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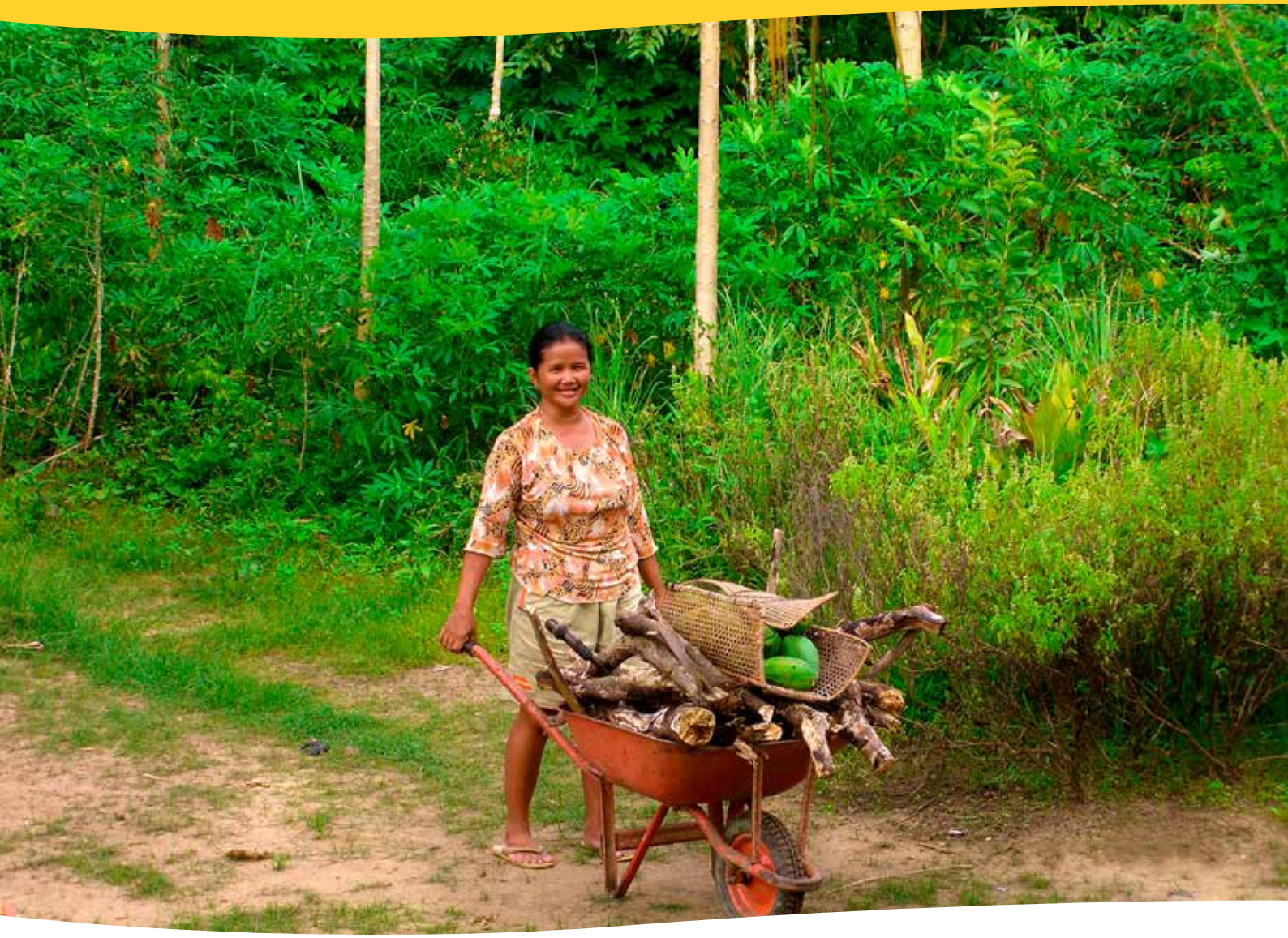

Integrating adaptation into REDD+

Potential impacts and social return on investment in Setulang, Malinau District, Indonesia

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Abbreviations

Bappeda	Badan Perencanaan Pembangunan Daerah (Regional Development and Planning Agency)
Bappenas	Badan Perencanaan Pembangunan Nasional (National Development Planning Agency)
BMZ	Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung (Federal Ministry for Development Cooperation)
CBA	cost–benefit analysis
CIFOR	Center for International Forestry Research
dbh	diameter at breast height
DNPI	Dewan Nasional Perubahan Iklim (National Climate Change Council)
DRC	dry rubber content
ENSO	El Niño–Southern Oscillation
FORCLIME	Forests and Climate Change Programme
GCM	general circulation model
Gerdema	Gerakan Desa Membangun (Village Self-Sufficiency Development Movement)
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
ICRAF	World Agroforestry Centre
IPCC	Intergovernmental Panel on Climate Change
NTFP	non-timber forest product
PKK	Pemberdayaan dan Kesejahteraan Keluarga (Enhancing Family Welfare)
REDD+	Reducing emissions from deforestation and forest degradation and enhancing forest carbon stocks
SROI	social return on investment
WWF	World Wildlife Fund

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About FORCLIME

The Forests and Climate Change Programme (FORCLIME) supports the Government of Indonesia in their endeavour to mitigate the effects of climate change through forestry sector reform, capacity development and implementation of best management practices for sustainable forest management and biodiversity conservation. Demonstration activities are being supported in selected districts of Kalimantan to reduce emissions from deforestation and degradation (REDD activities). FORCLIME is funded by the German Federal Ministry for Economic Cooperation and Development and implemented by German International Cooperation and the German Development Bank, with the Indonesian Ministry of Forestry as the Programme Executing Agency.

The Programme's overall objective is to reduce greenhouse gas emissions from the forest sector while improving the livelihoods of Indonesia's poor rural communities. To achieve this goal, the Programme team assists the Indonesian Government in designing and implementing legal, policy and institutional reforms for the conservation and sustainable management of forests, at local, provincial and national level. Support to REDD demonstration activities are a key feature of the Programme, providing decision-makers with experience of how REDD can be implemented "on the ground".

For more information, please visit: www.forclime.org.

Executive summary

Reducing emissions from deforestation and forest degradation and enhancing forest carbon stocks (REDD+) interventions can help both people and forests adapt to climate change by conserving or enhancing biodiversity and forest ecosystem services. However, additional adaptation measures might be needed, such as the protection of agriculture and livelihoods for communities and the development of fire management strategies in forests. Such measures could support the sustainability of REDD+ interventions and the permanence of carbon stocks by preventing activity displacement and induced deforestation and by limiting or avoiding damage to the ecosystem from extreme weather events.

To design community-based adaptation interventions and assess their potential outcomes within a REDD+ project area, community members from Setulang Village, Malinau District, formerly in East Kalimantan Province (now North Kalimantan) were involved in a bottom-up, stakeholder-focused process. A social return on investment framework was applied. Community representatives discussed climate and non-climate challenges and the effectiveness of their current coping strategies. Adaptation interventions were then conceived and planned, using future visioning exercises.

The challenges, coping strategies and adaptation interventions were also discussed with stakeholders from relevant district organizations (e.g. local government agencies) through individual semi-structured interviews. Projected future climate scenarios, the sensitivity of key resources and adaptive capacity were also discussed. This resulted in a holistic understanding of the costs, benefits, opportunities and challenges associated with implementing the selected adaptation strategies not only in the target area, but also in the district more broadly.

Setulang is in a relatively advantageous geographic location, close to both the forest and the town of Malinau. It has a variety of assets and resources that contribute to the population's adaptive capacity, such as strong social capital, unity and cohesion, relatively non-degraded forest resources, expertise and knowledge in forest management, and strong village institutions.

However, gaps in adaptive capacity are apparent in the lack of agricultural and information infrastructure (e.g. absence of irrigation infrastructure and telecommunications network). Furthermore, the rights over the protected forest area known as Tane' Olen are uncertain, and conflicts over boundaries with neighboring villages arise frequently.

Other factors that weaken the community's adaptive capacity include insecure access to natural resources, low diversification of activities within and outside agriculture, and lack of access to education and health care.

Additional challenges identified by community members are substance abuse by the young, abuse of power, river pollution due to mining activity and inadequate waste management, diseases, drought and illegal logging, as well as the trend of young people migrating to cities.

Stakeholders from government agencies and NGOs at the district level view climate-related hazards, such as floods, drought and shifts in seasonality, as a major problem for Malinau. Model projections indicate that climate hazards in Malinau are highly likely to become more frequent and intense. Forests and agricultural production, particularly of crops such as rice, banana, cassava and sweet potato, are vulnerable to variability in climate, extremes and longer-term climate change.

Community members feel that their strategies for dealing with challenges have not generated any long-term and sustainable solutions. One longer-term adaptation strategy they are applying proactively is the deliberate conservation of the forest so that it can serve as a 'food bank' in times of scarcity. Villagers stated that greater livelihood diversification and capacity to store surplus food and cash would make them feel more secure.

During the workshops, Setulang community members conceived and selected two adaptation interventions that they believed would have benefits and could capitalize on existing resources: (1) rubber agroforestry and (2) manufacture and sales of rattan handicrafts.

The perceived benefits of rubber agroforestry were livelihood diversification, production of a cash crop and increased resilience to climate hazards because rubber agroforestry systems can withstand flood and drought pressures better than annual crops such as rice. Rubber agroforestry is expected to rehabilitate degraded land and, as it is not very time consuming, give farmers time for other agricultural or livelihood activities.

The operational costs associated with rubber agroforestry are viewed as low. The main costs are inputs such as seedlings and labor, use of land and training in techniques; the need for training is a particular barrier because of the lack of relevant expertise in local government agencies.

The idea behind the sale and manufacture of rattan handicrafts is to capitalize on the long tradition of crafts in the village. Although women mainly make handicrafts for personal or domestic use, selling handicrafts could generate additional income, especially for women, when there is insufficient crop surplus to sell. In addition, handicrafts can be made by women during their leisure time or by those who do not work in the fields. Potential markets are neighboring villages, tourists and fair trade organizations.

The cost of raw materials (rattan, natural dyes) is low, as they are usually freely available as a common good from Tane' Olen forest, or can be bought cheaply from neighbours or other villages. Other costs include transportation and distribution and the need to train would-be entrepreneurs in product design and marketing.

Forecast climate changes are unlikely to affect the strategy to sell handicrafts, as the source of materials, Tane' Olen, is a relatively intact and sustainably managed forest. However, for rubber agroforestry, certain climate and biophysical thresholds need to be monitored to ensure farmers are prepared to take measures to prevent yield losses and damage. The productivity of fruit tree species cultivated with the rubber, such as durian and rambutan, could also be affected by extreme temperatures and rainfall.

In addition to the direct impacts of the suggested adaptation projects, the interventions could have positive indirect outcomes for REDD+. Synergistic benefits could be pursued from the joint implementation of REDD+ and adaptation strategies to optimise the overall positive impact. For example, REDD+ networks and finance could be used to deliver timely climate information of relevance for the adaptation both of agrarian communities and of forests. Such information could be integrated into an adaptive governance and management model, where the results of interventions are constantly monitored, evaluated and readjusted according to changing circumstances and needs (e.g. changing drivers of deforestation and degradation, changing climate pressures). Adaptive management should be the foundation of any intervention under uncertainty.

1. Objectives and activities

1.1 Main goal and objectives

The study Integrating Adaptation into REDD+ Projects: Potential Impacts and Social Return on Investment (SROI) was conducted by the Center for International Forestry Research (CIFOR) in two pilot sites, one in Indonesia and one in the Philippines. It was funded by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) with a grant from the Federal Ministry for Development Cooperation (BMZ).

The main goal of the study was to determine the possible impacts of integrating community-based adaptation interventions into reducing emissions from deforestation and forest degradation and enhancing forest carbon stocks (REDD+) pilot projects by assessing their potential social return on investment. Forest-dependent communities and local and subnational decision makers and practitioners that influence or are affected by REDD+ pilot activities were the main target groups.

More specifically, the following objectives were pursued:

1. Assess vulnerability to climate variability and change using desktop analysis and participatory methods, and design adaptation interventions with stakeholders at various levels.
2. Analyse the potential social, economic and environmental outcomes of selected adaptation interventions based on stakeholders' perceptions.
3. Determine the potential impact and overall value that could be created if the interventions achieve their intended outcomes, especially compared with the scenario of inaction (no adaptation interventions).

The study also aimed to evaluate and refine the SROI framework for adaptation planning and produce a practitioner's guidebook for the replication of activities in other sites.

1.2 The social return on investment framework

SROI is a framework that draws on the principles of economic cost–benefit analysis, impact assessment and social accounting in order to understand and manage the value of the social, economic and environmental outcomes of an activity or an organization. SROI was pioneered by the Roberts Enterprise Development Fund in early 2000 and has been evolving ever since. This study is based on the version of the framework in *A Guide to Social Return on Investment* (Nicholls *et al.* 2012), which the Government of the United Kingdom recommends for use in evaluating nonprofit and social enterprise activities and organizations.

The SROI process involves reviewing the inputs, outputs, outcomes and impacts of an intervention or organization within an "impact map." Social, environmental and economic outcomes are determined by the stakeholders that are experiencing them. A monetary value is put on outcomes wherever possible, using prevailing market prices for commercial goods and financial proxies for intangible and nonmarketable outcomes (e.g. more free time for women).

Stakeholder participation and analysis are at the center of the approach, which requires that stakeholders themselves conceptualize the social or other impacts. SROI thus reflects stakeholders' actual needs, priorities and potential role in the implementation of the adaptation strategy (Chaudhury 2012). In contrast to traditional cost–benefit analysis (CBA), SROI is used to analyse change in a way that is relevant to the people or organizations that experience or contribute to it.

SROI is based on theory of change (Figure 1), which takes into account the chain of events and outcomes connected to a specific intervention. It identifies where and how value is being created and by whom, and who benefits from it and how. It examines how outputs are, or will be, used to create value and identifies the initial changes or benefits, as well as the longer-term results in time and space. Theory of change clearly articulates the assumptions behind early, intermediate and long-term outcomes and how they are interconnected, as well as the conditions that must be present for these outcomes to materialize.

SROI can be used for evaluation or for forecasting. Evaluative SROI analyses are conducted

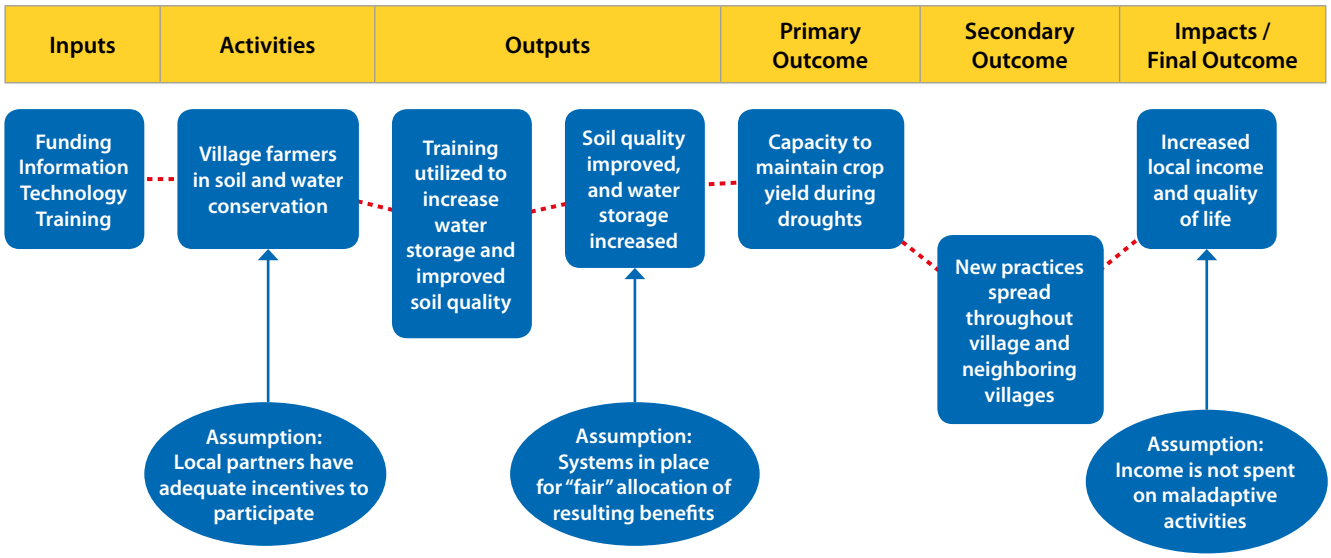

Figure 1. Example of theory of change
Source: Spearman and McGray, WRI (2011)

retrospectively based on actual outcomes of past or ongoing interventions. Forecast analyses aim to predict the extent of the impact and social value that will be created if planned activities achieve their intended outcomes. Forecast SROI analyses are especially useful when planning an activity because they can show how to maximize the impact of investment and reveal any barriers that must be overcome. They are also useful for identifying what should be monitored and evaluated once the project or program is fully operational.

SROI has been applied extensively for forecasting and evaluating social value in the nonprofit sector for programs such as skills training for disadvantaged groups, housing and community development services, mental health rehabilitation and community gardening, mostly in western countries. Only recently was the forecasting form of SROI applied in relation to climate change adaptation, as part of the CGIAR Research Program on Climate Change, Agriculture and Food Security (Sova *et al.* 2012). That research showed that the SROI framework can be useful when planning adaptation activities and for assessing the likely impact of adaptation interventions. To make the SROI framework more applicable to adaptation planning and related cost projections, Sova *et al.* (2012) incorporated some of the core principles and practical components of community-based adaptation, participatory rural appraisal and strength-based approaches to development. The enhanced forecasting framework broadens the bottom-up nature of the approach by holding participatory workshops where communities are assisted in designing their own adaptation interventions based on their values and capacity.

2. Study site and context

2.1 Study site

The village of Setulang (Malinau District, now in North Kalimantan Province) was selected as the study site for Indonesia after consulting the GIZ Forests and Climate Change Programme (FORCLIME) team. Although Setulang was the focus for the community-level adaptation planning, the whole district was considered in the climate and vulnerability analysis.

The site in Setulang forms part of the GIZ FORCLIME–supported Community Forest Project, which conducts REDD+ pilot activities. The objectives of FORCLIME activities in Kalimantan are to help local authorities introduce sustainable forest management, establish forest management units and secure the preconditions necessary for pilot REDD+ activities.

Setulang Village (3°27'12"N, 116°29'56"E) is located in the Malinau River watershed at the junction of the Setulang and Malinau rivers, 29 km upstream from Malinau Town, the district capital (Wunder *et al.* 2008). The Malinau watershed is the most densely populated and developed rural area in the district, whose overall rural population density is otherwise low. The total community area of Setulang covers 11,530 ha, of which 5314 ha is forested land protected by traditional law (Tane' Olen) (Figure 2). The 2010 official census put the number of people living in Setulang at 883, all of whom are members of the Dayak ethnic group of Kenyah Oma' Long.

Setulang people have a long history of conserving and protecting their sacred Tane' Olen forest through traditional (*adat*) laws and management institutions. With the help of GIZ FORCLIME, in 2011 the community applied for official legal

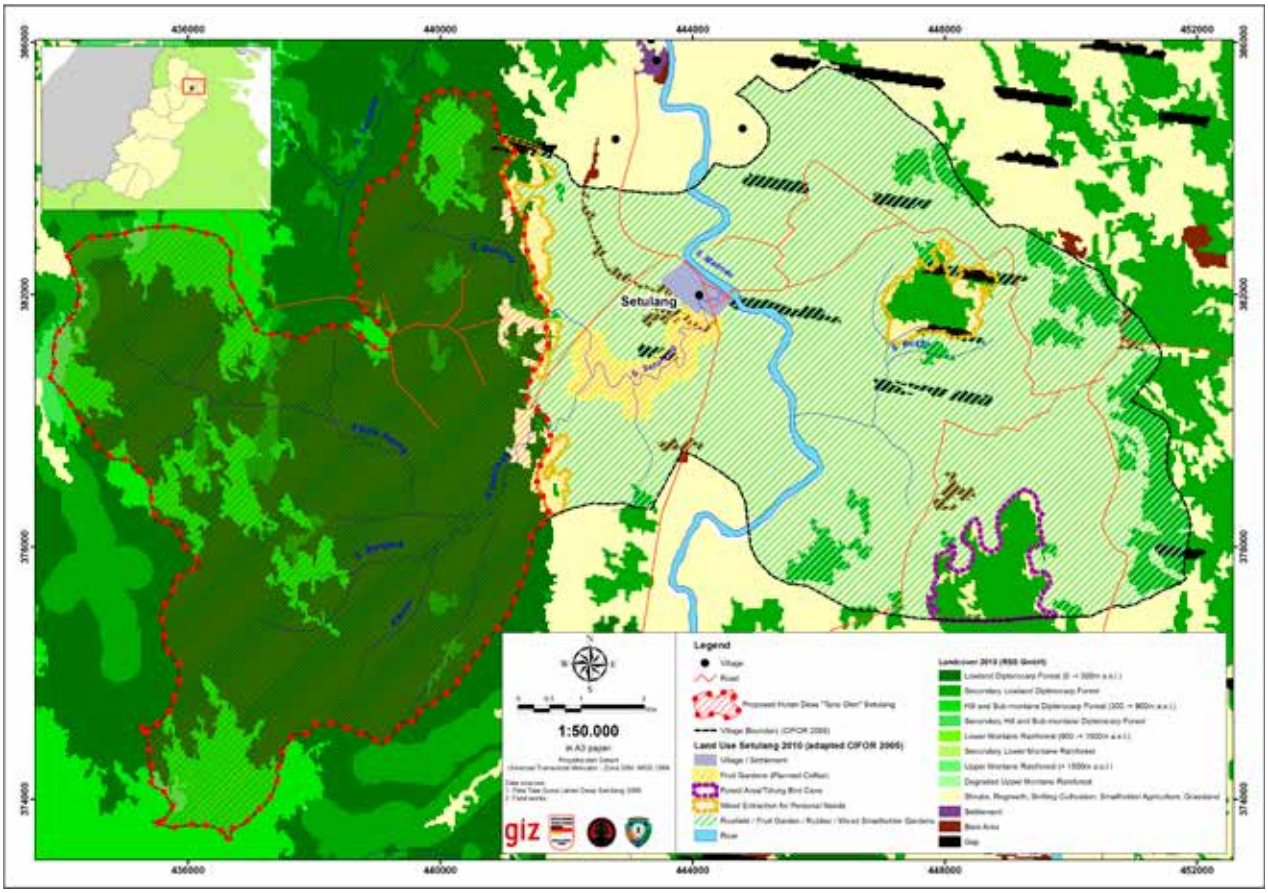

Figure 2. Tane' Olen forest and Setulang village map
Source: Timo Beiermann/GIZ FORCLIME

recognition of their rights over Tane' Olen through the Village Forest (*hutan desa*) scheme. In April 2012, Tane' Olen, the proposed Village Forest for Setulang, underwent field verification to ensure that the location does not overlap with any other licenses or claims. FORCLIME supported the village's preparations for the technical aspects of verification, such as by improving the draft map previously developed by CIFOR and the Malinau Forestry Service, and facilitated coordination between the community, the district government and the field verification team, which was composed of officials from local government agencies and representatives of the Tane' Olen management body. The field verification found that Setulang Village Forest complies with all legal requirements. Setulang's application is supported by the district and provincial governments, but final approval from the Ministry of Forestry is pending.

Although Tane' Olen is actively protected by Setulang, Malinau's forested areas are under pressure from various drivers of land-use change. The main drivers of deforestation are conversion to oil palm, mining and agriculture, population growth and illegal logging. There are plans for oil palm and mining concessions close to Setulang; these will not encroach upon the Tane' Olen forest but are expected to affect the broader village area.

