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RESEARCH ARTICLE

Farmer portfolios, strategic diversity management and climate-change adaptation – implications for policy in Vietnam and Kenya

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Climate variability is contributing to water-scarcity problems in Kenya and to extreme flooding and drought in Vietnam. This paper compares diversity-based climate adaptation approaches in current land use in the Cam Xuyen district, Ha Tinh province, Central Vietnam and in the Kapingazi river watershed in Embu district, Eastern province, Kenya, in order to understand local responses to climate variability and examine the potential for policy support of diversity management by local people. Literature reviews and trend analysis of local time series of rainfall and temperature were combined with stakeholder interviews and workshops to identify technology and policy options for dealing with current and future climate variability. At all study sites, diversity in land use at farm level and along agriculture–forestry landscape gradients was a key strategy. Policy options to support such an approach could include legalization of agroforestry in Vietnam and a combination of regulations and incentive-based approaches to reconcile household decision-making with longer term and collective actions to benefit landscape diversity in Kenya. Lessons learnt in both study areas about payments for environmental services can be used in policy discussions.

Keywords: agroforestry; climate variability; incentive; Kenya; Vietnam; payment for environmental services; landscape; water scarcity

1. Introduction

1.1 *Climate change and its impacts*

Climate change involves changes in mean values and variability patterns of meteorological parameters over a 30-year time scale at specified locations. The vulnerability of humans and ecosystems to climate change is to a considerable extent determined by changes in the frequency or severity of extreme events, including droughts and floods that directly affect human food supply and income (Cruz et al., 2007). Increased climate variability has been predicted for both East Africa and Southeast Asia, including Kenya and Vietnam. For Kenya, the reported 0.7–2.0°C increase in temperature during the last 40 years, together with irregular and unpredictable rainfall, has increased water-scarcity problems, alongside degradation of catchment areas and lakes (Mutimba, Mayieko, Olum, & Wanyama, 2010). The predicted changes in annual maximum and minimum temperatures in East Africa by the late twenty-first century are 1.8°C and 4.3°C, respectively (IPCC, 2007). Global climate change is expected to have significant effects on the Asian monsoon circulation with consequences for the mean and variability of regional climate in Southeast Asia, including Vietnam. Expectations are that climate warming will cause intensification of the monsoon, resulting in greater interannual and multidecadal variability in the form of more frequent and more severe droughts and floods (Overpeck & Cole, 2007). In Vietnam, heavy rain, droughts and floods are becoming more frequent, particularly in central coastal provinces (Beckman, 2011; IPCC, 2007).

These changes are of direct economic importance to national governments. Degradation of water resources in Kenya costs an estimated KES 3.3 billion (about US$ 39 million) annually (Mogaka, Gichere, Davis, & Hirji, 2006), while in Vietnam the total damage caused by extreme flooding in 1996 and 2001 alone in the Red River Delta, Mekong Delta and Central Region was

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estimated at US$ 680 million (ADB, 2009). As a result, the Kenya Government launched the National Climate Change Response Strategy in 2010 and the Government of Vietnam adopted the National Target Program for Climate Change in 2008. However, operational aspects of these strategies are still a challenge. Research in Tanzania and Kenya has found that government tree-planting efforts that do not match local ambitions and preferences have a low chance of success and that indigenous knowledge could be integrated into formal adaptation planning (Kangalawe et al., 2011). Therefore, understanding the local context and the responses of households is critical in addressing the challenges of climate change. Formulation of appropriate policy options that can support effective local adaptation is also important.

1.2 *Local response to climate change and diversification management*

Maintaining a diversity of options within a portfolio is an important management tool that allows farming to survive climate variations. With portfolio diversity, many components that do not appear particularly productive for much of the time can suddenly assume key importance when others fail.

