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ORIGINAL ARTICLE

Indicators for assessing Indonesia's Javan rhino National Park vulnerability to climate change

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Abstract Climate change is already affecting ecosystems in protected forest areas. The Intergovernmental Panel on Climate Change (IPCC) has predicted its impacts will accelerate rapidly over the coming decades. The components of vulnerability have been defined as exposure, sensitivity and the capacity to adapt to climate change. Vulnerability, however, is not an easy concept for policy makers, local communities and other affected stakeholders to understand. This paper illustrates the use of participatory processes in understanding climate change adaptation and defines indicators for assessing the vulnerability of the Javan rhino's national park habitat in Indonesia. The processes generated local vulnerability indicators, organised hierarchically as principles, criteria and indicators (PCIs). While vulnerability principles and criteria were pre-determined and globally defined, the indicators were designed to address the local context. We found the PCIs to be practical tools for communicating vulnerability and for multi-stakeholder dialogues on vulnerability to climate change.

Keywords Adaptation · Climate change · Javan Rhino · Participatory approach · Vulnerability indicator

1 Introduction

The fourth assessment of the Intergovernmental Panel on Climate Change (IPCC 2007a) cited human activities as a major cause of global climate change, with less than 10% caused

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by astronomical factors. It projected global temperature increases of 1.1°C to 6.4°C for 2090–2099 relative to 1980–1999 (Meehl et al. 2007), which is a concern for many global and sub-global organisations. Despite growing mitigation efforts, climate change will continue. Accordingly, climate adaptation is becoming increasingly important.

Though limited spontaneous and planned adaptation actions have been implemented, more intensive adaptation measures are required to reduce vulnerability to current and future climate change. Vulnerability could be reduced, for example, by applying sustainable development practices. However, climate change could hinder nations' abilities to achieve sustainable development pathways (IPCC 2007b). Adaptation, therefore, should be integrated into sustainable development to reduce vulnerability and simultaneously increase resilience to climate change.

Climate change affects biodiversity and biodiversity conservation efforts at the species and ecosystem levels, as it alters species distribution, reproduction timings and plant phenology, and increases extinction rates (Secretariat of the Convention on Biological Diversity 2007, 2009). Changes in precipitation and temperature patterns due to climate change impact upon forest ecosystems (IPCC 2007b). Such changes increase incidences of drought and result in mortality, and increased prevalence of pests, diseases and fires. Sea-level rise due to climate change can reduce tiger habitat in Asia and threaten the survival of the species. Dry periods and shrinking living space due to climate change may cause African elephants to be highly vulnerable (Secretariat of the Convention on Biological Diversity 2007).

IPCC (2007b) defined the components of vulnerability as exposure, sensitivity and the capacity to adapt to climate change. Vulnerability, however, is not an easy concept for policy makers, local communities and other affected stakeholders to comprehend. Furthermore, vulnerability is currently defined at national and global levels, and is context independent. The vulnerability assessment in this paper addresses issues in a forest ecosystem context. Forest ecosystems are recognised as playing a vital role in climate change mitigation, but are themselves affected by climate change.

The objective of this paper is to provide a process for developing Principles, Criteria and Indicators (PCI) for assessing vulnerability to climate change. Generic principles and criteria for assessing a system's vulnerability were developed by a group of Center for International Forestry Research (CIFOR) scientists, whereas, the development of indicators involved local stakeholders from Ujung Kulon National Park; the Javan rhino's natural habitat. This paper also provides examples of effective means for communicating climate change vulnerability to local stakeholders, and developing local indicators through participatory and integrated processes.

2 Conceptual framework

2.1 Vulnerability assessment

The IPCC fourth assessment report defines vulnerability to climate change as 'the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes' (IPCC 2007b). Vulnerability includes an external dimension, which is represented here by the 'exposure' of a system to climate variations, as well as an internal dimension, which comprises its 'sensitivity' and its 'adaptive capacity' to these stressors (Fussel and Klein 2006). The concept of vulnerability

is useful because it includes interconnected processes that occur at different scales and also shows the dynamic features of a system (Belliveau et al. 2006).

Turner et al. (2003) explained a diagram representing cross-scale interaction between the exposure, sensitivity and resilience components of vulnerability. The essential elements for vulnerability analysis are multiple interacting perturbations and stressors, exposure, sensitivity, resilience and nested scales. Vulnerability assessments may be taken at any spatial or temporal scale appropriate to the problem in a so-called place-based approach. The growing role of local and multiple stakeholders in defining vulnerability problems makes local-level vulnerability analyses essential while simultaneously linking to other places and scales of analysis. A particular strength of place-based assessment analysis is its potential for improving public involvement and collaborative assessment. A comprehensive vulnerability analysis ideally considers the whole system. However, this is frequently unrealistic in the case of developing countries with limited infrastructure, budgets and expertises. It may be necessary to 'reduce' complexity when implementing analyses in developing countries.

