A systematic regional approach for climate change adaptation to protect biodiversity

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Abstract Developing appropriate climate change adaptations to protect biodiversity requires taking into account the dynamics of agro-ecological and socio-economic change. A framework for approaching this problem was proposed, but not applied in detail, as part of a major biodiversity and climate change report prepared in Australia. This paper describes the first trial application of the method. It was applied across Vietnam as the Government is interested in identifying adaptation options and detailed data are readily available for its 65 provinces. The process involves identifying ecoregions and collating information for each region based on the current conditions and trends in biodiversity, population, income and agricultural production. Climate change scenarios are identified for each region, together with governance options. Educational needs and key adaptation actions are then identified for each region taking into account the agro-ecological and socio-economic input data. It is concluded that the framework could easily be applied in other countries and should assist the development of strategic adaptation options.

1 Introduction

As efforts to establish international mitigation agreements have faltered in recent years the attention of many governments has turned to identifying climate change adaptation options. There are significant challenges in developing policies and adaptation options to reduce the negative impacts of climate change on biodiversity. Appropriate strategic adaptation options cannot be developed in isolation. There is a need to appreciate interactions between the

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biophysical environment, current and future socio-economic trends, and climate dynamics. A relatively simple framework is needed to summarize the factors that are key components of linked social-ecological systems (Liu et al. 2007).

This paper describes a method to assess at a regional scale conditions and trends in key environmental, social and economic factors of importance to conservation issues. These data summarize the dynamics of agro-ecological and socio-economic change. The condition and trend information are used in a table along with climatic change scenario data to provide background information that assists identifying appropriate adaptation options. The data also help to identify regions that have similar characteristics and may require similar adaptation options.

The general method used here was proposed, but not applied in detail, by Steffen et al. (2009) in section 7.7 of their book on 'Australia's Biodiversity and Climate Change'. The sections of Chapter 7 that precede section 7.7 consider the nature of the climate change threat and provide a very useful overview of general principles for managing biodiversity under climate change. For example, principles and approaches for minimizing loss of biodiversity, such as maintaining a representative array of ecological systems and minimizing existing stressors, are described. Ten ecological principles are recognized and linked to management strategies at local, regional and continental scales. Anyone considering applying the method described here would be well advised to study these sections carefully.

Subsection 7.7 is entitled 'Towards a systematic regional approach for biodiversity conservation in the 21st century', and outlines a procedure for integrating ecological values and socio-economic information as an aid to planning biodiversity conservation under climate change. The first paragraph discusses the need for a regional approach, with regions being defined by common ecological, socio-economic and climate change characteristics. The aim is to avoid individual solutions being developed for individual regions and to encourage synergies, collaboration and learning. The following couple of paragraphs describe in general terms how different agro-climatic and socio-economic zones may be recognized using the work of Barr (2005), Hobbs and McIntyre (2005) and Holmes (2009) as examples.

A further two paragraphs then briefly describe how a table can be constructed summarizing ecological, socio-economic and climate change trends as well as implications of climate change, government and investment sources, and education needs. On the basis of these factors key points for an integrated response package and a short-term (0–5 year) action plan are also developed and included in the table. To illustrate the approach they provided eight example table entries taken from different regions of Australia. The regions were mostly not mapped and the evaluations were based on subjective assessments of conditions and trends. They were clear that "it must be emphasized that the table is meant only to demonstrate the approach, and is not meant to be complete, representative or thoroughly researched. It is a 'proof-of-concept' exercise". They suggested that a more complete systematic analysis would involve:

- collating the various socio-economic typologies for different regions;
- intersecting these with an appropriately resolved classification of environments;
- identifying climate change scenarios useful for planning in each region.

In this paper we show how these aims can be met for regions across an entire country. Further, we show how quantitative data, rather than subjective assessments, can be used to describe present conditions and trends for the major socio-economic factors selected by Steffen et al. (2009). We also identify an existing dataset that describes ecoregions for any country and develop a table summarizing climate change scenarios and adaptation options appropriate for the ecological and socio-economic trajectories.

