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Trees and agroforestry for coping with extreme weather events: experiences from northern and central Viet Nam

Elisabeth Simelton · Bac Viet Dam · Delia Catacutan

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Abstract Although tree-based farming systems are often assumed to be "resilient" or "climate-smart" options, adoption is limited. It could be that the sensitivity of individual tree species to extreme weather events is poorly documented or new systems include unfamiliar species and technologies. This paper reports on initial results of an evaluation of farmers' experiences with trees and crops for responding to major climatic exposures in 21 villages in northern and north-central Viet Nam. Our study assessed the suitability and roles of trees by analyzing data gathered through focus group discussions, workshops and a survey of 661 households. The results showed that a majority of households were exposed annually to what they perceived as natural hazards. Experiences with using trees for coping and adaptation depended on household income status, awareness and policies. In particular, farms with trees had shorter recovery time after most types of natural disasters, except for cold spells, demonstrating economic and environmental buffers. Many leaders were unfamiliar with agroforestry and mainly looking for economies of scale, hence oriented to land use rather than landscape planning. This indicates disconnects between farmers' needs and policymakers' priorities with respect to climate change adaptation strategies. Existing agroforestry systems reflected a transition from indigenous or current farming systems via changing to either new species or technologies rather than changing both at the same time. Gaps in current adaptation strategies and key areas for policy and research interventions are finally discussed.

Keywords Climate-smart agriculture · Agroforestry · Adaptation · Natural hazard · Impact · Sensitivity

Introduction

Modern agriculture cover a range of risks related to production, prices and markets, financial, institutional and social aspects (Harwood et al. 1999) that often are directly or indirectly associated with weather impacts. For poor households, health risk factors closely relate to the ability to ensure food security during hungry periods and without being forced to spend savings on food (Thorlaksen and Neufeldt 2012). Hence, to live with and reduce the risks of capricious weather farmers have continuously adapted farming systems to minimize crop failures by changing crops, adjusting planting windows or combining crops that spread the risk (Altieri and

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E. Simelton (✉) · B. V. Dam · D. Catacutan
World Agroforestry Centre (ICRAF), 17A Nguyen Khang, Cau Giay, Hanoi, Viet Nam
e-mail: e.simelton@cgiar.org

Nicholls 2013). Studies show that by optimising sequential cropping patterns the projected yield losses under climate change scenarios can be halved (Waha et al. 2013). In contrast, the buffers provided by trees and forests during periods of food insecurity may be adversely affected by climate change impacts and environmental degradation (Kirilenko and Sedjo 2007). In response so-called 'climate-smart agriculture' solutions are intended increase "resilience" to climatic impacts improve livelihoods and food security, as well as addressing adaptation and mitigation objectives (FAO 2013). One example of climate-smart practice is agroforestry, whereby the deliberate addition of trees on farms is expected to sequester carbon while providing protection to adjacent crops, such as shading, wind-break and binding erosive soils (Nair 1993; Neufeldt et al. 2011). Despite many observed benefits (Lasco et al. 2014), the uptake of agroforestry is unpredictable. A review by Ajayi and Place (2012) shows agroforestry adoption in Africa and Asia sometimes was autonomous, sometimes planned, sometimes evolved through interaction between farmer, market and policy, where policies directly or indirectly supported agroforestry—occasionally prevented it.