2.2 The context in Malinau and Setulang

The district of Malinau was part of East Kalimantan Province at the time of the present study, but is one of the four districts that formed the new North Kalimantan Province in October 2012. As Malinau held the largest remaining natural forest in East Kalimantan Province, only 15% of East Kalimantan is now forested, since the creation of North Kalimantan.

The landlocked district covers 42,000 km^2, of which more than 90% is officially designated as state forest land. The area of Malinau comprises the largest remaining contiguous dipterocarp forest in Southeast Asia. It is extraordinarily rich in biodiversity, as well as in high-value timber species and high-quality coal, a feature that leads to tension between conservation and development objectives (Moeliono and Limberg 2009). Most of the accessible lowland forests of the district, such as areas along the lower Malinau River, have been degraded by logging, mining and extensive swidden agriculture.

Malinau has a population of approximately 80,000, according to the 2010 census. The population is made up of at least 18 ethnic groups, including the largest group of Punan hunter-gatherers in Borneo (Moeliono and Limberg 2009). The more remote villages depend quite heavily on the gathering of forest products, whereas people living downstream mostly depend on agriculture for their livelihoods, especially swidden agriculture (Levang 2002; Moeliono and Limberg 2009).

Agriculture and forestry are the major economic sectors of Malinau, although mining, construction, trade and services have been growing rapidly (Moeliono *et al.* 2007). Mining is probably the largest and most important sector for the cash economy, although accurate statistics are yet to confirm this. Forestry and non-timber forest products (NTFPs) contribute approximately 40% of Malinau's GDP (DNPI and GoEK 2010). As much of the land in the district is steep and erodible and the soil is nutrient-poor and acidic, land suitable for the sustainable production of cash crops is limited; most of this land is in middle and upper Malinau (Moeliono *et al.* 2009).

Although more than half of the population is classified as poor, with the exact numbers varying between sets of statistics (Moeliono *et al.* 2007), the communities do not experience starvation (Levang 2002). Rather, poverty is linked to lack of access to education and health facilities, especially in the more remote areas. The government had previously sought to alleviate poverty in these areas by resettling villages downstream, closer to the district capital. As this approach is no longer considered viable, the focus has shifted to construction of roads.

All local communities have shifted location several times in recent decades because of floods, disease, crop failure or tribal war, as well as resettling through government programs (Sheil 2002). However, despite recurrent floods, most villages are located on low ground beside the river. The shifts in locations have caused conflicts between communities, which mark the history of Malinau (Sudana 2009). The nature of the conflicts depends on whether they concern village boundaries, agricultural lands, competition over benefits from timber and NTFPs, or encroachment of logging, mining and oil palm concessions (including

land and pollution compensation schemes or the lack thereof). One of the underlying causes of conflicts is the lack of clarity over village boundaries and the rights to agricultural land, with each of the many ethnic groups residing in the area holding a different basis for its land claim (Sudana 2009). Conflicts over land rights increased markedly after the community relocation strategies encouraged by the government. Historically, tenure was linked to *adat*, defined as cultural beliefs and rights and the customary practices, laws and institutions of communities (Moeliono *et al.* 2009). However, with a complex mix of informal and formal rules, the enforcement of government regulations has been problematic. *Adat* rights can gain formal legal recognition, if the community or village complies with certain criteria and passes verification.

The community of Setulang has had conflicts both with logging companies encroaching on Tane' Olen and with neighboring villages making claims to the land. Tane' Olen is predominantly composed of lowland dipterocarp forest with some areas of hill and submontane dipterocarp forest and secondary dipterocarp forest. These forests are a vital source of game, NTFPs, building materials and fresh clean water for Setulang. Consequently, only the sustainable extraction of NTFPs is allowed, as regulated by *adat* and monitored by the Tane' Olen management committee.

During the past few years, the people of Setulang have become concerned about the shortage of available land, not only because of population growth and the need for village expansion, but also because of the delineation of village territories, logging operations, reforestation programs and plans for mining and oil palm concessions (Iwan 2006; Iwan and Limberg 2009).

The economy of Setulang is based on a combination of subsistence agriculture, the sale of surplus crops, particularly rice, in Malinau Town, the extraction of forest products, and fishing (Iwan 2006; Wunder *et al.* 2008). The main crop is dry rice (*ladang*), with semi-permanent gardening and agroforestry also practiced. Off-farm income is derived mainly from remittances from younger people working for timber companies in Malaysia and other foreign countries. Ecotourism is in the early stages of development. Setulang is not considered poor by local standards.

3. Methods

3.1 Community workshop

This study adopted the approach to community-based adaptation planning suggested by Sova *et al.* (2012) and CARE International (a list of useful resources such as CARE International's Community-based Adaptation Toolkit, at http://www.careclimatechange.org/tk/cba/en/, is contained in the Annex to the upcoming guidebook).

A two-day participatory workshop (22–23 June 2012) held in Setulang village was attended by 21 community members, including the village chief (*kepala desa*) and representatives of village groups and authorities such as the Women's Group, Community Empowerment Group and Tane' Olen Management Agency. The main objectives of the workshop were to determine the underlying causes of vulnerability, understand how climate fits into the broader challenges faced by the community, and incorporate community values and priorities in the selection, planning and evaluation of adaptation interventions. Special attention was given to forest and tree resources and their role in coping and adapting strategies.

The following activities were included:

1. identifying community values and assets and ranking them in order of priority (in gender-based breakout groups and in plenary sessions)
2. identifying environmental and other challenges and ranking them in order of importance (in breakout groups and plenary discussions, and then voting)
3. identifying historical responses and coping strategies for challenges and assessing their effectiveness
4. developing visions for the future through community mapping (in gender-based breakout groups)
5. designing and selecting priority adaptation interventions by eliciting community members' common aspirations and voting on their relative importance
6. planning the implementation of priority interventions
7. identifying the costs and benefits and the overall impact of priority interventions from the perspective of the community members, also in relation to forest management and REDD+, through break-out group discussions.

The threats and challenges identified by community members were grouped into clusters (Figure 3). In a plenary discussion, participants identified and mapped the relationships between the challenges.

Community-based adaptation principles and tools were applied in the workshop when devising and ranking adaptation interventions in the context of multiple stressors. Community members were asked to envisage their village in 10 years in a scenario where stressors and challenges are addressed in an integrated manner, with existing assets and resources

Figure 3. Workshop activity: Putting important assets and challenges into thematic clusters

(natural, financial, human, physical and social) used wherever possible. Ten years was considered an appropriate time frame for Setulang. The desired future characteristics were then clustered as a way to guide the ranking and planning of 'no regrets' adaptation interventions based on the community's needs, aspirations and capacity.

For the future visioning exercise, participants broke into gender groups and made village maps for the future (Setulang in 10 years); the groups then presented their maps, explaining the changes. Future characteristics were clustered into groups and rephrased as statements (aspirations) to be used when planning the strategies. Participants were also asked to vote on the priority of each aspiration cluster, with a focus on strategies that involve the use of existing assets.

The original plan was to use 'back casting', a process of systematically moving backward from a desired future situation to the present by continuously asking "what must we do to achieve this?"(Sova *et al.* 2012). However, based on the advice of a workshop facilitator who knows the community well, forecasting was used instead. Forecasting involves predicting all the intended and unintended consequences, as well as the costs and benefits, of an intervention by systematically going forward from the present to the desired future situation, marking progressive milestones across time. The list of priority community assets was kept in a prominent position during the planning exercise to foster discussions on how best to capitalize on them during implementation.

3.2 Interviews with stakeholders in district-level organizations

As individual schedules prevented efforts to organize a workshop with district-level stakeholders such as government agencies and NGOs, individual semi-structured interviews were conducted. The following stakeholders were interviewed:

- three stakeholders from the district forestry agency: head of the agency, head of the environment division and head of the conservation division
- head of the district agricultural agency
- head of the district agency for community development
- head of the planning division of the regional development and planning agency (Bappeda)
- head of extension services in the district plantations agency
- deputy director of the Kayan Mentarang National Park administration
- head of the district environment agency
- head of the NTFP division of the district industry and cooperation agency
- senior staff member from World Wildlife Fund (WWF) Malinau.

The main objectives of the district-level stakeholder interviews were to communicate the results from the community workshop and climate and vulnerability analysis, to elicit perceptions on the critical challenges facing the district in relation to adaptation and forest management/REDD+, and to discuss the costs, benefits, challenges, opportunities and risks associated with the priority adaptation interventions identified by the community. The semi-structured interview guide used is attached as an annex to this report.

After the district-level interviews had been completed, researchers again visited the community of Setulang to conduct more in-depth discussions on the two priority adaptation strategies selected for analysis in this study. Six community members were interviewed individually to get a better understanding of the opportunities and challenges related to the implementation of the strategies. The interviews were unstructured, with the interviewee encouraged to speak openly and frankly about issues of concern and to give as much detail as possible.

3.3 Climate change and vulnerability analysis

3.3.1 Framework

The climate and vulnerability analysis was conducted through the vulnerability framework, in which vulnerability is considered to be a function of **exposure**, **sensitivity** and **adaptive capacity** (Figure 4).

The component of **exposure** encompasses current climate variability and projected future climate change, including extreme events. It essentially describes the nature and degree of the climate stress upon a system. **Sensitivity** describes how the system reacts to or is affected by the climate stressors, and **adaptive capacity** focuses on the ability of the system to accommodate these stressors and their consequences in order to minimize harm or

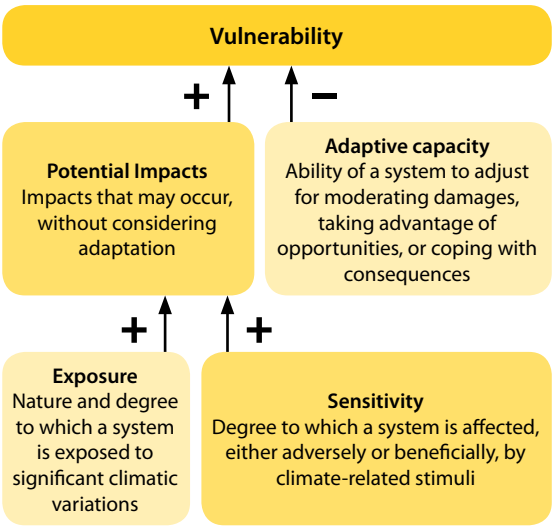

Figure 4. Vulnerability as a function of exposure, sensitivity and adaptive capacity
Source: Locatelli (2011)

maximize any opportunities. Adaptive capacity can be influenced by factors such as wealth, availability of and access to technology, education and information, ecosystem integrity, and infrastructure (Smit and Pilifosova 2001).

In summary, the severity of adverse climate hazard impacts in a system depends on the system's vulnerability. Negative impacts do not occur solely because of exposure to a climate hazard, but also because of high sensitivity to this hazard and limitations in the capacity to adapt to it.

Adaptation actions are usually planned with the aim of addressing one or several elements within this framework. They may aim to mitigate the underlying causes of vulnerability (e.g. ensuring access to resources and health care) or to modify the exposure to, and effects of, a specific climate hazard (e.g. building barriers to protect settlements against coastal storms). They can be either incremental or transformational. Incremental adaptations refer to extensions of existing actions and behaviors that already reduce vulnerability, while transformational actions are those "that are adopted at a much larger scale or intensity and/or are truly new to a particular region or system" (Kates *et al.* 2012).

However, climate hazards and their impacts rarely occur in isolation. Systems are usually under the pressure of various stressors that frequently interact, resulting in compound impacts and feedback loops of vulnerability. Socio-ecological systems in Malinau exist in a multistressor environment, where many of the stressors influence sensitivity and the capacity to adapt to other challenges, especially the climate-related ones. As discussed below, forest degradation and deforestation, for example, increase the risk of forest fires and render ecosystems more sensitive to drought. With repeated fires, the sensitivity to future disturbances (including new fires) increases considerably.

The analysis focuses on the issues of concern for communities in Setulang and for Malinau more broadly. The climate and vulnerability analysis aims to complement the stakeholder consultations and perceptions by providing additional input from the literature on possible scenarios and critical vulnerability thresholds. It also aims to provide input for adaptation planning and serve as the basis for an initial assessment of the robustness of the priority adaptation interventions under plausible climate scenarios.

3.3.2 Exposure

Exposure is related to both current and projected climate variability, trends and extremes. It concerns the nature and degree of climate stress on a system at various levels and scales. Different types of exposure to climate hazards can occur at different temporal scales. Exposure can relate to the frequency and intensity of abnormal or extreme events (e.g. stronger and more frequent storms), the frequency and intensity of climate variability (e.g. shifts in wet and dry months or years and fluctuations in daily minimum and maximum temperatures), the shifting of seasonality in time and space (e.g. long rainy periods in the dry season) or long-term incremental trends and slow-onset changes (e.g. increase of 1°C annual mean temperature by 2050).

As there are no meteorological observing stations within the boundaries of Malinau District, we used interpolated datasets, that is, datasets that use measurements from numerous weather stations around the world and apply tested algorithms to infer climatic data for any point in a global grid. We used the WorldClim (http://www.worldclim.org; Hijmans *et al.* 2005) dataset for the mean climate, and the climate databases of Tyndall Centre's Climate Research Unit (www.cru.uea.ac.uk/home; Mitchell and Jones 2005) for past annual data and climate trends. A point close to the town of Malinau (marked by the star in Figure 5), which is also located near Setulang,

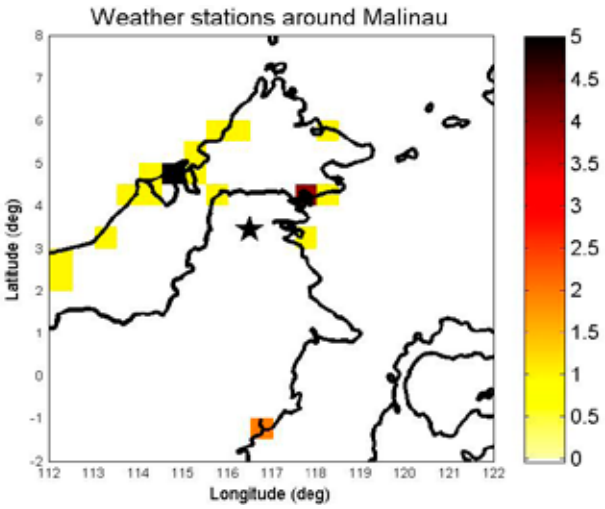

Figure 5. Weather stations around Malinau
Source: CRU TS 3.1, Mitchell and Jones (2005)

was used as the reference point for retrieving all climate data.

WorldClim constitutes a set of global climate layers (climate grids) with a spatial resolution of about 1 km. Interpolations of observed data are representative of the years 1950–2000. The Climate Research Unit datasets include month-by-month variations in climate at a resolution of 0.5 arc-degree (around 50 km), based on climate archives from more than 4000 weather stations around the globe. For both datasets, we considered only two climate variables: precipitation and temperature.

Future climate trends were retrieved from the TYN SC 2.0 dataset of the Tyndall Centre for Climate Change Research (Mitchell *et al.* 2004). The TYN SC 2.0 dataset comprises monthly grids of modeled climate including cloud cover, diurnal temperature range, precipitation, temperature and vapor pressure for the period 2001–2100, and covers the global land surface at a resolution of 0.5 degree (50 km^2).

We used the outputs of four general circulation models (GCMs), which are mathematical representations of the climate system, simulating the physical and dynamical processes that determine the global climate; these computer models divide Earth into horizontal and vertical grid cells, where each cell represents a specific climatic state for a specific time based on a set of equations. The four GCMs used were CGCM2, CSIRO mk 2 (CSIRO2), DOE PCM (PCM) and HadCM3 (HAD3).

We combined the GCMs with four emission scenarios from the Intergovernmental Panel on Climate Change (IPCC; http://www.ipcc.ch/ipccreports/sres/emission/index.php?idp=0): A1FI (integrated world characterized by rapid economic growth and high use of fossil fuels), A2 (more divided world, regionally oriented economic development), B1 (world more integrated and more ecologically friendly) and B2 (world more divided and more ecologically friendly). Data were calculated for the years 2020, 2050 and 2080, using as a reference point a location close to Malinau Town (as above).

Relevant secondary data from other climate analyses (national reports and vulnerability assessments) are also included in exposure.

3.3.3 Sensitivity and adaptive capacity

The degree of sensitivity indicates how responsive a system is to certain climate variables or extremes. More sensitive systems will show larger changes in composition or structure in response to disturbance events.

The sensitivity of key resources and sectors to climate hazards (e.g. agricultural production systems, health and settlements) was analysed by conducting a literature review. Key resources and sectors were identified from the community consultations and desktop analysis. The analysis of adaptive capacity was also based on stakeholder perceptions (of both the community and district/provincial-level respondents) and the literature.

Adaptive capacity is generally associated with the capability of a socio-ecological system to be robust to disturbance and to adapt to actual or anticipated changes, whether exogenous or endogenous (Plummer and Armitage 2010). The adaptive capacity of social systems is determined by the suite of resources that are available and the social processes and structures through which they are employed and mediated. One of the most important factors shaping the adaptive capacity of individuals, households and communities is their access to and control over natural, human, social, physical and financial resources. Examples of resources affecting adaptive capacity include irrigation infrastructure and weather stations (physical), community savings groups and farmers groups (social), reliable fresh water sources and productive land (natural), micro-insurance and diversified income sources (financial) and knowledge, skills and education (human).

4. Stakeholders' views

4.1 Community members: Perceptions of resources, challenges and coping strategies

4.1.1 Assets and resources

Community members were asked to list the resources (environmental, social, human, financial etc.) and assets of value in their community, rank them in order of importance, and describe their availability and accessibility (Table 1). Both women and men listed water, agricultural assets and human resources, although with different rankings; men also mentioned social and financial resources and forest resources.

Participants noted that water resources are very important for cooking, washing, bathing and transportation. Women ranked water resources most highly because a stable fresh water supply is essential for most household activities. The village gets its water piped from the Tane' Olen spring because pollution has made the river water in Setulang unsafe for community needs. The men noted that the pipe is too narrow for sufficient water supplies to reach the village and needs to be reconstructed.

Men ranked human resources most highly, although both groups agreed on the importance of knowledge of farming, health and health care, forest management and resource management for all economic activities in the village. However, many young and educated people are choosing to pursue opportunities in cities instead.

Agricultural resources were defined as fields and gardens and the produce derived from them. Although every household owns a field, about 50% of the villagers also have gardens with vegetables, coffee and fruit trees. Harvests are considered sufficient to meet needs throughout the year, but villagers have noticed a decline in the surplus available for storage and disaster insurance.

Forest resources and Tane' Olen are valued for their provision of products needed for food security and livelihoods, as well as for their role in ensuring a

Table 1. Assets and resources in order of priority and current condition (by gender groups)

Rank	Women		Men	
	Resource	Condition	Resource	Condition
1	Water	Quality of river water has deteriorated. Only water from Tane' Olen spring is good.	Human	Same statements as made by women's group.
2	Human	Human resources are diminishing as educated young people seek opportunities in big cities and do not return to Setulang.	Social	Social bonding and cohesion are strong. It is easy to mobilize collective action.
3	Agriculture	Harvest is decreasing. It is enough to cover needs, but the surplus is getting smaller.	Financial	Some funding for community projects is available from village groups and government agencies but it is not sufficient.
4			Water	Volume of spring water channeled to the village is inadequate as the pipe is too narrow.
5			Forest	Forest resources are in good condition but availability for future generations is unclear.
6			Agriculture	Same as statements by women.

supply of fresh water. Villagers extract food and NTFPs (fruit, rattan, medicinal plants and bush meat), building materials and firewood from the forest, and have started to develop ecotourism in Tane' Olen.

Social resources comprise social cohesion, *adat* and traditions, and networks and groups for mutual support. These groups mobilize collective action, assist the sick and vulnerable, support farming and cultural activities, and manage various funds for village development. These resources are still in good condition, according to the villagers, thanks to the rather strong culture of unity and mutual support in Setulang (Figure 6).

Financial resources were associated with the funds needed for purchasing farming equipment, seedlings and for building facilities (e.g. establishing electricity and telecommunication networks). Although financial assistance is available from government agencies through the farmers group in Setulang and other villages, people feel that the amount of funding available is insufficient for their needs. Setulang has a community savings and loans group but its funds also are deemed insufficient, especially for constructing new facilities.

Both men and women named important village institutions (Table 2), as well as the institutions from outside that have an influence on village affairs.

The large number of village institutions could be attributed to the social cohesion that is characteristic of Setulang. Participants mentioned the following institutions as having an influence on the village:

1. GIZ
2. CIFOR
3. District Tourism Agency
4. District Forestry Agency
5. Agricultural Extension Agency
6. Farmers Groups Association
7. Political parties
8. Army Development Assistance (Bintara Pembina Desa, or Babinsa)
9. Borneo Tropical Rainforest Initiative.

4.1.2 Challenges, hazards and coping strategies

The community made a list of challenges and hazards, which were reduced to eight priority challenges, ranked in the following order (see also Table 3):

1. tenure-related social conflicts with neighboring villages and concessions
2. alcohol and drug abuse by the young
3. abuse of political power
4. river pollution
5. floods
6. diseases (diarrheal, infectious and vector-borne)
7. prolonged dry seasons
8. illegal logging.

Table 2. Institutions in the village

	Name	Villagers involved
1	Village government	Men and women
2	Village Parliament	Mostly men
3	Adat Agency	Mostly men
4	Institute for Community Empowerment	Men and women
5	Church Governing Agency	Men and women
6	Social and Cultural Agency	Men and women
7	Empowerment and Family Welfare Agency	Mostly women
8	Tane' Olen Governing Agency	Men and women
9	Health center for mothers, children and pregnant women	Mostly women
10	Youth Agency	Men and women
11	Economic Cooperation Agency	Men and women
12	Interagency Village Council	Men and women
13	Community-based Savings and Loans Groups	Men and women
14	Indonesian Gospel Church Camp	Men and women
15	Early Childhood Education Agency	Men and women

Figure 6. The *adat* house in Setulang, where village meetings are held

Table 3. Challenges/hazards and coping strategies: Community responses

No.	Challenge/hazard	Coping strategies/solutions	Suggestions for improvement
1	Tenure conflicts	Negotiation with other villages, occasional reports to local government	More government and third-party involvement in mediation
2	Alcohol/drug abuse	*Adat* law	
3	Abuse of political power	No strategy	No suggestions
4	River pollution	Reports, pleas, demonstrations	More government backing
5	Floods	Elevate housing Practice proper waste management to avoid blocking drains and rivers Move surplus crop storage (barn) to higher ground	Village *adat* institution for disaster management (e.g. rescuing the property of people who are in the fields when floodwaters rise)
6	Diseases	Avoid bathing in river Seek health care advice Increase nutrition for babies and pregnant women	Treated bed nets for each household to protect against malaria
7	Longer dry seasons	Plant drought-resistant crops Resort to forests for food and livelihoods Seek assistance from authorities	Greater livelihood diversification Greater capacity to store surplus food and cash
8	Illegal logging	Strong *adat* laws	Formal recognition from government through the Village Forest permit

Interestingly, even though floods, droughts and other environmental and climatic hazards occur frequently in the area, people did not include them among the most serious problems. The community members believe that they can cope with climate hazards, for example by elevating their houses, carefully managing their forests, keeping a crop surplus and maintaining grain storage facilities on safe ground. However, social challenges such as conflicts have a more profound impact both on their lives and on their overall ability to cope with all the other challenges.

The community is aware of the links between social issues and their ability to cope with climate hazards. Tenure conflicts with neighboring villages, for example, make them reluctant to cultivate fields near the village borders. This leaves less land available for agricultural diversification and for offering fields with good prospects to the young. Local decision makers, abusing their political power, often secure deals with concessions and sell village land without consulting the communities. People know that if they lose their forested land, they will become more vulnerable to other hazards because the forest protects their water supply and serves as a food bank.