Based on the Millennium Ecosystem Assessment (Hassan et al. 2005), Locatelli et al. (2008) illustrated links between ecosystem services and vulnerability to climate change (Fig. 1), using the exposure, sensitivity and adaptive capacity components of vulnerability defined by the IPCC (2007b). The Millennium Ecosystem Assessment has been widely used in understanding the wide role of natural ecosystems and projecting their services into the future. Ecosystem services contribute by reducing the exposure, sensitivity and vulnerability of human–environmental systems in numerous ways. Hale et al. (2009) recognise the essential role of ecosystem-based adaptation in an integrated approach to adaptation. Investments in ecosystems for the provision of ecosystem services can be used effectively, efficiently and sustainably for coping with the impacts of climate change. The roles of ecosystem services, however, are not easily visible to all people where everything is going well, and are frequently undervalued.

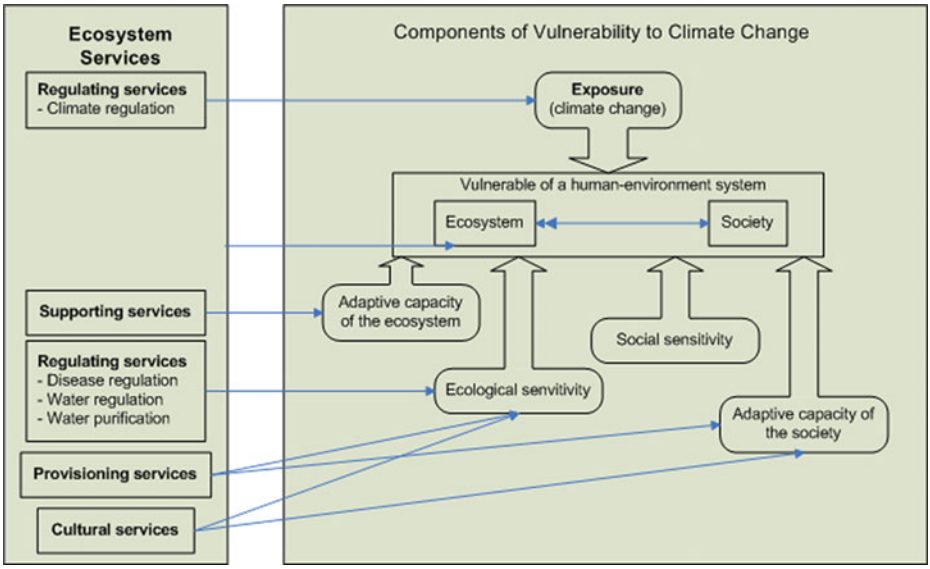

Fig. 1 Ecosystem services and their links to climate change vulnerability (after Locatelli et al. 2008)

2.2 Organising indicators

2.2.1 Why criteria and indicators?

Adaptation to climate change has become a worldwide concern over the past decade. Consequently, many national and international initiatives have been launched to promote vulnerability assessments, and develop strategies and measures for adapting to climate change. One example of these vulnerability assessments uses criteria and indicators as tools for collecting and organising information in a manner useful for conceptualising, evaluating, communicating and implementing adaptation to climate change.

Criteria and indicators have been widely used in formulating sustainable forest management (SFM) standards since the 1990s. These standards were defined as a set of principles, criteria and indicators (PCIs). For example, the Forest Stewardship Council or FSC (1994) proposed a set of principles and criteria for SFM, while the International Tropical Timber Organization or ITTO (1998) proposed a set of criteria and indicators for the same purpose. Purnomo et al. (2005) provide examples of local stakeholders' using criteria and indicators for determining the sustainability of forest management practices in East Kalimantan.

Recently, the Community, Climate and Biodiversity Alliance (CCBA) proposed as list of criteria and indicators for assessing climate change projects. CCBA is a partnership of leading companies, NGOs and research institutes that is developing voluntary standards to help design and identify land management projects that simultaneously minimise climate change, support sustainable development and conserve biodiversity. Its standard is structured as follows: sections (i.e. general, climate, community and biodiversity), subsections, concepts for each sub-section and indicators for each subsection.

The limitations of principles, criteria and indicators lie in their contrary definitions. For instance, the ITTO definition of 'criteria' for sustainable forest management does not correspond with the FSC definition, and is actually closer to the FSC definition of 'principles'. Indicators are sometimes formulated in ways that make them difficult to gauge in the field, or are insensitive to change.

