Tropical forests and adaptation to climate change

In search of synergies

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Biodiversity in a changing climate: A framework for assessing vulnerability and evaluating practical responses

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1. Introduction

Habitat conversion and degradation, overexploitation, displacement by invasive alien species and global climate change are the main processes currently impacting biodiversity. In particular, it is expected that within the next 100 years, terrestrial ecosystems will suffer the most from land use change, followed by climate change and nitrogen deposition (Sala *et al.,* 2000). Although past changes in the global climate during the last 1.8 million years produced dramatic contractions of the habitat range of most species, as well as marked reorganisation of biological communities, these shifts occurred in response to rates of climate change that were much lower than those experienced today, and which occurred in landscapes not as fragmented and/or degraded as present and with little human influence.

The effects of global environmental change are already being felt on the Earth's biodiversity at unprecedented rates. Over the last few decades, increases in global temperature linked to anthropogenic greenhouse gas emissions have changed both the timing of reproduction of animals and plants and their habitat distributions, the length of the growing season, and the frequency of pest and disease outbreaks (IPCC, 2002; CBD *Ad Hoc* Technical Expert Group on Biodiversity and Climate Change, 2003; Root *et al.,* 2003; Parmesan and Yohe 2003). Modern climate change has been directly responsible for the extinction of at least one vertebrate species (Pounds *et al.,* 1999). Even if all anthropogenic additions of greenhouse gases to the atmosphere were to be halted today, the associated impacts of global climate change would be expected to continue for decades to come, making adaptation options and policies to climate change necessary. However, climate change is not likely to affect all species similarly. Certain species or communities will be more prone to extinction than others due to the direct or underlying effects of such change. Particular ecosystem types that are expected to be more vulnerable to global warming are mangroves, coral reefs, high mountain ecosystems, and ecosystems overlying permafrost. The risk of extinction will increase especially for those species that are often characterised with one or more of the following features: limited climatic ranges; restricted habitat requirements; long generation times; and small breeding populations.

There is strong evidence that biodiversity significantly influences the provision of ecosystem services. Examples of ecosystem services affected by biodiversity are pollination, seed dispersal, climate regulation, carbon sequestration, agricultural pest and disease control, and human health regulation. Also, by affecting processes such as primary production, nutrient and water cycling, and soil formation and retention, biodiversity indirectly supports the production of food, fibre, and drinking water. Therefore, human well-being in the face of changing global climate is directly linked to ecosystem conservation and for human systems to adapt to climate change. For the purposes of this chapter, we use the term biodiversity as the variability among living organisms from all sources, including terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part. The definition includes diversity within and between species and among ecosystems types. The most appropriate measure of biodiversity will depend on the value and/or process being assessed.

In light of the value of biodiversity, it is important to assess the vulnerability of populations, species, and ecosystems to both contemporary climatic change and other anthropogenic stresses, and to evaluate the prospects for reducing these impacts. While the physical environmental aspects of climate change are largely beyond human control, other biological and environmental stresses can limit the resilience to these changes, and should be addressed where possible. Enhancing the resilience of biodiversity to climatic changes therefore involves a dynamic assessment of the degree of impact resulting from any significant stresses versus the difficulty of mediating the effects of these stresses. This will inevitably require consideration of the local conditions in each given context, which may often involve methods that are highly case-specific (e.g., impacts of localised industrial pollutants).

Thus, this chapter aims to provide an overview of methods and approaches which may be generally applicable across a wide variety of contexts and at different levels of biological organisation in order to perform vulnerability assessments to enable users define relevant issues and provide adaptation options to minimise biodiversity loss due to climate change. The next section relates on assessing a system's vulnerability to climate change; its first part considers stresses to the system in question and the second part considers the ability of the system to adapt. As a response to this assessment, the chapter finishes with a range of policy/management options.

2. Assessment Process

2.1 Vulnerability assessment

Climate plays a fundamental role in the physiology and ecology of species. Factors such as the ambient environmental temperature and the availability of moisture (in terrestrial ecosystems) are defining characteristics in the niches of all species on earth. Climatic change therefore poses a considerable threat to species survival and biodiversity, and changing environmental conditions are thought to be a principal cause of previous periods of widespread species extinction (Wilf *et al.,* 2003). To survive climatic changes, species must either adapt to the changing conditions or migrate to areas where the climate resembles their niche and is suitable to their survival. In most cases, responses to climate change will likely involve both of these aspects (Davis and Shaw, 2001). The principal aim of a vulnerability assessment is therefore to predict the probable extent of climatic change and to examine the likelihood that a given species will be able to adapt or migrate, taking into account existing non-climatic stresses affecting its survival. In many cases, non-climatic stresses may exacerbate problems caused by climate change, or limit the ability of a species to respond to the changes in their environment. A simple example is how anthropogenic habitat fragmentation presents barriers which can limit migration and the tracking of changes in climate. As plants are typically much more limited in their migratory ability and are often more directly impacted by changes in climate, the following sections will focus heavily on assessing vulnerability in plant species; however, many of the methods described will also be of general applicability.

Here we divide the vulnerability assessment into two sections: stresses to the system and adaptive capacity. We have also divided these into sub-sections describing various methodologies, however it should be kept in mind that many of these sections are inter-linked and must not be considered in isolation (e.g., genetic diversity may often depend upon the connectivity between populations). While a variety of other environmental threats can also impact the ability of species and ecosystems to survive climatic change (e.g., pollution, invasive species), here we discuss only the most generally applicable stresses and techniques for assessment, as a full survey of these more specific impacts is beyond the scope of this paper. Nevertheless, any assessment of vulnerability should always consider the full spectrum of impacts including those not covered in detail. Following the Intergovernmental Panel on Climate Change (IPCC), vulnerability is defined as "the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes". It must be pointed out also that while climate change is an ongoing process with anticipated lag-time effects, most of the types of analysis discussed here require the definition of a given window in which the changes and biological responses are to be considered.

2.1.1 Stresses to the system and assessment tools

2.1.1.1 Modelling climate change

Knowing the potential magnitude of change that a specific location is expected to experience is a fundamental variable in assessing impact and adaptation of biodiversity in the face of climatic change. Global Circulation Models (GCMs) provide scenarios for future climatic change, the details of which are discussed in previous chapters. GCM models produce climate change scenarios at a coarse scale (typically with grid cells exceeding 2x2 degrees), which is inappropriate for examining potential changes in biodiversity. The fundamental problem occurs because biodiversity varies spatially at a much finer scale than the results of GCMs, so the first step in examining climate change effects on biodiversity requires downscaling of GCM data. Temperature changes can easily be downscaled using a digital elevation model (DEM), through application of lapse rate models which adjust the ambient temperature based on the elevation. However, changes in rainfall are a little more complicated to deal with. Jones *et al.,* (2003) used co-variable interpolation to combine large-scale climatic changes (derived from GCMs) with more regional-scale spatial variation in climate (using the present distribution of temperature, rainfall etc.). This method assumes that regional distribution of climate stay the same (i.e., areas of rain shadow in present day climate will also be rain shadow in future climates), but applies GCM derived absolute changes to these values. The resultant surfaces of predicted climate change have a grid cell size of 10 minutes (approximately 18 km at the equator), representing a more suitable scale at which to examine the potential changes expected to impact biodiversity in any given site.