Conflicts in Malinau escalated after decentralization, when concessions started approaching villages in the area to offer compensation for exploiting their land and forests. This provoked boundary disputes between villages because the lack of clarity over land tenure rights meant it was unclear which villages would reap the perceived benefits of exploitation. The people of Setulang have been rejecting offers and have been in conflict with companies that tried to encroach upon their area without asking their permission.

Community members in Setulang feel that their strategies for dealing with the challenges and hazards have not yielded any long-term and sustainable solutions. With tenure conflicts, for example, Setulang has been negotiating with neighboring villages to try and agree on boundaries, but they feel that this process requires a more substantial involvement of local government and third-party independent mediators to be fair and just.

To prevent substance abuse by the young, the village has created an *adat* law to regulate the use of alcohol and drugs. However, as these can be purchased in neighboring villages, stronger cooperation between villages is needed to solve the problem.

River pollution is another critical problem that people feel needs more involvement from local authorities. The river in Setulang has become so polluted from coal mining exploration upstream and in surrounding areas that the people can no longer safely use it for bathing or other activities because it causes skin and diarrheal diseases. Villagers have also noticed a marked decrease in the number of fish caught from the river. Reports to government agencies, petitions to mining companies and demonstrations have not had any significant effect.

To cope with the longer dry seasons in recent years, which have caused crop failures and lower river levels, Setulang has employed a proactive and longer-term adaptation strategy of making efforts to conserve the forest so that it can serve as a 'food bank' in times of scarcity. However, assistance is sometimes required from local authorities when the effects of drought become overwhelming. Villagers recognized a need for greater livelihood diversification and capacity to store surplus food and cash to enhance their security.

Another fear was that Tane' Olen, which is so integral to addressing challenges such as flood and drought, could be under threat of degradation and logging, and that the *adat* law might not be enough to stop encroachment. Consequently, villagers are hoping that the Ministry of Forestry will promptly approve their application for Village Forest status, under which their tenure rights to Tane' Olen will be formally recognized.

4.2 District-level interviews: Perceptions of the main challenges and hazards in Malinau and Setulang

Semi-structured interviews with stakeholders at the district level were used to elicit their perceptions of the main climate and non-climate challenges and hazards in Setulang and Malinau more broadly, their thoughts on current strategies employed to address them, and their feedback on recommended interventions.

4.2.1 Climate-related hazards in Malinau

All but one district-level stakeholder stated that climate-related hazards had become a threat in Malinau, because of increases either in impacts associated with compounding factors or in hazard frequency and intensity.

All stakeholders see flooding as a widespread problem in Malinau, which receives an average of 2000–4000 mm rainfall each year. Flooding affects cropping patterns and yields, transportation, property and health. However, floods are seen as normal events, to which people are accustomed, and the severe impacts are attributed to compounding factors (see the following section on relationships between hazards). Furthermore, flooding predominantly affects the lowlands, whereas drought and shifts in seasonality are perceived as being of greater concern for the district.

Drought is perceived as a relatively new phenomenon in the region. People have noticed that some months that are normally wet may have very little or no rain, with severe impacts on people's cropping calendars. For example, land preparation and planting for dry rice (*ladang*) usually take place in August, a typically dry month, so that the rains expected from September onward can give the crop the water it needs during its critical development stages. However, in recent years, December and January have been exceptionally dry, causing multiple crop failures in Malinau. Another change observed is higher-than-average rainfall during typically dry months.

Local communities have reported a decrease in the amount of fruit available, an increase in the intensity and frequency of plant diseases, and greater difficulty in hunting wild animals.

4.2.2 Other challenges in Malinau

Stakeholders perceive challenges not related to climate as of greatest concern, especially because they amplify the impacts of climate and other hazards.

Unsustainable coal mining and deforestation were the issues raised most often. Many mining concessions do not follow recommended best practices, and mining activities conducted upstream have adversely affected residents as well as the flora and fauna. River pollution has led to a marked reduction in fish populations, with those that had previously been abundant no longer easily found. Water pollution has also led to health problems such as skin diseases (also reported by the Setulang community).

Despite the problems associated with unsustainable mining, the number of coal mining concessions has increased and so has the demand for land. This has led to further deforestation and less land available for farming. The combination of deforestation and pollution from mining has resulted in further deterioration of the Malinau River and high levels of sedimentation. Some local communities in the lowlands have reported water scarcity during the dry season, which they link to mining and deforestation upstream.

Figure 7. Down the Malinau River
Source: Douglas Sheil/CIFOR

Another issue discussed was the difficulty of establishing paddy rice and irrigated rice fields (*sawah*) in areas other than the lowlands. Irrigated fields are generally considered to be more productive and resilient to hazards such as changes in seasonality and drought. However, establishing *sawah* in upstream areas is expensive, and so shifting cultivation remains the most feasible and hence preferred option. However, more and more land will be needed to sustain it because of increases in competing land uses and in population.

Respondents were divided as to whether crop pests and diseases (e.g. the rice pest *wereng* – also known as brown plant hopper) are a severe problem. According to some respondents, pests and diseases are not a major threat because they occur at a small scale and can be anticipated. Furthermore, as fields in Malinau are quite spread out, pest and disease outbreaks can be easily contained.

However, other respondents reported an increasing frequency of pest and diseases, including maggots, rice pests (blast and wilted shoots), caterpillars and leaf hoppers. An increase in the number of forest wildlife attacks on crops (e.g. macaque attacks) was also flagged as a concern, and is attributed to the

animals having difficulty finding food in the forest because of changes to flowering patterns and reduced availability of NTFPs such as nuts.

District-level stakeholders appeared somewhat reluctant to discuss land tenure conflicts: the issue was mentioned as significant but not explored in detail. Land tenure and village boundaries are very sensitive matters, and decisions about them are not made easily either within or between district authorities out of fear of enraging a community, exacerbating existing conflicts or sparking additional conflicts. The process by which the Setulang community and NGOs marked the boundaries of Setulang village and Tane'Olen is not widely accepted, as Setulang villagers are viewed as relatively new settlers in the area and most district-level stakeholders believe that other villages were not adequately considered or consulted. In general, the strict, rigid, and mostly top-down and non-participatory demarcation of village areas and borders is seen as the underlying cause of tenure conflicts. The local government has sought to alleviate the conflicts but has not addressed the underlying problems.

Closely related to tenure conflicts is the issue of improper land-use planning. Most of the problems in Malinau (e.g. deforestation) can be attributed to the lack of clear spatial plans. The district lacks synergistic land-use planning, where plans are made for the whole district, based on cross-sectoral communication between agencies and alignment of policies, and take into account the often conflicting goals of development and forest conservation. Although spatial plans should clearly designate areas for production, protection and agriculture, existing land-use and development plans cause considerable uncertainty and confusion among stakeholders. Policies are formed without in-depth examination of all inter-related issues, and no attempts to balance forest conservation, population growth and village expansion have been made so far. Exacerbating the problem is that Malinau has been declared a conservation district, but extensive coal mining exploration is simultaneously underway. Greater collaboration is needed to balance conservation and development trade-offs.

4.2.3 Relationships between challenges

Almost all district-level respondents pointed out linkages and feedback loops between climate and non-climate stressors, particularly heavy precipitation, mining, deforestation and flooding. Malinau communities generally cope well with heavy rainfall events, but flooding has been exacerbated by upstream deforestation and damage caused by coal mining. The number of coal mining concessions has increased, as has the demand for land, leading to even more deforestation and less farmland availability, and to pollution and sedimentation of the Malinau River, all of which exacerbate the adverse impacts. The natural capacity of the Malinau River to accommodate excess precipitation has been greatly reduced. The overall degradation of the river was also cited as an underlying cause of flood damage.

Communities have complained about these effects of coal mining, as well as the pollution of the river, but mining companies do not comply with regulations and their waste management practices are difficult to control. By contrast, villages upstream, such as Loreh, actually reap benefits from coal mining, and have received compensation from a company that transports coal through the village.

Other relationships mentioned in passing were the links between crop failure from drought and the almost complete lack of irrigation facilities in rural areas, and between the more frequent occurrence of pests and diseases, shifts in seasonality and the villagers' resistance to new farming practices.

4.2.4 Current and suggested strategies to address challenges

District agencies are employing various strategies or have suggested interventions to address some of the hazards and challenges in Malinau (Table 4).

The agricultural agency is trying to encourage adaptive cultivation practices based on climate predictions and pest and disease risks. Extension officers offer farmers advice on optimal cropping patterns and biannual harvesting (e.g. using shorter cycles and planting another round of crops right after the first harvest); however, villagers are reluctant to move to two harvests a year because of worries it will increase the risk of pest invasions, as it makes more food available for the pests. The agency, which focuses on paddy rice and corn, suggests alternating the crops planted each year (e.g. rice one year, another crop the next) as a way of avoiding pests and diseases. The agency also actively encourages irrigated rice plantations (*sawah*) to cope with drought and shifts in seasonality. However, communities are reluctant to change cropping patterns because they are associated with centuries-old cultural

Table 4. Challenges/hazards and coping strategies (district-level respondents)

Agency	Challenge/hazard	Current strategies	Suggested future interventions
Forestry	Deforestation	Completing and managing Village Forest (*Hutan Desa*) applications	
Agriculture	Drought and shifts in seasons	Advising farmers on optimal cropping patterns and encouraging biannual harvesting	
Agriculture	Crop pests and diseases		Encourage yearly alternation of crop types
Community Development	Lack of development	Deploying technical staff in villages to assist in planning activities under the community development program Gerdema	
Planning and Development (Bappeda)	Deforestation		Synergistic land-use planning with interagency cooperation Devolution of forest management to communities as they are the best stewards of the ecosystem
Plantation	Lack of diversification	Promoting cultivation of oil palm, cocoa and rubber	
Kayan Mentarang National Park administration	Tenure conflicts (exclusion from forests)	Including communities in conservation and park management Giving advice on using forest products and park zoning	Award Tane' Olen management rights to affected communities
Environment	River pollution	Issuing permits for mining operations to regulate waste management	
Environment	Flooding	Raising communities' awareness of appropriate waste and tree management	
WWF Malinau	Lack of diversification	Encouraging farmers groups and cooperatives, mentoring, developing organic production and ecotourism	

practices and irrigated rice can only be developed in downstream areas. Another limitation for the agency is that, as rain gauges are not available in every subdistrict, it must resort in some cases to coarser-resolution provincial-level data.

The agency for community development works on livelihood issues of priority to the community. It uses bottom-up processes and the government-initiated rural development program Gerakan Desa Membangun (Village Self-Sufficiency Development Movement, known as Gerdema). Projects include the development of handicraft micro enterprises in interested villages with suitable expertise or related cultural practices. The agency also deploys technical staff/advisors (Satgas) to assist the villages and build capacity in implementing Gerdema interventions, especially in project and financial management. The goal is for each village to have at least one Satgas with either technical (e.g. management or finance) or social expertise, depending on its needs.

The vision behind Gerdema is to achieve rural development through bottom-up processes based on community aspirations and sound environmental management. The program is based on principles of sound environmental management for development. The success of the Gerdema program varies from village to village. Although some villages strive for economic transformation, their infrastructure is so poor that they cannot achieve it without larger-scale investments; in these cases, the focus is shifted to cultivating and managing resources for household consumption (subsistence).

A central concern of Bappeda, the district planning and development agency, is to reconcile conservation with development, which can only be achieved through more cooperative, deliberative and multisectoral land-use planning. Bappeda believes that communities should be given responsibility for forest management, because they will be better

stewards of the forest than the government or the private sector and hence will help avert deforestation.

The plantations agency, under the direction of the central government, focuses on oil palm, cocoa and rubber. In particular, cocoa has already been developed to some extent and has good prospects and returns on investment. Furthermore, extension services are well developed and people are familiar with its management. By contrast, coffee has been problematic because the imported seeds that were used yielded crops with a sour taste. The agency has established several demonstration plots for coffee and other cash crops, but has encountered problems associated with the staff's limited field experience and resistance from communities. No demonstration plots have been developed yet for rubber, but there are plans to do so in the near future. The communities have also suggested cultivating other produce such as fruit, which is well suited for livelihood diversification programs as it is easy to market and people know how to manage it.

The Kayan Mentarang National Park administration has aimed to help reduce conflicts related to the protection of forests on community lands by awarding use and management rights over Tane' Olen to communities. Before Kayan Mentarang received national park status in 1996, it was a reserve, which meant people could not access the forest or its products, a situation that provoked conflicts. The concept of Tane' Olen (villagers protecting forests with *adat* laws) can be applied in other areas beyond Setulang, but programs should actively engage with young people. The Kayan Mentarang National Park administration runs several conservation and park management programs with communities, especially with younger community members. They also give advice on the use and management of firewood, on park zoning and on the functions of the national park.

The environment agency has tried to tighten regulations governing mining operations and waste management by issuing permits restricting the amount of waste that can be generated and disposed of in the river. An intra-agency team works with community members to supervise mining operations and restrict pollution. Community waste disposal in the rivers is another major issue. The agency has introduced a waste collection program, in collaboration with the Department of City Planning. To help minimize floods, other agencies are undertaking technical work such as dredging and handling of construction along riverbanks, and the environment agency is working to educate communities about waste management (e.g. proper disposal to avoid blocking drains and rivers) and tree management (e.g. educating people on why they should not to cut down trees on or near riverbanks and to encourage tree planting). However, the agency has had difficulties in accessing remote villages and in gathering information about specific challenges. Although having agents stationed close to villages would mean they could provide quick information on environmental hazards (e.g. waste discharge in rivers) and prompt the timely handling of problems, there are no resources to do so.

WWF Malinau focuses on encouraging communities to form farmers groups (e.g. in Krayan) in order to further develop and market local commodities. Mentoring programs have been introduced for the institutional strengthening of cooperatives, the development and certification of organic produce and ecotourism in some villages near Kayan Mentarang National Park. The NGO perceives the development of organic agriculture and agroforestry as an important strategy for helping communities adapt to climate change.

4.2.5 Challenges in Setulang

District-level respondents perceived no major challenges in Setulang, except for the tenure-related social conflicts. The village is considered to be well off compared with other villages in the district, and there is a fear that this constant focus on Setulang will make other villages envious and exacerbate conflicts. Most of the district-level respondents believe that NGOs favored Setulang during past attempts at conflict resolution and took the view that the other villages were bullies. Local stakeholders see this view as unfair, given that the Setulang villagers are relatively new settlers in the area and that other villages were not consulted adequately during the delineation of Tane' Olen and village area boundaries. There is general agreement that these conflicts are a serious problem because they limit the further development of agricultural fields, not only in Setulang but also in surrounding villages.

The shortage of available land is a possible future problem for Setulang. With more than half of the village area under protected-area status and the rest set aside for agriculture, housing and facilities, the growing population will have difficulty with land use and village expansion, especially if conflicts with neighboring villages are not resolved.

5. Climate and vulnerability analysis

5.1 Exposure

5.1.1 Past and current climate trends in Malinau

Average climate in Malinau

Mean seasonality in Malinau is lower than in similar climates in other parts of the world. That is, on average, seasons (whether hot/cold or dry/wet) are not markedly different. The mean monthly temperature ranges from 26.4°C to 27.3°C and precipitation from 205 to 360 mm/month (Figure 8).

Annual climate variability data show that Indonesia has three distinct rainfall regions. Malinau is in what is characterized as Region B, with an equatorial climate and two precipitation peaks, in October–November and March–May (Aldrian and Susanto 2003). Those two peaks are associated with the southward and northward movements of the inter-tropical convergence zone. Although traditionally there had been no pronounced dry season, drought has been occurring with increasing frequency (Hilman *et al.* 2010).

Interannual variability and trends in precipitation and temperature

Past climate data indicate that the inter-annual variability in precipitation is relatively normal: 55% of sites with similar climates in the world (with ±1°C in annual mean temperature and ±10% in annual precipitation) have lower interannual variability (or 45% have higher interannual variability). Drier and wetter years have occurred but these deviations are not considered exceptional. The five years with the lowest precipitation since 1960 are 1964, 1965, 1967, 1992 and 1997, and the five years with highest precipitation are 1962, 1974, 1980, 1988 and 1999. There is a notable trend of increasing precipitation (black solid line in Figure 9), but this trend is not significant.

The interannual variability in temperature is also considered normal: 58% of sites with similar climate have lower interannual variability (or 42% have higher interannual variability). The five years with the lowest temperatures are 1962, 1963, 1964,

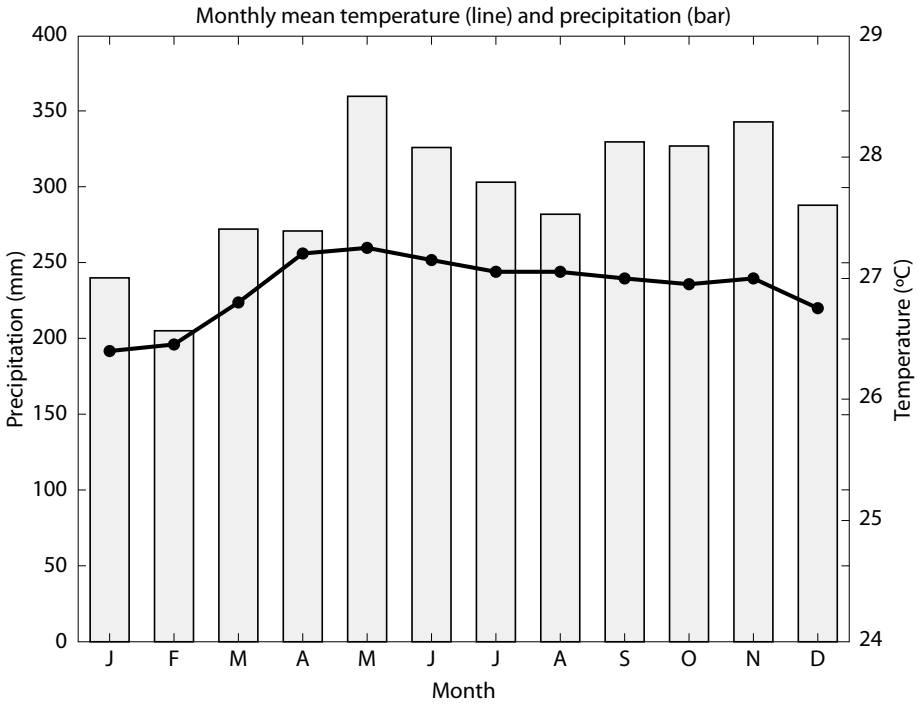

Figure 8. Average climate in Malinau

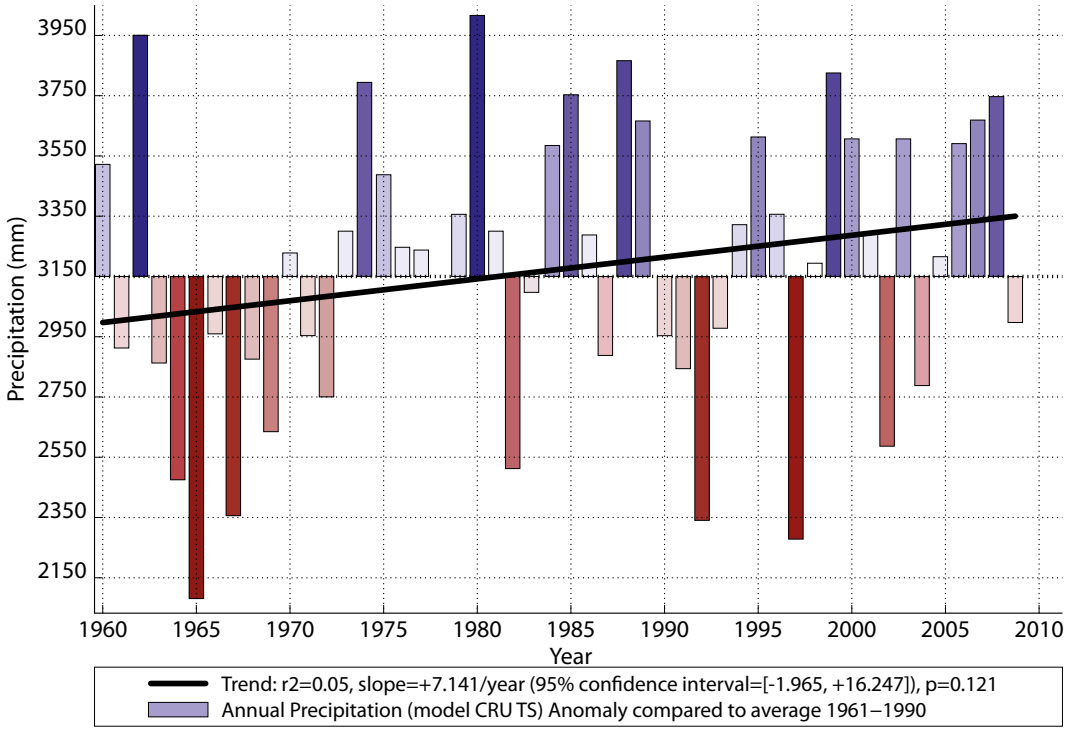

Figure 9. Variability in annual precipitation in Malinau, 1960–2010

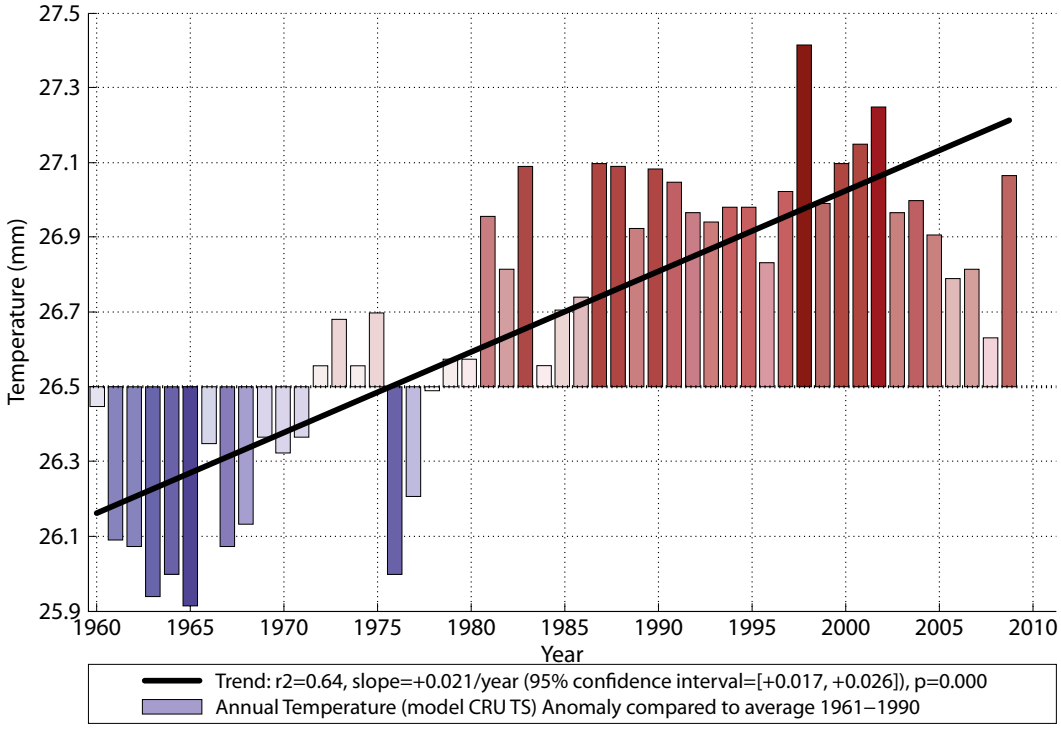

Figure 10. Variability in annual temperature in Malinau, 1960–2010

1965 and 1976, and the five years with the highest temperatures are 1987, 1998, 2000, 2001 and 2002. The clear trend of increasing temperature is significant (Figure 10).