Vietnam was chosen for a trial application of the method, as the Government of Vietnam is increasingly concerned with developing climate change adaptations, and the country has excellent data availability. There are several good descriptions of the biodiversity of Vietnam (see, for example, ICEM 2003 and World Bank 2005), but there is no existing framework to assist in identifying what climate change adaptations could be appropriate for different regions. The following sections apply the Steffen et al. (2009) approach to frame and fill out a simple procedure for assessing information and identifying suitable adaptations.

2 Methods

The method involves collating key environmental and socio-economic data in spreadsheets and using a geographic information system (GIS) to move from administrative land units to ecologically meaningful regions. A table is then used to summarise key conditions and trajectories. This information provides a background from which policy responses are developed.

The process involves six stages:

1. Identifying administrative land units at a scale that is relevant to governance and the issues to be addressed.
2. Identifying ecoregions representing the underlying biophysical environment across the administrative regions.
3. Assessing social, economic and ecological conditions and trends.
4. Identifying climate change scenarios for each region.
5. Identifying key drivers and/or constraints for each region.
6. Developing key policy responses and actions.

These steps are used to populate a table where each row describes a particular ecoregion, its characteristics and suitable adaptation options. Table 1 shows an example entry for one ecoregion and the following subsections describe how the complete table was developed. A copy of the complete table is presented in the supplementary material available online.

2.1 Identifying administrative land units

In most cases a study will involve a country or major region within a country. Within this study area key socio-economic data will generally be available for some form of administration units. In the case of Vietnam there are 65 provinces and a wide range of statistical data are collected for these provinces by the General Statistics Office of Vietnam (www.gso.gov.vn/default_en.aspx).
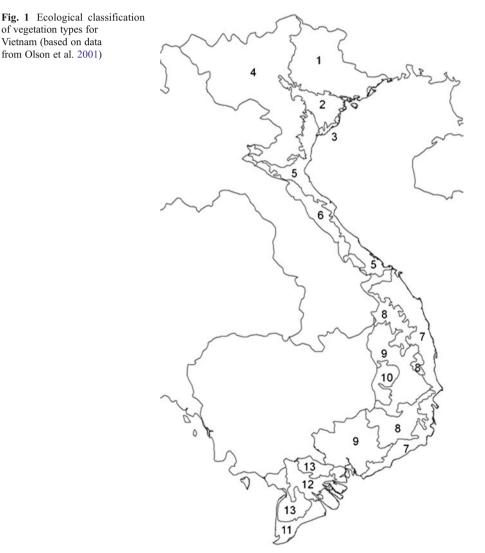
2.2 Identifying ecoregions

In some cases it may be appropriate to simply use the administrative units as the basic planning areas. However, administrative units generally have little ecological meaning, so it will often be helpful to identify major ecoregions. In this case we chose to use the data for terrestrial ecoregions of the world described by Olson et al. (2001). These data are well suited to this task as they were designed to assist conservation planning, take account of the best available local systems, provide worldwide coverage, and can be downloaded free of charge in ARCGIS format (www.worldwildlife.org/science/data/item6373.html). The data

Table 1 Example entry from climate change adaptation table

Regions (all Vietnam)	Biome, agro-ecol. zone	Current conditions and trends	Future climate scenarios: quarterly temp (°C) & rainfall (%) changed for 2030 & 2070 relative to 1980–1999 (Medium (B2) scenario)	Implication of climate change scenario	Governance and investment sources (off park)	Education	Integrated response package	0–5 year action plan
1. North East - The region includes significant intact forest areas and contains four near-endemic mammals.	South-China-Vietnam subtropical evergreen forests	**Biodiversity** High, decreasing **Population** Low, increasing **Income** Medium, increasing **Agricultural productivity** Low, increasing	T2030: 0.9,0.8, 0.5,0.7 R 2030: 1.1,−1.3,3.7,0.9 T 2070: 2.2,2.0,1.2,2.0 R2070: 2.8,−3.3,9.4,2.2 (North East Region in MONRE (2009))	This region and region 3 (North West) have the most extensive cool climates in Vietnam with large areas with mean annual temps (MAT) between 20 and 22 °C. A 1 °C rise in temp will significantly reduce these areas and a 2 °C rise will eliminate many sites suitable for cool adapted species.	Northern areas of the region have relatively low populations and low agricultural productivity, so biodiversity related investment opportunities may be mostly related to forestry and carbon sequestration in native forests and plantations. There are higher populations and agricultural production in south of region eg Bac Giang province.	Provide mainly forestry and conservation management training. Target projects that provide both carbon and biodiversity benefits.	Seek REDD (reduced emissions from deforestation and degradation) opportunities that preserve native forest areas and benefit biodiversity as well as local communities.	a) Assess climate change risk to key cool adapted species and ecosystems (MAT 20–22 °C) b) Trial REDD projects. c) Concentrate efforts on developing appropriate adaptations in cooler northern parts of the region including Cao Bang and Bac Can provinces.