2.2.2 Definitions of principles, criteria and indicators

The Principle, Criteria and Indicator (PCI) concept forms a hierarchy (van Bueren and Blom 1997) as shown in Fig. 2. The hierarchical framework describes hierarchical levels (P, C and I) to facilitate the formulation of a set of parameters in a consistent and coherent way. It describes the function of each level as well as the common characteristics of the parameters appearing on a particular level. The potential value of a hierarchical framework is that it increases

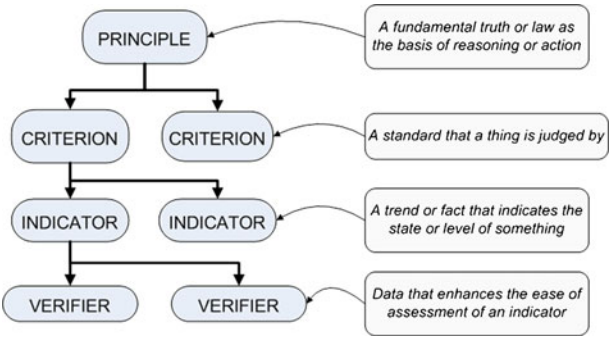

Fig. 2 The principle, criteria and indicator hierarchy concept

the chances of complete coverage of all the important aspects to be monitored or assessed; avoids redundancy; limits the set of PCIs to a minimum without superfluous indicators; and shows a clear relationship between indicators measured, as well as compliance with the principles.

According to the Concise Oxford Dictionary, a principle is 'a fundamental truth or law as the basis of reasoning' (Fowler and Fowler 1995). A principle refers to a function of a forest ecosystem, or to a relevant aspect of the social system(s) that interact with the ecosystem. This means that all forest functions, and relevant aspects of the social system(s) that interact with it, are covered. A principle could be described as an objective or attitude in relation to these functions and aspects. However, measures and prerequisites for the realisation of the objective or attitude, for instance, issues concerning legislation and institutions, should not be formulated as principles (van Bueren and Blom 1997).

A criterion is 'a standard, rule or test by which something can be judged' (Fowler and Fowler 1995). The function of a criterion is to show the level of compliance with principles related to the forest ecosystem or its related social system. Compliance with the principles is translated into descriptions of resulting specific and concrete states or dynamics of the forest ecosystem, or the resulting states of the interacting social system. These descriptions will reveal the practical results of complying with each principle, and also provide more concrete principles, which are easier to assess than abstract non-measurable principles. As the function of criteria is to show the level of compliance with a principle for the forest ecosystem or related social systems, criteria should be formulated in terms of outcome (van Bueren and Blom 1997).

An indicator was defined by the International Tropical Timber Organization (1998) as 'a quantitative, qualitative or descriptive attribute that, when periodically measured or monitored, indicates the direction of change'. To 'indicate' is defined by Fowler and Fowler (1995) as 'to point out, make shown, show, or be a sign or symptom of, or express the presence of'. FSC defined indicators as 'any variable, which can be measured in relation to specific criteria'. An indicator is an assessable parameter describing features of the ecosystem or social system (outcome parameters), or policy and management conditions and processes (input or process indicators). An indicator as an outcome parameter often describes the actual condition of an element in the forest ecosystem or related social system in quantitative or relative terms. Indicators may also refer to a human process or intervention which is to be executed—or to an input (e.g. the existence or characteristics of a management plan or a law). These types of indicators are known respectively as process and input indicators. They are in fact indirect indicators that reflect elements of the management and policy system (van Bueren and Blom 1997).

A fourth hierarchical level, below the level of indicators, may be needed to describe the way the indicators are measured in the field. The parameters at this level are called verifiers. Verifiers are not shown in the hierarchy because they are optional. They refer to the source of information for the indicator and relate to the measurable element of the indicator. The verification procedure clarifies the way the indicator is measured in the field and the way reference values are established. Choosing a reference value is always difficult when formulating target values or thresholds because it is often an arbitrary procedure (van Bueren and Blom 1997).

3 Context and methods

3.1 Context

Javan rhinos (*Rhinoceros sondaicus*) used to be found in all over Southeast Asia, but their habitat is shrinking (International Rhino Foundation 2010a). Now they can only be found in

Ujung Kulon National Park in West Java, Indonesia and Cat Loc within Cat Tien National Park in Vietnam (Fig. 3). The Javan rhino is one of the rarest species of mammals, the most endangered rhinoceros species and the most seriously under threat (UNESCO World Heritage Centre 2009). In Cat Tien as few as six individuals remain (van Strien et al. 2008). This is, in all likelihood, a non-viable population. The Javan Rhino is under Genus of *Rhinoceros*, Family of *Rhinocerotidae*, Order of *Perissodactyla*, Class of *Mammalia*, Phylum of *Chordata*, and Kingdom of *Animalia*.