Some autonomous adaptation is already taking place in the areas vulnerable to climate-change-related disasters in Southeast Asia (Fransisco, 2008). This kind of adaptation is mainly made by farmers in order to cope with climate risks, and is defined by Malik, Qin, and Smith (2010) as ‘private adaptation’. In order to cope with climate risks, local farmers in central Vietnam have changed crop varieties, adjusted the seasonal calendar, built irrigation systems, dug pump wells, introduced alternative livestock breeds, found new feed and fodder sources, and participated in vaccination programmes organized by the government (Oxfam Vietnam and Kyoto University, 2008). Furthermore, paid work, trade in commodities, migrating to find work and sending money back to families are also common (Adger, 1999; Kelly & Adger, 2000). The farmers in the Mekong delta diversify local livelihoods through introducing agriculture and forestry activities along with rice farming (Vo, 2003). Adaptation strategies in Kenya mainly consist of crop diversification, mixed cropping patterns and tree planting for providing fodder and shade/shelter for crops, water-conservation measures and irrigation (Kabubo-Mariara and Karanja, 2007). Social networking and indigenous knowledge have been important in climate-change adaptations in Kenya, as they allow local communities to predict droughts and rainfall patterns and farmers to adapt by changing to drought-tolerant species or early-maturing crops (Ifejika, Kiteme, Ambenje, Wiesmann, & Makali, 2010; Lenhart, 2009).

Nguyen, Hoang, Öborn, and van Noordwijk (2013) showed how existing diversity-based approaches using trees on farms and in the landscape are relevant for current climate-change adaptation approaches in central Vietnam. The present study tested the approaches in a different landscape in Kenya and compared the results. It was assumed that farmers base their managed diversity portfolios on recalled performance in past extreme weather events and that analysis of past and existing portfolios would be an appropriate entry point for defining appropriate policy to help reduce human exposure to climate variability. Our argument is based on the observation that diversity-based approaches to agriculture have been used by farmers for thousands of years to minimize risk and to ensure at least some productivity in unfavourable years (Cooper et al., 2008; Lin, 2011). Therefore, policy support to promote what farmers like, and are familiar with, would bring the best result. This assumption is supported by the examples from Vietnam and Kenya mentioned above as well as from other places. For example, research in Ghana has shown that to confront future extreme climate events, local communities expect to use similar adaptation strategies to those found to be effective in the past, with some new additions (Codjoe & Owusu, 2011).

The overall objectives of this study were to identify local farming responses to climate variability and to examine the potential of policy support for on-farm diversification, for both climate-change adaptation and ensuring food security. Contrasting local ecological knowledge with current science and with public knowledge, policy discourses and perspectives can support more effective communication programmes (where key gaps are identified) and lead to policies with a good chance of implementation (where no major knowledge gaps exist; Clark et al., 2011).

2. Theory and methodology

2.1 *Concepts and definitions*

Adaptation is defined by the Intergovernmental Panel on Climate Change (IPCC, 2001) as ‘adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities’. This study investigated existing adaptation of farming and land-use systems to climate variability as a basis for adaptation to climate change, especially regarding changes in weather patterns and in the frequency and intensity of climate extremes. Adaptation can be treated as a state variable (‘being adapted’, ‘adaptedness’, ‘low vulnerability to existing stressors’) and as a process (‘increasing the degree of adaptedness’, reducing vulnerability to increase in stressors). Vulnerability to climate change can be considered to be dependent on the character, magnitude and rate of climate change and variation to which a system is exposed, its sensitivity and, when assessed over longer time frames, its adaptive capacity. Exposure to climate change can be interpreted as the changes in a location's climate variables (temperature, precipitation, wind speed and extreme weather events) beyond the impact-reducing effects of local buffers. Sensitivity describes the human–environmental conditions that exacerbate or ameliorate the hazard or trigger an impact. Thus exposure and sensitivity are intrinsically linked and mutually influence potential impacts. Adaptive capacity represents the human potential to implement adaptation measures in efforts to avert negative impacts (Gbetibouo & Ringler, 2009). Resilience, defined as 'the amount of change a system can undergo without changing state' (IPCC, 2001), is an important dimension of adaptation. According to Schipper (http://www.climate-adaptation.info/?page_id=51) 'Resilience may either refer to the extent to which a system is able to absorb adverse effects of a hazard or it may refer to the recovery time for returning after a disturbance'. Thus highly resilient systems are characterized by an ability to endure despite high stress or to recover quickly and resilience allows individuals or systems to cope during an event without depleting all their resources or recovery capacity. However coping measures are generally short-term, while continuous or permanent threats require different survival strategies.