for Vietnam included 13 ecoregions (see Fig. 1 here and also map 1.2 in World Bank (2005)). The ecological type is shown in the first part of the description below. However, as these types often extend outside Vietnam shorter descriptions were also used for the table, so that the location of the ecoregions within Vietnam could be readily identified. The 13 regions, and their short descriptors used here, were as follows:

    1 = Southeast China-Hainan moist forests – North East
    2 = Red River freshwater swamp forests – Red River Delta
    3 = Indochina mangroves - Red River Delta coastal area
    4 = Northern Indochina subtropical forests - North West
    5 = Northern Vietnam lowland rain forests - North Coastal
    6 = Northern Annamites rain forests – North Central Inland
    7 = Annamite Range moist forests - South Central Coast

Fig. 1 Ecological classification of vegetation types for Vietnam (based on data from Olson et al. 2001)

    8 = Annamite Range moist forests - Central Highlands I
    9 = Southeastern Indochina dry evergreen forests - Central Highlands II
    10 = Central Indochina dry forests - Central Highlands III
    11 = Tonle Sap-Mekong peat swamp forests - Mekong Delta
    12 = Tonle Sap freshwater swamp forests – Tonle Sap freshwater swamp forests
    13 = Tonle Sap-Mekong peat swamp forests - Tonle Sap-Mekong peat swamp forests

Ecoregion 1 (North East) is used as an example in Table 1 here, while information for the other ecoregions is included in the electronic supplementary material. Ecoregion 1 includes Cao Bang, Bac Kan, Lang Son provinces as well as much of Quang Ninh, Thai Nguyen and Bac Giang provinces. While there are still areas of intact forests in north east Vietnam, agricultural activities have increased rapidly in recent times (Nikolic et al. 2008; Petrtyl et al. 2011; Sekhar 2007; Verburg et al. 2004). The region remains relatively poorly surveyed for many plant and animal groups, though studies have included legumes (Heider et al. 2002) and small mammals (Lunde et al. 2007). The coastal regions of Quang Ninh province include the most northern extents of mangrove forest in Vietnam, which have high levels of biodiversity (Beharrell 2004).

Relatively little is known of the bioclimatic relationships of individual species within this, or other, regions of Vietnam (see, for example, Booth et al. 1999; Hu et al. 2010). The whole country would benefit from a Generalised Dissimilarity Modelling (GDM) study i.e. community level bioclimatic analysis for thousands of species within their major groups such as vascular plant species (see, Booth 2012 for a brief summary of GDM climate change related work that has been carried out in Australia and Ferrier et al. 2007 for a more detailed description of GDM). A GDM analysis would help to identify regions likely to be under high ecological stress under climate change.

2.3 Assessing social, economic and ecological conditions and trends

Steffen et al. (2009) suggested current condition and rates of change for four important measures should be included in the adaptation table. These factors were biodiversity, human population, income and agricultural productivity. Steffen et al. (2009) described relative current conditions as high, medium or low. They described trends as increasing, stable or decreasing. For this study 'increasing rapidly' was added as a category.

The assessment of current condition of biodiversity for each region was based on map 1.4 in the World Bank (2005) report, which shows key biodiversity areas (KBAs). Eken et al. (2004) have described how KBAs can be identified using standardised, globally applicable, criteria related to the distribution and population of species that require site-level conservation. In the absence of any quantitative assessments, regional trends in biodiversity were subjectively derived from chapter 2 of the World Bank report that discusses trends and threats. For human population, income and agricultural productivity, quantitative data were downloaded from the web site of the General Statistics Office for Vietnam. Current conditions were based on the most recent data available, while trends were based on linear regressions of data for the most recent year and the preceding 11 years' data.