5.1.2 Projected future climate trends

Future precipitation in Malinau

As in most tropical regions, the future precipitation in Malinau is highly uncertain (Figure 11). Depending on the GCM and the emission scenario, mean annual precipitation will either increase or decrease. In general, eight scenarios show an increase, whereas the other eight show a decrease. The maximum projected increase by 2020 is 38.18 mm/year (with scenario csiro2.b1a), while the maximum decrease is 62.80 mm/year (scenario cgcm2.a1fi). The maximum projected increase by 2050 is 83.19 mm/year (scenario csiro2.a1a), while the decrease is 154.76 mm/year (scenario cgcm2.a1fi). The maximum projected increase by 2080 is 152.00 mm/year (scenario csiro2.a1a), and the maximum projected decrease is 280.83 mm/year (scenario cgcm2.a1fi).

More concerns arise in relation to extremely wet or dry years (interannual variability) and extreme events than to the mean annual future precipitation for 2020, 2050 or 2080. However, climate models do not simulate interannual variability very well.

The future mean monthly precipitation, which is critical for defining cropping patterns, is also uncertain (Figure 12). The mean is not very informative, but the extremes (maximum increase and decrease) could be used to inform robust strategies.

Projected annual temperature in Malinau

Future trends in annual mean temperature in Malinau are more certain (Figure 13). All models show an increase in temperature of

- at least 0.45°C (with scenario pcm.b1 predicting the lowest increase) to 0.87°C (with scenario had3.b2m predicting the highest increase) by 2020;
- at least 0.76°C (pcm.b1) to a maximum 2.08°C (had3.a1fi) by 2050;
- at least 1.03°C (pcm.b1) to a maximum 3.77°C (had3.a1fi) by 2080.

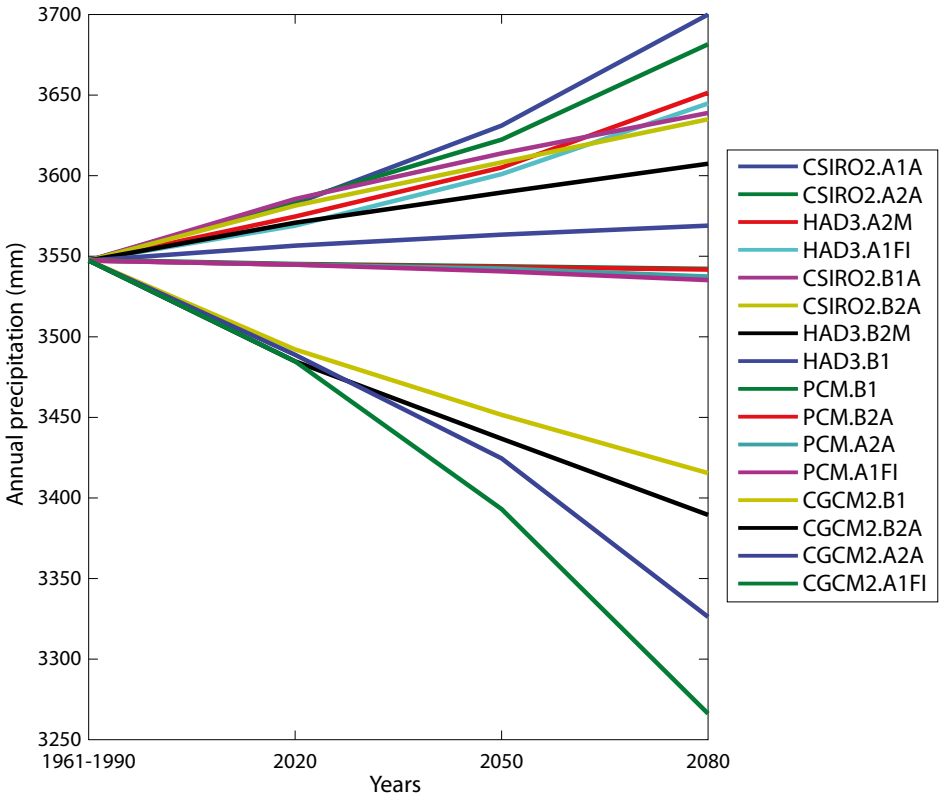

Figure 11. Annual precipitation in Malinau in 2020, 2050 and 2080, according to 16 climate scenarios

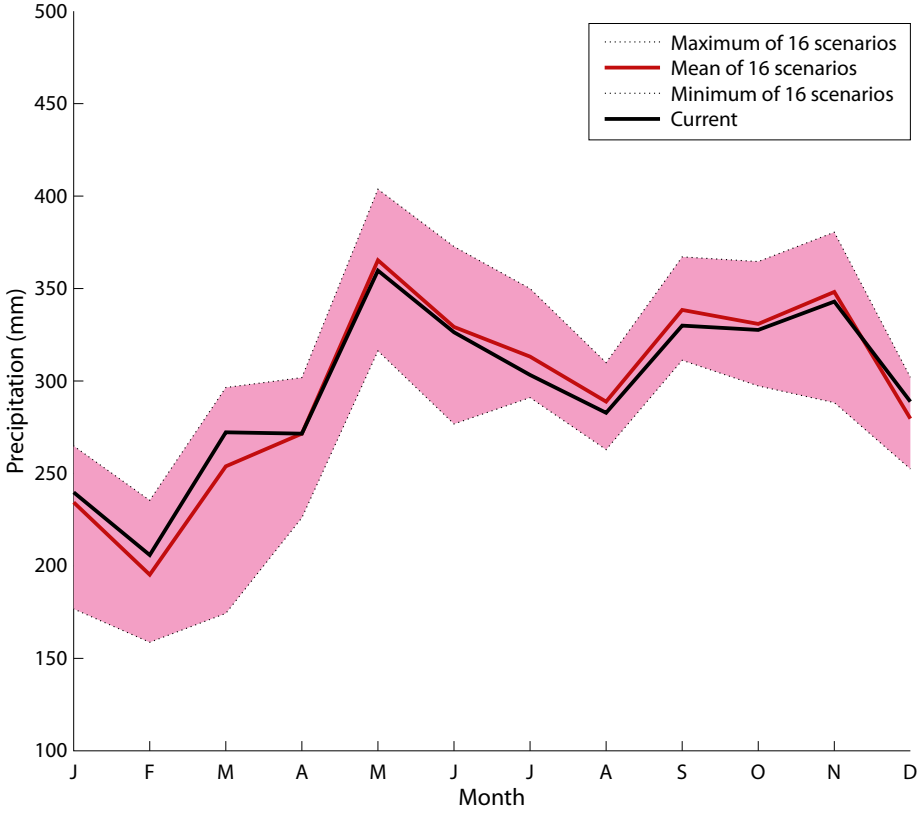

Figure 12. Predicted monthly precipitation in Malinau for 2080

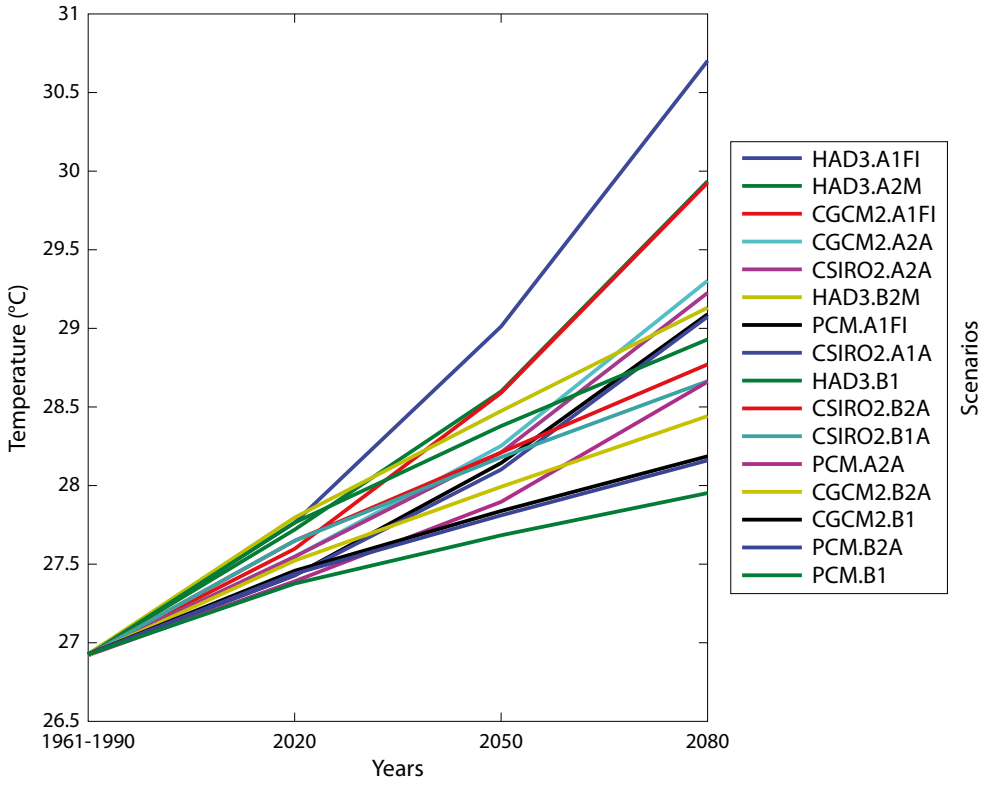

Figure 13. Mean temperatures in Malinau in 2020, 2050 and 2080, according to 16 climate scenarios

This increase is of concern for Malinau, especially given that interannual variability in temperature has been low in the past (around 2°C difference in annual temperature between the warmest and coolest years in the past 25 years). Heat waves and increases in daily maximum and minimum temperatures are of major concern.

Extreme events

There is scientific consensus that climate change increases the likelihood of some types of extreme events, such as droughts and heat waves (Field *et al.* 2012; Peterson *et al.* 2012). However, because of natural climate variability, it is difficult to estimate whether or not this likelihood will increase each year and, if so, by how much (Peterson *et al.* 2012). Climate change will, however, make extreme events more unpredictable and their patterns, intensity and locations are likely to shift.

El Niño–Southern Oscillation

El Niño–Southern Oscillation (ENSO) events are expected to result in more extreme droughts and precipitation events with climate change. ENSO events alternate between El Niño and La Niña. During El Niño years, unusually warm water forms across much of the tropical eastern and central Pacific, resulting in a drastic decrease in precipitation over Southeast Asia. La Niña is the counterpart to El Niño: La Niña years are characterized by cooler-than-normal sea-surface temperatures across the equatorial eastern and central Pacific, resulting in intense precipitation (IRI 2007). ENSO events are a normal part of Earth's climate (ENSO is the most dominant feature of cyclic climate variability on sub-decadal timescales) and they have been occurring for hundreds of years (Yeh *et al.* 2009). The time between successive El Niño events is irregular, but they typically tend to occur every 2–4 years (high-frequency oscillation period) or every 4–6 years (low frequency) (An and Wang 2000). A La Niña event often follows an El Niño and vice versa, although this is not always the case. ENSO events last for roughly a year, although occasionally they may persist for 18 months or more (IRI 2007).

Aldrian and Susanto (2003) noted that, during the 1997/1998 El Niño event, virtually the entire country had rainfall below the 10th percentile. Hendon (2003), using rainfall time series data from an average of 43 rainfall stations, concluded that Indonesian rainfall is coherent and strongly correlated to ENSO variations in the Pacific Basin.

Although the future frequency of ENSO events under climate change cannot be predicted with accuracy, several analyses show that ENSO is likely to transition from a stable oscillatory behavior to an unstable oscillation with changes in the amplitude, structure and frequency (Timmermann 2001). Some projections indicate that ENSO events will only occur in high frequency (every 2–3 years) after the 2050s (Sofian 2010). This oscillation instability is already noticeable in recorded data from the 1980s onward, showing more frequent and intense ENSO events (IRI 2007).

5.2 Sensitivity

5.2.1 Agricultural production

Rice

All rice, whether rain-fed or irrigated, is sensitive to a number of climate variables including precipitation, vapor pressure, soil moisture, seasonal temperature, daily maximum and minimum temperatures, solar radiation and annual input of atmospheric carbon dioxide (CO_2) concentration (Lansigan *et al.* 2000; Wassmann *et al.* 2009). Both long-term changes in climate and its variability (e.g. rise in annual temperature means) and short-term weather events (e.g. drought) influence rice productivity and yield. The effects of short-term events and extremes on yield largely depend on the development stage of the crop at the time of exposure, with dry rice being generally more sensitive than irrigated rice (Lansigan *et al.* 2000).

An increase in CO_2 will have some positive effects on rice productivity and yields but these effects will be nullified by the negative impacts of temperature rise (Baker *et al.* 1992). The optimum temperature for most rice growth stages is in the range of 25–30°C (Table 5).

Although the annual mean temperature in Malinau is not projected to rise above 30.5°C, the scenarios only indicate the mean across all months of the year and daily minimum and maximum temperatures. If an increase in this mean is to be expected, increases in daily minimum and maximum values are almost certain, especially during heat waves, droughts and El Niño events. Daily maximum temperatures could even rise beyond 35°C.

Table 5. Critical temperatures for rice development at different growth stages

Growth stages	Critical temperature (°C)		
	Low	High	Optimum
Germination	16–19	45	18–40
Seedling emergence	12	35	25–30
Rooting	16	35	25–28
Leaf elongation	7–12	45	31
Tillering	9–16	33	25–31
Initiation of panicle primordia	15	–	–
Panicle differentiation	15–20	30	–
Anthesis	22	35–36	30–33
Ripening	12–18	> 30	20–29

Source: Yoshida (1978)

High temperatures induce sterility in rice during highly sensitive physiological processes such as anther dehiscence and the early events of fertilization. Anthesis (flowering) in rice is extremely sensitive to high temperature, and spikelets opening during the flowering period can be affected profoundly depending on the duration of exposure (Wassmann *et al.* 2009).

High temperature also influences the ripening phase, by affecting cellular and developmental processes, ultimately leading to reduced fertility and grain quality (Barnabás *et al.* 2008). Common effects of exposure during this stage include decreased grain size and weight, reduced grain filling, and higher percentages of white chalky and milky rice, all of which reduce the prices that farmers can fetch for their rice (Wassmann *et al.* 2009).

Rice is highly sensitive to increases in minimum daily temperature (nighttime temperature). Studies in Nepal have shown that an increase in the minimum daily temperature is more risky than an increase in the maximum daily temperature for obtaining high rice yields (Rai *et al.* 2012). In the Philippines, grain yield has been shown to decline by 10% for each 1°C increase in growing-season minimum temperature during the dry cropping period (Peng *et al.* 2004).

The rice crop is also sensitive to variability in both the amount and distribution of rainfall. In the freely drained uplands, moisture stress severely damages or even kills rice plants in areas that receive as much as 200 mm of precipitation in 1 day and then receive no rainfall in the next 20 days (Nguyen n.d.). Flooding constrains rice production in the lowlands too. Excessive water at the vegetative growth stage hampers rooting and decreases tiller production. Although rice is a semi-aquatic plant, it is generally intolerant of complete submergence and plants die within a few days if completely submerged (Wassmann *et al.* 2009). Most rice varieties can tolerate complete submergence, for about 6 days before 50% of the plants die. The mortality rate rises to 100% when submergence lasts for 14 days or more, although a few varieties can survive the 14-day threshold (Nguyen n.d.; Wassmann *et al.* 2009).

On the other hand, drought during flowering causes spikelet sterility and major yield losses (O'Toole and Namuco 1983; Ekanayake *et al.* 1989; Wassmann 2009). Soil water deficit in general influences all the physiological processes in rice plant growth and development (Wassmann *et al.* 2009), with drought being the biggest production constraint in rain-fed rice systems, affecting 10 million ha of upland rice and more than 13 million ha of rain-fed lowland rice in Asia (Pandey *et al.* 2007).

More frequent and intense ENSO events, related to both El Niño and La Niña, will therefore have a serious impact on rice production, because of either drought and temperature increase or heavy precipitation and flooding. Incidences of pests and diseases will also intensified by fluctuations in climate variables (Lansigan *et al.* 2000). Studies in Indonesia have shown that the area of rice affected by the brown plant hopper (*wereng*) tends to increase significantly during the prolonged precipitation of La Niña years (Susanti *et al.* 2010).

Root crops

Although the optimum temperature for cassava (*Manihot esculenta*) is in the range of 22–32°C (Lebot 2009; Jarvis *et al.* 2012), this root crop is exceptionally tolerant of higher temperatures and drought. It can survive temperatures of up to 45°C and an annual mean rainfall of only 300 mm (Jarvis *et al.* 2012) but it is not tolerant of waterlogging (Lebot 2009). Furthermore, cassava is highly vulnerable to pests and diseases (Herrera Campo *et al.* 2011). The four principal biotic constraints on cassava production are whiteflies, cassava green mites, cassava mosaic disease and cassava brown streak

disease, with pest and disease outbreaks occurring throughout most of Southeast Asia (Herrera Campo *et al.* 2011). Higher temperatures are very likely to result in increased outbreaks, thus requiring careful pest and disease management for cassava to thrive under climate change (Ceballos *et al.* 2011; Jarvis *et al.* 2012).

Like cassava, sweet potato (*Ipomoea batatas*) is drought resistant and can grow in harsh conditions with poor soils (Lebot 2009). It is highly tolerant of weeds and has relatively few natural enemies. However, it is even less tolerant of water logging than cassava and needs to be harvested and stored before heavy rains start (Lebot 2009). An increase in annual precipitation and heavy rainfall days will make sweet potato cultivation difficult.

Other crops of significance

Bananas, cultivated in most parts of Indonesia, need sufficient water uniformly distributed throughout the year and grow optimally in a temperature range of 24–27°C (Jarvis *et al.* 2012). Temperatures outside this range impair the crop's growth and development (Figure 14). Research has shown that the crop suffers heat injury at minimum (nighttime) and maximum (daytime) daily temperatures of 30°C and 37°C, respectively (Turner and Lahav 1983). High temperatures lead to lower unit leaf rates and less dry matter in the roots and corn compared with plants grown under the optimum daily minimum/maximum temperatures of 18/25°C. In general, productivity and yields start decreasing above the optimum temperature of 27°C (Sastry 1988). The crop is also very sensitive to pests and diseases, which may become more destructive with climate change.

Other crops cultivated in Malinau include corn, cocoa and, to a lesser extent, coffee (Sheil 2002; Ruf and Lançon 2004).

Cocoa (*Theobroma cacao*) yields are influenced by environmental conditions during flowering, pollination, fruit set and fruit development and maturation (Schwendenmann *et al.* 2010). Non-shaded monocultures are significantly more sensitive than cocoa grown in shaded agroforests. Low rainfall and drought induce leaf fall and affect development and maturation, resulting in a lower number of cocoa pods. Farmers in Sulawesi reported yield declines of up to 38% after strong ENSO-related droughts in 1997 and 2002 (Keil *et al.* 2008); drought events can induce yield reductions of up to 50% (Zuidema *et al.* 2005). On the other hand, increases in rainfall can lead to increases in yield losses due to black pod disease (*Phytophthora palmivora*) (Schwendenmann *et al.* 2010).

Coffee plants are quite sensitive to changes in microclimate. For example, the optimal temperature range for Arabica coffee is 18–21°C, with net photosynthesis decreasing markedly beyond this threshold, ultimately approaching 0 at 34°C (Lin 2007). Above 23°C, the development and ripening of fruit are accelerated, leading to loss of quality, and below 18°C, growth is depressed. Maintaining shade trees in a coffee system is an easy and suitable strategy for limiting yield losses during microclimate fluctuations. Growth and development are also related to seasonal water cycles. Flowers depend on an extended dry spell for bud formation, while water availability in the wet seasons determines fruit size (Lin 2010). The timing or amount of rainfall at

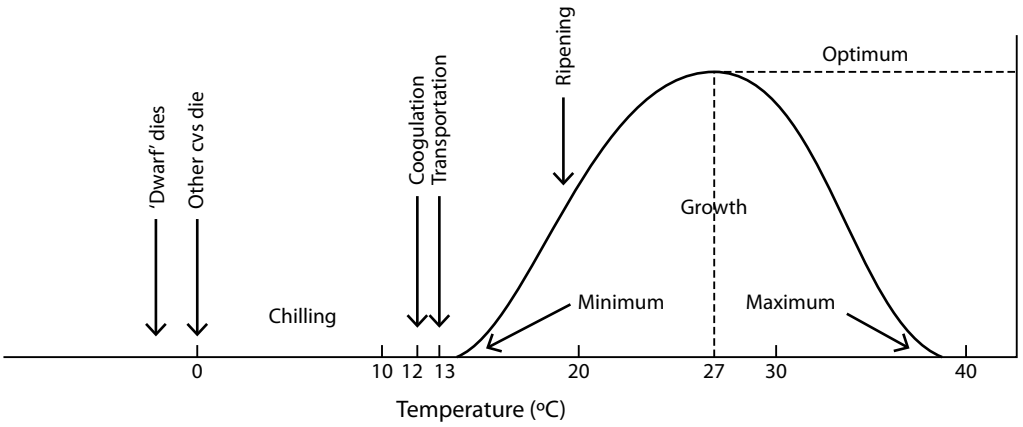

Figure 14. Relationships between temperature and banana growth
Source: Sastry (1988)

critical moments of coffee development can have a significant effect on yields.

For maize, average optimum temperatures for temperate, highland tropical and lowland tropical maize crops lie in the ranges of 20–30°C, 17–20°C and 30–34°C, respectively (Cairns *et al.* 2012). Any maximum daily temperatures above 34°C can cause significant losses in Malinau, while accumulated degrees of daily maximum temperatures above 32°C during the grain-filling period have been shown to be negatively correlated with yields.

A recent analysis of thousands of historical maize trials combined with weather data showed that for every degree above 30°C, grain yield was reduced by 1% in optimal rain-fed conditions and by 1.7% in drought conditions (Lobell *et al.* 2011). Although drought affects all stages of growth and production, the reproductive stage is the most sensitive. Drought during this period results in significant reductions in yields, associated with reductions in kernel size (Cairns *et al.* 2012). However, maize is also sensitive to waterlogging, which affects 18% of the production area in South and Southeast Asia, leading to production losses of 25–30% annually (Cairns *et al.* 2012).

If soils are unable to drain after intense precipitation, the gradual decline in oxygen concentration within the rhizosphere causes plant roots to suffer hypoxia (low oxygen) and, during extended waterlogging (more than 3 days), to suffer anoxia (no oxygen) (Zaidi and Singh 2001; Zaidi *et al.* 2003). A secondary effect of waterlogging is a deficit of essential macronutrients and an accumulation of toxic nutrients resulting from the decreased plant root uptake and changes in redox potential (Cairns *et al.* 2012). The crop is more susceptible to waterlogging during the stage from early seedling to tasseling.

5.2.2 Forests

Forests and trees are less sensitive than agricultural crops to climate variability and extreme events, and CO_2 accumulation is even beneficial for their productivity, yet over the longer term, climate change could alter the structure and composition of forests. However, research on forest sensitivity and vulnerability to climate change in Indonesia is in its infancy and a lot of knowledge gaps need to be filled.

Several studies from Indonesia and the Amazon have demonstrated the sensitivity of tropical forests to drought events associated with El Niño. ENSO events increase the risk, intensity and spread of forest fires because of the rise in temperature and decline in precipitation, especially in disturbed forests.

Under normal rainfall and humidity conditions, most of the fires (both naturally occurring and anthropogenic) are extinguished with the arrival of the rainy season. The moist microclimate within intact tropical evergreen forests will usually not sustain fire (Roberts 2000). However, forest fragmentation and changes in landuse have resulted in canopy discontinuity, allowing sunlight to penetrate and dry the forest leaf litter, decreasing the overall humidity retention. The result is a build-up of highly flammable fuel (Roberts 2000). Forest remnants are heavily degraded by logging and have dry, fire-prone edges, which further increases forest desiccation and fuel loading (Cochrane and Laurance 2002).