2.2 *Study sites*

The fieldwork was conducted at four locations: two villages in central Vietnam and two watershed-management divisions referred to as Focal Development Areas (FDAs) in Eastern Kenya.

The two villages (nos. 4 and 8) at the Vietnamese site are located in Cam My commune, Cam Xuyen district, Ha Tinh province (7°53′50″–18°45′40″N; 105°05′50″–106°30′20″E; 60–180 m a.s.l). The climate in the area is characterized by tropical monsoons, i.e. intense rainfall with regular flooding, during September and October (up to 2200 mm in October), followed by a long dry period from December to July, during which high temperatures in June and July and dry winds from the west exacerbate drought conditions. Village 4 has access to a water reservoir and forest, while Village 8 has better access to the main road and market. Village 4 cultivates more paddy rice, while Village 8 has more rain-fed crops and livestock (Nguyen et al., 2013).

The two FDAs in Kenya, Kithunguriri and Muthatari, are located in upstream and downstream sections of the Kapingazi River basin in Embu district, Eastern Province (0°22′–0°32′S; 37°27′–37°30′E; 1230–2100 m a.s.l). The main farming and economic activities in Kithunguriri are tea production and dairy cattle, while coffee, horticulture and off-farm work are more common in Muthatari. The Kapingazi River basin is located on the southern windward side of Mount Kenya and covers an area of 61 km^2. Mean annual rainfall varies from 1000 mm in the lower part of the catchment to 2000 mm in the upper part and mean annual temperature is 18–22°C. The highest temperatures occur in March and October (mean 26.3°C and 25.8°C, respectively) and the lowest in January and August (mean 12.1°C; Jaetzold, Schmidt, Hornetz, & Shisanya, 2006). The rainfall pattern is divided into 'long rains' in March−May and 'short rains' in October−December (Shisanya, Recha, & Anyamba, 2011), with light showers occurring during the remainder of the year (Ovuka & Lindqvist, 2000).

2.3 *Climate patterns analysis*

Trend analysis was conducted using 43 years (1965–2008) of rainfall and air temperature data for the Vietnamese site and 28 years (1980–2007) of air temperature data and 32 years (1976–2009) of rainfall data for the Kenyan site. Changes in monthly and annual air temperature and rainfall over time were statistically analysed using Minitab Software (version 14.0). Slopes with significant p-values were further analysed using pair-wise comparisons with dummy variables in Minitab. Detail about methods used and results of the statistical analysis for the Vietnam site can be found in Nguyen et al. (2013), while those for the Kenyan site will be reported in a future paper. Some main findings for the Kenyan site, cited in this paper, have been presented at Embu stakeholders' workshop.

2.4 *Surveys on local perceptions of climate variability, its impacts and solutions*

Participatory rural appraisal (PRA) tools, including village sketches, timelines, transect walks and brainstorming techniques, were used in combination with semi-structured interviews with individuals and groups, followed by a structured questionnaire. The semi-structured interviews were used to elicit local perceptions of climate variability, its impacts and solutions and the questionnaire to obtain data on local conditions (farm structure, access to land, labour composition, income sources and farming activities) and choice of tree species by different wealth groups. The total number of interviewees at all levels was 243 in Vietnam and 103 in Kenya (Table 1).

The field survey data were analysed and feedback was obtained through three workshops during 2011, namely two workshops for the researchers involved, held in Vietnam and in Sweden, and a one-day stakeholders' workshop in Embu district, Kenya. At the latter, survey results on climate-change analyses were presented, causes and solutions to water scarcity were discussed and technology and policy options for water conservation, including climate variability adaptation, were jointly explored. Twenty-five stakeholders attended the workshop, including farmers, researchers, administrators, government officers, extension officers and representatives from relevant projects in Embu district and local universities.

Table 1. Survey methods at the two sites.