These models can be used to extract information to gain an understanding of the likely degree of climate change in any areas of interest. This information can then be used to experimentally assess species responses or can also be applied to species distribution modelling (described below) to predict changes in range. Techniques are more fully described in Chapter 1 of this volume.

2.1.1.2 Assessment of species distribution and conservation coverage

The combination of analyses of species distribution and coincidence with areas under different levels of protection permits a crude assessment of vulnerability of a species. Species distribution models provide an extra layer of information for vulnerability assessments, providing detailed quantification of the 'adaptation envelope', often climate related. These results can then be coupled with future climate predictions from GCMs to provide scenarios for future movement in species distribution, and potential implications for conservation.

Harvesting and land-use change present significant stresses to the long-term survival of both species and ecosystems. By imposing a limit on these impacts, conservation areas present one means of mitigating such stresses. The degree to which the range of a species or ecosystem type is included in reserves and protected areas is therefore a useful indicator of the level of stress it faces at present. While reserve coverage may have little effect on mitigating the direct impacts of climate change (i.e., physical temperature and moisture availability), it may aid in protecting biodiversity by reducing other indirect threats which limit the ability of populations and ecosystems to adapt to climatic change (e.g., fragmentation or reduced population size).

Numerous approaches to assess the effectiveness of conservation coverage have been developed over time. Generally speaking, they consist of two parts: an analysis of the geographical distribution of the species or ecosystems of interest, and a comparison to the spatial coverage and degree of protection afforded by any existing conservation areas. This general approach also requires considerable understanding of the species or ecosystem biology, since raw numbers describing percentage or absolute area of conservation coverage are of little meaning without an accompanying understanding of the minimum requirements of a population or ecosystem.

Methods used to describe the distribution of the species or ecosystem will depend upon the resources available and the extent of current scientific understanding. Species distribution maps were often originally prepared using field-based observations of the presence/absence of the species. More recently, various methods have been developed to predict the distribution of a species or ecosystem using components that are considered to be predicting factors in its niche or characteristic environmental adaptation. Species distribution models use the conditions at points where a species has been found to build a statistical model of the species adaptation envelope. The model is then applied across the larger region to locate areas where the conditions are potentially suitable for the species in question. Many of these range estimation methods assume that climatic variables are the principal drivers of geographic distribution (Walker and Cocks, 1991; Franklin, 1995; Guisan and Zimmerman, 2000), although other factors also have been used, including soils (Anderson *et al.*,, 2002), topography (Draper *et al.,* 2003), specific habitat conditions (Reutter *et al.,* 2003), landform type, or solar radiation (Maggini *et al.,* 2002; Ray *et al.,* 2002; Powell *et al.,* 2003; Lipow *et al.,* 2004). Guisan and Zimmerman (2000) discuss some of the applications of species distribution modelling and the various algorithms that have been applied to the problem. Perhaps the most widely recognised method uses generalised linear models (GLMs), specifically logistic regression, to predict species distribution (Cumming, 2000; Pearce and Ferrier, 2000; Guisan *et al.,* 2002; Osborne and Suárez-Seoane, 2002; Draper *et al.*, 2003), though many other methods exist, including principal components analysis (Jones *et al.,* 1997; Jarvis *et al.,* 2003) and neural networks (Anderson *et al.*, 2002). No single method is better than the other, and very much depends on the type of data available and the precise aims of the study.

Studies can also use remotely-sensed information (e.g., vegetation cover) to further refine model-based predictions, as has been used for mapping the distribution of great bustards (Osborne *et al.,* 2001). Since different types of ecosystems can often be delineated by satellite image analysis alone, it is sometimes possible to map ecosystem types using remotely-sensed images, as was done by Armenteras *et al.* (2003).

It is important to note that the predictive models discussed above are based on an evaluation of the niche conditions in areas that are known to be inhabited by the given species. As such, these predictions could be biased by under-collection of samples (which would tend to underestimate niche breadth and species distribution) or by collection of samples in areas that are non-typical of their niche (which would tend to overestimate the breadth and niche distribution). It should also be noted that since these models calculate the maximum probable extent of a species distribution, they will tend to overestimate the distribution in areas where other unaccounted factors could exclude a species (e.g., human impacts, particular edaphic conditions, or inter-specific competition).

To evaluate coverage, these species distributions can then be compared with maps of conservation areas, which are typically obtained by digitizing existing paper maps for use in geographical information systems (GIS). Studies typically rank conservation areas based on the degree of protection that they provide, and how effectively this coverage will protect the species or ecosystem involved from harvesting and land-use change. A global GIS map of conservation coverage is also available from the World Database on Protected Areas (World Commission on Protected Areas, 2004). Nevertheless, the categories describing the type of conservation area should always be compared with local policy and assessments to ensure accuracy. Quantitative comparisons can generate statistics such as the percentage of a species range under conservation, absolute area of a species range under conservation, and number of populations conserved.

Evaluating only the current extent of reserve coverage for a species fails to account for possible changes in the geographic distribution of species and ecosystems if they migrate as a response to climate change. Jarvis *et al.* (2001) coupled climate change scenarios from GCMs with species distribution modelling to evaluate the potential changes in species range. This method uses the downscaled future climate scenarios of Jones *et al.* (2003) to apply the species climatic envelope to surfaces of future climate. The method was applied on 17 species of wild peanut in South America, and predicted that 12 of these species had no overlapping species distribution between the climatic envelope in the present climate and a 2055 predicted climate. This method assumes no degree of adaptation for the species in question, though it is expected that each species has a certain degree of adaptability.

2.1.1.3 Assessment of harvesting activities

The harvest of plants and animals is a major non-climatic stress to biodiversity. The assessment of this stress is necessary for evaluating the vulnerability of biodiversity to climate change, as unsustainable harvesting of resources may reduce the adaptability of populations or ecosystems. The assessment of harvesting activities aims to determine which resources are harvested, where, when, at which rate, and also to evaluate the sustainability of the current harvesting regime.

In an overall adaptation programme, the assessment of harvesting activities is also a way to evaluate social vulnerability to climate change because of the relevance of harvesting in many livelihoods strategies. For reducing the non-climatic stress on biodiversity, some current harvesting regimes may be modified as an adaptation measure. This modification require knowing who are the harvesters and how, when, where, and particularly why they harvest. Taking into account that major threatened ecosystems by climate change (e.g., mountain forests, mangroves, etc.) are natural assets for rural livelihoods, the assessment of harvesting will help conservation and management practices and identify information dedicated to future adaptation needs for both community and biodiversity, e.g., the 'domestication/replanting' of useful species, the management of corridors and of protective forests (coastal, riparian, mountain zones).

How can harvesting practices be assessed?