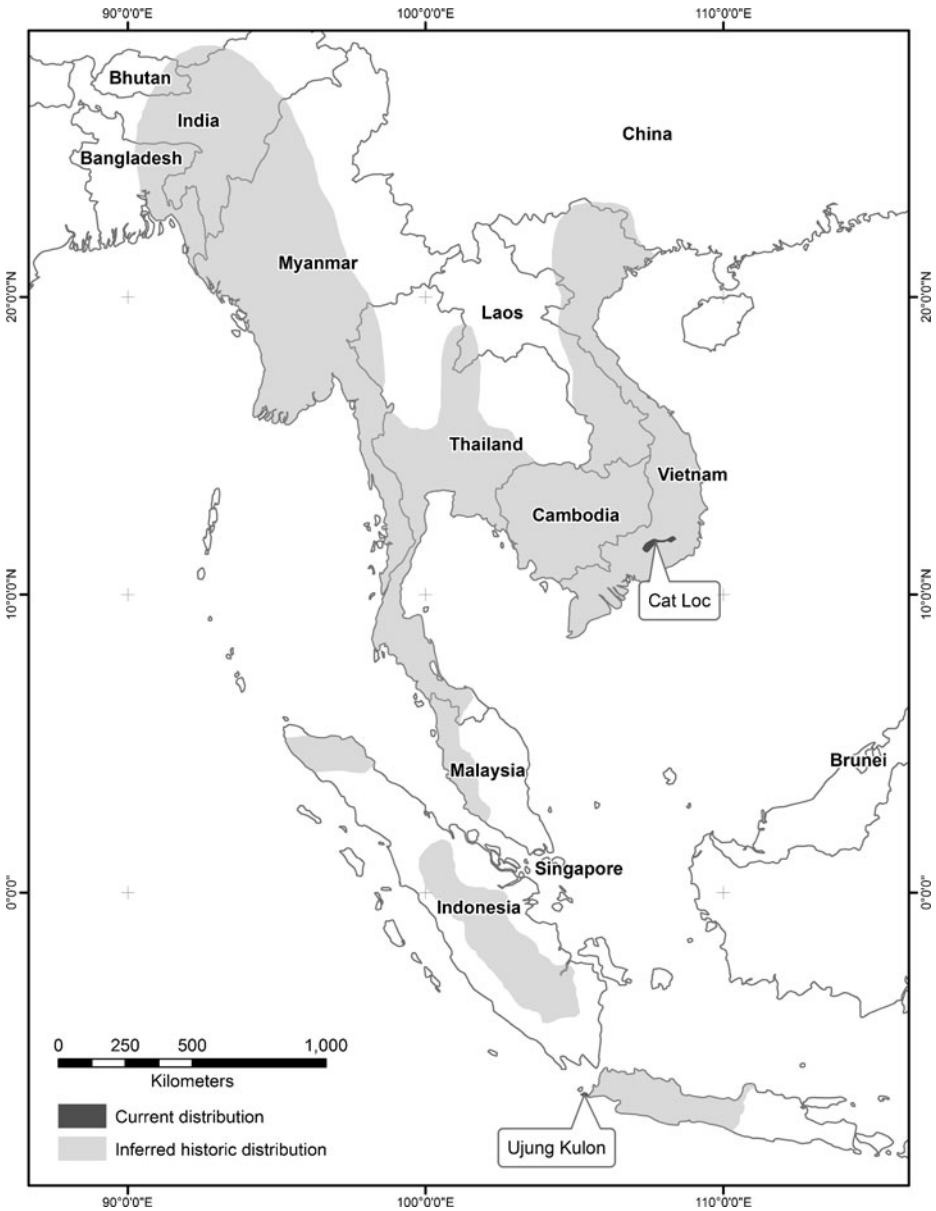

Fig. 3 Historic and current distribution of Javan rhino (Modified from Foose and Van Strein 1997)

Established in 1980 (Ministry of Forestry 2010), Ujung Kulon National Park is located in Banten Province, West Java, Indonesia (Fig. 4). The Park was designated specifically for conservation of the Javan rhino. In 1991, the park was listed as a World Heritage Site as it met World Heritage natural criteria *vii*: 'to contain superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance', and *x*: 'to contain the most important and significant natural habitats for in-situ conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of science or conservation' (UNESCO World Heritage Centre 2009).

Ujung Kulon National Park covers 122,956 ha of lowland rainforest and mangrove ecosystems, and is home to 700 plant, 35 mammal, 5 primate, 59 reptile, 22 amphibian, 240 bird, 72 insect, 142 fish and 33 coral species (Ministry of Forestry 2010). Many of these species, including the critically endangered Javan rhino, are on the IUCN Red List of Threatened Species (International Rhino Foundation 2010b). The park is home to approximately 40–60 Javan rhinos (van Strien et al. 2008).

