IFPS) scheme; the Forest Information Management and Resource Assessment Scheme; and the Forest Infrastructure Development scheme. These non-regret actions are chosen to enforce adaptation for the 2010-2030 period. Annual costs have been calculated for these actions and amount to $144.13 million per year. Net present value for the period 2010-2030 and using a 5% discount rate is $1.8 billion.

This method can be used to estimate the scope for adaptation given current existing policies, and serves as a primer approximation to the magnitude of the costs of adaptation. However, it doesn't overcome the main gap found in the literature, where adaptation costs are not specifically linked to physical projections of change in the ecosystems, and therefore has many caveats. If a state needs to know the costs of adapting natural ecosystems to climate change, these no regrets options give a first number but may not be enough as to avoid expected climate impacts as it could be well overstating climate adaptation costs.

5. DISCUSSION AND RECOMMENDATIONS

The aim of the present paper has been on analysing the current state of costing adaptation in natural ecosystems and presenting some guidelines for future work. Current estimates are greatly detached from climate impacts projections and bridging this gap is critical. From this review, key methodological challenges inherent for natural ecosystems have been discussed, where adaptation costs should be derived from the amount that adaptation that is needed at each region. One way we propose is through desired targets of adaptation based on the projected impacts. In the present state of knowledge, cost benefit analyses of adaptation measures remain too difficult to conduct under the existing uncertainty on the success of adaptation against climate impacts.

The main challenges that remain in practice are those related to the magnitude of the impacts and, therefore, the magnitude of adaptation needed. From the case study we have successfully measured the expected impact in forest ecosystems in India as the hectares of forest that are expected to shift to other forest types, and which are associated with negative consequences for productivity, biodiversity or wildfires. However, these impact estimations have been modelled for the long term (2085), while the debate on adaptation is within a closer timeframe (2030). In this respect, we have developed a no regrets strategy to estimate short term adaptation costs and we discuss its performance as an alternative methodology for adaptation costs in ecosystems. Also, mitigation options could have an effect of decreasing these impacts in such a long term (UNFCCC, 2007) and this has not been taken into account. This problem may be common to other types of ecosystems and to biodiversity in general. As a result we have shown how estimated adaptation costs in India raise to the range of $1.15 to $2.56 billion per year with impact based adaptation in the long term, while for the shorter term (2030) adaptation costs based on non-regret options sum $144.13 million per year. The recent World Bank adaptation costs study, although not directly comparable to this one due to methodological and timeframe significant differences, estimated total adaptation costs for developing countries to 2050 impacts in the range of $75 to $100 billion per year (World bank, 2009). The study also reports total adaptation costs to South Asia, giving a figure of $12.6 to $15.5 billion per year. We may take into account that expanding time horizon from 2050 to 2085 will increase the costs of adaptation, as well as the uncertainty regarding climate impacts and the success of adaptation.

In the present analysis, we have used a fixed baseline instead of a projected baseline for forest ecosystems. This was necessary as information at the regional level for future trends in ecosystems cover without climate change is not always available. It has been difficult in precedent studies to establish projected scenarios for several sectors, where fisheries, natural ecosystems and forestry do not take a projected scenario in the WB report. Another issue is that we have identified the magnitude of adaptation needed based on vulnerable areas, and have not developed the necessary tool to identify and map these vulnerable forests. This was out of the aim of the case study, which had the objective of giving a cost figure for the entire country, but complementing this methodology with the geo-location of the vulnerable areas is essential for policy intervention. Further work is thus recommended in this line.

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Tables

Table 1. Studies assessing global adaptation costs for natural ecosystems

Study	Area covered	Adaptation measure	Methodology	Cost estimates ($billion/yr)
James et al., 2001	Global	Increase in protected areas	Costs of a 10% increase	12.0
	Global	Increase in highly protected areas	Costs of a 10% increase	21.5
Blamford et al., 2002	Global	Increase in terrestrial protected areas	Costs of a 15% increase per region	20-28
	Global	Increase in marine protected areas	Costs of a 15% increase per region	23
Berry, 2009	Global	Adaptation needed in terrestrial ecosystems	From James et al. (2001) assuming total biodiversity expenses would be tree times greater	64.5-83.5
	Global	Adaptation needed in marine ecosystems	From James et al. (2001) assuming total biodiversity expenses would be tree times greater	36-64.5
Lewandroski et al. (1999)	Global	Increase in protected land	Foregone benefits from other land uses in 5% of total land	45.5
	Global	Increase in protected land	Foregone benefits from other land uses in 10% of total land	93.3
	Global	Increase in protected land	Foregone benefits from other land uses in 15% of total land	143.8

Table 2. Case studies valuing adaptation costs in natural ecosystems.

Studies	Area covered	Adaptation	Methodology	Cost estimates
Ferrano and Kiss, 2000	Costa Rica	Prevention of forests habitats conversion	Government payments to rural residents	$35 /ha.yr
Ferrano and Kiss, 2000	Costa Rica	Conservation of tropical forests	Conservation International payments to locals for the conservation of 81.000 hectares of tropical forests	$1.25 /ha
Ferraro and Kiss, 2002	Kenya	Migration corridors	Expenses on migration corridors	$9.88/ha.yr
Pagiola et al. 2004	Croatia	Coastal reforestation	Cost-benefit analysis, restoration costs	$740 /ha
Naidoo and Ricketts, 2006	Paraguay	Corridors between protected areas	Costs of the construction of three corridors between PA	$9.000-89.995
Metroeconomica, 2006	UK	Restoration and creation of natural habitats	costs for restoration and re-creation under high-emissions 2050 scenario	$4 million/yr.
Busch et al. 2009[a]	Madagascar	Assuring species habitat in a forest managed for community wood needs	Costs of assuring minimum habitat for 72 plant species	$160-165 /ha
Seijo 2010	Developing countries	Replanting, fire control and rehabilitation of forests	Replanting costs, fire control costs and funds for rehabilitation of natural forests	$30-50 million/yr

[a] Cost estimates in the case study are presented for different baseline scenarios, varying whether it is a forest area and if it is already managed for biodiversity or for community wood needs. Only one scenario is reported here as an illustrative example.

Table 3. Per hectare costs of the adaptation options selected (prices in 2009$/ha)[vii]

Adaptation Options	Total present costs of the measure (2009$/ha)
Plantation of drought tolerant species	201.10
Allow natural adaptation	54.71
Reduce forest dependency	66.76
Plantation of productive species	175.15
Forest fire prevention	7.89
Rehabilitation of degraded forest	471.33

Source: Government of Haryana (2003); Government of India (2002, 2007); Karnat (2007).

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[i] Forest types ranking based on net primary productivity were obtained from Ravindranath et al. (2006).

[ii] Biological Richness is an indicator of biodiversity that takes into consideration the ecosystem uniqueness, the diversity of species, the value of biodiversity, terrain complexity and a disturbance index.

[iii] Forest types ranking for biological richness and fire vulnerability were provided by Prof. P.K. Joshi, from the TERI University (India).

[iv] Note that shifts refer to the change of a given forest type to another due to climate variation. Land use changes are not included in the analysis.

[v] Rupees have been updated to year 2009 with the consumer price index, from the World Economic Outlook database from the International Monetary Fund (IMF) (WEO, 2009), and converted to US$ with the most recent exchange rate of September 2009, also from the IMF (IMF, 2009).

[vi] The set of adaptation options in both scenarios are available in Markandya and Mishra (2010).

[vii] Each adaptation option is implemented in all the vulnerable area identified, based on two scenarios. These measures are estimated to operate from 2010 to 2085 although no implementation timeline is defined.