Stakeholder analysis is a way to study the key actors of natural resource management, their actions, and their interests (Grimble and Chan, 1995). A stakeholder analysis starts with the identification of principal stakeholders in relation to resource management. Then, the stakeholder interests, characteristics and circumstances must be analysed. Interviews of sampled stakeholders must collect data on how they use and manage the resource, what benefits they receive from the resource, and how they take individual or collective decisions on resource use and management. The information related the spatial distribution of practices may be stored in simple maps or more elaborated GIS. The stakeholder analysis gives an insight into the harvesting practices and the possibility of modifying current management, as stakeholder interest and motivations are investigated. However, the method is not suitable for situations where stakeholders are not transparent with the interviewer, for instance by concealing some harvesting activities.

Another way to study the harvesting practices may use field estimations, especially in the case where the harvesters can not be identified or interviewed (e.g., illegal or diffuse activities, migratory stakeholders). The objective is to get an estimation of the harvesting rates (e.g., hunted animals or gathered medicinal plants) by evaluating quantities carried by stakeholders met during field trips in the ecosystem or at strategic points, such as at markets or along roads. Some information may be gathered by interviews with the harvesters. This method is generally expensive as it requires an extensive fieldwork.

How can the sustainability of harvesting practices be evaluated?

A first approach for evaluating the sustainability of harvesting practices is based on an estimation of regeneration rates. The comparison of harvesting and regeneration rates help to assess the stress on the resources. Models of renewable resource dynamics may be used to predict the evolution of the resources under distinct harvesting scenarios, such as the logistic curve or more complex population models (Caddy, 1999; Saphores, 2003; Rosser, 2004). Simulation is useful when the temporal and spatial heterogeneity of natural dynamics and harvesting practices has to be taken into account. However, regeneration dynamics and growth rates are very scarcely documented, principally for less-known species, non-timber forest products (NTFPs) and a lot of wildlife species (e.g., marine). This may prevent the comparison between harvesting and regeneration or the calibration and validation of models.

Regarding timber, the classic assessment methods are based on the regular quantification of standing volume by forest surveys and the estimation of timber yield (Biolley, 1920; Prodan, 1968; Assmann, 1970; Loetsch *et al.,* 1973; Clutter *et al.,* 1983). These methods determine the possible harvested volume that maintains a defined sustainable standing volume. When past harvesting practices (fluxes of resources) are known, they may be correlated to current spatial patterns of resource (stocks) estimated by inventories, in order to evaluate the impact and the sustainability of harvesting practices. In forestry, numerous sampling designs have been developed (see Schreuder *et al.,* 1993; Frayer and Furnival 1999). The recent multi-phase forest surveys combine terrestrial plots to aerial photographs and/or satellite data to improve the cost-efficiency (Köhl, 1995). However, forest surveys remain generally expensive and assessments methods have to be adapted to available means and to existing strategies. Recent statistical works tried to optimise the sampling schemes according to fixed costs (Mandallaz and Ye, 1999).

Recent guidelines and tools (Carter 1996; Doig 2001; CIFOR - CIMAT, Purnomo *et al.,* 2002; FSC approach - WWF 2004; ITTO - Pokorny and Desmond, 2004) propose step-by-step (iterative) implementation and assessment processes and are now already linked with social considerations. In the case of the use of non-timber forest products (NTFPs), the characteristics of the resources (e.g., the harvested part of plant) should be known in order to design the inventories.

Unlike timber, NTFPs such as flowers, seeds and leaves of plants are regularly produced and shaded, and there is no accumulation of products through the year. This means that periodic production and temporary available biomass are better indicators for determining sustainable harvesting rates than increment and production (Ohja *et al.,* 2001). Aluma (2000) gives a review of current assessment methodologies and the issue is now analysed at regional scales (see for example the results of the fourth regional workshop of the NTFP exchange programme on Community Assessment and Monitoring of NTFP Sustainability in South and Southeast Asia held in 2004).

Harvesting assessment and management adaptation

Assessment methods were adapted to new ecosystem management principles, such as the 'close-to-nature silviculture' which intends to enhance biodiversity (Parviainen and Bücking, 1997), the sustainable forest management as defined by criteria and indicators (ITTO, Appanah and Kleine 2000; FSC, principle 8) and the multifunctionality of the forests. Thus, they became more and more integrated and participatory (Davis-Case, 1990), as demonstrated by the multidisciplinary landscape assessments initiated by CIFOR (Sheil *et al.,* 2003). Nevertheless, for determining management practices (areas, timing, etc.), the basic set of variables under consideration usually still includes the composition and quantity of natural resources, and the regeneration and growth rates of major products.

Spatial and vocational mapping using GIS (Jeffers, 1996) help to adapt harvesting regulations to landscape and regional considerations (Oliver, 1992). However, in several developing countries, the harvesting rules have to be adapted to local capacities, especially with regards to professional skills and financial resources for planning or transactions. In remote areas, simple limitations (fixed harvesting periods, minimal timber diameter, etc.) and minimal planning requirements may be more efficient than ideal complex management requirements. Refinement of management practices in response to the results of an impact assessment can be done in four major steps: scenario-building; enhanced monitoring, biological survey; and review and revision of management practices (Hannah, 2003).

In the case of assessment of harvesting activities as well as in the case of the facilitation of adaptation to climate change, local level and management skills form the core of the necessary monitoring process. At this local level, climate change may influence the ecosystems by extreme events (hurricanes, floods, droughts) or in a more linear way through changes in moisture content, light and temperature conditions. The assessment of harvesting activities must link local livelihoods and the expected climate impacts on the ecosystem structure and composition. Key elements such as plant aspect, plant yield or key species may be traditionally known and observed; local knowledge will thus be central in the assessment phase as well as for the monitoring process. On the scientific level, a specific issue will be to adapt continuously the estimated growth and regeneration models according to the observed effects of changing climatic conditions.

2.1.1.4 Assessment of socio-economic baseline

A socio-economic baseline will help in assessing the current and future stress on biodiversity (e.g., through harvesting) and understanding which adaptation options are socially and economically adequate. Socio-economic assessments have a long methodological history. Approaches shifted from externally analysed perceptions to participatory rural assessments (Chambers, 1997) and they are now becoming increasingly interactive between local stakeholders and external assessors or facilitators from public structure or NGOs (Burdge, 2004). Modern socio-economic analyses distinguish social groups within a community, including the marginal people (Stakeholders analysis, cf. Brugha and Zsuzsa, 2000; Jennings and Lockie, 2004; Gilmour and Fischer, 1991) and they may be adapted to the context of conservation (The Nature Conservancy, 2001; Borrini-Feyerabend, 1997).

The livelihoods approach developed by the UK Department for International Development (DFID, 2000) provides a framework for analyzing household situations and activities. It considers five types of capital asset: human, natural, financial, social and physical. The households use and valorise their asset through activities based on natural resources (e.g., agriculture or forestry) or access to financial resources (e.g., through employment). The activities will depend on the vulnerability context (shocks, trends, and seasonality) and on policies, institutions and processes (Ellis, 2000).

Bond and Mukherjee (2002) developed a 'Livelihood Asset Status Tracking' (LAST) which has already been tested in an applied project for adaptation to climate change (SEI, 2003). Key elements are the ability to provide 'ad-hoc learning exercises' to enforce the good understanding and the follow-up of the process and to select a 'reasonably' homogenous area in terms of cultural, economic and agroecological practice. The sustainable livelihood approach gives a useful framework to design baseline assessment of the socio-economic conditions and the LAST-system may initiate a 'lasting' monitoring process. Numerous other specific assessment tools and methods (Rietbergen-McCracken and Narayan, 1998) may be combined to study more in depth one or the other 'asset'.