The 195 current condition values and the 195 regression slope values for the three factors across 65 provinces were entered into a GIS to derive data for the 13 ecoregions. Maps of the current conditions and trends for the 65 provinces are included in the supplementary material available online.

2.4 Identifying climate change scenarios for each region

The climate change scenario data were derived from quarterly data provided for low, medium and high scenarios for seven regions by the Ministry of Natural Resources and Environment of Vietnam (MONRE 2009). As recent studies have indicated that global emissions and climate changes are tracking at medium levels of expectations (see, for example, Figure 3 in Garnaut 2011, which is a Rahmstorf update of Rahmstorf et al. 2007) the medium (B2) scenario was used. Changes shown in Table 1 are in comparison to mean data for the period 1980–1999.

Annual precipitation across Vietnam ranges from about 1,200 mm to 3,000 mm, with the exception of a coastal zone between about latitude 11°N and 12°N, where annual precipitation falls to around 800 mm. This region, which is in a rain shadow, corresponds to the southern part of ecoregion 7. Given the relatively high rainfalls across Vietnam it's unlikely that the projected changes will cause dramatic impacts in ecosystems. The precipitation data are included here in Table 1, as projected changes in other countries, such as Australia (see Steffen et al. 2009), could certainly be important, so it would be desirable that precipitation data are a standard inclusion in the climate change adaptation table.

Steffen et al. (2009) suggested a somewhat different climate change adaptation approach based around the concept of planning for three possible schematic futures. These were: a 'recovery' scenario, that involves climatic conditions changing but returning to those similar to the present within 200 years; a 'stabilization' scenario, that anticipates change, but in which conditions stabilize about 2100 at mean annual temperatures about 3 °C higher than the present; and a 'runaway' scenario involving temperatures continuing to increase. Their approach is unusual as it involves managing for all these different scenarios at the same time. For example, within the same region, one third of reserves would be managed for a recovery scenario, while another third are managed for stabilization and yet another third for runaway conditions. We have not taken this course as yet, since this approach has not been widely accepted. However, as Steffen et al. (2009) point out an advantage of the approach is that it allows risk hedging under conditions of uncertainty. It also allows 'no-regrets' decisions that warrant implementation regardless of the scenario to be distinguished from those decisions that require a different (e.g. precautionary principle, robust decision making or risk hedging) approach to risk management (see, for example, Dessai et al. 2008; Stafford Smith et al. 2011).

2.5 Identifying key drivers and/or constraints for each region

The next two columns to be completed in Table 1 deal with 'Implications of climate change scenario' and 'Governance and investment sources'. If the Steffen et al. (2009) procedure of considering the recovery, stabilization and runaway scenarios is being followed then the 'implications' column would suggest how each of the three alternative scenarios might be addressed. So, in an area with significant forests, such as the North East example in Table 1 the implication for a recovery scenario could be to focus on helping existing species to persist. By comparison, a stabilization scenario could require replacing key species with ones more tolerant of future conditions and a runaway scenario might require facilitating on-going shifts in species composition.

The idea of managing different parts of natural resources at the same time for three radically different outcomes has yet to gain wide acceptance, so, as described in the previous section, here we chose to provide information for a single moderate (B2) climate change scenario for 2030 and 2070. As noted in Table 1 the importance of the North East and North

West regions is that they contain some of the most extensive cool climates in Vietnam. While changes in climatic conditions will be complex, and novel climatic conditions are likely to emerge, there will be a general trend for the climatic conditions currently found in the North East and North West regions to be dramatically reduced, or even eventually lost from the country altogether, as conditions warm. Some species, such as the tree *Styrax tonkinensis*, have distributions restricted to northerly areas of Vietnam and Laos, so conservation strategies may need to operate across state boundaries as climate change makes parts of southern China increasingly suitable for such species.