Purpose	Interviewees	Vietnam (*n*)	Kenya (*n*)
1. *Semi-structured interviews with individuals and groups*			
At landscape level to select study areas	Provincial farmers' association at Vietnamese sites and representative of Water Resources Association (WRA) and local government officials at Kenyan sites	3	3
In the four study areas to understand coping strategies	Representatives of the study areas (FDA committee members and WRA members at Kenyan sites and communal and village leaders at Vietnamese sites)	10	7
	Group meetings of farmers (representing variations in gender, age, social group and areas at Vietnamese sites)	36	none
2. *Individual semi-structured in-depth interviews*			
At farm level to understand reasons behind coping strategies	Representative for three different wealth groups (PRA wealth ranking method was used for Kenyan sites, while government wealth ranking was used for Vietnamese sites)	6	13
3. *Structured Questionnaire*			
At farm level to confirm the findings of the in-depth interviews	82% and 85% of the farm households in the two study villages in Vietnam, and 4% of farm households of each FDA in Kenya	188	80
Total		243	103

2.5 *Comparative analysis*

An extensive review of the literature on climate variability, local adaptation and relevant policy provisions in Southeast Asia and East Africa was conducted in order to examine the validity of our findings for the study sites in Vietnam and Kenya. The focus of this study is on three major aspects: (i) defining and comparing proof-of-climate variability from scientific and local perspectives; (ii) understanding local perceptions of climate-variability impacts on current farming systems and local responses and (iii) examining other approaches and supportive policies.

3. Results and discussion

3.1 *Climate variability, its impacts and local response*

Local knowledge and statistical analysis at both sites indicated a trend of climate change towards lower rainfall and higher temperature, particularly in the driest months. The current intra-annual variation in temperature and rainfall and the incidence of extreme events appeared to be more pronounced at the Vietnamese sites, while at the Kenyan sites local people reported water scarcity, which was to a larger extent caused by increased water extraction (Table 2; Embu stakeholders' workshop). While interviewed Vietnamese farmers could recall their adaptation action in a particular year with extreme weathers, the interviewed Kenyan farmers tended to report their response to drought, in connection with the change in rain pattern (Table 2) and water scarcity in the Kapingazi basin (Table 3). In Vietnam, for example, due to the prolonged winter (extended by 38 days) and two flood events in 2008, approximately 70% of rice seedlings were killed, forcing farmers to replant rice varieties of short duration but lower yield, resulting in yield losses of up to 40%. Home gardens with tree-based systems and livestock were reported by the farmers interviewed to be one important 'safety net' when crops failed. The tea, acacia, eucalyptus, jackfruit and rattan grown in home gardens are resilient to extreme weather and can be sold to provide year-round income. Other crops such as banana, cassava and sweet potato supplement family food needs, while also providing animal fodder when rice crops fail. To cope with the increased climate variability, the crops listed above are being planted by farmers in village 4 in a new land-use form named 'forest garden' – a home garden type of illegal planting in forests near the village. We understood that farmers planted food crops in the forest garden as a 'permanent' strategy in anticipation of coming needs due to climate variability. Village 8 does not have forest land, but is using its good access to the market to raise more cattle for sale (Nguyen et al., 2013; Table 2).

At the Kenyan site, farmers' response to climate changes differed, with 50% of farmers (who rely for their livelihoods on tea and coffee production) interviewed admitting to 'doing nothing' when it gets too dry, but waiting until the weather improves. The other 50% of farmers interviewed reported a range of adaptation strategies, with diversification of the farm portfolio leading to diversified farm income and helping them to adapt to climate variability. Tea and coffee are the main crops, but these farmers also grow banana, cassava and beans and raise cattle. During the dry season, the farmers feed their animals with commercial feeds and with grasses which they 'cut and carry' from neighbouring areas (referred as zero grazing by farmers). Exotic tree species such as *Grevillea robusta L.* and *Eucalyptus* (90% of

Table 2. Climate variability, its impacts and local response at the study sites.