In the UNDP/GEF Adaptation Policy Framework, Malone and La Rovere (2004) propose to describe the socio-economic conditions using quantitative or qualitative indicators under five categories: demographic analysis (population density and spatial distribution, growth, migration, age distribution, etc.), economics analysis (activities, food security, sources of income, markets, infrastructure), natural resource use (land, water, forest, biodiversity, etc.), governance and development policies (development and environmental policy, recent or planned state reform, capacity of institutions, policymaking process), and culture (cultural aspects related to the relationships among stakeholders and between stakeholders and institutions, forms of governance, implementation of new technologies, etc.).

With any method, information on current socio-economic conditions may be gathered through fieldwork (stakeholder interviews and activity observations). If the method works with indirect indicators and does not require direct contact of stakeholders, expert opinion may be used to reduce costs. As adaptation to climate changes is intended to be integrated into a long-term planning process, assessment of baseline socio-economic conditions must ideally also be long-term. For estimating future socio-economic scenarios, various methods and sources of information can be used, such as expert opinion, statistical methods of forecasting applied to quantitative data, and models. Simulation models may be developed for representing the functioning of a simplified socio-natural system and for developing future scenarios for the system under different assumptions.

2.1.2 System adaptive capacity

Many consider that resilience is key to enhancing adaptive capacity of human-ecological systems. Likewise, the adaptive capacity of a socio-ecological system determines its ability of to cope with novel situations without compromising options for the future (Folke *et al.,* 2002). Resilience is defined here as the amount of change a system can undergo and still remain within the same state, be capable of self-organizing, and adapt to changing conditions (Carpenter *et al.,* 2001). The attributes that enhance resilience and that make reorganisation possible include redundancy, diversity, spatial heterogeneity, rapid feedbacks and ecological and social "memory" (see Box 1). As these attributes are found in all natural systems, adaptive capacity to climate change and biodiversity are thus highly interlinked—as more resilient ecosystems may be better able to cope with global climate change and have the adaptive capacity necessary to reorganise themselves following disturbance so to keep providing essential services to people.

2.1.2.1 Adaptive genetic diversity and phenotypic plasticity

A comprehensive assessment of the adaptive function of genetic diversity requires lengthy and expensive investigation. Where possible, this should include common garden experiments planted to reflect the predicted changes in climate. Diversity in neutral molecular markers should not be used as a surrogate for adaptive diversity, however it may be useful as a general indicator of population fitness (as per Reed and Frankham, 2003). Mapping of environmental heterogeneity may prove a useful method for rapid estimation of adaptive diversity, however at present, this still requires further testing. In cases where practical limitations do not permit the establishment of common garden experiments, it is recommended that conservation programmes take a precautionary approach and assume that populations will not be able to

Box 1. Main Attributes that Enhance Ecosystem Resilience

Redundancy:
The number of species is less important to an ecosystem than the presence of 'functional groups' (e.g., short-lived and long-lived trees, shrubs, annual and perennial grasses). If a functional group loses a species, other species within that group are likely to take over by increasing in abundance.

Complementarity:
The number of species plays an important role in the way an ecosystem works, as different species contribute to its structure and function in complementary ways (e.g., co-existing tree species with shallow and deep root systems).

Spatial heterogeneity:
Tends to favour the co-existence of different species in a given area (to fulfil the above-mentioned roles) and makes reorganisation possible.

Memory:
(i) Genetic makeup present in current biological communities selected over long time periods (favourable/unfavourable) and that is expressed in a selective manner under different environmental conditions.
(ii) Dormant seeds in the soil that allow a forest to regenerate after large-scale or extreme events such as hurricanes, deforestation.

adapt to changes in climate. In this case, plans should be made to assess the possibility of migration as a coping strategy.

High levels of adaptive genetic diversity can improve the likelihood that a species will be able to survive changes in climatic conditions. Alleles that offer comparatively low survival advantages in a given environment can be of significant advantage when conditions change. As a result, populations with a diversity of adaptive responses are more likely to be able to persist in the face of environmental change. Much like adaptive genetic diversity, phenotypic plasticity gives a species a certain capacity to adapt to changes in the environment. Genes which are phenotypically plastic can be expressed differently depending on the environment, thereby allowing adaptation to a range of conditions within a single individual or genotype. Populations that are genetically homogenous can therefore still cope with changing climates provided the genes responsible for environmental adaptation are phenotypically plastic.

In order to adequately assess how these factors may contribute to survival under changing climatic conditions, it is necessary to test the responses of populations to different climates under common garden conditions (Davis and Shaw, 2001). By planting provenances from various populations in areas where the present-day climate closely resembles that of the predicted future climate, this method can aid in directly assessing the probability of survival through adaptation. Where populations occupy diverse environments, it can aid in assessing whether their adaptive responses are plastic or genetically based. Similarly, this method can be used to assess how adaptive diversity is partitioned throughout the range of a species, and whether there are high levels of variation within and/or between populations. This approach has been used to examine adaptation and the effects of climate change on the pine trees *Pinus contorta* and *Pinus sylvestris* (Rehfeldt *et al.,* 1999; 2002) and to assess plasticity in *Pinus ponderosa* (Maherali *et al.,* 2002). While this is the most robust approach to assessing physiological adaptive capacity, it tends to be expensive and time-consuming, and may therefore be an unacceptable option for all but the most highly-valued species.

An alternative to investigating both diversity and adaptive function is to focus directly on measuring levels of genetic diversity and assume that this will be correlated with actual adaptive function. Ideally, this approach should focus on genes with an identified adaptive function, however with the exception of a few model experimental species, very few such genes have been identified and studied extensively. Furthermore, the search for these genes is often prohibitively time-consuming and expensive, and therefore beyond the reach of most conservation programmes. As a result, many conservation biologists have used easily-measured molecular markers as surrogates for examining overall diversity and for inferring levels of adaptive diversity (Geburek, 1997). Molecular markers however are increasingly being seen as poor surrogates for adaptive diversity. As most markers are selectively neutral (or nearly-neutral), they do not respond to the same evolutionary forces that shape adaptive traits, and as such have often found to have patterns of diversity that are uncorrelated to those of adaptive traits (Reed and Frankham, 2001). While adaptive traits are preferable to neutral markers, any studies of diversity completed without an accompanying physiological component may inaccurately assess the actual degree to which adaptive genetic diversity may prepare a species to cope with climatic change. Another limitation of both genetic surveys and common garden experiments is that they require species-by-species and population-by-population assessments, and as such are often not feasible for the characterisation of an entire species distribution.