The 'governance and investment sources' column of the table allows some of the opportunities to support adaptation options to be considered. For example, the North East region has relatively high biodiversity associated with significant areas of intact forests, though it is under increasing pressure, as both population and agricultural productivity, though currently low, are rapidly increasing (see Table 1). It should be well suited for investment opportunities related to Reducing Emissions from Deforestation and Degradation (REDD) and REDD+.

While the important links between climate change, conservation and deforestation have long been recognized (see, for example, Booth 1991) the UNFCCC Conference of Parties in Bali in 2007 emphasized the need for sustainable forest management to assist forest conservation and encourage carbon sequestration. Forests currently absorb about one third of fossil fuel CO_2 emissions, so the potential benefits of maintaining and enhancing these sinks are great (Pan et al. 2011). Section 6 of the Copenhagen Accord of 2009 recognized the need to support REDD and organizations such as the World Bank are actively involved in developing and supporting REDD projects. REDD+ expands REDD to include forest restoration, rehabilitation, sustainable management and/or reforestation (Wertz-Kanounnikoff and Kongphan-apirak 2009).

Tree species are of particular concern in the northern regions of Vietnam, as the survival of many other plants and animals is dependent on the maintenance of healthy forests. A book on Vietnam's trees (Forest Inventory and Planning Institute 1996) provides information about the ecology and distribution of nearly 750 species, while Nghia (2000) describes 40 tree species which are already threatened under current conditions.

2.6 Developing key policy responses and actions

The three final columns of Table 1 are headed 'education', 'integrated response package' and '0–5 year action plan'. It may be helpful to develop the key items of the integrated response package first. Steffen et al. (2009) state that 'a significant strength of the approach is that the integrated response package (management, education, governance) is tailored to the characteristics of the particular region, where the region is considered as a linked social-ecological system'. When the key items of the integrated response package are identified it should be easier to identify educational requirements, as well as short term actions.

In the case of the North East region training would be likely to be needed to assist conservation management, and particularly to underpin the development of REDD or REDD+ projects that provide both carbon and biodiversity benefits as well as sustainable livelihoods. Attracting REDD funding from organizations such as the World Bank would be a main feature of the integrated response package. Immediate actions would focus on assessing climate change risks for cool adapted species and establishing REDD trials.

The framework described here is only intended to assist identifying key strategic adaptation options appropriate for the socio-economic environment of particular regions. In the case of the North East region, where forests are important, information for developing more

detailed adaptation plans can be found in publications such as 'Adaptation of Forests and People to Climate Change (Seppälä et al. 2009). For example, Appendix 6.1 includes 15 pages of specific adaptation options including eight adaptation options specifically directed at REDD. Driscoll et al. (2012) have also provided a useful general checklist of climate change adaptation options related to biodiversity conservation. More detailed planning with the participation of relevant stakeholders would be needed to develop sustainable livelihood options to realize the strategic adaptation options identified by the framework described here within particular regions. Park et al. (2009) provide an example from Pacific islands showing how the livelihoods approach can be applied to climate change issues.

A joint GIZ-AusAID project in Kien Giang province in the southernmost part of Vietnam provides a good example of moving from the strategic level of the approach described here to practical on-ground actions. Kien Giang province is located mainly in region 13, but also includes part of region 11 of the ecological regions used here. The first phase of this project 2008–2011 (Chu Van Cuong and Dart 2011) identified 13 key conservation problems related to climate change and has developed practical solutions. For instance, the project made satellite imaging available to local planners to assist identifying regions likely to be worst affected by climate change and associated sea level rise. Before the project only about 50 % of planted mangroves used in rehabilitation activities survived. The project has devised new melaleuca fences that protect the planted mangrove seedlings more effectively and dramatically increase survival rates. Phase two of the project entitled the 'Climate Change and Coastal Ecosystems Program' (2011–2016) will extend the work to five provinces (Kien Giang, An Giang, Ca Mau, Soc Trang and Bac Lieu), which cover much of regions 11 and 13 included in the strategic analysis presented here.