Climate change is a potential additional threat to the Javan rhinos in Ujung Kulon National Park. A report by Firdaus (2008) stated that:

Analyses from 1980 to 2008 showed the temperature of Ujung Kulon to be between 25.6 and 26.8°C. Under scenarios A2, B1 and A1B (fast economic growth), temperatures may rise by approximately 1.95, 2.68 and 4.27°C respectively in 2100 compared to those in 2000. January precipitation in 2100 may increase by 139 mm from 2000 levels under scenario A1B, but by 92 and 78 mm respectively under scenarios A2 and B1.

The changing climate may increase pressure on the Javan rhino, as it will affect the species and its forest habitat. For example, higher temperatures may cause rhinos to wallow more often in order to cool down, and will increase the evapotranspiration of the forest. Too much rain in the park may result in floods and too little rain in

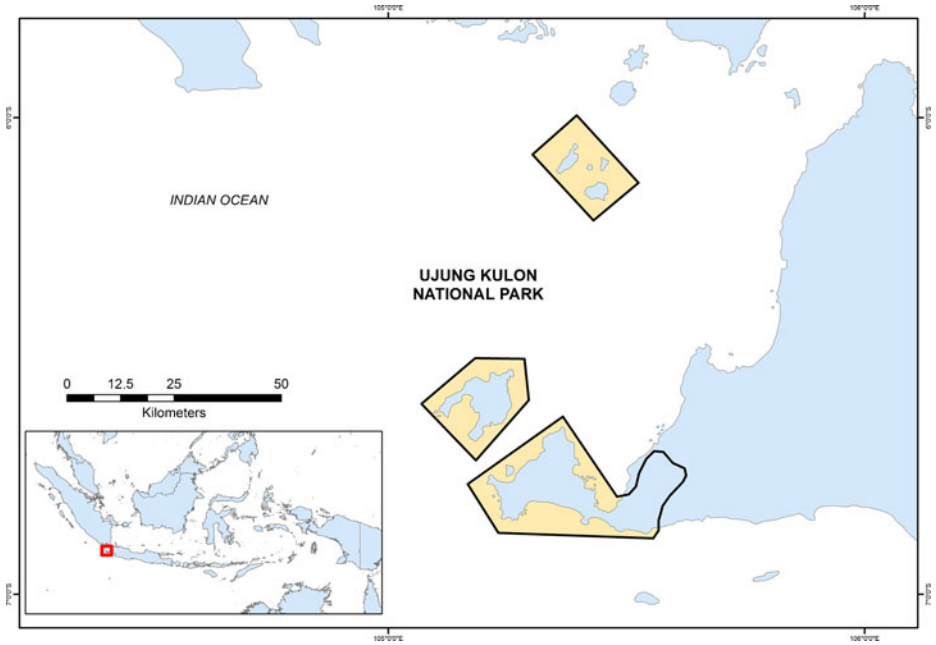

Fig. 4 Ujung Kulon National Park (Modified from International Rhino Foundation 2010b)

droughts. Socio-economic threats will also increase as climate change affects the livelihoods of local communities living around the park.

3.2 Methods

We used the following methods for producing integrated and participatory development indicators. Firstly, a group of scientists at the CIFOR Indonesia office discussed and developed a list of principles and criteria on climate change, forestry and forest governance and institutions. Secondly, a participatory Focus Group Discussion (FGD) was conducted in collaboration with WWF-Indonesia to communicate these principles and criteria, adjust them where necessary and develop localised indicators. The list of principles and criteria was taken to the FGD in Pandeglang District, where Ujung Kulon National Park is located. The FGD aimed to (a) observe whether the PCIs were useful for communicating climate change vulnerability; (b) observe the applicability of generic climate change vulnerability assessment principles and criteria; and (c) develop a list of localised indicators in a participatory and integrated manner.

One of the most important aspects of social research is the identification of relevant stakeholders for involvement in the development of indicators. This is particularly true in most mitigation and adaptation processes because of the typically large number of interest groups, users, organisations and other institutions involved. In this study, identification of relevant stakeholders was done using intensive communication with local communities identified by previous WWF projects, local government and the national park authority. We invited stakeholders who fulfilled the criteria of proximity, pre-existing rights, dependency, knowledge of forest management (indigenous knowledge), forestry spirit (culture), daily activities on site and legal rights (Colfer et al. 1999).

The participatory and integrated FGD was organised by and involved the selected stakeholders. What we mean by participatory is the involvement of all stakeholders, including local communities, in the FGD for developing vulnerability indicators. The integrated approach considered how to include the different perspectives and rationales of local stakeholders—local communities, the national park authority, local government, NGOs, universities and experts from different disciplines including meteorology, ecology, forestry, veterinary science, tourism and community empowerment—in the discussions. This process, by which members of a community identify problems, collect and analyse information, and act upon the problem to find solutions is fundamentally important for approaching social transformations (Selener 1997).