Since adaptive genetic diversity is the result of heterogeneity in selective pressures (Hedrick *et al.,* 1976; Linhart and Grant 1996), it may be possible to estimate relative levels of diversity by measuring variation in environmental variables. A recent study found significant correlation between regional heterogeneity in drought stress conditions and within-sub-population diversity in adaptive responses for drought tolerance in the Andean conifer *Araucaria araucana* (Yeaman and Jarvis, *submitted*). Since this type of surrogate can be calculated from maps of precipitation or temperature, it may be used for estimating relative levels of genetic diversity across the entire range of a species with minimal cost and time. This approach could be of very broad utility, in that measurements of heterogeneity are non-species-specific and could be applicable to predicting diversity in any species inhabiting the study area. This method has not yet been extensively tested however, and as such, is of questionable practical utility until it is more rigorously examined.

2.1.2.2 Genetic connectivity, migratory ability, and fragmentation

While both migration and physiological/genetic adaptation are thought to be integral to coping with climate change, migratory capacity tends to be more directly impacted by human activities. As such, enhancing migratory capacity is more often within the reach of conservation activities, as discussed below. Assessment of migratory capacity tends to be fairly species-specific however, and as such, there are few broadly-applicable models or tools. A comprehensive assessment of migratory capacity will generally require the species-specific methods discussed here, together with an assessment of both the predicted spatial change in climatic conditions and the regional patterns of land use/fragmentation, as described above.

Migration is one of the principal ways in which a species can cope with climatic change. Where changes in environmental conditions are too rapid for species to adapt, migration to new areas with favourable climates provides an alternative survival strategy. Migration from one area to another may be relatively rapid in the case of highly mobile animals but require several generations in the case of plants with limited seed dispersal. The specific factors that affect the possibility of migration differ greatly from one species to the next, but in all cases, successful migration requires both a viable path for displacement, and a suitable area for colonisation. In the first case, the nature of the intervening environment and presence of a suitable transport vector (e.g., wind, water, animal host) can have considerable impacts on success of migration. Mountains, large bodies of water, and unsuitable land use/habitat types (e.g., agriculture, urban development, dense forest) can all effectively act as barriers to migration, depending on the species and its method and rate of displacement. In the second case, any areas where an organism must reside for any length of time must be of a suitable habitat to enable their survival.

Any analysis of the migratory ability of a species therefore depends upon the distance that it will likely have to migrate to encounter suitable climate and habitat, and its ability to travel through the intervening landscape. Because of the great differences in migratory ability from one species to another, assessment generally requires specific research into species biology. Field-based experiments however are costly and time-consuming, and for the purposes of conservation research and planning a literature review will often provide sufficient information for an approximate estimate of species migratory capacity and ecological requirements. Various models have been developed to assess migration and dispersal, which can also be used as a surrogate for fieldwork (Dyer, 1995; Malanson and Cairns, 1997; Higgins and Richardson, 1999).

The actual likelihood of a species being able to migrate to cope with climate change can then be assessed by comparing its migratory ability to the assessments of habitat fragmentation and displacement of climatic envelope (species distribution). Habitat fragmentation can generally be analysed by measuring distances between appropriate patches using maps or GIS-based data, while modelling of a climatic envelope is described above. This type of assessment has previously been completed with *Pinus virgiana* in the United States (Iverson *et al.,* 1998) and with *Arachis* species in South America (Jarvis *et al.,* 2001; 2003). A general review of migration and climate change is covered in Pitelka (1997). Ray *et al.,* (2002) used GIS-based maps to model spatial migratory routes, which is an approach which could similarly be applied to assess capacity to migrate as a way of coping to climate change.

2.2 Identification of options

Adaptation options are thought to be the most practical options since mitigation of climate change itself is a long-term endeavour. Human interventions that enhance ecosystem resilience – and hence its adaptive capacity – need to focus first on treating the causes of biodiversity loss (i.e., reduce habitat conversion, over-harvesting, pollution, and alien species invasions on native ecosystems), maintain ecosystem structure and function, and maintain natural disturbance regimes that create heterogeneous conditions, minimise habitat fragmentation, and promote, when feasible, rehabilitation/restoration practices that enhance ecosystem integrity and maximise historical levels of biodiversity. In other words, conserving the composition and structure of present biological communities through reducing non-climatic stresses – rather than simply maximizing species numbers – is more likely to maintain higher levels of ecosystem service provision. Recent studies show that a loss of resilience is thought to lead to switches to so-called "alternative ecosystem states" (Scheffer *et al.,* 2001) suggesting that long-term sustainability should focus on maintaining resilience. Integrated approaches to natural resource management also constitute an essential element of adaptation to climate change. Adaptation options for selected ecosystems are presented in Box 2.

2.2.1 Protected areas

A major adaptation option is to conserve biodiversity in protected areas and to counter habitat fragmentation by establishing biological corridors between protected areas, particularly in forests. Adaptation options through protected areas may need to incorporate climate-driven scenarios of biodiversity change as a reserve selection criterion. Managing both for landscape connectivity and the surrounding matrix becomes essential to biodiversity conservation in a changing climate. One example is the proposed Greater Addo National Park in South Africa. The park covers a large area within a range of elevations and ecosystems. By protecting as many different habitats as possible, park planners were able to take into account the potential effects of climate change on species distribution and migration. An existing reserve which is likely to allow for climate-driven species migration is the La Selva–Braulio Carrillo land corridor in Costa Rica which is the last intact gradient of rain forest (from near sea level to ~ 2900 m elevation) on the Caribbean slopes of the Central

Box 2. Adaptation Options in Selected Ecosystem Types: Links to Enhancing Ecosystem Resilience

Forests - Options may include:
(i) maintaining representative forest ecosystem types across environmental gradients, providing buffer zones for possible spatial shifts in reserve boundaries and practice low-intensity harvesting and site preparation methods;
(ii) avoiding fragmentation and providing ecological connectivity through planted forests;
(iii) as there are strong links with mitigation (Chapter 3), when planting forests: establish indigenous, mixed-species stands, maximise natural genetic diversity (and minimise highly selected material), mimic the structural properties of surrounding natural forests, and avoid the direct replacement of native ecosystems.

Marine and coastal – Options may include:
(i) designing marine protected areas so that they include reef areas that have demonstrated resilience/resistance to raised sea temperatures;
(ii) conserving and restoring coastal ecosystems to protect coastlines from the impacts of climate induced sea-level rise;
(iii) undertaking aquaculture and mariculture as options to potential climate-change induced decline of wild fisheries in a sustainable manner. In the context of integrated marine and coastal area management, these options are important as unsustainable farming of carnivorous fish species can have further detrimental impacts on wild populations (e.g., use of small fish for food) in addition to current over-harvesting, and because large-scale aquaculture projects that lead to clear-cutting of coastal forests may reduce the ecosystem's capacity to mitigate floods and sea-level rise.

Inland waters – River biota is – within reasonable limits – relatively well adapted to rapid and unpredictable changes in environmental conditions. In contrast to many terrestrial ecosystems, much of the functions of inland water ecosystems are determined to a large extent by physical features rather than species composition/diversity *per se*. Thus, options may include maintaining near-natural flow patterns, channel morphology, water quality and quantity, and overall connectivity.