Forest sensitivity to fire increases with repeated fires, leading to positive feedback loops. Forest fires in the Amazon, for example, usually have a moderate fire line intensity of less than 50 kW/m^2. After the fire, however, highly flammable fuel builds up from dead tree stands, colonizing grass species and leaf shedding, directly increasing the severity of any secondary fires (Cochrane and Schulze 1998). This also occurs in the Sumatran lowland tropical forests where El Niño fires lead to mass dieback, collapse of trees and a dominance of softwood pioneer species, which has greatly increased the risk of fires (Kinnaird and O'Brien 1998). The average rate and intensity of forest burning and deforestation will increase as previously burned forests accumulate (Cochrane *et al.* 1999). Burned forests also become sensitive to heavy precipitation, which leads to soil erosion and nutrient leaching because of the poor interception of rainfall by the damaged canopy.

Drought also causes mortality in trees, especially if it is prolonged. Tree mortality was high in dipterocarp-dominated forests in East Kalimantan after the drought of the 1997/1998 El Niño event. Whereas fire mainly killed trees with a smaller stem diameter, drought caused mortality in trees of larger stem diameter. Trees died because of either energy reserve exhaustion due to decreased photosynthesis or inability to recover after hydraulic failure (van Nieuwstadt and Sheil 2005).

In the Sungai Wain Protection Forest in Kalimantan, mortality rose to 20%–26% among trees with a diameter at breast height (dbh) greater than 10 cm 2 years after the drought, and species-specific mortality among trees with a dbh greater than 30 cm varied tenfold, thus altering the species composition (van Nieuwstadt and Sheil 2005). However, fire-induced tree mortality cannot easily be distinguished from drought die-back, as fires occur only during drought events whereas drought-caused mortality is ongoing.

5.2.3 Health and settlements

Health

Many infectious bacteria and vectors causing diseases in Indonesia are sensitive to the climate, and changes in temperature and precipitation are highly likely to increase their spread. Diarrheal diseases are linked to poverty and hygiene, but are compounded by the effect of high temperatures on bacterial proliferation (Checkley *et al.* 2000). Several studies have demonstrated the link between El Niño events and the increase in the prevalence of diarrhea in communities, especially among children (Checkley *et al.* 2000; Bennett *et al.* 2012). Heavier rainfall and frequent floods will also lead to more gastrointestinal diseases and other water-borne infectious diseases such as dermatosis because of the degradation of surface water quality and the increase in pollution (Cruz *et al.* 2007).

Greater rainfall, in combination with warmer temperatures and poor sanitation, is projected to expand the vectors for malaria and dengue fever across Southeast Asia (Cruz *et al.* 2007). By 2085, approximately 6 billion people globally are likely to be at risk of dengue transmission as a consequence of climate change, which is 2.5 billion more than if the climate were to remain unchanged (Hales *et al.* 2002). In Indonesia, positive correlations have been found between increased monthly precipitation and the number of dengue cases (ADB 2011). Dengue is currently not a threat to health in Malinau but could become so if no measures are taken.

Settlements

Inland flooding has displaced more than 80,000 people in East Kalimantan since 2007 (DNPI and GoEK 2010). However, the relationship between inland flooding and rainfall is complex, and it depends on the frequency and intensity of rainfall, as well as on the area's specific hydrological characteristics and rivers (and not just on the average amount of rainfall). An area's sensitivity to intense precipitation, or the risk of disaster impacts from flooding, also relates to other influencing factors such as watershed degradation, clogging of drainage canals, deforestation and the status of buildings and infrastructure.

Despite the uncertainty surrounding future mean annual precipitation, a recent Intergovernmental Panel on Climate Change (IPCC) report on extreme events warns of more frequent heavy precipitation events (e.g. with rain exceeding 300 mm in one day) in Southeast Asia (Field *et al.* 2012). Furthermore, the Indonesian Climate Change Sectoral Roadmap has identified areas along the major rivers of East Kalimantan that are at very high future risk of flooding (Hadi 2010). Severe localized floods are a common hazard in Malinau, where flood waters can rise 2–4 m above normal levels (Liswanti *et al.* 2011).

5.2.4 Summary and conclusion

Agricultural production and forests are sensitive to variability in climate, extremes and longer-term climate change. Rice is very sensitive to high temperatures, especially at critical development stages, and to both increases and decreases in precipitation. Banana needs abundant rainfall with production decreasing at temperatures above 27°C, while cassava thrives in drought conditions and at 32°C. Sweet potato is resistant to drought but cannot tolerate waterlogging, while cocoa and coffee are sensitive to heat and water stress. Tropical rainforests are prone to drought-related mortality and fires during El Niño events.

The degree of sensitivity is influenced by other destabilizing pressures and feedback loops. Forests, for example, are more sensitive to drought events and fires if they are degraded or logged (Roberts 2000). Crops that are produced through monocultures and in degraded soils are more sensitive to increases in temperature, precipitation, drought and pest outbreaks than crops grown in more complex systems or agroforestry (Verchot *et al.* 2007; Garrity *et al.* 2010; Pramova *et al.* 2012). Poor sanitation, pollution, and riverbank and watershed degradation increase the severity of floods and the proliferation of bacteria and vectors during heavy precipitation (Cruz *et al.* 2007). Enhanced and sustainable environmental management can decrease sensitivity, and ultimately impacts, in almost all sectors and systems.

5.3 Adaptive capacity

As noted above, resources that support adaptive capacity include irrigation infrastructure and weather stations (physical); community savings groups and farmers groups (social); reliable fresh-water sources and productive land (natural); micro-insurance and diversified income sources (financial); and knowledge, skills and education (human).

In the rural areas of Malinau, communities do not have secure access to the natural resources that are available not only because of social conflicts and land tenure ambiguity, but also because of the increasing presence of logging, mining and oil palm concessions. Although people in these areas rely on forest resources when normal sources are disrupted, there are few instances of proactive resource management strategies employed to achieve adaptation over time, with the exception of Tane' Olen in Setulang.

Diversification of livelihood activities within and outside agriculture is also low, especially in upstream rural areas where swidden agriculture and gathering of forest products predominate. Most households cannot rely on any off-farm income, which leaves them very vulnerable in the event of crop failure. Exceptions are villages such as Setulang, whose residents receive remittances from young household members who have migrated to work on plantations in Malaysia and other countries. This form of migration has both positive consequences, such as households having the cash to purchase tools, and negative consequences, such as the depletion of social capital and knowledge, as community members discussed during the workshop. Within the district, salaried work is available mainly to downstream communities close to Malinau Town, or to the few villagers that can find work in subdistrict administration offices (Moeliono and Limberg 2009). In the middle reaches of the rivers, where people depend almost exclusively on agriculture, obtaining cash can be problematic. Although swiddens provide staple foods, they do not bring in cash, and the low-technology coffee and cocoa plantations are managed too extensively to provide any regular income (Levang *et al.* 2002).

Poverty in Malinau is linked not to income but to lack of access to education and health facilities. In the upper reaches of the Malinau and Tubu Rivers, for example, there are no schools, and sanitary conditions have been described as appalling (Levang *et al.* 2002). Accessibility is another issue, as many mid- and upstream villages are not connected to adequate road networks. This hampers communication with and access by local government and extension services, as well as efforts to minimize disaster risks during extreme weather events. However, thanks to their close proximity to forests, these villages have a good supply of bushmeat (e.g. wild boar, several species of deer, monkeys and birds) and other products of immense local value.

Most villages have almost no agricultural infrastructure, such as grain storage facilities or irrigation systems. Neither does the district have any weather stations to keep farmers informed. The district agricultural agency stressed that, in the absence of rain gauges, which could be used to provide farmers with timely information, only provincial-level data are available.

Setulang village has the advantage of being close to both the forest and Malinau Town, although access to the town has only recently become possible with the construction of a new dirt road. Assets and resources that contribute to the village community's adaptive capacity include strong social capital, unity and cohesion, relatively intact forest resources, expertise and knowledge in forest management, and strong village institutions (see Chapters 2.2 and 4.1). The village's gaps in adaptive capacity are primarily related to the lack of agricultural infrastructure, such as an irrigation system, and information infrastructure, such as a telecommunications network.

Other major problems for adaptive capacity are the legal uncertainty concerning rights to Tane' Olen and, especially, conflicts with neighboring villages over boundaries. As discussed in Chapter 4.1, Setulang villagers are reluctant to develop fields near village borders, which reduces both the amount of land available for agricultural diversification, especially for new households, and the crop surplus.

Cash, the need for which is increasing, is obtained by selling surplus rice and vegetables and, occasionally, from ecotourism. However, with the effects of climate change and land shortages due to population growth, villagers may find it difficult to secure surplus rice for cash or for food security. Young adults, needing cash and opportunities for development, are likely to start exploiting the forest intensively for income or leave the village altogether. Setulang villagers are

worried that these trends will result in erosion of local knowledge and poor stewardship of Tane' Olen, a concern that emerged in previous studies in the village (Iwan 2006; Iwan and Limberg 2009).

Setulang land-use plans are not integrated into the plans and priorities of the main district agencies (with the exception of the forestry agency, which was involved in the Village Forest permit application). Consequently, district and province plans to develop coal mining and oil palm in the area might come into conflict with the objectives of the villagers. This could further threaten their adaptive capacity, which heavily depends on their expert understanding of the forest and its resources (a point also made by Sheil *et al.* (2009) for other rural areas in Malinau).

5.4 Adaptation policy

The Government of Indonesia has taken several steps designed to mainstream climate change into other national development priorities. First was the National Action Plan on Climate Change, in 2007, which set out actions aimed at reducing greenhouse gas emissions and promoting adaptation.

A second document was then developed, titled *National Development Planning: Indonesia's Responses to Climate Change*, also known as the Yellow Book. The Yellow Book serves as a multisectoral guide to the government for integrating climate change into the country's overall National Development Plan through long- and short-term interventions. It laid the groundwork for the Indonesia Climate Change Trust Fund and the integrated planning strategy with pro-poor, pro-job, pro-growth and pro-environment principles.

The National Development Planning Agency (Bappenas) subsequently released the Climate Change Sectoral Roadmap to adapt the National Action Plan on Climate Change to the 5-year Mid-Term Development Plan 2010–2014, and to provide input for the subsequent National Mid-Term Development Plans until 2030. The Roadmap is essentially a policy guide for mainstreaming and implementing national adaptation and mitigation activities (related to regulations, programs and projects, funding schemes and capacity building) into the National Mid-Term Development Plans for 2010–2030.

The Roadmap identified three sectors with major influences on mitigation and adaptation efforts in the forestry sector, namely agriculture, energy and mining. It also identified several other sectors that can indirectly affect forests and forest-dependent communities, namely seas and fisheries, transportation, industry and health. The Roadmap also makes a first attempt to assess the vulnerability of the Indonesian forestry sector at the national level, but concludes that more detailed data are necessary for effective adaptation planning, such as downscaled climate data and maps of critical vulnerability hotspots.

Examples of adaptation strategies are given for three focus areas: (1) forest resources, (2) forest-dependent people and (3) forest industries. Measures related to forest resources include adjustment and expansion of national parks and wildlife reservoirs, revitalization of riverbanks and expansion of maritime conservation areas. Capacity building and institutional and network strengthening are recommended for forest-dependent communities so that they can form groups, resolve conflicts, clarify roles and responsibilities, obtain forest management rights and proceed with collective decision making on resources. Adaptive forest management is recommended for all areas of focus, with a particular emphasis on forest monitoring.

The National Climate Change Council (Dewasan Nasional Perubahan Iklim; DNPI) was established as the national focal point for designing climate change policy, strategies and programs, and to coordinate sectoral agencies when planning adaptation interventions. The DNPI, which is chaired by the President, includes members from all ministries and operates with several working groups that have full-time staff. However, it is not an executive agency and does not have any legal status.

The Indonesia Climate Change Trust Fund, jointly created in 2009 by the Ministry for National Development Planning and the Ministry of Finance, serves to attract, manage and mobilize financial investments in climate change mitigation and adaptation. It acts as a financial portal for receiving and distributing resources from international funds, other governments, development partners and other climate change funding mechanisms such as the Adaptation Fund. It also combines these fund with national and private sector funding where appropriate.

A new National Action Plan for Climate Change Adaptation was released in late 2012 by Bappenas and the DNPI (*Rencana Aksi Nasional Adaptasi*

Perubahan Iklim Indonesia), which set out adaptation interventions in key development sectors. It is basically an update of the sectoral Roadmap with a greater focus on adaptation.

At the local level in Malinau, the Village Self-Sufficiency Development Movement (Gerdema) could make an important contribution to adaptive capacity in the district. The movement was created in early 2000, and, in its second phase, was improved through the introduction of Community Empowerment for Rural Development, to support a more bottom-up planning process at the community level. However, the process did not operate as intended, and it is hoped that, with the implementation of Gerdema and the deployment of technical staff (Satgas; see Chapter 4.2.4), community priorities will be better reflected.

6. Community-based adaptation interventions

6.1 Community priorities for the future

The community aspirations that emerged during the visioning exercise were grouped into strategy clusters. Setulang villagers then ranked in order of priority those interventions that they can start implementing by capitalizing on the village's existing assets and resources. Three strategy clusters were discussed: (1) agricultural development (AD); (2) village area management (VAM); and

Table 6. Priority strategies based on community assets

	Intervention	Follow-up activities
AD.1	Development of irrigated rice fields (*sawah*)	Obtain assistance for negotiating *sawah* land rentals from landowners/ other villages.
		Obtain assistance for equipment (e.g. tractors, thresher engines, plows).
		Request extension services on irrigation techniques.
		Construct irrigation network from the river with irrigation tubes/pipes.
		Construct road to the fields.
AD.2	Development of rubber agroforestry	Apply agroforestry knowledge (e.g. what crops are resilient to drought and flood) and ask for extension services from the plantations agency when necessary.
		Develop trial plots and assess feasibility of different options.
AD.3	Development of fruit, coffee and cocoa gardens	Seek extension services on handling pests and diseases.
		Employ more intensive management (e.g. with fertilizers) to increase fruit yields.
VAM.1	Construction of new adat house	Combine with living areas to create an integrated space.
		Plan the design.
		Collect the materials: ulin, kapur and meranti wood.
		Obtain assistance (e.g. from Gerdema) to purchase or lease tractors and other needed tools.
		Build, carve and paint.
VAM.2	Development of road networks leading to Tane' Olen	Obtain assistance (e.g. from Gerdema) to purchase or lease tractors and other tools.
TOM.1	Development of tourism activities	Build a tourism station.
		Place tree identification labels and other information.
		Develop hunting tourism based on traditional hunting customs.
TOM.2	Development of handicraft micro-enterprises	Manufacture rattan handicrafts to sell to tourists and buyers outside the village.
		Improve the design of handicrafts.
		Establish a village market.
TOM.3	Enhancement of management of forest resources, especially NTFPs	Improve management facilities (e.g.Tane' Olen management group facilities).
		Develop working groups for managing NTFPs (e.g. rattan, bamboo, sang leaf).
		Conduct comprehensive forest resource inventory, covering all important NTFPs, to support sustainable management.

(3) management of Tane' Olen and livelihood diversification (TOM) (Table 6).

The agricultural development strategies have multiple objectives. One important objective is to develop new fields with good prospects to offer to the young as an attractive alternative to migrating to the city. Planting a greater variety of crops, beyond rice and cassava, is intended to enhance livelihoods and food security under the threat of drought and floods. The development of rubber, fruit, coffee and cocoa production through agroforestry systems is expected to increase overall resilience and sustainability under climate change.

Rubber received particular emphasis because several Setulang villagers had observed other villages' good economic returns from selling latex. The community said they would be able to sell rubber easily, as buyers had approached them in the past. It is also perceived as a lucrative activity that would be attractive for the young.

The strategies designed to enhance village management also have multiple objectives and expected benefits. The construction of a new *adat* space in a residential longhouse on higher ground will be of use during floods, offering shelter for people whose houses are under water. At other times, the *adat* house will serve as a hub for cultural activities and as accommodation for visitors. Furthermore, attaching living spaces to the *adat* building will be a return to the Dayak traditions of *Lamin Adat*, which uses longhouses, in which 20–30 families can live in a manner that allows for both interaction and privacy. All construction materials are available locally, and experienced carpenters in Setulang can carve and paint the Dayak designs.

The last cluster of strategies discussed is the management of Tane' Olen, encompassing tourism, resource management and alternative livelihoods programs. The villagers hope to increase the economic returns from managing Tane' Olen sustainably, while also preserving biodiversity and cultural practices. Building ecotourism is seen as an important step in achieving this goal. For this purpose, tourism facilities need to be built or upgraded and the English-language proficiency of the villagers increased. Hunting tourism is another option, based on traditional Dayak practices for hunting wild boar and other bushmeat. Information materials could be created in conjunction with the comprehensive resource inventory that is already underway with the assistance of GIZ. The resource inventory is designed to support better and more sustainable management of non-timber forest products (NTFPs); a working group could be established for each NTFP.

One important NTFP is rattan, which the Setulang community uses to make traditional handicrafts and household items such as mats and baskets. These handicrafts themselves are a tourist attraction, as the Dayak Kenyah have distinctive and beautiful patterns, and a handicraft market could be established to create an alternative source of income and to inform visitors about Dayak culture. Currently, rattan handicrafts are manufactured for household use only.

6.2 Selected interventions

Based on the community's priorities, two adaptation interventions were selected for further planning and analysis: (1) rubber agroforestry and (2) manufacture and sale of rattan handicrafts.

6.2.1 Rubber agroforestry

Each household interested in undertaking rubber agroforestry could allocate 1 ha without compromising their rice production. The rubber agroforestry system with associated fruit trees (RAS-2), as developed and tested by the World Agroforestry Centre (ICRAF), could be used as a model (Wulan *et al.* 2008).

In the RAS-2 system, rubber trees are planted at normal density (550 stems/ha) along with perennial timber and fruit trees (92–270 trees/ha) after slashing and burning. Annual crops, mainly upland rice, can be intercropped for the first 2–3 years with the help of fertilizers. Tree species such as rambutan (*Nephelium lappaceum*), durian (*Durio zibethinus*), petai (*Parkia speciosa*) and tengkawang (*Shorea* spp.) can be included, according to ICRAF field tests. All of these fruit tree species already grow in the village area or in Tane' Olen. With RAS-2, natural regeneration occurs between rubber rows and farmers decide which naturally regenerating species to maintain.

The main inputs apart from land and labor are rubber and fruit tree seedlings, fertilizers and formic

acid for treating the latex. The average marketable latex yield (100% dry rubber content [DRC]) per year of RAS-2 systems is 1131 kg/ha. According to the latest published data (Peramune and Afs 2007), the farm gate price per kg/DRC ranges between IDR 3000 and 4000. Harvesting usually begins at year 8 or earlier.

Rubber planting material is sold either as budded stumps or in polybags. In South Kalimantan, clonal plants in polybags are available at licensed nurseries for around IDR 3500 each and at unlicensed nurseries for IDR 1500–2000 each. In Central and East Kalimantan, good planting material is available at IDR 4000–6000 per plant depending on the distance (Peramune and Afs 2007). To grow about 550 stems/ha, 650 stumps or polybags must be planted.

The average yields of fruit trees (low and high) are given in Table 7. Yields vary depending on management practices and environmental parameters (e.g. climate and soils).

If dry rice is planted and harvested during the first 1–2 years, total yields of up to 1000 kg per hectare can be obtained (Budidarsono *et al.* 2010).

Labor requirements during the establishment phase of the RAS-2 are 125 person-days in year 1 and 100 person-days in year 2. During the operational phase, on average 85 person-days are required each year, although there is a peak of 200 person-days in years 9 and 10, when tapping and fruit harvesting in the rubber agroforestry system begin (Wulan *et al.* 2008). The reported daily wage for agricultural workers in villages near the Malinau township is IDR 60,000–70,000 which is above the national average (interview with Ibu Ros, member of the cooperative PKK [Pemberdayaan dan Kesejahteraan Keluarga or Enhancing Family Welfare]). In the more remote villages outside Malinau, the daily wage is approximately IDR 50,000 plus some food.

Fertilizer is not usually applied in the RAS-2 system, although it can help rubber tree growth, especially if it is applied during the first 2–4 years. The need for fertilizer is greater if rice is intercropped as well. Results from trials with fertilized RAS-2 systems in Kalimantan suggest adding 100 g of urea per tree until the end of year 4 (Ilahang *et al.* 2006). Unsubsidized retail prices of urea average IDR 5173/kg in East Kalimantan; subsidized urea is significantly cheaper at IDR 1600 (Rahmad 2011).

Rambutan needs fertilizer in four equal dressings every 3 months for the first 4 years (ICRAF 2013). For fruiting trees, 200 g nitrogen, 25 g phosphorus and 130 g potassium per tree per year of age is recommended. The maximum fertilizer rate is reached at 12 years, and should remain constant thereafter.

Fertilizer is usually not applied to durian (Morton 1987; Brown 1997; ICRAF 2013), although a monthly application of 5 g/tree of 6-6-6 complete formula until trees reach maturity can be beneficial (Morton 1987). This is equivalent to 60 g per tree per year or 3 kg per 50 trees per year until production year 14. Fertilizer usually comes in 50 kg bags.

Formic acid is needed for treating the latex. Based on the expected yields under the RAS-2 system, an

Table 7. Fruit tree yields and prices

Fruit type	Age at first harvest	Annual yield per tree in orchards	Average farm gate price, Malinau, 2012	Average retail price, East Kalimantan, 2011[a]	References (first harvest and yields)
Durian	7–8 years	8–13 years = 40 kg 14–25 years = 80 kg or 50–100 fruits	IDR 25,000 for 1 fruit	IDR 95,700 for 1 fruit	FAO 2007; ICRAF 2013
Rambutan	8 years	8–15 years = 10–42 kg 16–25 years = 45–300 kg	IDR 10,000 for 1 kg	IDR 9945 for 1 kg	Tindall 2004; ICRAF 2013
Petai	7 years	200–500 pods	Unknown	Unknown	Subhadrabandhu 2001; Abdullah *et al.* 2011; ICRAF 2013

a Source: Provincial Statistics Office: http://kaltim.bps.go.id/web/publikasi lain/harga pedesaan/

average of 23 bottles per hectare per year are needed beginning at year 8 (after trees reach tapping age). This number is calculated for rubber agroforestry based on the average number of bottles needed per tapping year for monoculture rubber (Leimona and Joshi 2010), using the fact that average annual DRC yields are 24.2% lower under RAS-2 (Wulan *et al.* 2008) than for monoculture rubber (Leimona and Joshi 2010).

The size of bottles of formic acid varies between manufacturers, but roughly 4 ml of formic acid is needed to treat 1 kg rubber, which will yield 500 g DRC) (http://rubberboard.org.in/ManageCultivation.asp?Id=192). A25 kg bottle of formic acid currently costs IDR 312,500 (http://www.cvputeradaradjat.web.id/_item?item_id=016002). If the price of formic acid is prohibitive, farmers could employ natural coagulation but should avoid using sulfuric acid, alum or kaolin, which are contaminating and harmful to the final product (Peramune and Afs 2007).

The costs and benefits of rubber agroforestry as perceived by community and district-level stakeholders are listed in Table 8. Discussions with district-level stakeholders centered on the feasibility of implementing the strategy in Setulang.

The main direct benefit, as perceived by both groups of stakeholders, is greater overall economic well-being due to livelihood diversification and the production of a cash crop (rubber). Another perceived benefit is increased resilience to climatic hazards, because rubber agroforests can withstand flood and drought pressures better than annual crops (e.g. rice) and will contribute to diversifying the portfolio of crops available for cash and direct consumption throughout the year.