4 Results

4.1 Principles and criteria for vulnerability

We developed a generic set of three principles for assessing vulnerability: ecosystem exposure to climate change, sensitivity of human systems to ecosystem services loss, and adaptive capacity of social systems (Locatelli et al. 2008). Here we defined a principle as a fundamental law for the basis of reasoning. The first principle (P1) deals with the vulnerability of ecosystem services in providing relevant goods and services to climate change and variability. This principle provides the basic argument that a system is vulnerable if it is exposed to and affected by climate change and variability. This principle can be judged by criterion C1.1. 'Ecosystem goods and services are exposed and sensitive to climate change and variability' and C1.2. 'Ecosystem natural adaptive capacity is low'. Following the Millennium Ecosystem Assessment (Hassan et al. 2005), the terms of ecosystem services not only include services

but also ecosystem goods. The first criterion judges the amount and flow of ecosystem services under climate change. The second criterion judges the capacity of the ecosystem to adapt to climate change.

The second principle (P2) deals with the sensitivity of human systems to the loss of ecosystem services. This principle provides the basis for reasoning that a system is vulnerable if the human system is sensitive to ecosystem goods and services loss. This principle is judged by criterion C2.1. 'Dependency of the human system to ecosystem services', and C2.2. 'Availability of sustainable and cost-effective substitutes for the lost goods and services'. The first criterion judges the degree of dependency of the human system to the loss of ecosystem services, while the second criterion judges the availability of substitutes for the lost of those services.

The third principle (P3) deals with the lack of adaptive capacity of social and governance systems to respond to changes in goods and services. This principle provides the basis for reasoning that a system is vulnerable if the social and governance systems lack the adaptive capacity to respond to loss of ecosystem services. This principle is judged by criterion C3.1. 'The social system lacks adaptive capacity to respond to or to avoid changes in goods and services', and C3.2. 'Policies and governance system are increasingly vulnerable'.

These six criteria (C1.1 to C3.2) are used for judging the vulnerability of a system. A criterion, nevertheless, needs indicators to measure the facts on the ground. While principles and criteria are limited, and can be hypothesised from the assessment framework, indicators are enormous and context sensitive. Therefore, indicators for assessing the vulnerability of Ujung Kulon National Park (including its Javan rhino) are site specific. The participation of stakeholders, especially local ones, is extremely important due to their key roles in adaptation actions. Furthermore, vulnerability is not an easy concept for policy makers, local communities and other stakeholders affected by climate change to understand. Vulnerability is in most cases defined at national and global levels, whereas addressing vulnerability assessments and adaptation at the local level is more challenging.

4.2 Localised criteria and indicators for assessing park ecosystems' vulnerability to climate change

A multi-stakeholder and participatory Focus Group Discussion (FGD) was held near Ujung Kulon National Park in Pandeglang, Banten, Indonesia. Climate change adaptation was presented to all stakeholders, then vulnerability assessment principles and criteria were explained to share understanding on climate change, its impacts on ecosystem services and how to adapt.

FGD participants were selected based on criteria of proximity; pre-existing rights; dependency on Ujung Kulon National Park ecosystems; knowledge of the Javan rhino, the national park and climate change; forestry spirit (culture) and legal rights. We ended up with 27 participants, representing local communities, academia, national park management, local government, NGOs and experts.

We discussed each principle and criterion and modified them when necessary. All stakeholders accepted P1, P2 and P3, and identified these principles as relevant to forest (national park) ecosystems, social systems and governance. The first principle (P1) for the national park: 'The national park ecosystem (including Javan rhino) will be vulnerable if the provision of relevant goods and services produced by the national park ecosystems is vulnerable to climate change and variability' was accepted by all stakeholders. They also accepted the first criterion (C1.1.) of this national park principle: 'National park ecosystem goods and services are exposed and sensitive to climate variability and climate change'. Using a participatory approach, we discussed the potential indicators of C1.1. which were

locally specific and relevant to the national park. Stakeholders identified the following indicators:

- Changes in air temperature and humidity
- Changes in river flow
- Rises in sea level (risk of park area reduction and fragmentation)
- Availability of nutrients, shelters and mud pools for rhinos
- Physiological changes and diseases in rhinos

For the second criterion (C1.2.): 'The natural adaptive capacity of the national park ecosystem is low', the stakeholders accepted the criterion but had difficulty gauging it on the ground. They had problems determining how to judge the adaptive capacity of the national park's ecosystems and rhinos, to climate change. Consequently, this criterion will require further discussion.