Traditional agroecosystems – Local, traditional agroecosystems harbour centuries of locally adaptive information that result in diverse landscapes managed for multiple uses. They are more knowledge- than use-intensive and are shown to spread the risk of climatic variability through: high species numbers, high structural diversity in time and space, exploitation of the full range of micro-habitats available, complex biological interactions leading to pest suppression, and use and maintenance of local varieties of crops, wild plants and animals. Resilience in the face of changing climate has been documented for smallholder farmers that depend on local agroecosystems in many locations across the globe. Options may include conservation of crop genetic resources, and their incorporation in breeding programmes to maintain future options arising from the impacts of climate change.

Mountain and arctic ecosystems are under particular stress and threat of degradation due to their high sensitivity and vulnerability to climate change but few adaptation options are available except for building barriers against coastal erosion. Adaptation activities that best address how mountain ecosystem management leads to adaptation benefits may be those that link upland-lowland management strategies.

Source: CBD *Ad Hoc* Technical Expert Group on Biodiversity and Climate Change, 2003.

American isthmus – although this one was not explicitly set up with climate change considerations in mind. Is should be noted that the design of these 'dynamic' conservation systems at the landscape/regional scale may have to rely on local/regional models, as discussed in Chapter 1.

2.2.2 Replanting/colonisation/assisted migration

Replanting *via* reforestation and afforestation need to pay attention to species selection and site location in order to promote – and not displace – the return, survival, and expansion of native ecosystems. Afforestation of native grasslands and other indigenous ecosystems would entail significant loss of biodiversity. Plantations of exotic species support only some of the local biodiversity but may contribute to biodiversity conservation if appropriately situated in the landscape. Tree plantations may be designed to allow for the colonisation and establishment of a diverse understory. Specific sites may make better candidates than others for implementing such activities based on past history, level of degradation, and the local or regional importance of the their associated biodiversity. Furthermore, plantations may contribute to providing ecological connectivity in fragmented habitats (CBD *Ad Hoc* Technical Expert Group on Biodiversity and Climate Change, 2003).

2.2.3 Ex-situ conservation

Overall, species whose natural range is likely to be most threatened by climate change should have the highest priority for *ex-situ* conservation. One limitation of captive breeding is the lack of space available. Zoos and off-site breeding facilities can be expected to accommodate no more than a small fraction of the number of species that might be threatened. In the case of plants, botanical gardens are better suited to accommodate many plant species threatened by climate change. Due to our incomplete known of the biology of many plants, particularly the endemics, these species will not be able to survive and reproduce in habitats created in botanical gardens.

Captive breeding and translocation, when combined with habitat restoration and *ex-situ* conservation may help to prevent local extinction of key taxa under small to moderate climate change. Captive breeding for reintroduction and translocation is likely to be less successful if climate change is more dramatic, as such change could result in large-scale modifications of environmental conditions, including the loss or significant alteration of existing habitats of some or all of a species' range. However captive breeding is technically difficult, often costly, and unlikely to succeed in the absence of complete knowledge of the species' biology (CBD *Ad Hoc* Technical Expert Group on Biodiversity and Climate Change, 2003).

It is important to note that efforts designed to minimise genetic changes in order to maintain the original genotypes to the extent possible (mostly connected to breeding programmes), versus efforts which support continued natural selection in response to new or changing environments (evolutionary conservation) are different but complementary parts of *ex-situ* conservation programmes. Both types of conservation efforts have a role to play in strategies for sustainable use and conservation of genetic resources in the face of changing climate.

2.3 Key challenges for identifying options

Adaptation helps both to reduce and spread future risk and plans for the movement of species and ecosystems. Yet the effects of specific adaptation strategies on biodiversity in particular ecosystems are less known. Emphasis will be needed on species/ecosystems either with restricted dispersal capability to the projected nearest suitable 'climate space' or with extreme habitat specialisation. Increasing our understanding of ecosystem/species adaptations to *current* environmental change may provide important information for designing future options.

Similarly, documenting long-term responses in agricultural practices in regions with extreme and/or deteriorating climatic conditions is likely to identify key determinants of adaptation. It is estimated that 10-15% of the 960 million hectares of land under cultivation in the developing world are managed through traditional agroecosystems (Altieri, 2004). Scientists can help small farmers translate the principles of species and functional diversity, organic matter accumulation, species interactions, and minimisation of resource loss into practical strategies to enhance production.

Management that expands across protected area boundaries to include the matrix may have to be co-ordinated across political sub-divisions as species range shifts will not respect political boundaries. Countries that are drawing up plans to deal with climate-induced disasters could identify not simply vulnerable human settlements but also the local ecosystems on which they depend both for economic and conservation reasons.

3. The adaptation strategy: Development and implementation

Identifying which aspects of biodiversity will be most vulnerable to climate change and the management strategies for coping with such change is meant to be an objective, scientific process. At the same time, it is a process that can be approached from a number of directions, depending on the objectives. Effective adaptation strategies will be motivated by clear and focused objectives that respond to the unique needs and context of the vulnerability assessment. The first step in clarifying these objectives is of course to identify the biodiversity priority or priorities to which the strategy aims to respond. The priority could be an individual species or population, a specific area of habitat or habitat type, a landscape, an ecosystem process, etc. The priority of the adaptation strategy will likely be the initial priority of the vulnerability assessment, but it may also be a more focused subset of that assessment, based on the assessment findings.

The manner in which a strategy responds to priority needs – i.e., the form it takes and the manner in which it functions – will depend on the context within which the strategy is being developed. For instance, in certain countries, biodiversity may be included as one of the handful of sectors prioritised for vulnerability and adaptation assessment within the countries' national communications to the UN Framework Convention on Climate Change. In these instances, the resulting adaptation strategy may include highly integrated options, which accomplish objectives in several sectors (e.g., water, forests and biodiversity), as well as a set of sector-specific options, focused on key sectoral needs. In other cases an adaptation strategy focused solely on biodiversity might be developed independently (e.g., as part of a migratory corridor long-term management plan). In such cases, the resulting strategy might include a richer array of options focused specifically on biodiversity, but perhaps only a series of recommendations (as opposed to an agreed plan) for integrating with other sectoral management strategies. As still another example, adaptation strategies may be developed which focus on areas other than biodiversity (e.g., coastal zones, rangelands, water), but include adaptation options (e.g., hillside reforestation, mangrove restoration) that are based on ecosystem management and other biodiversity-focused approaches.

In general, efforts to increase the resilience of biological systems to the impacts of climate change will be more successful if the scope is sufficiently broad to incorporate the non-climatic root causes of biodiversity loss. In all instances, implementation of adaptation strategies is an iterative process, and will require long-term dedication to monitoring, and revision of management strategies as the need arises. By entering the strategy development process with a clear understanding of the priority needs, desired outputs and larger policy and planning context, planners can help to ensure that a targeted and effective strategy is produced.

Efforts to increase the resilience of biodiversity to climate change can be carried out at a range of temporal and spatial scales, can be worked with a number of different policy processes, and can draw on a variety of resources. A key preliminary step in developing an adaptation strategy is therefore to clarify the scope, scale and inputs to the process, a step that is closely linked to the initial prioritisation process outlined above.

The range of participants included in the development and implementation of the adaptation strategy will be dependent on both the scope and scale of adaptation efforts. It will be necessary to identify whether the adaptation strategy is at the regional, national, landscape or site level. Transboundary efforts that include multiple geo-political units will also become more important as species assemblages shift with climate change.