The use of rubber agroforestry is also expected to rehabilitate degraded land, which would otherwise be left fallow for quite some time, and to control erosion (an additional benefit noted by district-level stakeholders). As the management of rubber agroforestry is not perceived as very time consuming,

Table 8. Costs and benefits of rubber agroforestry, according to community members and district-level stakeholders

	Description	Perceived by community members	Perceived by district stakeholders
Benefits	Overall economic well-being in the village is increased.	Yes	Yes
	Degraded land is rehabilitated and erosion is controlled.	Yes	Yes
	Young people remain in the village.	Yes	No
	Livelihoods and food security during climate hazards are enhanced.	Yes	Yes
	Villagers have more free time (rubber maintenance is not intensive).	Yes	Yes
	Shifting cultivation is reduced, and hence so is deforestation.	No	Yes
Costs	Seedlings	Yes	Yes
	Labor	Yes	Yes
	Time: extension services and capacity building	Yes	Yes A major cost because of limited technical capacity for cultivating rubber
	Land	Yes	Yes
		Perceived as abundant	Perceived as scarce because of Tane' Olen protection and conflicts over boundaries
	Marketing activities and capacity building	No	Yes
	More conflicts between villages	No	Yes

stakeholders pointed out the additional benefit of having time to undertake other agricultural or livelihood activities. The operational costs of rubber are viewed as low, especially in relation to the high operational and distributional costs associated with small-scale oil palm plantations.

Setulang community members also noted the importance of using rubber production, an attractive source of income, to encourage young people to stay in the village, a benefit that is linked to the overall economic well-being of the village. District-level stakeholders did not mention this factor but noted that the development of rubber would most likely reduce shifting cultivation and, consequently, deforestation. This point does not necessary apply to Setulang villagers, whose agricultural practices are not causing deforestation in Tane' Olen or other forested areas, but could be valid for other areas in Malinau.

District-level stakeholders noted that a major cost, apart from inputs such as seedlings and labor, was the allocation of land, given that much of Setulang's area is under forest protection or is used for agriculture and settlements. Most of the available land is close to disputed borders with other villages. By contrast, community members do not consider land to be scarce because each household could devote 1 ha of their present land for the implementation of the strategy. For the community, land availability is more of an issue in relation to future generations.

The time and resources needed for community members to learn the new technique of rubber agroforestry constitute another cost for both community members and district agencies such as the agency for plantations and community development. This cost is viewed as a major barrier to adoption of the intervention. Agencies are currently struggling with the scarcity of resources, especially skilled staff, and given the lack of experience with rubber in general, agencies prefer to encourage cocoa and coffee. There are no demonstration plots for rubber but the plantations agency plans to develop some. However, villagers in Setulang have worked with many NGOs and research organizations over the years so they are quick learners and should be able to adopt the new strategy easily, although extension services will still be needed.

Some district agencies suggested that marketing the rubber would be difficult because rubber is a new commodity for the district. Villagers in Setulang, however, said that rubber buyers had approached them in the past.

However, the implementation of the rubber agroforestry strategy could have the indirect effect of escalating conflicts. Other villages might get envious of any economic or well-being improvements in Setulang as a result of the intervention, especially as they are likely to use land claimed by the other villages.

6.2.2 Rattan handicraft micro-enterprises

The women of Setulang have a long tradition of making various handicrafts from rattan, including baskets, traditional hats, bags and household items such as plates (Figure 15). Villagers mainly manufacture them for personal use, with a few items sold to the small number of tourists that visit the area. Rattan resources are available in Tane' Olen and a recent assessment (Sidiyasa *et al.* 2006) found a large number of rattan species in abundance there. During the community workshop, however, villagers reported that the resource has started to decline, although not yet at alarming rates. If not harvested from the forest, rattan can be grown effortlessly in fallow fields, together with the other naturally occurring vegetation, as noted by Belcher *et al.* (2004).

Building rattan handicraft micro-enterprises will involve capacity building, such as through training to improve the design and marketing of handicrafts, to set up a village market to sell handicrafts to tourists and other visitors, and to promote the products outside the village through the channels described below.

Products could be branded as coming from Tane' Olen. The protected forest of Setulang could

Figure 15. Baskets made by the women of Setulang
Source: Hangga Prihatmaja

form the basis of a strong and recognizable brand in Kalimantan and abroad. The marketed Tane' Olen handicrafts would work well with plans for ecotourism related to the forest and cultural traditions.

There are a number of governmental and nongovernmental organizations that could conduct the necessary training. The Non-Timber Forest Products Exchange Programme (http://www.ntfp.org) conducts training on setting up and running handicraft micro-enterprises in Kalimantan and abroad. WWF Malinau conducts on-demand training on selling rattan products for local communities that express an interest, and has conducted training specific to handicrafts in Krayan.

The district agency for industry and cooperation operates training centers in Kuala to support the development of the rattan handicrafts industry, with a focus on modern furniture (as discussed during the district-level stakeholder interviews). They currently work with several artisans from Java on design training. The training centers include exhibition halls where communities can display their handicrafts, and the agency is trying to encourage villagers to transition from production for personal and household use to a more small-enterprise production strategy and mind-set. Because production is currently for personal use only, people do not pay much attention to the aesthetics of the handicrafts and are not aware of their potential economic value in sectors such as fashion and interior design.

The agency can provide communities with start-up capital and mentoring. They are also building networks of buyers for the community handicrafts. Currently, the agency can only show handicrafts in their training centers and at exhibitions, but very few villagers have expressed an interest in the agency showing their handicrafts at exhibitions. Marketing efforts will expand with the help of the department for cooperation and trade and other interested organizations.

Other organizations that could not only train community members in handicraft design but also purchase and help market final products include Threads of Life (http://www.threadsoflife.com/fairtrade.asp), Pekerti Nusantara (Indonesian People's Handicraft Foundation Marketing Service; http://pekerti.com/about.php), the Rattan Project and Yayasan Pecinta Budaya Bebali (http://www.ypbb.org/contactus.htm). Forum Fair Trade Indonesia is also working to promote fair trade in Indonesia and to improve market access for local producers.

The prices at which handicraft makers (i.e. communities) sell their products can vary according to the buyer and final destination of the product. During follow-up interviews, we learned that women in Setulang sell traditional bags, baskets (*anjat*) and hats (*sa'ong*) for IDR 50,000 to buyers from other villages; the price is higher if the handicrafts are sold directly to tourists. Simple mats for sleeping (70 × 120 cm) can sell for up to IDR 400,000. Earlier studies conducted in East Kalimantan showed that a producer's profit margin for a rattan mat can range from 115% to 519% (Purnama *et al.* 1998). Rattan baskets can sell for up to USD 60 through fair trade vendors that market products to consumers abroad (e.g. SERRV, www.serrv.org/product/rattan-basket-set/baskets?refid=truefairtrade). About 20% of this retail price goes directly to the producer, which would translate into about IDR 116,000 per piece, depending on the vendor and marketing arrangement.

Many women in Setulang are already members of the PKK cooperative, which is active in the village. They could thus easily link to the organizations mention above. The community could also request the help of a Satgas (see Chapter 4.2.4) under the Gerdema program to assist with the technical, logistical and financial aspects of developing handicraft micro-enterprises.

In terms of costs, raw materials (rattan and natural dyes) are usually freely available as a common good from the Tane' Olen forest, where the sustainable management of NTFPs is a priority. Setulang women reported that if they do not have time to collect rattan from the forest, or have physical impediments preventing them from doing so, they can always purchase rattan bundles from neighbors or other villages. One bundle of rattan, enough to weave one basket, costs IDR 5000–15,000.

The women may not always have time, because of their other work in the fields. Many usually make handicrafts in their leisure time, such as during the period after the rice harvest. When made only during leisure time, an *anjat* basket can take up to a month to finish (interview with Ibu Yurita, PKK member). However, some groups of women make and sell handicrafts all year round; they frequently also sell the handicrafts of women who do not have the time to sell them themselves.

As with the rubber agroforestry strategy, the community and district-level stakeholders listed several costs and benefits (Table 9). The discussions with the district-level stakeholders again focused on the feasibility of implementing the strategy in Setulang.

Selling rattan handicrafts can provide an important source of income, especially for women, when there is not enough of a crop surplus to sell. Furthermore, women can make handicrafts during leisure time, or women who do not work in the fields can make them, which lowers the opportunity costs. However, district-level stakeholders pointed out the costs of transportation and distribution, and the limited capacity of local communities to engage in larger-scale marketing beyond production for personal or household use.

Both groups of stakeholders noted that the lack of handicraft skills among younger people is an important barrier to implementation. Many younger community members focus on their education, pursue other activities or see agriculture as enough to earn a living. For their own household needs, the young prefer to buy mats and baskets from neighbors or other villages. Training could help raise young people's awareness of the attractive opportunities linked to fair trade, fashion and interior design, and also help them take advantage of these opportunities.

6.2.3 Viability in the face of major climate threats

Future climate scenarios are uncertain, but it is exactly this uncertainty that makes it important to analyse the robustness of proposed adaptation interventions given the main future climate threats. The particular climate conditions or thresholds under which an intervention fails or stops being effective need to be singled out to identify any additional vulnerabilities that might occur (and develop plans to address them). This also helps to pinpoint early warning indicators that could be embedded in adaptive management once implementation begins.

The intervention of selling rattan handicrafts does not present any risk of failure under any of the plausible climate scenarios because rattan is sourced from Tane' Olen, a forest that is relatively intact and sustainably managed and thus not susceptible to forest fires. However, certain climate and biophysical thresholds need to be monitored with regard to the rubber agroforestry system.

As described in Chapter 5.1, the main future climate threats for Malinau are:

- temperature
  - increase in annual and seasonal means (extremely likely)

Table 9. Costs and benefits of selling rattan handicrafts, according to community members and district-level stakeholders

	Description	Mentioned by community members	Mentioned by district-level stakeholders
Benefits	Women have alternative livelihood opportunities all year round (regardless of climate conditions and crop harvests).	Yes	No
	Overall economic well-being in the village is enhanced.	Yes	Yes
	Setulang's distinctive cultural identity becomes better known.	Yes	No
	Visitor/tourist experiences are enhanced through visits to the handicrafts market.	Yes	No
Costs	Training to improve the design of handicrafts and marketing	Yes	Yes
	Labor (time)	Yes	No
	Rattan collection (time) or purchase (money)	Yes	No
	Transportation and distribution	No	Yes

  - increase in the number of days with maximum temperatures over 35°C (likely)
- precipitation
  - increase in the number of days with rainfall above 300 mm (likely)
- extreme events
  - increase in frequency and intensity of ENSO events (likely).

Studies on the vulnerability of rubber to climate hazards are scarce and are predominantly from Thailand and Malaysia. Rubber grows in a temperature range of 22–35°C (Sdoodee and Rongsawa 2012) although the optimal growth temperature is 25–28°C.

Rubber production needs rainfall of at least 2000 mm/year that is evenly distributed and does not interfere with tapping and latex collection. A dry period of up to 1 month is tolerated well, but extended dry periods could lead to reduced yields (Sdoodee and Rongsawa 2012). Consequently, the biggest threats to rubber production are extended drought due to ENSO and heavy rainfall leading to flood-related damage. The combination of higher temperatures and an increase in precipitation could also lead to more outbreaks of rubber pests and diseases.

To minimize the impact of dry spells during the establishment period, well-grown polybag plants with a good root system can be used for deep planting, followed by mulching with rice straw (Rodrigo *et al.* 2011). The high potassium content of rice straw will help alleviate any moisture stress on the plants.

The productivity of fruit trees could also be adversely affected by extreme climate temperature and precipitation. Durian, for example, grows best with a mean annual temperature of 22°C and a mean annual rainfall of 1500–2000 mm (ICRAF 2013). Soils should be well drained to limit losses from root rot. Rambutan, on the other hand, has higher tolerance and can thrive with an annual mean temperature as high as 35°C, but does not favor waterlogging either.

However, the use of an agroforestry system for producing rubber could significantly minimize risks related to reduced yields because produce will be diversified and the nutrient cycles improved. Additional measures such as irrigation and drainage canals might be needed to prevent damage from drought and heavy rainfall.

7. Linkages with REDD+

7.1 Adaptation and mitigation

Adaptation and mitigation strategies generally differ in their objectives and spatial scales. Mitigation has global benefits that manifest in the longer term whereas adaptation is primarily a local issue with more immediate benefits at that scale (Locatelli 2011). However, mitigation projects can have positive or negative impacts on the adaptive capacity of communities, and adaptation projects can either support or hinder mitigation goals (Locatelli *et al.* 2011). These linkages are particularly evident in the agriculture and forestry sectors, especially in interventions such as REDD+, and there is a growing interest in exploring how adaptation and mitigation can be pursued simultaneously to enable win–win strategies and impacts in these sectors (Locatelli 2011).

For example, REDD+ projects can contribute to the adaptation of forests to climate change by decreasing degradation pressures and forest vulnerability, maintaining biological diversity and increasing ecosystem connectivity for enhanced resilience (Fischlin *et al.* 2007). They can have positive impacts (e.g. enhanced provision of ecosystem services, diversified incomes and economic activities and strengthened local institutions) or negative impacts (e.g. restricted access to forest resources and dependence on external funding) on the capacity of local communities to adapt to climate change (Sunderlin *et al.* 2009; Caplow *et al.* 2011; Larson 2011).

Adaptation projects can contribute to carbon sequestration and storage through ecosystem restoration or measures such as agroforestry. Successful adaptation to climate change in agriculture can reduce additional degradation or conversion of forests and thus contribute to global mitigation and REDD+ objectives (Locatelli *et al.* 2011). On the other hand, lack of adaptation or implementation of poorly targeted interventions can lead to more forest degradation or conversion, increase forest vulnerability (e.g. increase risks of fire during drought) and ultimately hinder efforts to achieve REDD+ targets.

Maximizing synergies and acknowledging and minimizing trade-offs between REDD+ and the adaptation of local communities will ensure that REDD+ is both contributing to national priorities and providing benefits to poor and vulnerable people (Graham 2011). Taking this approach to REDD+ and adaptation can lead to the 'triple wins' of climate-compatible development: keeping emissions low, building resilience to the impacts of climate change and supporting development (Mitchell and Maxwell 2010).

For the Malinau region, the linkages between successful REDD+ implementation and the two community-based adaptation interventions analysed above can be explored through two scenarios: (1) the continuation of the current situation, characterized by exploitation and coping strategies; or (2) an alternative future scenario in which the two adaptation interventions have achieved their intended outcomes. The linkages illustrated below are based on the desktop analysis and stakeholder consultations and are relevant to forest-dependent communities throughout the district. Some of the points are analysed in more depth using evidence from field studies conducted elsewhere.

7.2 Scenario with existing coping strategies and unsustainable exploitation

In Malinau, several interacting challenges can have an impact on forests and their resilience, and consequently on the accomplishment of REDD+ objectives. Conflicts and insecure land tenure inhibit both district and community investments in sustainable forest and resource management and in agricultural interventions such as agroforestry. In the absence of agricultural investments (especially ones with adaptation benefits), climate stressors and disasters such as flooding and drought can lead to reduced crop yields or even crop failure. This could force communities to clear more land in the uplands or to extract more forest resources such as timber,

wild boar and NTFPs to supplement their incomes (coping strategies). The lack of diversification coupled with conflicts over resources has led in the past to the degradation of important NTFPs, such as eaglewood (*gaharu*) and birds' nests (Moeliono *et al.* 2009). Failure to take measures to redress this could exacerbate the problem.

Lack of tenure clarity allows mining and logging to be more extensive and uncontrolled, even in areas that were previously considered inaccessible. Intensified industry is already reducing communities' adaptive capacity, through river pollution and sedimentation, increased forest vulnerability and reduced access to forest resources. Furthermore, fish populations have been decreasing; fish is the main source of protein in the area, although people prefer to consume wild pigs, which are highly valued culturally. However, wild pigs are known to be harder to find after logging, largely because of understory slashing (clearing all undergrowth following timber extraction). Understory slashing in logged compartments has been shown to hurt local communities and degrade forest biodiversity (Sheil *et al.* 2009).

The lack of incentives for sustainable forest management renders forests more vulnerable to climate change (e.g. increases the risk of fires). Without integrated and cross-sectoral land-use planning, it is unlikely that government organizations and the private sector will engage in sustainable forest management. Tenure insecurity also makes it difficult to engage communities in proactive and collaborative measures such as participatory forest monitoring and fire risk reduction. The incentives to accept cash compensation from mining or logging concessions are becoming much stronger than those for sustainable forest management, especially among younger people.

Observer organizations and NGOs also noted that the formation of the new province of North Kalimantan might increase the risk of deforestation of Malinau's primary forests (Parker 2013). A large percentage of East Kalimantan's wealth comes from extractive industries in the south of the province. Districts that have become part of North Kalimantan will no longer receive dividends from extractive industries, and new officials in search of new funds may issue new mining, logging and plantation permits.

As seen elsewhere in the world, it is generally the poor and most resource-insecure that depend on forest resources after a disaster (Pramova *et al.* 2012). In Malawi, for example, forests are important for reactive adaptation strategies, particularly for households with no other options, but they do not feature in anticipatory adaptation (Fisher *et al.* 2010). Other studies in Malinau have found that people affected by floods sold or ate wild pigs from the forest to supplement their incomes and diet (Liswanti *et al.* 2011), and in Honduras, poor rural households sold timber after being unable to recoup landholdings lost due to Hurricane Mitch (McSweeney 2005).

It is important to differentiate between products as safety nets for coping strategies (short-term, usually after a disaster) and products as a major source of livelihood diversification for adaptation strategies (proactive management of resources in anticipation of shocks). The poorest of the poor might turn to the forest during or after a disaster in order to survive, but some farmers also use forest and tree products as an integral income diversification strategy for dealing with climate variability on an ongoing basis. Many of these agrarian communities maintain trees on their farms for this purpose. When harvests fail due to climate events, people can sell timber and NTFPs from their farms to supplement their income (Pramova *et al.* 2012).

With coping strategies such as those encountered in Honduras and Malinau, high dependence on forest products during climate events can create vulnerability when the ecosystem is degraded or mismanaged, when conflicts arise between forest users or when access becomes restricted. The future value of natural assets and how communities will be able to use them under REDD+ is a noted concern (Peskett *et al.* 2008). As populations grow, and in response to other development or climate pressures, REDD+ may lead to a situation where communities are not able to rely on natural assets as much as they have previously — for example, for cash income from logging, as safety nets in times of shock and as a source of agricultural land (Graham 2011). Disasters could force communities to abandon their REDD+ commitments. It is therefore critical to enhance the adaptive capacities of communities and integrate adaptation strategies into REDD+ planning to foster an effective transition from coping to adapting.

7.3 Scenario with adaptation and sustainable management

Community-based adaptation strategies such as rubber agroforestry and handicraft businesses will have benefits for both forests and people only if they achieve their objectives and people manage the challenges and potential unintended consequences appropriately.

The first challenges to overcome are the social conflicts and the need to clarify land tenure. As described in Chapters 4.1 and 4.2, conflicts and insecure tenure are among the main impediments to local agricultural development. However, if communities had greater incentives to invest in resource management and agricultural and diversification strategies such as rubber agroforestry and selling rattan handicrafts, their livelihoods would be enhanced and become more resilient, as would the ecosystems in the landscape. This would contribute to a reduction in deforestation, especially in cases where shifting cultivation can become a problem or where younger community members are inclined to allow industrial exploitation in return for compensation.

Adaptation projects can have positive indirect impacts on REDD+ activities if they prevent activity displacement and induced deforestation; an example of this is if an agricultural adaptation intervention supports crop productivity and livelihoods and reduces forest clearing for agricultural expansion (Locatelli 2011). Although evidence on these linkages in the climate change literature is scarce, studies have examined the relationships between practices such as agroforestry and community-based forest management (which are relevant for adaptation) and reduced deforestation (relevant for REDD+) outside of the climate change debate.

The potential of agroforestry to boost rural incomes, increase resilience to climate hazards and restore degraded land is well documented (Verchot *et al.* 2007; Garrity *et al.* 2010; Pramova *et al.* 2012). However, agroforestry can also have direct and indirect effects on climate change mitigation through carbon sequestration and reduced deforestation, respectively. The Alternatives to Slash-and-Burn Programme documented the carbon sequestration and storage potential of various agroforestry systems (Verchot *et al.* 2007). Converting row crops or pastures to agroforestry systems can greatly enhance the amount of carbon stored in aboveground biomass because agroforestry systems contain 50–75 mg/ha of carbon, whereas row crops contain less than 10 mg/ha of carbon. Intercropping with fruit trees and other agroforestry systems have also been found to be more profitable than short fallow monocultures and row crops, which are the typical focus of agricultural intensification programs (Gockowski *et al.* 2001).

Nevertheless, governments in many tropical countries have been promoting agricultural intensification as a replacement for simpler agro-ecological and swidden systems, with the aim of enhancing food production, increasing farmers' income and protecting forests from extensive clearing (Lin *et al.* 2008; van Vliet *et al.* 2012). This trend has contributed to a widespread belief that trees have a negative impact on food crops because of competition for water and nutrients. However, research has shown that poorly planned intensification actually exacerbates vulnerability to climate change (Lin *et al.* 2008) and can lead to permanent deforestation with severe consequences for ecosystem services and soil fertility (van Vliet *et al.* 2012). Under the alternative approach of agroforestry intensification, agricultural intensification occurs in association with trees, with the objective of conserving ecosystem services and increasing farmers' income (Steffan-Dewenter *et al.* 2007).

Agroforestry systems can have benefits for biodiversity and forest adaptation as they can serve as biological corridors and reduce human pressure on natural forests (Schroth 2004; Bhagwat 2008). It has been demonstrated that agroforestry systems host significantly more species than monoculture systems (Bhagwat 2008). Therefore, agroforestry production, even at the forest margins, can be beneficial to both people and forests.

Studies from Kerinci Seblat National Park in Sumatra, Indonesia, have shown that households that own mixed gardens with trees extracted much fewer resources from the national park than households that cultivate rice fields alone (Murniati *et al.* 2001). A similar situation was observed around the Nyungwe Forest Reserve in Rwanda (Masozera and Alavalapati 2004). Research in small islands of the Pacific has also demonstrated that the presence of valuable trees for livelihoods outside of the forests has significantly reduced deforestation and forest degradation in the reserves (Bhagwat *et al.* 2008).

Rattan can serve as a valuable risk management tool as it is a long-living, low-maintenance source of savings or income that people can not only resort to in times of need but also use for diversification all year round through the manufacture and sale of handicrafts (Pambudhi *et al.* 2004). This is especially critical in systems without other risk management strategies or institutions (e.g. bank accounts and insurance policies). If there is an urgent need for cash, rattan is readily available and the 'rattan savings' can be liquidated anytime because harvesting periods are very flexible and rattan stems grow all year round with little to no management (Belcher *et al.* 2004). This provides a viable and effective alternative to felling trees for timber or giving land away to concessions. However, this is only possible if markets are available for selling raw rattan, and in Malinau they are quite limited. Making and selling rattan products will take considerable time, but this does not diminish their important role in livelihood diversification strategies.

Having a greater and more diverse asset base (including natural, physical, financial, human and social assets) leads to enhanced adaptive capacity at the local level (Plummer and Armitage 2010). How REDD+ is implemented will have an influence on these community assets. For example, securing tenure and implementing livelihood diversification strategies such as the development of rattan handicraft micro-enterprises can be used as an opportunity to educate local communities about sustainable forest management (including the management of NTFPs such as rattan), handicraft marketing, and monitoring, reporting and verification of REDD+ activities. Human capital will therefore be built, with positive impacts on adaptive capacity (Graham 2011). However, local communities can only become effective forest stewards when their rights are recognized, avenues exist for meaningful participation, forest management costs and benefits are distributed fairly and appropriate external support is provided (Cronkleton *et al.* 2008).