Poor adoption may depend on that climate-smart initiatives require strong technical, institutional and political support (Scherr et al. 2012). Uptake and maladaptation can also be associated with perceptions of risk. For the purpose of this study, risk can be defined as the level of harm and the likelihood of that harm (Hay 2007), e.g. the type of damage and the frequency. Lachlan et al. (2009) studied how people reacted to information about risk for natural hazards in the case of hurricane Katrina, and their specific non-routine actions. In particular, people weighted current risks against previously experienced disasters. Additionally, the perceived risk may be different from an objective risk, such as weather forecast or some kind of statistical measure. Hence, the perception of risk may vary among farmers, agricultural advisors and local land-use planners, so may their ability and their choices available to respond. When hazards are regular such as droughts in southern Africa, Simelton et al. (2013b) found that disaster relief lead the poorest farming communities to abandon the adaptation of farming systems. Furthermore, they found that certain types of state support aggravated environmental effects rather than mitigating them, causing maladaptation. Similarly, in Viet Nam a popular agroforestry system, taungya, is typically rotated in 5-7-year reforestation cycles. After the first 2–3 years of intercropping the canopy closes and household incomes reduce, resulting in premature tree-felling and soil degradation (Lambin and Meyfroidt 2010; Simelton and Dam 2014), such as landslides after heavy rainfalls. Maladaptation may also depend on misperceptions of direct climatic impacts *vis-à-vis* indirect impacts related to changes in the farming system's sensitivity to weather, e.g. shifting from traditional to high-yielding varieties with more narrow climate tolerance (Simelton et al. 2013b). Therefore, for identifying sustainable adaptation options, scientists are increasingly interested in co-learning with farmers (Newsham and Thomas 2011; Van Noordwijk et al. 2011). Institutionalising participatory processes that build on local knowledge also resonates with required mechanisms for integrated landscape management (Scherr et al. 2012).

Examples of climate-smart agriculture and landscapes in the literature are often synthesised in general terms or drawn on case studies from Africa and South Asia (Scherr et al. 2012; Lasco et al. 2014; Mbow et al. 2014), while from Southeast Asia, despite being among the most impacted regions by natural hazards, there are so far few systematic studies. Some exceptions include studies of interaction effects between trees and crops on small farms (Mercado et al. 2009) and architecture of shelterbelts (Dang et al. 2014). In Viet Nam farmer groups assessed climatic impacts on fruit trees in home gardens in exposed areas (Nguyen et al. 2013) and ranked ecosystem services, including resilience to weather impacts associated with seven land-uses in upland areas (Simelton and Dam 2014).

This research was conducted under a project aiming to support local adaptive land use planning in two exposed districts in Viet Nam. Specifically, this paper aimed to document experiences with trees, and to assess the roles of trees and agroforestry under the exposure of extreme weather events at the household, village and landscape levels. Here, "roles" of trees refer to climatic sensitivity, economic returns, and environmental interaction effects, including tree-crop interactions. A household vulnerability assessment will be published separately.

Methods

Study sites

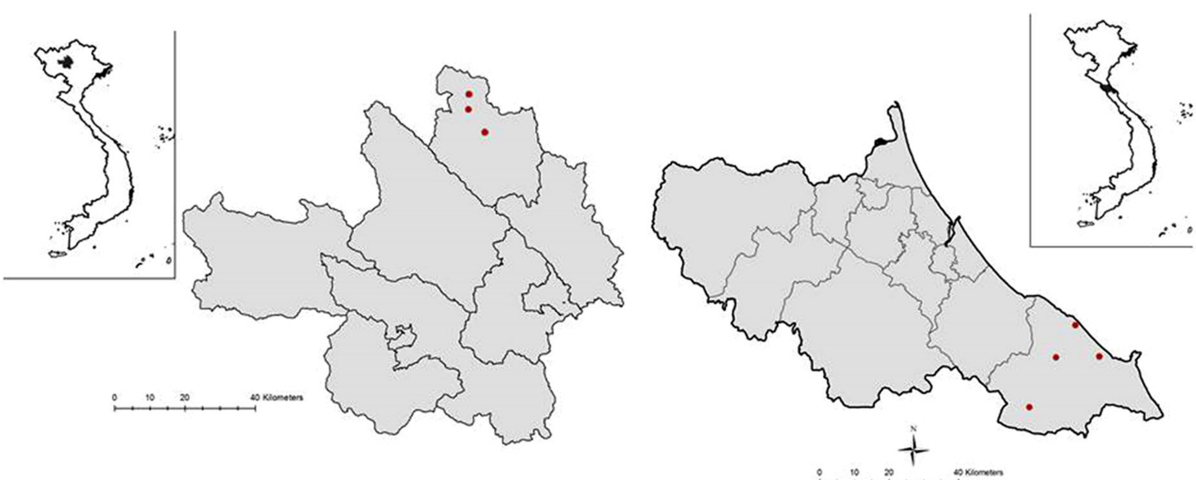
The study areas were selected in two climatically exposed districts and provinces that have received relatively little attention from development organisations: Ky Anh district in the northcentral coastal province Ha Tinh and Luc Yen district in the northern upland province Yen Bai are particularly exposed to natural hazards (Map 1). The communes and villages in each commune were located at relatively higher, intermediate and lower elevations to capture potential upstream–downstream differences.