Method	Kenyan site	Vietnamese site[a]
T-test and linear regression analysis of monthly data	Linear regression of 28 years of data showed an increasing trend for mean annual temperature ($p = .0$) and maximum temperature (May and December), as well as minimum temperature (March and October) ($p < .05$), indicating hotter weather[b] T-test to compare annual rainfall in two seven-year period (1977–1983 and 2002–2008) showed that the more recent period had lower rainfall than the earlier period ($p = .02$)[c]	Increased mean annual temperature by 0.8°C during the 44-year period ($p < .001$). Mean monthly temperature increased during the period for June, August, October and November ($p = .005$, .033, .003 and .015, respectively) There was no statistically significant trend for the rainfall data over 44 years
Timeline via focus group meetings (Vietnam) and stakeholders' workshop (Kenya) to establish local perception of climate variability	'In the past, rain started in early March. The rainfall was stronger and more continuous over the year.' 'Now, rain starts in late March. The rainfall is weaker and the dry season is clearer.'	Sudden increase in rainfall during main flooding seasons in September−October, and a low rainfall but high temperature pattern from May to July, when the weather is extremely hot and dry 'Changes in the weather pattern, especially extended cold, prolonged drought, early or long flood seasons, exert more pressure on the paddy and crop production that is already under weather stress.'
Impacts: Brainstorming by focus group meetings (Vietnam) and stakeholders' workshop (Kenya)	Contribute (together with increased water extraction) to drying of the Kapingazi River. Drought leads to reduction of crop and fodder yields, but differs from farm to farm. Risks of outbreak of diseases and pests among humans, crops and livestock Difficult to plan farming and decreased fodder availability for livestock	Extended flooding and drought lead to 40% yield losses for paddy rice Trees and livestock farming are less vulnerable than rain-fed crops. But prolonged rain can cause diseases that are sometimes fatal to livestock, including cattle
Adaptation activities (Questionnaire)	Adjust seasonal calendar according to climate variability 'Do nothing', just wait for better weather. Growing new drought-resistant varieties; growing early- or late-maturing crops Diversification of crops and trees suitable in different landscapes; water harvesting and irrigation. Storage of animal feed (silage) for when grazing is not possible; tea and cattle for cash serve as a 'safety net' during drought. Seeking employment in nearby towns	Adjust seasonal calendar according to climate variability Rely on products and incomes from home garden, forest garden and livestock when crop failed due to extreme weather
Vulnerability factors (Brainstorming)	Water scarcity in the Kapingazi watershed due to climate variability, together with other factors such as rapid growth in water abstraction and increased water demand	Forest gardens with agroforestry, which is resilient to extreme weather, provide food, but are still considered illegal since the forest land is allocated for forest planting only

[a]Nguyen et al. (2013).
[b]Statistical analysis (using the Minitab programme) of 28 years of annual and monthly air temperature data (1980–2007).
[c]32 years of annual and monthly rainfall (1976–2009) data obtained from Nyeri and Irangi meteorological stations, Kenya.

farmers with an adaptation strategy) are also commonly grown, particularly on sloping land in the upper FDA. The use of drought-resistant or early-maturing crop varieties, water tanks and drip-irrigation techniques, seasonal adjustment of farming practices, constructing food storage facilities, selling cattle and tree products, using savings and off-farm employment were all mentioned by farmers as their adaptation strategies to climate variability (Table 2). Embu town, which is only about 10 km away from the lower FDA, provides seasonal employment for farmers.

Despite the different impact levels of climate change and variability between the Vietnamese and Kenyan sites, there were similarities in terms of the patterns farmers

Table 3. Water scarcity in the Kapingazi basin – causes, impacts and solutions.