While the first principle deals with forest ecosystems, the second deals with social sensitivity. The second principle (P2): 'The national park ecosystem (including Javan rhino) will be vulnerable if the social system is sensitive to changes in the provision of relevant goods and services', was accepted by the stakeholders as the basic reasoning for vulnerability assessment. This principle is judged by criterion of C2.1. 'The social system is highly dependent on the relevant national park goods and services'. This criterion judges the dependency of communities on goods and services provided by national park ecosystems. The stakeholders accepted C2.1 and proposed the following indicators for measuring this criterion:

- Dependency on climate-sensitive activities (e.g. agriculture)
- Dependency on natural products (e.g. fuelwood, medicines, honey, sea-grass)
- Dependency on water from rivers
- Dependency on ecotourism (national park and rhino related)

The second criterion for P2 is C2.2. 'Sustainable and cost-effective substitutes for the lost goods and services produced by the national park are unavailable'. The stakeholders accepted this criterion and proposed the following indicators for its assessment:

- Availability of sustainable and cost-effective substitutes for natural products, e.g. fuelwood and timber
- Availability of livelihood opportunities and lands (e.g. for agriculture activities) outside the national park
- Access to sustainable and cost-effective agricultural intensification practices (agricultural inputs e.g. fertiliser, pesticides and seeds)

The third principle (P3) for vulnerability assessment is 'The national park ecosystem (including the Javan rhino) will be vulnerable if the social and governance systems lack the adaptive capacity to respond to, or avoid national park goods and services changes'. This principle deals with governance. The first criterion (C3.1.): 'The social system lacks the adaptive capacity to respond to goods and services changes' that judges the principle was accepted by the stakeholders, who proposed the following indicators for measuring it:

- Availability of social and community organisations focusing on food and energy security
- The engagement of NGOs and other civil society organisations in dealing with climate change

Stakeholders also accepted the second criterion for this principle (C3.2.) 'Policies and governance systems are increasingly vulnerable'. This criterion judges the policy and governance systems hindering climate change adaptation efforts. Stakeholders proposed the following indicators for measuring this criterion,

- Availability of relevant national and local-level policies e.g. on spatial planning and energy
- Presence of national and local-level policies that increase communities' vulnerability

Meanwhile, for the governance aspect of this criterion, stakeholders accepted the following governance indicators as proposed by Kaufmann et al. (2004):

- Voice and accountability—measuring political, civil and human rights;
- Political instability and violence—measuring the likelihood of violent threats to, or changes in, government, including terrorism;
- Government effectiveness—measuring the competence of the bureaucracy and the quality of public service delivery;
- Regulatory burden—measuring the incidence of market-unfriendly policies;
- Rule of law—measuring the quality of contract enforcement, the police, and the courts, as well as the likelihood of crime and violence;
- Control of corruption—measuring the exercise of public power for private gain, including both petty and grand corruption and state capture.

Though these governance aggregate indicators have been widely used for measuring the level of good governance, particularly at the national level, stakeholders felt they could be applied at the local level.

The developed and agreed upon indicators were then taken to the field for further discussion and measurement. Some indicators may become verifiers, and WWF Indonesia, the park authority and local government are working collaboratively to follow up this possibility. The process includes outreach activities to provincial and local governments using established sub-national and local working groups such as regional development planning agencies.

5 Discussion

This exercise argues for the use of a qualitative approach in developing local indicators of vulnerability to climate change. Using this qualitative approach, we gathered an in-depth understanding of local stakeholders' behaviour, and the reasons governing this behaviour. Qualitative methods investigate 'why' and 'how' climate change adaptation can be understood and responded to. The qualitative approach enabled us to gain a general sense of local indicators for further testing using a quantitative approach. We believe it is easier for local stakeholders to use a qualitative approach and reasoning.

Principles, criteria and indicators for vulnerability assessments are potent tools for communicating climate change vulnerability and developing local adaptation options. It is useful to instigate discussions on vulnerability and its assessment, and on climate change adaptation efforts, as they enable local stakeholders to understand the concepts of vulnerability and adaptation more easily and to communicate them more effectively. This also enabled stakeholders to develop indicators for assessing the vulnerability of Ujung Kulon National Park (including its Javan rhino) in a participatory and integrated manner.

These indicators can be used for planning and prioritising adaptation measures. By using these tools, stakeholders were able to identify the following potential adaptation measures for Ujung Kulon National Park:

- Increasing national park ecosystem benefits for local communities (e.g. using the park buffer zone for producing timber and non-timber forest products and for tourism related activities);
- Reducing socio-economic pressures on the national park;
- Providing alternative livelihoods for local people;
- Promoting agricultural intensification programmes in the area; and
- Improving access to energy sources (particularly for domestic use), and to health services.

This exercise was useful for outlining climate change adaptation measures in a set of principles, criteria and indicators of vulnerability. We found the principles and criteria system to be valuable for communicating climate change vulnerability and adaptation. PCIs helped make discussions on the hazy concepts of vulnerability and adaptation to climate change more understandable to stakeholders. Though the exercise did not produce a complete document, it did generate the confidence to use PCIs as a framework for assessing issues of vulnerability and adaptation to climate change in different contexts and places. The process has also proved that principles and criteria can be defined at the global level, and indicators determined locally.