Ky Anh district, Ha Tinh province

Ha Tinh province slopes eastwards from the high mountainous zone with peaks above 2200 m.a.s.l. towards the 140 km coastal plain. The average annual temperature is 24.5 °C and total rainfall varies between 1500 and 2000 mm. The province is on average hit by one severe storm per year; the peak storm period August and September is associated with heavy rainfall ranging between 150 and 250 mm (Table 1). A UNEP-supported study estimated the province's economic losses from tropical cyclones between 2000 and 2008 to 2.7 billion VND for infrastructure damage alone. Although livelihoods are vulnerable to repetitive losses under natural hazards, agroforestry contributes considerably to the province GDP. In 2006, the province's agroforestry production was valued at 6.4 billion VND, which was equivalent to an annual 16 % increase of GDP between 2001 and 2006. Further preparedness and planning are needed for the expected sea level rise, salt water intrusion, increasing storm frequency and magnitude, as well as dry spells. (ISPONRE 2009). The study included in total 12 villages in Ky Phu, Ky Hai, Ky Son and Ky Trung communes. The population in the investigated villages ranged from 470 to 1785, with none to 0.18 ha forestland per capita and between 0.05 and 0.09 ha agriculture land per household.

Luc Yen district, Yen Bai province

Yen Bai province in the northern uplands has a complex topography ranging from 50 to over 1300 m. a.s.l. The average temperature in Luc Yen is 23.9 °C and total rainfall about 1900 mm. Crop failures are reported every year due to a range of natural hazards (Table 1). For example, after a cold spell in 2008 about 10,000 ha rice had to be replanted, 3800 ha rice were totally destroyed and another 770 ha of maize was affected. In the same year, floods destroyed 1600 ha of rice. In 2010 a winter-spring drought reduced 2800 ha of paddy fields while 420 ha were converted into maize and soybean. Autumn crops were affected by an early cold spell that continued to



Map 1 Yen Bai (*left*) and Ha Tinh (*right*) provinces with Lam Thuong (northernmost) and Ky Anh (southernmost) districts and location of seven communes (*dots*) for household interviews

Table 1 Main risk periods for extreme weather events in Ha Tinh and Yen Bai (n = 18 focus group discussions) in current climate and scenarios for 2030s

<table>
<tr><th></th><th>Dec</th><th>Jan</th><th>Feb</th><th>Mar</th><th>Apr</th><th>May</th><th>Jun</th><th>Jul</th><th>Aug</th><th>Sep</th><th>Oct</th><th>Nov</th></tr>
<tr><td rowspan="2">Ha Tinh[a]</td><td colspan="2" rowspan="2">Cold spell
Tmin 7°C
Cold rain
(drizzle)</td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td colspan="3">Drought
Hot spell
Tmax 41°C</td><td rowspan="2"></td><td colspan="2" rowspan="2">Flood
Flashflood
(Rain)storm</td><td rowspan="2"></td></tr>
<tr><td></td><td colspan="2">Dry winds</td></tr>
<tr><td rowspan="2">Yen Bai[a]</td><td colspan="3">Cold spell
Tmin 6-10°C</td><td rowspan="2"></td><td rowspan="2"></td><td colspan="3">Drought
Hot spell
Tmax 38-41°C</td><td colspan="2">Big
difference
Tday-Tnight
Storm</td><td rowspan="2">Dry
winds</td><td rowspan="2"></td></tr>
<tr><td colspan="3">Cold rain (drizzle)</td><td></td><td colspan="2">Dry hot
winds</td><td></td><td>Flood</td></tr>
<tr><td rowspan="2">Scenarios 2030s[b]</td><td colspan="2" rowspan="2">Less
frequent
cold spells</td><td rowspan="2"></td><td></td><td colspan="6">Increased average and maximum temperatures</td><td></td><td rowspan="2"></td></tr>
<tr><td colspan="4">Drought risks increase</td><td colspan="4">Rainier
Storm intensity increase</td></tr>
</table>