Some climate change adaptation actions would be recommended for all regions, so are not listed in the table. These include expanding protected areas, improving connectivity (using either continuous corridors or series of 'stepping stone' protected areas) and reducing impacts of invasive species. The details of how they should be implemented will often be influenced by the drivers included in the table, but it is not appropriate to list them repeatedly for every region. Actions that are recommended in Table 1 concentrate on more region-specific actions, such as the opportunities around REDD+ in region 1.

2.7 Trial application and workshop

A preliminary version of Table 1 was prepared for an AusAID South East Asian workshop 'Towards regionally relevant biodiversity, poverty and climate change policy' (Miller et al. 2009). This involved participants from Australia, Vietnam, Cambodia, Indonesia and the Philippines. A few modifications were made to the method before and after this workshop. The most significant, which has already been mentioned in section 2.4, was the use of one climate change scenario in preference to planning in parallel for recovery, stabilization and runaway scenarios. A minor change, suggested at the workshop, was to add a brief summary of ecological conditions to the first column.

While the regional workshop provided an excellent opportunity to demonstrate and discuss the method it would be desirable to obtain support to apply the method across Vietnam or another country as part of adaptation planning. Such a practical application would involve both national and regional staff, as well as drawing on the expertise of university based scientists. In Vietnam agencies such as the Ministry of Natural Resources and Environment (MONRE) would be involved at the national level, as well as representatives of appropriate provincial government departments. The Vietnamese Government has recently announced a requirement for each province to develop climate change adaptation

plans. This is a challenging task and the Danish aid agency Danida is providing assistance to five provinces. Using the method described here to identifying groups of provinces among the total of 65 that experience similar ecological as well as socio-economic conditions could well assist with selecting suitable adaptations to protect biodiversity under climate change. The outcomes would be expected to affect development of national guidelines, as well as resource allocation both within and between provinces.

3 Discussion

This trial of the Steffen et al. (2009) method has shown how it can be applied across a whole country. The Olson et al. (2001) data provide ecoregions that are readily available for any country, while the Eken et al. (2004) key biodiversity areas provide an appropriate method for assessing biodiversity conditions. The accessibility of socio-economic data from the General Statistics Office of Vietnam is excellent. Many countries will have similar data available, though it may not always be so easy to access. In the worst-case, subjectively estimating conditions and trends should be better than not considering them at all.

   Linear regression was used here to determine current trends from sets of 11 years of data. Socio-economic factors especially in developing countries are rarely linear over a 60 year period. It would be desirable for the complete contents of Table 1 to be reviewed preferably every 5 years and at least every 10 years. This would include re-analysis of the trend data.

   Though the concept of planning in parallel for recovery, stabilization and runaway scenarios was not applied here, it is certainly worth further consideration. The uncertainties associated with revisions of climate change scenarios mentioned at the start of section 2.4 provide support for considering a risk-hedging approach rather than attempting to pick a winner in terms of quantitative projections. As the three generalized scenarios diverge significantly in the mid-21st century then the Steffen et al. (2009) approach is of most concern only for long-lived species such as trees and to management decisions of about 50 years or longer.

   The columns on implications and governance/investment provide useful background information to complement the summary socio-economic condition and trends information. Using this information the key adaptation themes of the response package and action plan can be identified. Other sources, such as Seppälä et al. (2009) and Driscoll et al. (2012), can then be used to develop these plans in detail, but this is beyond the scope of the creation of this adaptation table, which focuses on strategic rather than tactical options. The key adaptation themes will also strongly influence requirements outlined in the education column, in ways that result in integrated policy packages for each region, differentiated according to the regional social-ecological context.

   Identifying regions experiencing similar ecological conditions as well as socio-economic conditions and trends will help to share information both within and between countries. For example, the North West region of Vietnam has somewhat similar conditions and trends as well as adaptation opportunities as the North East region. Recognizing ecoregions experiencing similar conditions is relatively simple with the 13 regions used here, but would be much more challenging for the 65 provinces. For large numbers of regions or provinces, status and trend data could be usefully analysed using classification and ordination techniques to identify similar groups of provinces and how relatively similar any individual provinces are to one another.

   Overall, the Steffen et al. (2009) method is one that could be easily applied in other countries. Its simple procedures should assist in the early stages of identifying appropriate climate change adaptations both at regional and provincial scales.

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