From a biodiversity perspective, adaptation efforts will ideally be defined by the size and distribution of land and habitat areas required for conserving key biodiversity that will be affected by climate change – a concept referred to as the 'biological landscape' (Loucks *et al.,* 2003). The vulnerability analysis should assist in the definition of the biological landscape by identifying species, habitats, and processes that will need to be conserved given projected impacts. An expert workshop can be used to gain consensus on the implications of climate impacts from a management perspective. A Decision Support System (DSS) is increasingly used to define critical habitats, a computer-based tool that assists decision-makers to evaluate scenarios about land uses; and is often paired with geographic information systems to help define boundary areas (Loucks *et al.*, 2003). Smaller priority areas can be compiled for the national or regional level to ensure harmony with approaches at a broader geographic scale.

The scope of an adaptation strategy will therefore be governed by both the participants and the resources, as well as by the identified problems and their causes, as discussed above. For example, a degraded coastal site vulnerable to inundation from rising sea-level due to lack of erosion control could focus explicitly on regeneration of the ecosystem (e.g., planting of mangroves). A broader scope would include activities that address the source of coastal degradation (e.g., alternative uses of mangrove wood, or increased efficiency of wood-burning stoves). In general, efforts to increase the resilience of biological systems to the impacts of climate change will be more successful if the scope is sufficiently broad to incorporate the non-climatic root causes of biodiversity loss. In all instances, implementation of adaptation strategies is an iterative process, and requires long-term dedication to monitoring, and revision of management strategies as the need arises.

The collection of data for assessing vulnerability and understanding the realm of adaptation options will likely include participation of multiple types of stakeholders. Moreover, weighing that information and determining what course of action is realistic and desirable will require extensive input from an even broader community of stakeholders. Thus, the importance of involving a wide array of stakeholders in the development and implementation of an adaptation strategy cannot be overemphasised. As Loucks *et al.* (2003) have stated, an effective mechanism for engaging key stakeholders marks the difference between an excellent plan that is never used, and one that has sufficient cross-sector support to be implemented. The long-term nature of climate change requires that segments of a particular community, from local communities to national government authorities are included in the process. Broad participation will help ensure the long-term success of an adaptation strategy, especially as it is revised and reworked as further monitoring and research is undertaken. Likely participants in the development and implementation of an adaptation strategy will include the following:

- **Ecosystem managers** – those currently 'in charge' of management of the given area. This could include government foresters, as well as local communities, and private land-holders.
- **Local communities** – people who are affected by the impacts of climate change and changes in management in order to conserve biodiversity. Communities living in or near the focal area will likely have extensive knowledge of past impacts and will be a wealth of knowledge in observing changes.
- **Government staff** – besides government-employed land managers, those principally responsible for environment and biodiversity and involved in

policy and legislation that affects the area in question will have a role to play in the adaptation strategy. Participation of government staff, including local, regional, and national will be necessary at various stages, both for assisting in overcoming legislative or policy barriers to adaptation as well as assistance with funding, and eventually to facilitate the sharing of lessons and awareness-raising at higher levels beyond the specific area in question.
- **Scientists** – preferably those biologists that conducted the vulnerability analysis, or who have expertise in conservation of species that are likely to be especially impacted by climate change (e.g., biologists with specialty in coral reefs, mangroves, tropical mountain cloud forests, boreal forests, grasslands, or arctic environments).
- **Civil society organisations (CSOs)** – non-governmental organisations, from national-scale conservation groups down to the small-scale, community-based organisations, have been shown to be important actors and innovators in the sustainable management of biodiversity (see e.g., Banuri and Najam, 2002). In their proximity to the community level, CSOs can help to facilitate the harmonisation of community needs with the needs of biodiversity. In particular, groups with experience related to the specific priority(ies) of the adaptation strategy (from a river basin facing multiple stresses to a degraded micro-catchment) can provide key insights during the planning process.

The first order of priority is to designate a co-ordinator who will facilitate the development and implementation of the adaptation strategy. Consultation amongst stakeholders will assist to identify the co-ordinator as well as determine the roles of other participants throughout the process. For example, a government agency with capacity and interest in managing for climate change may lead the process, with research and conservation organisations and local communities serving as catalysts and active participants.

3.1 Developing an adaptation strategy

A biodiversity adaptation strategy provides a framework for prioritising and organising efforts to address the impacts of climate change on the focal elements of an ecosystem. It will likely be based upon a set of management and policy measures. A comprehensive adaptation strategy will include the following components:

1. Strategy priorities and objectives.
2. Area of focus (scope and geographic scale of adaptation efforts, including priority landscapes or sites).
3. Stakeholders and project participants.
4. Overview of climate impacts on biodiversity in area of focus (baseline and future projections).
5. Identification and formulation of adaptation options.
6. Evaluation and selection of adaptation options.

7. Action plan of selected adaptation options:
    a. Description of planned activities,
    b. Timetable,
    c. Resources needed,
    d. Baseline and targets,
    e. Participants and their roles.
8. Monitoring programme.

The first four components are described in the preceding section, and the following section discusses consideration of and planning for adaptation and monitoring activities.

3.1.1 Identification and formulation of adaptation options

An advisory group led by a scientific expert or land manager can assist in the identification and elaboration of potential adaptation options, building on the general categories outlined in Section 3.

3.1.2 Evaluation and selection of adaptation options

Once the options are laid out, a set of criteria can be used to identify which activities are most desirable and feasible. Box 3 below is a sample checklist for identifying a balanced suite of adaptation activities that should lead to increased resilience within a biological landscape. This type of list can be adapted to suit local circumstances and the specific biodiversity priority to which adaptation options should respond.

Box 3. A Checklist for Identifying Adaptation Activities that Enhance Biological Resilience

(To be rated 1-5, with 5 agreeing most with statement)

- o Does the activity address existing, non-climatic stresses to the system that decrease overall resilience?
- o Does the activity ensure that the affected species has sufficient habitat, distribution, and connectivity to maintain its function and ecological processes that will ensure successful response to changing climate? OR Does the activity have as its focus either the protection of functional groups, keystone species, climatic refugia, or multiple micro-habitats within a biome to provide adequate representation throughout the future?
- o Does the activity involve local communities or private sector interests with a stake in the focal area or resource? Does it improve the resilience of those dependent on the targeted site?
- o Is the land manager on-site to oversee the activity if necessary?
- o Are the economic costs surmountable?
- o Is the activity co-ordinated with existing management strategies for the area; or are potential implementation barriers surmountable?
- o Does the strategy include a mix of resilient and vulnerable focal areas to ensure a balanced strategy?

3.1.3 Monitoring programme

Ongoing monitoring of management and policy efforts geared towards ameliorating the effects of climate change are especially important. Not only will progress toward established targets need to be monitored to ensure activities are having their intended result, but long-term analysis of the targets and overall strategy itself is crucial. There is relative uncertainty about the exact impacts climate change will have on many systems, and also with regard to the cascading impacts upon the complex interrelationships between species structure, composition, and functions.