Ecosystems, including protected forest ecosystems such as national parks, provide essential provisioning, regulating, supporting and cultural services. These services encompass human well-being in terms of security, basic materials, health and good social relations (Hassan et al. 2005). The policies, laws and institutions governing their management also advantage protected areas (Dudley et al. 2010). Consequently, an ecosystem-based adaptation approach has the potential to reduce a community or environment's vulnerability and increasing its resilience. It integrates the use of ecosystem services into a strategy for helping people adapt to the adverse impacts of climate change. It may include the sustainable management, conservation and restoration of ecosystems to provide services that support people adapting to climate change (Colls et al. 2009). This approach is often more readily available to the rural poor, and is cheaper than other adaptation options like engineering.

Local people are usually aware of any changes in their environment. For example:

> The St'at'imc indigenous people in Canada—where salmon is the main source of protein and has important traditional, livelihood and cultural value—have noticed that precipitation is falling slightly, it is getting hotter (especially during summer time), that river water is getting warmer, and there are changes in the spawning season and abundance of salmon (Jacob et al. 2010).

Nevertheless, they often have limited knowledge of the global causes and effects of climate change. This is certainly the case in Indonesia, where information on, and awareness of the impacts of climate change and adaptation are still lacking at the local level. Vulnerability and its assessment appear to be new concepts for local stakeholders in this country, and few tools are available for helping local stakeholders understand and assess vulnerability, and implement adaptation measures.

It was apparent during the exercise that stakeholders had difficulty developing indicators for criteria C1.2. to judge the natural adaptive capacity of national park ecosystems. To develop these indicators, we could secure more input by holding additional local and

national-level FGDs. There is no reason to doubt the capacity of local stakeholders in defining local indicators. This is in line with what Purnomo et al. (2005) said about local indicators for sustainable forest management in East Kalimantan, Indonesia being determined by local stakeholders. PCIs can also be used as tools for negotiations between different stakeholders, and their hierarchical structure helps organise the conceptualisation of vulnerability, making it more coherent and easier to communicate to stakeholders.

Forest conservation managers' failure to prevent local communities from using land and forest resources has forced them to employ a community-based management approach (Kant and Nautiyal 1994). If not, conflicts could break out between local communities and conservation managers in connection with (1) land appropriation processes, (2) environmental impacts and (3) the recruitment of labour (Sakai 2002). Local community representation is essential for making discussions meaningful and providing space for social transformation (Selener 1997). Along with ecosystem-based adaptation, community-based adaptation is a highly relevant approach and as such needs to be promoted. This participatory approach—built on the knowledge, priorities and capacities of local people—can be initiated by encouraging communities to express their needs and perceptions, and can have poverty reduction and livelihood benefits as well as reducing vulnerability to climate change and disasters (Reid et al. 2009). It is important to include forest-dependent peoples and local communities when assessing vulnerability, and developing and implementing adaptation strategies, because even though they frequently lack the resources for responding or adapting to climate change, they are the main actors on the ground and the poor are usually the most vulnerable to climate change impacts. Ecosystem and community-based adaptation processes should be institutionalised for enhancing the capacity of local communities, which have to be perceived as credible by social actors.

Participatory processes in developing PCIs can be institutionalised within climate change mitigation and adaptation efforts. Local institutions play an important role in adaptation to climate change. For example, they connect households to local resources and collective action, determine flows of external support to different social groups and also link local populations to national interventions (Agrawal et al. 2008). Institutional functionality relies on its social acceptability or the credibility of its processes (Ho 2006). Agrawal and Gibson (1999) advocate focusing on institutions that value the role of local communities and their uniqueness in advancing community-based natural resource management. We cannot assume that a generic pattern will emerge (Sayer and Campbell 2004).

The use of participatory processes in developing indicators is a means for improving local institutions' capacity to adapt to climate change. Agrawal et al. (2008) highlight means for improving adaptiveness by increasing the role of institutional partnerships in facilitating adaptation; enhancing the capacity of local institutions; understanding the role of local institutions and their linkages; improving institutional coordination across scales, focusing on territorial development strategies and adopting an adaptive perspective on institutional development.

6 Conclusion

Participatory approaches for assessing the vulnerability of human-environmental systems to climate change are applicable for national parks in Indonesia and in other countries. In this case, we used principle, criteria and indicator (PCI) tools. To apply participatory approaches in establishing these tools, firstly, park managers, governments or scientists need to develop

a set of principles and criteria by incorporating the vulnerability components of exposure, sensitivity and adaptive capacity of a national park's human-environmental system to climate variations. Secondly, participatory Focus Group Discussions (FGDs) should be organised for national park stakeholders to discuss these principles and criteria and develop appropriate indicators. Finally, these PCIs can be used for assessing the vulnerability of a national park's human-environment system to climate change.

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