Months follow solar calendar

T temperature, *min* minimum, *max* maximum, *day* daytime, *night* nighttime

[a] Authors' fieldwork

[b] Downscaled climate change scenarios adapted from ISPONRE (2009) and PC YB and DONRE (2011)

affect production for two subsequent years. By 2012 the maize area dropped by 3000 ha, which is equal to a shortfall of 10,000 tonnes. Furthermore, between late 2007 and early 2011 cold spells killed 1800 ha of acacia and 300 ha rubber. The cold winters 2007–2008 and 2010–2011 killed in total 14,000 livestock. Changes in climatic patterns, especially violent storms, droughts and floods, are expected to cause higher economic losses due to destructions they cause on infrastructure (irrigation, road, houses) and agriculture production in Yen Bai (Trần 2012). The study included in total nine villages in Khai Trung, Lam Thuong and Tan Linh communes. The population in the investigated villages ranged from 129 to 658, with none to 0.21 ha forestland per capita and between 0.03 and 0.25 ha agriculture land per household.

Methods and data

The data was generated through a series of participatory consultations in 2012–2013.

Step 1. *Village-level assessment* Semi-structured focus group discussions (1 day per village) to identify frequency and extent of current impacts and roles of trees were carried out in 18 villages (9 villages per district; n = 90). The discussion included factors limiting agricultural livelihoods, exposure and impact mapping, coping and adaptation strategies, and matrix ranking of trees suitability during extreme weather events (participatory tools were developed specifically for the project, see Simelton et al. 2013a). The results also informed the household survey (Step 2).

Step 2. *Household-level assessment of roles of trees* Structured household survey with 661 randomly selected households covering all income levels, with at least 25 % of households per village (451 households in 9 villages in four communes in Ky Anh district and 225 households in 9 villages in three communes in Luc Yen district). The survey included detailed information on exposure and impacts under normal and extreme weather events, and related to different farming systems and lasted 45–120 min per household depending on the number of fields. To study the impacts of extreme events, each household compared 2 years with worst impact for each exposure, therefore not all households compared the same years. For statistical analyses we used One Sample *T* Test, Paired Samples Test and correlation with significant difference level set at p = 0.05 in IBM SPSS Software Version 21.

Step 3. *Participatory adapted land-use options* Focus group discussions were carried out in 6 villages in two communes, Ky Son and Lam Thuong (3 villages per commune; n = 96), with one group of men and one of women, respectively per village. The focus groups identified key areas and farming systems at risk (Step 1), then discussed alternative land uses that could reduce the (risks of) impacts of climatic stress and land degradation, while improving livelihoods.

Step 4. *Expert opinions on the role of trees and selection of agroforestry systems* Leaders and planners at village, commune and district levels were engaged in feedback dialogues throughout the process. Farmers' rankings of trees (Step 1) and adopted agroforestry systems (Step 3) were triangulated in two ways. First, ten leaders from the two communes selected and ranked the current ten most valuable crops/trees for respective commune and the anticipated top ten in the 2030s in the commune. Second, literature reviews and informal discussions with national forestry and agriculture experts commenting on sensitivity of certain trees to extreme weather events.

Results

Multiple exposures to extreme weather events

The periods with highest risk for extreme weather events are shown in Table 1 and the frequency as perceived by individual households are shown in Fig. 1 (n = 661). Over 60 % of the interviewees in Ha Tinh and Yen Bai provinces stated that they were affected by cold spells at least once per year and at least 40 % (often over 60 % in Ha Tinh) were affected by cold rain, hot spell, droughts and flooding.