A monitoring and evaluation plan should be established in the initial stages of planning for adaptation. The monitoring plan will need to monitor progress against a baseline which is defined in the vulnerability assessment process. Indicators should be chosen in order to measure whether actions are strategic and effective, that is whether biodiversity is becoming more resilient (and at least not less so) to the impacts of climate change. The outputs of monitoring can also be used as the vehicle for communicating results to stakeholders and external audiences for increasing awareness about climate change.

3.2 Implementing an adaptation strategy

An adaptation strategy is a plan for increasing the capacity, over time, of vulnerable groups and systems to cope with climate impacts and adapt to climate change. It is clearly a long-term endeavour, and one that will require strong stakeholder support, an able institutional framework, strategic use of existing policy synergies, careful monitoring, evaluation and adjustment, as well as long-term, if gradual, mainstreaming into more central policy and planning processes. Though by no means a universal recipe for implementation, this section outlines some steps that are likely to be common and useful across implementation processes.

3.2.1 Build stakeholder awareness and receptivity

It is widely appreciated that, across the range of policy processes, stakeholders are critical to implementation. This is true from the macro-scale, at which national government ministries can provide the political support necessary to ensure broader buy-in, to the meso-scale, where resource managers can help to ensure effective co-ordination of implementation, to the micro-scale, where local awareness and acceptance can determine the success of ground-level implementation. This holds true for implementation of an adaptation strategy, where the support of central ministries such as finance and development, and the buy-in of local farmer's unions can both determine whether a strategy for improving food security can be successfully implemented. Stakeholder awareness building – from high-level government meetings to community-based workshops – can be an important tool for laying the ground for strategy implementation. Finally, over the long-term, the awareness and support of the general public will be essential to successful implementation of adaptation policies and measures.

3.2.2 Create an institutional framework

An adaptation strategy will tend to include a collection of policies and measures that, generally speaking, no single institute will be suited to implement and sustain alone. Instead, some form of institutional framework will likely be necessary. This framework would include those institutions directly implicated in strategy implementation, affording a more central role to those institutions that can help to sustain the adaptation process over time. In the case of an adaptation strategy for biodiversity, the framework might include those government ministries responsible for implementing the national development strategy as well as plans to comply with multilateral environmental agreements (MEAs) and to meet the Millennium Development Goals. The framework may be strengthened by inclusion of institutions at smaller operational scales, from the sub-national to the local, and by the articulation of (and buy-in to) clear roles, responsibilities and divisions of labour.

3.2.3 Ensure policy integration

Because of the nature of adaptation, adaptation strategies will tend to involve activities with strong overlaps and synergies with existing policies and measures. In a world of limited resources (financial, human, institutional, etc.), there is clearly enormous value to identifying those synergies and designing an adaptation strategy that builds on and around existing, complementary activity. Viewed from a different angle, the *failure* to take advantage of synergies can introduce significant waste and redundancy. In terms of adaptation, commonly cited synergies are those with the global biodiversity and desertification conventions and national action plans, as well as general national conservation plans.

However, while recognised as an important adaptation planning principle (see e.g., Least Developed Countries' [LDC] Expert Group, 2002), the process of capitalizing upon synergies has not yet been adequately explored or operationalised. In response, new guidance (e.g., the LDC National Adaptation Programme of Action Guidelines and the UNDP/GEF Adaptation Policy Framework) is increasingly advising users to scope key policy integration opportunities related to each adaptation option. For adaptation in general, these opportunities may be found in disaster management policies, poverty alleviation strategies, natural resource management plans, to name a few. For biodiversity, synergies will clearly be found in National Biodiversity Strategy and Action Plans, and in a range of other natural resource and environmental policies. However, synergies with other policy arenas also exist and should be explored.

3.2.4 Monitor, evaluate and adjust

As the roadmap for a long-term process, an adaptation strategy must remain effective and well suited to the changing circumstances in which it operates. To do so, strategies will require careful, regular monitoring and evaluation (M&E), and adjustment based on M&E observations. Since each adaptation option will need to be followed independently in order to determine its relative success, planners may wish to develop a monitoring and evaluation plan, including outcome indicators, as part of the write-up for each of the candidate adaptation options. Periodic monitoring, coupled with evaluation and recommendations, can provide an indication of where an adaptation strategy requires adjustment in order to achieve its goals.

3.2.5 Mainstream

From the adaptation and biodiversity perspectives, mainstreaming is a process whereby adaptation and biodiversity goals become part of the 'mainstream' discourse and policy framework, in whatever scale they are operating. Sustainable development provides a useful example of a concept becoming more mainstream over the course of roughly a decade. However, it also captures many of the challenges of mainstreaming, including the ease with which mainstreaming is discussed and lauded in comparison to the infrequency with which it is achieved in a meaningful way. It is no surprise that the prospect of mainstreaming adaptation in general, and adaptation for biodiversity in particular, should pose a challenge, since there is no shortage of competing needs and concerns that warrant mainstreaming on some level. Conversely, there is only a limited capacity of policy processes and society in general (e.g., financially, socially) to respond to any of them. Thus, while mainstreaming is an essential and widely touted goal (see e.g., LDC Expert Group, 2002), it continues to prove elusive.

An adaptation strategy will benefit from a clear plan for mainstreaming that outlines specific entry points and ways of using these to their fullest. Key opportunities for mainstreaming adaptation for biodiversity will most likely be identified during the policy integration process outlined above. Here, planners will have identified near-term opportunities for connecting adaptation policies and recommended activities with existing policies and ongoing activities, in a mutually beneficial way. Exploiting these opportunities represents a valuable near-term step that can be made toward mainstreaming, and can lay the groundwork for more significant mainstreaming progress in the future.

3.3 Key challenges for implementation

Key challenges for implementing adaptation strategies include:

- **Sustaining stakeholder and institutional support:** The linked processes of adaptation strategy development and implementation require well-co-ordinated engagement of a variety of stakeholders, and sustained support of key institutions.
- **Identifying and exploiting synergies:** Taking advantage of synergies between proposed and existing adaptation policies and actions can provide significant benefits to both endeavours. Failure to do so can create significant waste and replication of effort. However, synergies are not always easily exploited, and doing so can require the revamping of policy, the reinvention of institutional relationships, and the weakening – or breaking down – of traditional institutional and policy boundaries. Therefore, careful shepherding and strong leadership are required to ensure that political inertia does not preclude innovation in policy implementation.

- **Monitoring and evaluating adaptation strategy impacts on biodiversity:** The process of monitoring change in biological systems can be complex and resource intensive, requiring involved observation and data collection, painstaking analysis, etc. Care should be taken to ensure that an M&E plan is developed which ensures a robust yet streamlined M&E process.
- **Achieving mainstreaming:** As outlined above, the process of mainstreaming will be essential for the long-term prospects of adaptation. At the same time, mainstreaming adaptation must contend with competing societal priorities, as well as a history of policy mainstreaming (certainly with regard to the mainstreaming of environmental issues) which is fairly mixed and inconclusive. Mainstreaming will require, among other conditions, sustained political will and thereby a sustained awareness-building programme focused on stakeholders and the public at large.

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