	Response from Embu stakeholders' workshop ($n = 25$)[a]
Reasons why the river is drying up	Drought, lower rainfall
	Illegal and excessive water abstraction for irrigation and domestic use
	Encroachment and poor riparian vegetation cover and cultivation in wetlands, such as cutting down of indigenous, water-friendly trees and planting of unsuitable exotic trees
	Weaknesses in policy and governance regarding abstraction, particularly poor enforcement of the Water Act
	Population pressure
Impacts of the river drying up	Disease outbreaks, including waterborne diseases
	Crop losses as yields decline, decreased availability of fodder resulting in low income, food insecurity, increase in food prices, loss of time searching for water, increased household spending and increase in poverty
	Decline in education standards as children drop out of school due to poverty and breakdown of families
	Water-related conflicts
	Reduced tax revenue by government
Solutions to mitigate and reduce the causes and impacts of water scarcity	Proper riparian management by planting water-friendly trees and grass (bamboo is an example); replace exotic tree species with indigenous species
	Good farming practices, e.g. agroforestry, soil conservation and planting perennial crops
	Diversification of crops, promoting indigenous, drought-resistant crops, such as tubers and indigenous vegetables
	Storage facilities for crops and fodder
	Apply water-harvesting technologies
	Awareness raising, capacity building and improving extension services
	Law enforcement, particularly environmental, land- and water-management policies
	Provide incentives for riparian management
	Accurate meteorological predictions
Advantages of indigenous species	Water-friendly and drought-resistant
	Increase biodiversity, improve soil fertility and promote aesthetics
	Promote pollination as they flower at different times, attract birds
	Provide herbal medicine
	Friendly to food crops – less competitive
	Diverse products, for example, fruits for people and animals
How to promote indigenous trees	Educate farmers
	Reward farmers
	Promote value addition
	Provide planting material and options for propagation
	Linkages to markets for indigenous tree products
	Review policy on the usage of indigenous tree species on farms

[a]Twenty-five (25) stakeholders attended the workshop, including farmers, researchers, administrators, government officers, extension officers and representatives from relevant projects in Embu district and local universities.

were using to adapt. At the study sites in both countries, besides diversifying crops and varieties, planting trees and raising cattle, farmers also designed appropriate land use along landscape gradients as a strategy to buffer against increased weather uncertainty (Tables 2 and 3). For example, farmers in Vietnam moved to planting gardens in the forest during extreme events, whereas farmers in Kenya accessed the nearby town for seasonal employment. There is thus a need for development policies that incentivize diversification in agriculture and landscapes and that maintain existing diversity in order to create agricultural systems that are resilient to climate change and protect food production under future climate change.

3.2 *Ways of enhancing local adaptive capacity*

According to UNFCCC (2007), the most effective adaptation approaches to climate change for developing countries are those (i) simultaneously addressing a range of environmental stress and factors and (ii) synergizing with coordinated efforts aimed at poverty alleviation, enhancing food security and water availability, combating land degradation and reducing loss of biological diversity and ecosystem services, as well as improving human adaptive capacity. The main vulnerability factor at the Kenyan sites was identified as access to water, while access to forest land was the prime issue at the Vietnamese sites. Addressing the underlying cause of limited access to water and forest land is key to enhancing the adaptive capacity of local people at these sites.

3.2.1 *Forest land access in Vietnam*

The forest garden system used in Village 4 when lower parts of the landscape are flooded is important to those local farmers, yet it is considered illegal. Farmers have set up these 'illegal' forest gardens on land belonging to the State Forest Enterprise because they need land to sustain their livelihood in the event of crop failure due to extreme weather. As suggested by the commune and village leaders interviewed, legalizing the establishment of forest gardens in this area could help farmers, particularly the poor, in their adaptation strategies (Nguyen et al., 2013). The conflict between forest protection policy for climate mitigation and the need for upland farmers to access land during extreme weather events was also observed by Beckman (2011). Currently, at the policy level in Vietnam, climate-change-mitigation action is led by the Ministry of Agriculture and Rural Development, while climate adaptation is under the Ministry of Environment and Natural Resources Management. This division is reported to be the main barrier to overcoming the policy conflict (McElwee, 2011). Furthermore, farmers may be aware of the importance of adopting resilient species when crops fail due to extreme weather, but are prevented from doing so by limited land and lack of finances (Nguyen et al., 2013). In Vietnam, allowing farmers to develop agroforestry in the forest would be an appropriate adaptation strategy.