Due to the lack of on-farm or nearby meteorological equipment and varying definitions of extreme events farmers may refer to impacts rather than the observed weather phenomenon. For example, Fig. 1 shows a variable frequency of 'no answer' responses. This may be interpreted as the respondent (a) was either less frequently or not affected, or (b) perceived some definitions vague or redundant, such as cold spell versus cold rain, flooding versus flash flood, hot spell versus drought, or rain storm versus storm (25 and 30 % said they were affected by 'rain storms' annually compared to 10 and 20 % for 'storms' (data not shown) for Yen Bai and Ha Tinh respectively).

Impacts on livelihoods with and without trees on farms

In terms of impacts of extreme weather events on livelihoods it is important to separate impacts on paddy fields, sloping lands and other farming activities (e.g. livestock, home gardens). Paddy rice was cultivated by all but 33 households (mainly in Ky Trung commune) and the single most affected crop by natural hazards (e.g. 88 % of all households stated losses due to cold spells, 68 % to droughts, Fig. 2). Although at least 25 % of the households were affected rainstorms or storms, windbreaker trees near paddy fields were mainly visible in the coastal communes of Ha Tinh. At least 323 of the 661 interviewed households had forestry while agroforestry was practiced by about one-fifth and largely depended on the availability of designated forestland in the village. Livestock were particularly lost during cold spells, floods and storms—and with nearly all households having some animals, the risk pertains widely: 68 % of the households had pigs, 53 % had buffalos, 22 % had cows and nearly all of the households, 96 %, had chicken and/or ducks.

Table 2 compares the economic recovery period after natural hazards for households with and without agroforestry, also contrasting the difference between two recent years with extreme events.[1] First, although the losses were not necessarily related to agroforestry production, the average recovery period after the two worst disasters was up to 1 month faster for households with agroforestry systems after droughts and floods and up to 3 months faster after storms. The exception was for cold spells with about 1 month longer recovery with agroforestry. Secondly, when

[1] The number of respondents varies because not all households compared the same years, and not all households answered all questions.

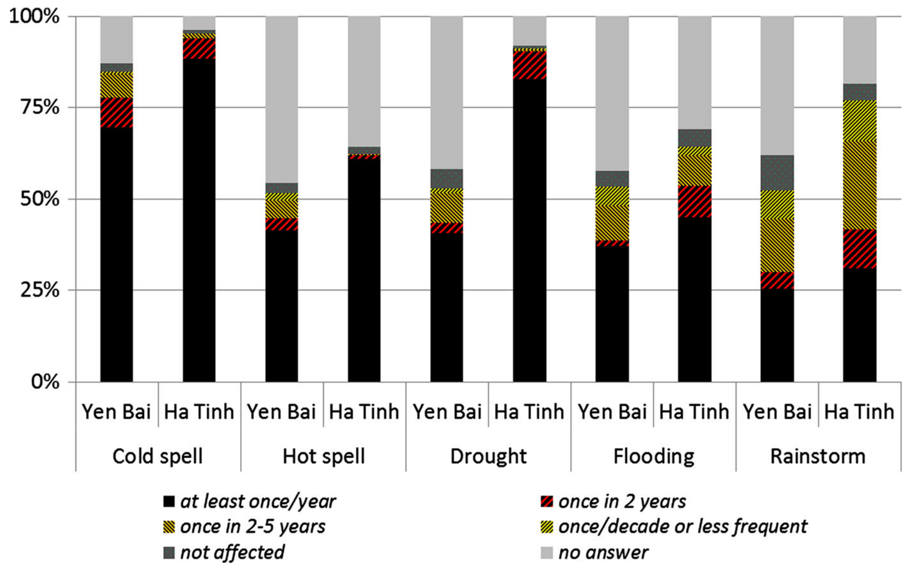


Fig. 1 Share of interviewed households and the perceived frequency of selected major extreme events in Yen Bai (n = 210) and Ha Tinh (n = 451)