Further synergistic benefits could be pursued from the joint implementation of REDD+ and adaptation strategies to optimize the overall impact. For example, REDD+ networks and finance could be used to deliver timely climate information and knowledge that is of relevance for the adaptation of agrarian communities as well as for the adaptation of the forests (Graham 2011). Such information could be integrated into an adaptive governance and management model, where the outcomes of interventions are constantly monitored, evaluated and readjusted according to changing circumstances and needs (e.g. changing drivers of deforestation and degradation and changing climate pressures). Adaptive management should be the foundation of any intervention under uncertainty.

8. Cost–benefit analysis and social return on investment

8.1 Cost–benefit analysis

As the monetary values for a complete SROI analysis could not be calculated because of the lack of available data, a CBA for each strategy (rubber agroforestry and rattan handicrafts) was conducted, based on the inputs and potential outputs. The best available data were used for the CBA, sourced from the literature, statistics offices (e.g. the Provincial Statistics Office) and stakeholder statements made during the workshop and interviews; however, these data are not optimal and the results should be interpreted with caution. For this reason, the most conservative estimates were used (e.g. lowest average yield and highest average prices of inputs) as described in Chapter 6.2.

For the rubber agroforestry strategy, the analysis was based on intercropping 550 rubber trees with 100 durian trees over 30 years. Other types of fruit trees could be integrated, but the data for rambutan yields, for example, are inconclusive (see Table 7). Rubber yields were estimated based on the RAS-2 system data in Wulan *et al.* (2008) amounting to an average annual DRC yield of 1131 kg/ha. The average DRC yield calculated by Wulan *et al.* (2008) was used until year 18. The percentage of reduction in yields in the following years was calculated according to Belcher *et al.* (2004). To calculate revenues, the average farm gate price of IDR 4000/kg for 100% DRC was used as estimated by USAID's assessment of the rubber industry value chain in Indonesia (Peramune and Afs 2007).

Durian yields were estimated conservatively as 20 fruits per tree each year (approximately 40 kg) for all years. Optimum yields that can be achieved in good orchards are usually double that amount (80 kg per tree annually). The farm gate price for one fruit was set at approximately IDR 25,000.

All labor and fertilizer inputs were calculated as described in Chapter 6.2.1. For urea, the retail prices of unsubsidized urea fertilizer in East Kalimantan were used (IDR 5173/kg).The higher average of the daily wage in Malinau was used (IDR 70,000) as reported during follow-up interviews in the village (interview, Ibu Ros). The average interest rate in Indonesia for the years 2005–2013 (7.8%)(www.tradingeconomics.com/indonesia/interest-rate) was used for discounting values for future years.

Upfront costs are high during the first few years, to cover labor, fertilizer and seedlings (IDR 12,284,515 in year 1; IDR 7,284,515 in year 2; IDR 4,134,515 in year 3), but once the positive cash flows begin in year 8, the profit can be significant. Assuming the best scenario for yield levels each year and the sale of all produce, a farmer can make a profit of IDR 40,095,000–48,019,810. As this could be a little unrealistic, the CBA for a second scenario was calculated where inputs and costs remain the same but yields and revenues associated with rubber and durian were reduced by 50% for all years. Even under this more realistic scenario, the profit remains significant: up to IDR 12,995,000–21,198,900 assuming all produce is sold. The net present value of this scenario is IDR 96,745,055.

The CBA for the rattan handicrafts strategy was based on the production of two items per month (by each household or woman) so that there is no interference with other activities and to keep the opportunity cost of labor/time to zero. Unfortunately, the cost of training in design and marketing could not be calculated. The only cost that was factored in was the cost of purchasing one bundle of rattan (IDR 15,000). The CBA of this strategy thus remains incomplete, but it can be stated with some certainty that there are no negative cash flows (or negative net benefit) for the households/women that make rattan handicrafts. Even when rattan bundles are purchased, the handicraft item could be sold for at least IDR 50,000 to other villages or for more to tourists or fair trade organizations (e.g. at least IDR 116,000 per item). The profit could be boosted by making mats (e.g. up to IDR 400,000, according to villagers).

However, any analysis must take into account that there will be bad years when crops fail or not all produce is sold. Production systems could also be damaged by fires or other extreme events, and farm gate prices might fall drastically. Nevertheless, the risks associated with these two strategies are relatively low, and their implementation could only add benefits, as land in Setulang remains abundant, rubber agroforestry is not very labor intensive and rattan handicrafts can be made during leisure time. The benefits for adaptation, mostly associated with diversification and capacity building, are also important, as are the nonmaterial benefits mentioned for the community such as keeping young people in the village and promoting Setulang culture beyond the district.

8.2 Social return one investment impact maps

8.2.1 Rubber agroforestry

Stakeholders	Intended/ unintended changes	Inputs		Outputs	Outcomes
1. Who will be affected? Who will produce the effect?	2. What will change for stakeholders?	3. What is invested?	4. Monetary value	5. Summary of activity in numbers	6. How would you describe the change?
Farmers	Enhanced livelihoods and food security during climate hazards Degraded land is rehabilitated More free time	(i) Land (ii) Seedlings (iii) Fertilizers (iv) Labor and time (v) Formic acid. As described in CBA per hectare	Described in CBA per hectare	550 rubber trees intercropped with 100 durian trees per hectare	(i) Income is diversified with rubber throughout the year and with fruit according to seasons. (ii) Income source is less sensitive to climate change than annual crops. Erosion is reduced and water regulation improved during drought and intense precipitation. Farmers have time to engage in other activities (e.g. rice production or other livelihoods) as the system is low maintenance and rubber tapping is not highly labor-intensive.

Outcomes					Adjusting impact: "What else contributed to the change?"			
7. Indicator: How do you measure the change?	8. Quantity: How much change?	9. Duration: How long does it last?	10. Financial proxy: What would you use to evaluate the change?	11. Value of change	Deadweight[a]	Attribution[b]	Drop-off[c]	Impact[d]
Annual rubber and fruit yield and income	After year 8, as described in CBA per hectare	30-year rotation of rubber Durian can fruit for 60 years	Farm gate price of yields (CBA)	As described in CBA per hectare	0%	0%	10–30% from year 18 for rubber[e]	As in CBA per hectare
(i) Extent of degraded land under production (ii) Improvement in water regulation (e.g. during floods)	1 ha per household	30-year rotation	(i) Covered by additional income (above) (ii) Cost of flood damage avoided (%)	(i) As described in CBA (ii) Unknown				
Time allocated for other activities (both on and off farm)	Unknown	30-year rotation	Any additional income from other activities (market prices)	Unknown				

a % of outcome/change that would have happened without the intervention

b % of outcome/change that was induced by other stakeholders not mentioned here or by outside forces

c % by which outcome diminishes in later years

d Quantity × financial proxy – (deadweight + attribution + drop-off

e Rubber yield decreases: years 19–20 (decrease 10% from year 18), years 21–22 (decrease 15%) and years 23–25 (decrease 30%)

Stakeholders	Intended/unintended changes	Inputs		Outputs	Outcomes
1. Who will be affected? Who will produce the effect?	2. What will change for the stakeholders?	3. What is invested?	4. Monetary value	5. Summary of activity in numbers	6. How would you describe the change?
Setulang Village	Overall economic well-being is increased.	(i) Land (ii) Seedlings (iii) Fertilizers (iv) Labor and time (v) Formic acid. As described in CBA per hectare	Described in CBA per hectare	550 rubber trees intercropped with 100 durian trees per hectare	Community has more surplus cash to invest in village infrastructure and facilities etc.
	More young people remain in the village.				Fewer young people migrate to cities, as they find economic activities in the village attractive. Presence of the educated younger generation increases village well-being.
	Conflicts with other villages are intensified.				More disputes are filed (or re-filed) for settlement.

Outcomes					Adjusting impact: "What else contributed to the change?"			
7. Indicator: How do you measure the change?	8. Quantity: How much change?	9. Duration: How long does it last?	10. Financial proxy: What would you use to value the change?	11. Value of change	Deadweight	Attribution	Drop-off	Impact
Amount and type of new investments	Unknown	Unknown	Monetary and other benefits of investments	Unknown				
Number of people <40 years old in the village (% difference from years before the intervention)	Unknown	Unknown	Social cost of migration (unknown)	Unknown				
Number of new disputes or older disputes that are revived	Unknown	Unknown	Days needed to settle disputes in terms of daily wages lost	Unknown				

Stakeholders	Intended/unintended changes	Inputs		Outputs	Outcomes
1. Who will be affected? Who will produce the effect?	2. What will change for the stakeholders?	3. What is invested?	4. Monetary value	5. Summary of activity in numbers	6. How would you describe the change?
District agencies[f]	Rural economic well-being and adaptive capacity are enhanced. Deforestation is reduced. Conflicts are intensified.	Extension services and capacity building (time and resources) for rubber agroforestry and marketing	(i) Wages of staff (ii) Cost of resources (e.g. seedlings if supplied by government[g])	Number of households or villages that have completed the training and capacity building and that have adopted rubber agroforestry	Less need for economic aid from district government, especially after disasters. Forested areas not cleared for new fields or sold to private companies More disputes filed (or re-filed) for settlement

Outcome					Adjusting impact: "What else contributed to the change?"			
7. Indicator: How do you measure the change?	8. Quantity: How much change?	9. Duration: How long does it last?	10. Financial proxy: What would you use to value the change?	11. Value of change	Deadweight	Attribution	Drop-off	Impact
% savings from economic aid/ assistance	Unknown	Unknown	Value of savings from economic aid/ assistance	Unknown				
% of conserved forest that was previously at risk	Unknown	Unknown	Cost of forest patrolling, management and monitoring that would have been employed to protect areas at risk (or environmental and social cost of deforestation [harder to calculate])	Unknown				
Number of new disputes or older disputes that are revived	Unknown	Unknown	Days needed to settle disputes in terms of staff costs and resources	Unknown				

f Perception of district-level stakeholders of the implementation of the intervention in other villages.

g If this is the case, the cost of seedlings should be omitted from the costs incurred by farmers.

Stakeholders	Intended/unintended changes	Inputs		Outputs	Outcomes
1. Who will be affected? Who will produce the effect?	2. What will change for the stakeholders?	3. What is invested?	4. Monetary value	5. Summary of activity in numbers	6. How would you describe the change?
Rubber buyers	Increase in the rubber available for purchase in the district	N/A	N/A	N/A	A more stable supply of rubber for sales and export is available in the district.
Neighboring villages	Conflicts with Setulang and other villages are intensified	N/A	N/A	N/A	More disputes are filed (or re-filed) for settlement.

Outcome					Adjusting impact: "What else contributed to the change?"			
7. Indicator: How do you measure the change?	8. Quantity: How much change?	9. Duration: How long does it last?	10. Financial proxy: What would you use to value the change?	11. Value of change	Deadweight	Attribution	Drop-off	Impact
% increase in rubber purchased from the district	Unknown	After year 8 until unknown	% increase in profits for buyers attributable to Malinau rubber Reduction in transportation costs if rubber has to be purchased from more distant places if the intervention is not implemented	Unknown				
Number of new disputes or older disputes that are revived	Unknown	Unknown	Days needed to settle disputes in terms of daily wages lost	Unknown				

Stakeholders	Intended/unintended changes	Inputs		Outputs	Outcomes
1. Who will be affected? Who will produce the effect?	2. What will change for the stakeholders?	3. What is invested?	4. Monetary value	5. Summary of activity in numbers	6. How would you describe the change?
Rubber buyers	Increase in the rubber available for purchase in the district	N/A	N/A	N/A	A more stable supply of rubber for sales and export is available in the district.
Neighboring villages	Conflicts with Setulang and other villages are intensified	N/A	N/A	N/A	More disputes are filed (or re-filed) for settlement.

Outcome					Adjusting impact: "What else contributed to the change?"			
7. Indicator: How do you measure the change?	8. Quantity: How much change?	9. Duration: How long does it last?	10. Financial proxy: What would you use to value the change?	11. Value of change	Deadweight	Attribution	Drop-off	Impact
% increase in rubber purchased from the district	Unknown	After year 8 until unknown	% increase in profits for buyers attributable to Malinau rubber Reduction in transportation costs if rubber has to be purchased from more distant places if the intervention is not implemented	Unknown				
Number of new disputes or older disputes that are revived	Unknown	Unknown	Days needed to settle disputes in terms of daily wages lost	Unknown				

8.2.2 Manufacture and sale of rattan handicrafts

Stakeholders	Intended/unintended changes	Inputs		Outputs	Outcomes
1. Who will be affected? Who will produce the effect?	2. What will change for the stakeholders?	3. What is invested?	4. Monetary value	5. Summary of activity in numbers	6. How would you describe the change?
Women	Alternative livelihood opportunities available all year round (regardless of climate conditions and crop harvests)	(i) Time (ii) Rattan (time or money to obtain raw resource)	Described in CBA per household	Two handicraft items per month (24 per year), per household, produced during leisure time	(i) Income is diversified throughout the year. (ii) Income source is less sensitive to climate changes than annual crops.
Setulang Village	Increase in overall economic well-being				Community has more surplus cash to invest in village infrastructure and facilities etc.
	Setulang's distinctive cultural identity becomes better known and tourism is enhanced				More tourists and other groups (e.g. cultural organizations) visit the village.

Outcomes					Adjusting impact:"What else contributed to the change?"			
7. Indicator: How do you measure the change?	8. Quantity: How much change?	9. Duration: How long does it last?	10. Financial proxy: What would you use to value the change?	11. Value of change	Deadweight[a]	Attribution[b]	Drop-off[c]	Impact[d]
Annual income from selling handicrafts	After year 1, as described in CBA per household	Indefinite	Revenue from selling either through fair trade organizations or within the district (CBA)	As described in CBA per household	0%	0%	0%	As in CBA per household
Amount and type of new investments	Unknown	Unknown	Monetary and other benefits of investments	Unknown	% depending on other livelihood programs		0%	
Number of visitors to the village	Unknown	Unknown	Revenue and any other nonmaterial benefits from increased visits (e.g. skills transmission)	Unknown	% depending on other tourism programs		% unknown[e]	

a % of outcome/change that would have happened without the intervention

b % of outcome/change that was induced by other stakeholders not mentioned here or by outside forces

c % by which outcome diminishes in later years

d Quantity × financial proxy – (deadweight + attribution + drop-off

e Difficult to predict as it depends on changing tourist interests, safety issues in the region, disasters etc.

Stakeholders	Intended/unintended changes	Inputs		Outputs	Outcome
1. Who will be affected? Who will produce the effect?	2. What will change for stakeholders?	3. What is invested?	4. Monetary value	5. Summary of activity in numbers	6. How would you describe the change?
Fair trade organizations	(i) Increase in high-quality well-designed handicrafts for sale (ii) Further achievement of organizational goals	Training and capacity building for design and marketing (if conducted by these organizations)	Unknown	50% of women in Setulang trained in improved design and marketing of rattan handicrafts	(i) More stable supply of quality handicrafts (ii) Further achievement of organizational goals in terms of enhancing economic and social well-being in rural areas communicated to investors and customers
District and provincial agencies	Enhanced promotion of the ethno-cultural identity of East Kalimantan/Malinau within and beyond the region	Resources for showrooms and to visit national and international trade exhibitions	Unknown	Unknown	Handicrafts with distinctive motifs from the region are viewed and purchased at exhibitions and beyond

Outcomes					Adjusting impact: "What else contributed to the change?"			
7. Indicator: How do you measure the change?	8. Quantity: How much change?	9. Duration: How long does it last?	10. Financial proxy: What would you use to value the change?	11. Value of change	Deadweight	Attribution	Drop-off	Impact
Number of handicrafts purchased from Setulang and sold per semester	Unknown	Unknown	% increase in profits derived from selling Setulang handicrafts	Unknown	% depending on other handicraft programs and sellers		% unknown[f]	
(i) Increase in showroom visitors and participation in exhibitions (ii) New partnerships with buyers	Unknown	Unknown	% increase in revenues from the additional showroom visits and new partnerships with buyers	Unknown	% depending on other handicraft and cultural programs		% unknown[g]	

f Depends on volume of handicrafts supplied each year and buyer interest

g Depends on buyer interest, number of exhibitions and trade fairs, and resources to participate in them etc.

9. References

Abdullah MHR, Ch'ng PE and Lim TH. 2011. *Some physical properties of* Parkia speciosa *seeds.* Paper, International Conference on Food Engineering and Biotechnology (ICFEB 2011), Bangkok, Thailand, 28–29 May.

[ADB] Asian Development Bank. 2011. *Accounting for Health Impacts of Climate Change*. Mandaluyong City, Philippines: ADB.

Aldrian E and Susanto RD. 2003. Identification of three dominant rainfall regions within Indonesia and their relationship to sea surface temperature. *International Journal of Climatology* 23(12):1435–52.

An SI and Wang B. 2000. Interdecadal change of the structure of the ENSO mode and its impact on the ENSO frequency. *Journal of Climate* 13(12):2044–55.

Baker JT, Allen LH and Boote KJ. 1992. Temperature effects on rice at elevated CO_2 concentration. *Journal of Experimental Botany* 43(7):959–64.

Barnabás B, Jäger K and Fehér A. 2008. The effect of drought and heat stress on reproductive processes in cereals. *Plant, Cell & Environment* 31(1):11–38.

Belcher B, Imang N and Achdiawan R. 2004. Rattan, rubber, or oil palm: Cultural and financial considerations for farmers in Kalimantan. *Economic Botany* 58(1):77–87.

Bennett A, Epstein L, Gilman R, Cama V, Bern C, Cabrera L, *et al.* 2012. Effects of the 1997–1998 El Niño episode on community rates of diarrhea. *American Journal of Public Health* 102(7):63–69.

Bhagwat S, Willis K, Birks HJ and Whittaker R. 2008. Agroforestry: A refuge for tropical biodiversity? *Trends in Ecology and Evolution* 23(5):261–27.

Brown M. 1997. *Durio, a Bibliographic Review*. New Delhi: International Plant Genetic Resources Institute.

Budidarsono S, Laxman J and Wibawa G. 2010. *Profitability assessment of smallholder rubber agroforestry systems in Jambi, Sumatra, Indonesia.* Project report. Bogor, Indonesia: World Agroforestry Centre.

Cairns JE, Sonder K, Zaidi PH, Verhulst N, Mahuku G, Babu R, Nair SK, Das B, Govaerts B, Vinayan MT *et al.* 2012. Maize production in a changing climate: Impacts, adaptation, and mitigation strategies. *Advances in Agronomy* 114:1–58.

Caplow S, Jagger P, Lawlor K and Sills E. 2011. Evaluating land use and livelihood impact of early forest carbon projects: Lessons from learning about REDD+. *Environmental Science and Policy* 14:152–67.

Ceballos H, Ramirez J, Bellotti AC, JarvisA and Alvarez E. 2011. Adaptation of cassava to changing climates. *In*Singh Yadav S,Redden R,Hatfield J,Lotze-Campen H and Hall AJ, eds. *Crop Adaptation to Climate Change*. Wiley-Blackwell. 411–25.

Chaudhury A. 2012. *Unlocking the Power of Local Knowledge: A Novel Framework to Cost Community-Based Adaptation to Climate Change*. Oxford, UK: Environmental Change Institute, University of Oxford.

CheckleyW, Epstein L, GilmanR, FigueroaD, CamaR, PatzJ and Black RE. 2000. Effect of El Niño and ambient temperature on hospital admissions for diarrhoeal diseases in Peruvian children. *Lancet* 355:442–50.

Cochrane MA and Laurance WF. 2002. Fire as a large-scale edge effect in Amazonian forests. *Journal of Tropical Ecology* 18(03):311–25.

Cochrane MA and Schulze MD. 1998. Forest fires in the Brazilian Amazon. *Conservation Biology* 12(5):948–50.

Cochrane MA, Alencar A, Schulze MD, Souza CM, Nepstad DC, Lefebvre P and DavidsonEA. 1999. Positive feedbacks in the fire dynamic of closed canopy tropical forests. *Science* 284(5421):1832–35.

Cronkleton P, Taylor PL, Barry D, Stone-Jovicich S and Schmink M. 2008. *Environmental governance and the emergence of forest-based social movements*. Occasional Paper No. 49. Bogor, Indonesia: CIFOR.

Cruz RV, Harasawa H, Lal M, Wu S, Anokhin Y, Punsalmaa B, *et al.* 2007. Asia. *In*Parry ML,Canzianni OF,Palutikof JP,van der Linden PJ and Hanson CE, eds.*Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth*

Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK: Cambridge University Press. 469–506.

[DNPI and GoEK] National Council on Climate Change and Government of East Kalimantan. 2010. *East Kalimantan environmentally sustainable development strategy* (draft for circulation).

EkanayakeIJ, DattaSK and Steponkus PL 1989. Spikelet sterility and flowering response of rice to water stress at anthesis. *Annals of Botany* 63(2):257–64.

[FAO] Food and Agriculture Organization of the United Nations. 2007. *Durio zibethinus*. Accessed 15 June 2013. http://ecocrop.fao.org/ecocrop/srv/en/cropView?id=963

Field CB, Barros V, Stocker TF, Qin D, Dokken, DJ, Ebi KL *et al.* 2012. *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change*. Intergovernmental Panel on Climate Change.

Fischlin A, Midgley GF, Price JT, Leemans R, Gopal B, Turley C, Rounsevell M, Dube P, Tarazona J and Velichko AA. 2007. Ecosystems, their properties, goods, and services. *In* Parry ML, Canziani OF, Palutikof JP, van der Linden PJ and Hanson CE, eds. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press. 211–72.

Fisher M, Chaudhury M and McCusker B. 2010. Do forests help rural households adapt to climate variability? Evidence from southern Malawi. *World Development*38(9):1241–50. doi:10.1016/j.worlddev.2010.03.005

Garrity DP, Akinnifesi FK, Ajayi OC, Weldesemayat SG, Mowo JG, Kalinganire A, Larwanou M and Bayala J. 2010. Evergreen agriculture: A robust approach to sustainable food security in Africa. *Food Security* 2(3):197–214.

Gockowski J, Nkamleu G and Wendt J. 2001. Implications of resource-use intensification for the environment and sustainable technology systems in the Central African rainforest. *In* Lee D and Barrett C, eds. *Tradeoffs or Synergies? Agricultural Intensification, Economic Development and the Environment*. Wallingford, UK: CAB International.

Graham K. 2011. *REDD+ and Adaptation: Will REDD+ Contribute to Adaptive Capacity at the Local Level?* London: Overseas Development Institute. Accessed 15 June 2013. http://www.odi.org.uk/publications/6147-redd-adaptation-local-adaptive-capacity

Hadi T. 2010. *Scientific Basis: Analysis and Projection of Temperature and Rainfall*. Bappenas, Jakarta.

Hales S, de Wet N, Maindonald J and Woodward A. 2002. Potential effect of population and climate changes on global distribution of dengue fever: An empirical model. *Lancet* 360(9336):830–34.

Hendon HH. 2003. Indonesian rainfall variability: Impacts of ENSO and local air–sea interaction. *Journal of Climate* 16(11):1775–90.

Herrera Campo B, Hyman G and Bellotti A. 2011. Threats to cassava production: Known and potential geographic distribution of four key biotic constraints. *Food Security* 3(3):329–45.

Hijmans RJ, Cameron SE, Parra JL, Jones PG and Jarvis A. 2005. Very high resolution interpolated climate surfaces for global land areas. *International Journal of Climatology* 25:1965–78.

Hilman M, Boer R, Sulistyowati, Las L, Zed F, Masripatin N, Kartakusuma DA, Hilman D, Mulyanto HS *et al.* 2010. *Indonesia Second National Communication under the United Nations Framework Convention on Climate Change*. Jakarta: Ministry of Environment.