3.2.2 *Causes of water scarcity in Kenya*

At the sites studied here, water scarcity was linked by local people to the drying up of the Kapingazi River due to lower rainfall, illegal and excessive water extraction, inappropriate land use along the river, weak policy enforcement and population pressure (Table 3). However, there has only been a minimal decrease in monthly mean precipitation over the past 30 years (Embu stakeholders' workshop), while in the same period there has been a 10-fold increase in abstraction of water, with the amount abstracted exceeding the available river flow in dry years. One important cause of increased water abstraction is a population increase (Embu stakeholders' workshop). According to Jaetzold (2006) and Embu district statistics, the population increased by 19,000 (6%) between 2000 and 2010. However, in 1984 and 2000, the Kapingazi River dried up completely although the population was lower, which means there could be other factors contributing to the river drying up in addition to abstraction. From workshop discussions, diversity of land use, planting 'water-friendly' trees and grasses in riparian areas, use of incentives and enforcement of legislation were highlighted by stakeholders as important actions to address the causes and mitigate the impacts of water scarcity in Embu and thus achieve overall resilience (Table 3).

3.2.3 *Landscape approach*

A landscape approach as defined by Scherr, Shames, and Friedman (2012) would include (i) planning and managing agroforestry at the field and farm scales to obtain diversity within farming systems and land uses across landscapes and (ii) optimizing land-use interactions across landscapes in order to achieve synergies of mitigation and adaptation while enhancing ecosystems and livelihoods.

The Kenyan policy objectives on forest and water conservation are closely linked and create good conditions for such a landscape approach. The Water Act in 2002 provides for the management of water resources along ecological and catchment areas, while promoting community participation in catchment and water-resource management. Kenyan forest development policy emphasizes two major roles of forests and trees: provision of ecosystem services (especially water-catchment protection) and supply of forest products (World Water Assessment Report, 2006). Protected native and plantation forests are used to protect catchments in all five major water sources in the highlands of Kenya, including Mount Kenya, while agroforestry and dryland forest are regarded as means of ensuring sustainable supplies of timber, fuel and other forest products.

The Mount Kenya East Pilot Project for Natural Resource Management (MKEPP) is an example of water and forest links. The project undertook different actions aimed at achieving integrated watershed management, which included enhanced community water access (springs, dams, tanks, pipes and boreholes) and river basin management planning and monitoring (MKEPP Report, 2007). The project also distributed tree seedlings to farmers, rehabilitated degraded indigenous forests, established plantation forests and planted trees on hilltops and along riverbanks (Ministry of Water and Irrigation, Kenya, 2006). However, MKEPP efforts in promoting tree planting for catchment ecosystem services were limited by institutional and policy challenges, including coordinating administratively discrete divisions along targeted river basins, low staffing levels and the duality of authority and sometimes differing goals of Kenya Wildlife Services and Kenya Forest Services in managing Mount Kenya Forest Reserve (Ministry of Water and Irrigation, Kenya, 2009). Forest sector actions are generally limited by insufficient budgetary allocations and low incentives to local communities and the private sector for sustainable management of natural forest resources.

In Vietnam, the government issued Decree no. 120/2008/ND-CP on 1 December 2008 on Watershed Management, but implementation mainly relates to the national payment for environmental services (PES) policy according to Decision No. 380/QD-TTg/2008. Watershed approach was used for defining PES buyers and sellers, as well as water flow and erosion in relation to different forest and land-use categories (Hoang, Do, Pham, van Noordwijk, & Minang, 2013; Kolinjivadi & Sunderland, 2012).

3.2.4 *Incentive-based approach*

Besides the institutional and policy challenges mentioned, balancing economic and environmental goals was another challenge for the MKEPP. *Eucalyptus* growing is widespread in the Kapingazi catchment due to its high economic value, despite the fact that government enforcement approaches have been applied in Embu since 2000 to remove blue gum eucalyptus species, which are considered to be too water-demanding (Kilimo Trust, 2011). While this was aimed at reducing water scarcity at the landscape level, it caused substantial loss of household income and of insurance against seasons of crop failure (FAO, 2011). Indigenous trees are considered to be more appropriate for watershed protection (Table 3), but due to the low economic returns, farmers still do not plant these as widely as exotic species. To promote indigenous species, recommendations were made to enhance marketing of their products, together with extension services, provision of incentives, increasing access to germplasm and policy support (Table 3).