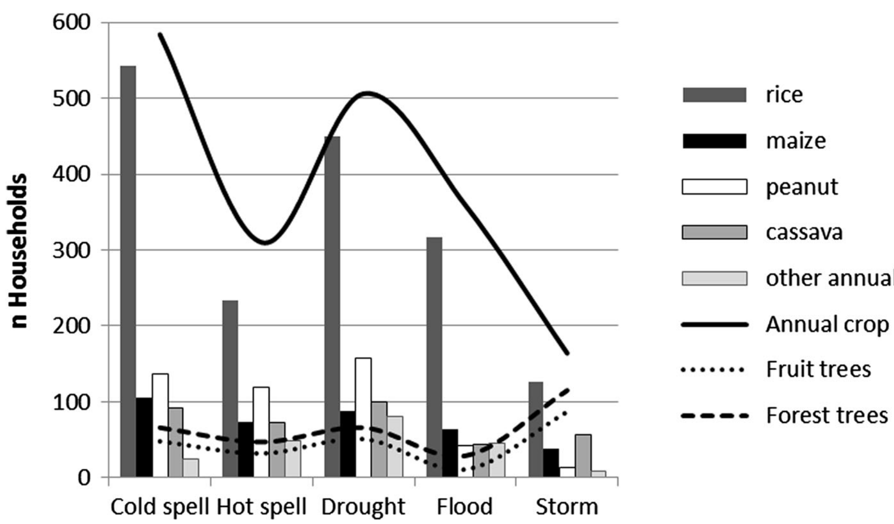


Fig. 2 Harvest losses associated with different land uses due to natural hazards. The *bars* represent annual crops. *Unit* number of 661 interviewed households. *Source* Household survey 2013

Table 2 Average duration (months) for economic recovery after natural disasters for household with and without agroforestry, comparing the two worst years (chronological order)

Natural disaster	Without agroforestry				With agroforestry			
	First year (SME)	Second year (SME)	t	df	First year (SME)	Second year (SME)	t	df
Cold-spell	5.4 (0.41)	4.4 (0.32)	2.741 ***	251	6.4 (0.89)	5.0 (0.90)	0.983	47
Drought	4.7 (0.25)	4.8 (0.37)	0.676	142	3.6 (0.35)	4.2 (0.43)	−1.525	29
Flooding	6.0 (0.57)	5.7 (0.44)	0.133	107	5.8 (1.41)	4.6 (1.43)	−0.763	12
Storm	10.9 (1.5)	12.9 (1.3)	−2.327*	102	8.1 (1.99)	9.9 (1.63)	−0.977	26

t Paired samples test of first versus second year, *SME* standard mean error, *df* degree of freedom

Significant difference between the first and second year per natural disaster is indicated by * $p < 0.050$, and *** $p < 0.001$

comparing the two recent extreme events, interviewees generally said that, except for storms the recovery was faster in the most recent of the 2 years (see "second year" in Table 2). This depended on that (i) the exposure was smaller the latter year, (ii) households had reduced the number of animals or areas planted due to e.g. earlier impacts, and the damage was therefore smaller, or (iii) households had gained experiences from earlier events and taken active measures to avoid future damage, i.e. adapted. The shorter recovery after cold spells may depend on that the typical damages were loss of rice (Fig. 2) and cattle, which often were compensated through government policies (one official standard compensation was 50 % of the seedling value and VND1 million per cattle head in 2008). This should be viewed against the fact that farms with agroforestry were larger, on average 1.6 versus 1.1 ha divided over 9 versus 7 plots (See Supplementary Table 2) because land with agroforestry had typically been allocated earlier (starting in the 1990s) and with less restricted land uses while recently established households received smaller plots with more restricted land uses. Hence, households with agroforestry invested themselves in diversified land uses and higher-value crops that were not covered by relief programs. With cold spells being the type of hazard affecting vast areas in contrast to local or topographical hazards, larger farms ran the risks of losing (often mortgaged) livestock and crops that were not covered by relief programmes. Likewise, having fields with less restricted land use also meant that one lost annual crop easily could be shifted for another, while crop failures on rice fields had to be replaced by another rice crop.