[ICRAF] World Agroforestry Centre. 2013. *Agroforestree database*. Accessed 15 June 2013. http://www.worldagroforestrycentre.org/Sea/Products/AFDbases/AF/index.asp

Ilahang, Wibawa G, Penot E and Budi. 2006. *Alternatif Pengembangan Karet Rakyat Dengan Sistem Wanatani Berbasis Karet*. Bogor, Indonesia: World Agroforestry Centre.

[IRI] International Research Institute for Climate and Society. 2007. Overview of the ENSO system. *Resources on El Niño and La Niña*. Accessed11 February2013. http://iri.columbia.edu/climate/ENSO/background/pastevent.html

Iwan R and Limberg G. 2009. Tane'Olen as an alternative for forest management: Further developments in Setulang village, East Kalimantan. *In* Moeliono M, Wollenberg E and Limberg G, eds. *The Decentralization of Forest Governance: Politics, Economics and the Fight for Control of Forest in Indonesian Borneo*. London: Earthscan. 193–202.

Iwan R and Limberg G. 2009. Tane'Olen as an alternative for forest management: Further developments in Setulang village, East

Kalimantan. *In* Moeliono M, Wollenberg L and Limberg G, eds. *The Decentralization of Forest Governance: Politics, Economics and the Fight for Control of Forest in Indonesian Borneo*. London: Earthscan. 193–202.

Iwan R. 2006. *Tane Olen: A piece in the village landscape land use planning in Setulang Village, East Kalimantan*. Presentation, 11th Conference of the International Association for the Study of Common Property, Bali, Indonesia.

Jarvis A, Ramirez-Villegas J, Herrera Campo B and Navarro-Racines C. 2012. Is cassava the answer to African climate change adaptation? *Tropical Plant Biology*5(1):9–29. doi:10.1007/s12042-012-9096-7

KatesRW, Travis WR and Wilbanks TJ. 2012. Transformational adaptation when incremental adaptations to climate change are insufficient. *Proceedings of the National Academy of Sciences* 109(19):1–6. doi:10.1073/pnas.1115521109

Keil A, Zeller M, Wida A, Sanim B and Birner R. 2008. What determines farmers' resilience towards ENSO-related drought? An empirical assessment in Central Sulawesi, Indonesia. *Climatic Change* 86(3–4):291–307.

Kinnaird MF and O'BrienTG. 1998. Ecological effects of wildfire on lowland rainforest in Sumatra. *Conservation Biology* 12(5):954–56.

Lansigan F, de los Santos W and Coladilla J. 2000. Agronomic impacts of climate variability on rice production in the Philippines. *Agriculture, Ecosystems & Environment* 82(1–3): 129–37.

Larson A. 2011. Forest tenure reform in the age of climate change: Lessons for REDD+. *Global Environmental Change* 21(2):540–49.

Lebot V. 2009. *Tropical Root and Tuber Crops—Cassava, Sweet Potato, Yams and Aroids*. Crop Production Science in Horticulture, 17. CABI, London.

Leimona B and Joshi L. 2010. *Eco-certified natural rubber from sustainable rubber agroforestry in Sumatra, Indonesia.* Final project report. Bogor, Indonesia: World Agroforestry Centre.

Levang P and FPP-Bulungan team. 2002. People's dependencies on forests.*In Technical report phase I 1997–2001: ITTO Project PD 12/97 REV.1 (F): Forest, science and sustainability: The Bulungan model forest*. Bogor, Indonesia: CIFOR and ITTO. 109–30. Accessed 15 June 2013. http://www.cifor.org/online-library/browse/view-publication/publication/1181.html

Lin BB, Perfecto I and Vandermeer J. 2008. Synergies between agricultural intensification and climate change could create surprising vulnerabilities for crops. *Bioscience* 58:847–54.

Lin BB. 2007. Agroforestry management as an adaptive strategy against potential microclimate extremes in coffee agriculture. *Agricultural and Forest Meteorology* 144(1):85–94.

Lin BB. 2010. The role of agroforestry in reducing water loss through soil evaporation and crop transpiration in coffee agroecosystems. *Agricultural and Forest Meteorology* 150(4):510–18.

Liswanti N, Sheil D, Basuki I, Padmanaba M and Mulcahy G. 2011. Falling back on forests: How forest-dwelling people cope with catastrophe in a changing landscape. *International Forestry Review* 13(4):442–55.

Liswanti N, Sheil D, Basuki I, Padmanaba M and Mulcahy G. 2011. Falling back on forests: How forest-dwelling people cope with catastrophe in a changing landscape. *International Forestry Review* (4 SP 442–55).

Lobell DB, Banziger M, Magorokosho C and Vivek B. 2011. Nonlinear heat effects on African maize as evidenced by historical yield trials. *Nature Climate Change* 1(1):42–45.

Locatelli B, Evans V, Wardell A, Andrade A and Vignola R. 2011. Forests and climate change in Latin America: Linking adaptation and mitigation. *Forests* 2(1):431–50.

Locatelli B. 2011. *Synergies between Adaptation and Mitigation in a Nutshell*. Bogor, Indonesia: Center for International Forestry Research.

Masozera M and Alavalapati JR. 2004. Forest dependency and its implications for protected areas management: A case study from the Nyungwe Forest Reserve, Rwanda. *Scandinavian Journal of Forest Research* 19:85–92.

McSweeney K. 2005. Natural insurance, forest access and compounded misfortune: Forest resources in smallholder coping strategies before and after Hurricane Mitch, northeastern Honduras. *World Development* 33(9):1453–71.

Mitchell T and Maxwell S. 2010. *Defining Climate Compatible Development*. London: Climate and Development Knowledge Network.

Mitchell TD and Jones PD. 2005. An improved method of constructing a database of monthly climate observations and associated high-resolution grids. *International Journal of Climatology* 25:693–712.

Mitchell TD, Carter TR, Jones PD, Hulme M and New M. 2004. *A comprehensive set of high-resolution grids of monthly climate for Europe and*

the globe: The observed record (1901–2000) and 16 scenarios 2001–2100. Norwich, UK: Tyndall Centre for Climate Change Research.

Moeliono M and Limberg G. 2009. The geography of Malinau. *In* Moeliono M, Wollenberg E and Limberg G, eds. *The Decentralization of Forest Governance: Politics, Economics and the Fight for Control of Forest in Indonesian Borneo*. London: Earthscan. 25–42.

Moeliono M, Limberg G, Gonner C, Wollenberg E and Iwan R. 2007. *Towards Wellbeing: Monitoring Poverty in Malinau, Indonesia*. Bogor, Indonesia: CIFOR.

Moeliono M, Wollenberg E and Limberg G, eds. 2009. *The Decentralization of Forest Governance: Politics, Economics and the Fight for Control of Forest in Indonesian Borneo*. London: Earthscan.

Morton J. 1987. *Fruits of Warm Climates*. Miami: Florida Flair Books.

Murniati, Garrity D and Gintings A. 2001. The contribution of agroforestry systems to reducing farmers' dependence on the resources of adjacent national parks: A case study from Sumatra, Indonesia. *Agroforestry Systems* 52(3):171–84.

Nguyen NV. n.d. *Global Climate Changes and Rice Food Security*. Rome: Food and Agriculture Organization of the United Nations.

Nicholls J, Lawlor E, Neitzert E and Goodspeed T. 2012. *A Guide to Social Return on Investment*. SROI Network. http://www.thesroinetwork.org/sroi-analysis/the-sroi-guide

O'Toole JC and Namuco OS. 1983. Role of panicle exsertion in water stress induced sterility. *Crop Science* 23(6):1093–97.

Pambudhi F, Belcher B, Levang P and Dewi S. 2004. Rattan (*Calamus* spp.) gardens of Kalimantan: Resilience and evolution in a managed non-timber forest product system. *In* Kuster K and Belcher B, eds. *Forest Products, Livelihoods and Conservation: Case Studies of Non-Timber Forest Product Systems.* Bogor, Indonesia: CIFOR. 347–65.

Pandey S, Bhandari H and Hardy B. 2004. *Economic Costs of Drought and Rice Farmers' Coping Mechanisms: A Cross-Country Comparative Analysis*. Manila: International Rice Research Institute.

Parker D. 2013. Indonesia's East Kalimantan loses forest area to new province in Borneo. Mongabay.com. http://news.mongabay.com/2013/0224-dparker-north-kalimantan.html. accessed 10 May 2013.

Peng S, Huang J, Sheehy JE, Laza RC, Visperas RM, Zhong X, *et al.* 2004. Rice yields decline with higher night temperature from global warming. *Proceedings of the National Academy of Sciences* 101(27):9971–75.

Peramune M and Afs D. 2007. *A Value Chain Assessment of the Rubber Industry in Indonesia*. Jakarta: United States Agency for International Development.

Peskett L, Huberman D, Bowen-Jones E, Edwards G and Brown J. 2008. *Making REDD Work for the Poor*. London: Poverty Environment Partnership.

Peterson TC, Stott PA and Herring S. 2012. Explaining extreme events of 2011 from a climate perspective. *Bulletin of the American Meteorological Society* 93(7):1041–67.

Plummer R and Armitage D. 2010. Integrating perspectives on adaptive capacity and environmental governance. *In* Plummer R and Armitage D, eds. *Adaptive Capacity and Environmental Governance*. Berlin: Springer-Verlag. 1–22.

Pramova E, Locatelli B, Djoudi H and Somorin OA. 2012. Forests and trees for social adaptation to climate variability and change. *Wiley Interdisciplinary Reviews: Climate Change* 3(6):581–96.

Purnama BM, Prahastó H and Nasendi BD. 1998. *Rattan in East and South Kalimantan, Indonesia: A case study of the production-to-consumption systems*. INBAR Working Paper No. 21. New Delhi: International Network for Bamboo and Rattan.

Rahmad 2011. Kebutuhan Pupuk Kaltim Capai 67.723 Ton. Antaranews.com, Kalimantan Timur. http://www.antarakaltim.com/berita/4228/kebutuhan-pupuk-kaltim-capai-67723-ton Accessed: 10 May 2013

Rai Y, Ale B and Alam J. 2012. Impact assessment of climate change on paddy yield: A case study of Nepal Agriculture Research Council (NARC), Tarahara, Nepal. *Journal of the Institute of Engineering* 8(3):147–67.

Roberts SJ. 2000. Tropical fire ecology. *Progress in Physical Geography* 24(2):281–88.

Rodrigo VH, Iqbal SM and Dharmakeerthi R. 2011. Potential for rubber (*Hevea brasiliensis* Muell. Arg.) cultivation in the Eastern Province of Sri Lanka. *Journal of the National Science Foundation of Sri Lanka* 39(4):403–11.

Ruf F and Lançon F. 2004. *From Slash and Burn to Replanting: Green Revolutions in the Indonesian Uplands*. Washington, DC: World Bank.

Sastry PS. 1988. *Agrometeorology of the Banana Crop*. Geneva: World Meteorological Organization.

Schroth G, Da Fonseca GA, Harvey C, Gascon C, Vasconcelos HL and Izac AM. 2004. *Agroforestry and Biodiversity Conservation in Tropical Landscapes*. Washington, DC: Island Press.

Schwendenmann L, Veldkamp E, Moser G, Hölscher D, Köhler M, Clough, Y, Anas I, Djajakirana G, Erasmi S, Hertel D *et al.* 2010. Effects of an experimental drought on the functioning of a cacao agroforestry system, Sulawesi, Indonesia. *Global Change Biology* 16(5):1515–30.

Sdoodee S and Rongsawat S. 2012. *Impact of climate change on smallholders' rubber production in Songkhla Province, Southern Thailand*. Presentation, 2012 International and National Conference for the Sustainable Community Development of "Local Community: The Foundation of Development in the ASEAN Economic Community (AEC)," Khon Kaen, Thailand.

Sheil D, van Heist M, Liswanti N, Basuki I and Wan M. 2009. Biodiversity, landscapes and livelihoods: A local perspective. *In* Moeliono M, Wollenberg E and Limberg G, eds. 2009. *The Decentralization of Forest Governance: Politics, Economics and the Fight for Control of Forest in Indonesian Borneo*. London: Earthscan. 25–42.

Sheil, D. 2002. Biodiversity research in Malinau. *In Technical report phase I 1997–2001: ITTO Project PD 12/97 REV.1 (F): Forest, science and sustainability: The Bulungan model forest*. Bogor, Indonesia: CIFOR and ITTO. 57–107. Accessed 15 June 2013. http://www.cifor.org/online-library/browse/view-publication/publication/1181.html

Sidiyasa K, Zakaria and Iwan R. 2006. *The forests of Setulang and Sengayan in Malinau, East Kalimantan: Their potential and the identification of steps for their protection and sustainable management*. Bogor, Indonesia: CIFOR.

Smit B and Pilifosova O. 2001. Adaptation to climate change in the context of sustainable development and equity. *In* McCarthy JJ, Canzianni OF, Leary NA, Dokken DJ and White KS, eds. *Impacts, Adaptation, and Vulnerability—Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge, UK: Cambridge University Press. 876–912.

Sofian I. 2010. *Scientific Basis: Analysis and Projection of Sea Level Rise and Extreme Weather Event*. Bappenas, Jakarta.

Sova C, Chaudhury A, Helfgott A and Corner-Dolloff C. 2012. *Community-based adaptation costing: An integrated framework for the participatory costing of community-based adaptations to climate change in agriculture*. Working paper No. 16. Cali, Colombia: CGIAR Research Program on Climate Change, Agriculture and Food Security. Accessed 15 June 2013. http://ccafs.cgiar.org/sites/default/files/assets/docs/ccafs-wp-16-psroi.pdf

Spearman M and McGray H. 2011. *Making Adaptation Count: Concepts and Options for Monitoring and Evaluation of Climate Change Adaptation*. Eschborn, Germany: Deutsche Gesellschaft für Internationale Zusammenarbeit.

Steffan-Dewenter I, Kessler M, Barkmann J, Bos MM, Buchori D, Erasmi S, Faust H, Gerold G, Glenk K, Gradstein SR *et al.* 2007. Tradeoffs between income, biodiversity and ecosystem functioning during tropical rainforest conversion and agroforestry intensification. *Proceedings of the National Academy of Sciences of the USA* 104:4973–78.

Subhadrabandhu S. 2001. *Under-utilized tropical fruits of Thailand.* RAP Publication No. 2001/26. Bangkok: Food and Agriculture Organization of the United Nations.

Sudana M. 2009. Winners take all: Understanding forest conflict in the era of decentralization in Indonesia. *In* Moeliono M, Wollenberg E and Limberg G, eds. 2009. *The Decentralization of Forest Governance: Politics, Economics and the Fight for Control of Forest in Indonesian Borneo*. London: Earthscan. 207–219.

Sunderlin W, Larson A and Cronkleton P. 2009. Forest tenure rights and REDD+: From inertia to policy solutions. *In* Angelsen A, ed. *Realising REDD+: National Strategies and Policy Options*. Bogor, Indonesia: CIFOR.

Susanti E, Ramadhani F, June T and Amien L. 2010. Utilization of climate information for development of early warning system for brown plant hopper attack on rice. *Indonesian Journal of Agriculture* 3(1):17–25.

Timmermann A. 2001. Changes of Enso stability due to greenhouse warming. *Geophysical Research Letters* 28(10):2061–64.

Tindall HD 1994. *Rambutan cultivation.* Rome: Food and Agriculture Organization of the United Nations.

Turner D and Lahav E. 1983. The growth of banana plants in relation to temperature. *Functional Plant Biology* 10(1):43–53.

Van Nieuwstadt MGL and Sheil D. 2005. Drought, fire and tree survival in a Borneo rain forest, East Kalimantan, Indonesia. *Journal of Ecology* 93(1):191–201. doi:10.1111/j.1365-2745.2004.00954.x

Van Vliet N, Mertz O, Heinimann A, Langanke T, Pascual U, Schmook B, Adams C, Schmidt-Vogt D, Messerli P, Leisz S *et al.* 2012. Trends, drivers and impacts of changes in swidden cultivation in tropical forest–agriculture frontiers: A global assessment. *Global Environmental Change* 22(2):418–29.

Verchot L, Van Noordwijk M, Kandji S, Tomich T, Ong C, Albrecht A, Mackensen J, Bantilan C, Anupama KV and Palm C. 2007. Climate change: linking adaptation and mitigation through agroforestry. *Mitigation and Adaptation Strategies for Global Change* 12(5):901–18.

Verchot L, Van Noordwijk M, Kandji S, Tomich T, Ong C, Albrecht A, *et al.* 2007. Climate change: Linking adaptation and mitigation through agroforestry. *Mitigation and Adaptation Strategies for Global Change*12(5):901–918. doi:10.1007/s11027-007-9105-6

Wassmann R, Jagadish SV, Heuer S, Ismail A, Redona E, Serraj R, *et al.* 2009. Climate Change Affecting Rice Production: The Physiological and Agronomic Basis for Possible Adaptation Strategies. *In* Sparks D, ed.*Advances in Agronomy.* Vol. 101. Elsevier. 59–122.

Wulan YC, Budidarsono S and Joshi L. 2008. *Economic analysis of improved smallholder rubber agroforestry systems in West Kalimantan, Indonesia—implications for rubber development.* Presentation, Sustainable Sloping Lands and Watershed Management Conference, Luang Prabang, Lao PDR.

Wunder S, Campbell B, Frost PG, Sayer JA, Iwan R and Wollenberg L. 2008. When donors get cold feet: The community conservation concession in Setulang (Kalimantan, Indonesia) that never happened. *Ecology and Society* 13(1):12. http://www.ecologyandsociety.org/vol13/iss1/art12/

Yeh SW, Kug JS, Dewitte B, Kwon MH, Kirtman BP and Jin FF. 2009. El Niño in a changing climate. *Nature* 461(7263):511–514. doi:10.1038/nature08316

Yoshida, S. 1978. Tropical climate and its influence on rice. IRRI Research Paper Series 20. Los Baños, Philippines

Zaidi P and Singh N. 2001. Effect of water logging on growth, biochemical compositions and reproduction in maize (*Zea mays* L.).*Journal of Plant Biology–New Delhi* 28(1):61–70.

Zaidi PH, Rafique S and Singh N. 2003. Response of maize (*Zea mays* L.) genotypes to excess soil moisture stress: Morpho-physiological effects and basis of tolerance. *European Journal of Agronomy* 19(3):383–99.

Zuidema PA, Leffelaar PA, Gerritsma W, Mommer L and Anten NP. 2005. A physiological production model for cocoa (*Theobroma cacao*): Model presentation, validation and application. *Agricultural Systems* 84(2):195–225.

Zuidema PA, Leffelaar PA, Gerritsma W, Mommer L and Anten NP. 2005. A physiological production model for cocoa (*Theobroma cacao*): Model presentation, validation and application. *Agricultural Systems* 84(2):195–225.

Annexes

Annex 1. Timeline of activities

Based on the stated objectives, the following activities were conducted from February to September 2012 for the two sites in Indonesia and the Philippines.

Time frame (2012)	Activity
February	Desktop analysis of published information related to GIZ REDD+ sites
February	Checklist created for site selection and sent to selected GIZ REDD+ project teams
March	Selection of sites based on communication with project teams and background information
March–April	Elaboration of detailed activity plan for workshops and discussion with partners on activities and suitable dates
April–June	Desktop study and climate modeling for the site in Indonesia
22–23 June	Community workshop (Indonesia)
July	Synthesis of results from desktop study for district-level presentation (Indonesia)
July–September	Desktop study and climate modeling for the site in the Philippines, synthesis of results for provincial-level workshop presentation
3–4 September	Community workshop (Philippines)
13 September	Provincial-level workshop (Philippines)
10–20 September	Semi-structured interviews with district-level stakeholders (Indonesia) and visit to Setulang

Annex 2. Guide for semi-structured interviews with district stakeholders

Climate hazards, impacts and challenges		
Main questions	Additional questions and probes	Clarifying questions
Can you tell me about the climate hazards affecting Malinau and/or your area of work?	What impacts do these hazards cause? What are the effects of these impacts? Which places are most affected and when? Who is affected most and why? Under what circumstances do serious problems arise? Have you noticed any changes in the situation over the years?	Can you expand a little on this? Can you tell me anything else? Can you give me some examples?
In your experience, which climate hazards bother people the most? OR In your opinion, what are the most worrisome climate problems in your area?	Why?	
What are the other important challenges (non-climate-related) in your area? OR In your opinion, what are the other important problems in the area?	Why do these problems occur? What are the effects of these problems? Who is affected most and why? Have you noticed any changes in the situation over the years?	
In your opinion, how will these challenges (both climate-related and non-climate-related) evolve in the future if no action is taken?	Who will be affected, how, and why? How will these challenges impact forest management, especially in relation to your area of work?	
Discussion on the main hazards and challenges faced by the Setulang community. In Setulang, the people consider the following to be the 5 most important challenges: Tenure-related social conflicts (with neighboring villages, concessions) Drugs (abuse by the young) Abuse of political power River pollution Floods	What is your opinion on these issues? What are the linkages between these challenges and the ones that we discussed earlier?	

Annex 2 (continued)

Resources and strategies		
Main questions	Additional questions and probes	Clarifying questions
What kinds of assets and resources are currently available that could help in managing the challenges discussed earlier? What other resources do you think are needed?	Related to the specific assets/resources and strategies that the respondent will mention. How can this asset/resource be used? What will be the benefits of doing this? Which target groups will benefit?	Can you expand a little on this? Can you tell me anything else? Can you give me some examples?
In your opinion, how will the activities of the Village Forest project and REDD help people in Setulang cope with climate and non-climate challenges?	What are the linkages between these activities and the assets/resources that you mentioned earlier (if any)?	
Discussion and questions related to the 2 main adaptation strategies proposed by the community in Setulang, which were selected for further analysis. Some indicative information on the strategies from experiences elsewhere could be provided. Rubber agroforestry gardens (rubber trees intercropped with rice during the first years, and with fruit tree species): In your opinion, what will be the benefits of this strategy? What are the associated costs and/or barriers? Improved utilization of non-timber forest products (e.g. rattan) for handicrafts, and the marketing of these handicrafts: In your opinion, what will be the benefits of this strategy? What are the associated costs and/or barriers?	For each strategy: Which benefits and costs, of the ones you mentioned, do you consider to be the most important and why? What other positive and negative impacts might occur from this strategy (for different kinds of groups — e.g. women and youth)? How do you see the implementation of this strategy? How will it impact your area of work? What will be the impact of this strategy on forest management? What will be the impact of this strategy on the REDD+ project objectives?	
Conclusion of interview Are there any other important issues that you would like to point out? OR Would you like to add anything to this discussion or to our study?		

***CIFOR Working Papers* contain preliminary or advance research results on tropical forest issues that need to be published in a timely manner to inform and promote discussion. This content has been internally reviewed but has not undergone external peer review.**

REDD+ interventions can help both people and forests adapt to climate change by conserving or enhancing biodiversity and forest ecosystem services. However, additional adaptation measures might be needed, such as the protection of agriculture and livelihoods and the development of fire management strategies. Such measures could support the sustainability of REDD+ interventions and the permanence of carbon stocks by preventing activity displacement and induced deforestation and by limiting or avoiding damage to the ecosystem from extreme weather events.

To design community-based adaptation interventions and assess their potential outcomes within the Community Forest (Hutan Desa) REDD+ project area in Setulang Village, Malinau District, Kalimantan,village representatives were involved in a bottom-up, stakeholder-focused process. A social return on investment framework was applied. Community members discussed climate and non-climate challenges and the effectiveness of their current coping strategies. Adaptation interventions were then conceived and planned, using future visioning exercises. Two interventions were prioritized: development of rattan handicraft enterprises and rubber agroforestry.

Challenges and adaptation interventions were also discussed with stakeholders from relevant district organizations (e.g. local government agencies) through individual semi-structured interviews. Projected future climate scenarios, the sensitivity of key resources and adaptive capacity were also discussed. This resulted in a holistic understanding of the costs, benefits, opportunities and challenges associated with implementing the selected adaptation strategies not only in the target area, but also in the district more broadly.

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