Similarly, in Vietnam exotic and indigenous tree species, market support and land tenure policy have been proposed to promote resilience (Nguyen et al., 2013). An incentives-based approach applied alongside policy can potentially reconcile the dichotomy between household actions and landscape planning objectives. The 2000s saw a rise in market-based incentives, such as payments for environmental services (PES), which were designed to arrest ecosystem degradation processes by placing an economic value on important ecosystem services such as water, biodiversity, landscape beauty and carbon sequestration (McElwee, 2011). However, PES implementation has proven problematic due to institutional challenges (van Noordwijk et al., in press). For example, in the Sasumua catchment in Kenya, some soil- and water-conservation actions implemented in certain hotspot areas by landowners could result in significant reductions in soil erosion and water degradation. Even though this could achieve overall policy objectives and benefit the Nairobi Water Company downstream, a PES agreement could not be structured, mainly because PES could not be fitted into the existing policy and institutional structures of fee collection and channelling of finances (Mwangi, Gathenya, Namirembe, & Mwangi, 2011). In Vietnam, Decision number 99 on Forest PES provided a clear guideline on fee collection and channelling of finances, but high transaction costs and unclear monitoring, reporting and verification of PES were reported to be the main challenges (McElwee, 2011). As a result, state-derived financing was insufficient to cover the opportunity costs of contracted land users.

We assume that there would be opportunities and constraints, similar to those mentioned above, if PES was applied to stimulate the type of agroforestry diversification that is discussed in this paper. However, several potential solutions are discussed to overcome the constraints. For example, bundling income from land uses' 'goods' together with PES will be able to provide more sustainable funding for supporting tree-based systems that can both enhance income for farmers and protect environmental services. Non-cash incentives, such as clear land tenure and technical assistance, should be given more attention in consideration of local budget constraints (Hoang et al., 2013). Technical and agricultural extension support for land-use transitioning and empowering community-based institutions and individuals through micro credits and loans are also suggested (Kolinjivadi & Sunderland, 2012). Combining PES and reduce emission from deforestation and degradation (REDD) mechanisms with support for climate-change adaptation would help to reduce fee collection and channelling of finances, as well as the high transaction costs. However, this requires good cross-sectoral coordination.

4. Conclusions and recommendations

Local knowledge and scientific analysis at our study sites in Vietnam and Kenya suggested a trend of increased climate change towards lower rainfall and higher temperature, particularly in the driest months. The degree of impact of climate change and the variability was higher at the Vietnamese sites, but there were similarities in coping strategies in the two countries. In both cases, diverse approaches involving a combination of farm, off-farm and non-farm strategies and in some cases illegal means are being used directly or indirectly to adapt to and/or mitigate the impacts of water scarcity, flooding and drought. In terms of farm strategy, tree-based systems with resilient species and zero-grazing cattle are being used by local farmers to secure their livelihood when crops fail. At both the Vietnamese and Kenyan sites, diversity management of land use at farm level and along agriculture−forestry landscape gradients was one of the key adaptation strategies identified.

The diversity of approaches used by farmers in Vietnam and Kenya highlights the need for a landscape approach within a 'rural development' framework. In order to apply a landscape approach, policy interventions must include incentive mechanisms (example PES) that enable collective action, taking into consideration trade-offs where private costs are incurred for public gain. To overcome several existing challenges to implementation of catchment approaches and PES in terms of institution, coordination and budget, further research is recommended in order to identify: (1) good rural development practices, particularly where landscape approaches are applied, and ways to integrate climate-change adaptation and mitigation into rural development; (2) appropriate incentive systems (e.g. PES) to promote agroforestry and indigenous species, as options for addressing mitigation and adaptation simultaneously in a landscape applying incentive-based approaches and (3) environmental indicators for monitoring the impacts of integrating mitigation and adaptation on farms and in agricultural landscapes and to act as the basis for targeted incentives.

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