The economic impacts of adverse weather on households were noteworthy. Nearly 85 % (equal to 558) of the interviewed households had borrowed money, out of whom 42 % invested in livestock, 9 % in agriculture or cash crops and only 2 % in forestry. More specifically, half took a loan to replace losses due to natural disasters (mainly house and livestock). The purpose of the loans depended on that after major disasters a limited selection of seedlings was supported. Although those replacements maybe cost-reduced or free-of-charge, farmers still have to cover the travel to the commune centre to collect the seeds, labour time, yield reductions in the replanted variety and subsequent harvest delays. Moreover, while market prices often increased after disasters, this was rarely reflected in farm-gate prices as the quantity and/or quality of annual crops, fruit trees and timber typically dropped. In these cases, damaged wood would be used for household needs, such as fuel or construction. The mismatch between certain annual crops and their sensitivity to extreme weather events is highlighted in the next section.

Ranking suitability of trees and crops to extreme weather events

Table 3 lists the ranked climatic suitability and environmental and economic roles of key tree and crop species selected separately by farmer focus groups and local leaders. Overall, only early rainfall was considered beneficial to most crops and is not shown. In contrast, storms, flooding and particularly landslides and flash floods posed the highest risks but occurred less frequently than cold spells and droughts. It was striking that all annual crops were ranked sensitive to droughts, and maize which was very common, was ranked sensitive to all the extreme events. The local ranking conflicted somewhat with the reference literature (second column from the right), which suggest a wide span of rainfall suitability. However, the farmer group contrasting ratings of monoculture and intercropping reflect well the comparatively shorter recovery time after hazards for households with agroforestry based on the survey (Table 2).

Although annual crops were generally adjusted to fit with the main exposures (Table 1), farmers' and leaders' rankings of climatic suitability agreed more for trees than crops (Table 3). As expected the tree rankings agreed more with the rather general optimal climatic conditions in the scientific references; typically adverse weather during seedling and flowering stages and other factors such as soil are more important.

Maize showed an interesting case of disparities between farmers' and leaders' ratings of its suitability. For example, farmers selected maize as one of the least preferred crops in nearly all villages, while the leaders had more variable opinions (Fig. 3). Leaders in Ky Son ranked lower suitability with drought and hot spell and higher suitability with floods, than their colleagues in Lam Thuong, which can be related to climatic differences between the two communes

Table 3 Rating suitability and environmental and economic roles of selected key crops and trees, presented in five sections: annual crops, agroforestry, timber trees, fruit trees, and industrial trees

District	Group	Specie	Ranking of extreme weather event					References	Economic and environmental functions
			Cold spell	Hot spell	Drought	Flooding	Storm		
Ky Anh	FGD	Peanut	4	4	4	5	3	T_{min} 14; T_{max} 40	Suitable for intercropping (legumes) and annual income
	Leaders	*Arachis hypogaea*	5	4	4	3	3	P 75–400 mm/month[a]	
Luc Yen	FGD		3	3	4	5	3		
	Leader		3	5	4	3	3		
Ky Anh	FGD	Sesame	4	3	2	5	3	n.d.	
	Leaders	*Sesamum spp*	3	2	3	5	3		
Ky Anh	FGD	Soybean	5	4	4	5	4	T_{min} 9, T_{max} 35	
	Leaders	*Glycine Max*	3	4	4	5	3	P 75–400 mm/month[a]	
Ky Anh	FGD	Cassava	3	3	4	4	4	T_{avg} −15 to 25; T_{diff} 2–10/day; $P_{tot} > 500$ mm[a]	Canopy protects soils during summer rains. Near factory (Ky Anh)
	Leaders	*Manihot esculenta*	3	3	4	4	4		
Luc Yen	FGD		4	3	4	4	4		
	Leader		3	3	4	3	4		
Ky Anh	FGD	Maize	4	4	4	4	4	T_{min} 9, T_{max} 35	Primary alternative to paddy rice. 1–2 crops year. Cold and storm sensitive
	Leaders	*Zea mays*	4	3	3	5	5	P 75–400 mm/month[a]	
Luc Yen	FGD		5	4	4	4	5		
	Leader		4	4	4	3	4		
Ky Anh	FGD	Acacia + cassava	4	2	3	2	2		Intercropped (taungya) for 1–3 years for income
Luc Yen	FGD		1	1	1	3	5		
Luc Yen	FGD		3	1	2	3	4		
Ky Anh	FGD	Acacia	4	2	2	3	4	T_{avg} 18–28	Free seedlings through reforestation programmes,
	Leaders	*Acacia mangium,* spp	3	3	2	3	4	P_{tot} 1500–3000 mm[b]	
Luc Yen	FGD		4	3	3	3	4		Suitable for taungya with maize and cassava (*Mangletia* not suitable with cassava)
Luc Yen	FGD	Bodhi	3	2	2	3	4	T_{avg} 15–26	
		Styrax tonkinensis						P_{tot} 1500–2200 mm[b]	
	FGD	*Mangletia* spp	3	3	3	3	3	n.d.	
	Leader	Mangletia/bodhi	4	3	4	3	4		
Luc Yen	FGD	*Melia azedarach*	3	3	3	2	4	T_{avg} 23–27	
	Leader		3	3	3	3	4	P_{tot} 350–2000 mm[b]	
Ky Anh	FGD	*Aquilaria crassna*	3	4	3	4	4	n.d.	High value of oil
	Leaders		3	3	3	3	5		

Table 3 continued

District	Group	Specie	Ranking of extreme weather event					References	Economic and environmental functions
			Cold spell	Hot spell	Drought	Flooding	Storm		
Ky Anh	FGD	Bamboo	3	4	4	3	4	n.d.	Sensitive to flooding. Good windbreak. Shoots give annual income
Luc Yen	FGD	*Dendrocalamus giganteus*	2	3	2	3	4		
	Leader		3	3	3	3	4		
Ky Anh	FGD	Banana	4	4	4	4	4	*Fruit trees in general*	Wind break, affordable, profitable, fast-growing
Luc Yen	FGD	*Musa* spp	3	3	3	4	5	T_{min} 13; < 4 months with T > 38; P_{tot} > 1000 mm[a]	
Ky Anh	FGD	Jackfruit *Artocarpus intergrifolius*	3	3	3	3	3	Jackfruit: 3–47; P_{tot} 1250–2500 mm (tolerates temporary water logging)	Most resistant of fruit trees, more fruit after drought
Luc Yen	FGD	Longan	3	3	3	5	3	Longan: T_{avg} 15	
	Leader	*Dimocarpus longan*	3	2	2	3	4		
Luc Yen	FGD	Mango	4	2	3	4	4	Mango: T_{avg} 19–35; P_{tot} 300–2500 mm; Orange: T_{avg} 5–40, P_{tot} 900–2500 mm)[b]	Hail stones damage fruit
	Leader	*Mangifera indica*	4	2	2	3	4		
Luc Yen	FGD	Orange	5	3	1	5	5		Famous local orange. Prone to pests.
	Leader	*Citrus sinesis*	3	3	3	3	3		
	FGD	Guava *Psidium*	3	3	3	3	3		
Luc Yen	FGD	Ginger *Zingiber officinale*	3	3	3	3	3	n.d	Understorey, annual income
Ky Anh	FGD	Black pepper	4	3	4	4	4	n.d.	Profitable
	Leaders	*Piper nigrum*	4	4	4	3	5		
Ky Anh	FGD	Tea	3	3	3	2	3	Summer T_{avg} > 17 T_{max} < 34; Winter T_{min} > −4[b]	Binds soil. Near factory
	Leaders	*Camellia sinensis*	4	4	3	3	3		

The ranking indicates *5* for the crop dies, *4* for decline in yield quality or quantity, *3* for not affected, *2* for increase in yield quality or quantity, and *1* for suitable and supporting other trees, i.e. suitable for intercropping. In total 18 farmer groups (FGD) and two leader groups (Leader) ranked during separate focus groups for Luc Yen, Yen Bai and Ky Anh, Ha Tinh; note that not all groups ranked the same trees. More site-specific trees are ranked in Supplementary Table 1

[a] Phạm and Nguyễn (2013)

[b] Orwa et al. (2010)

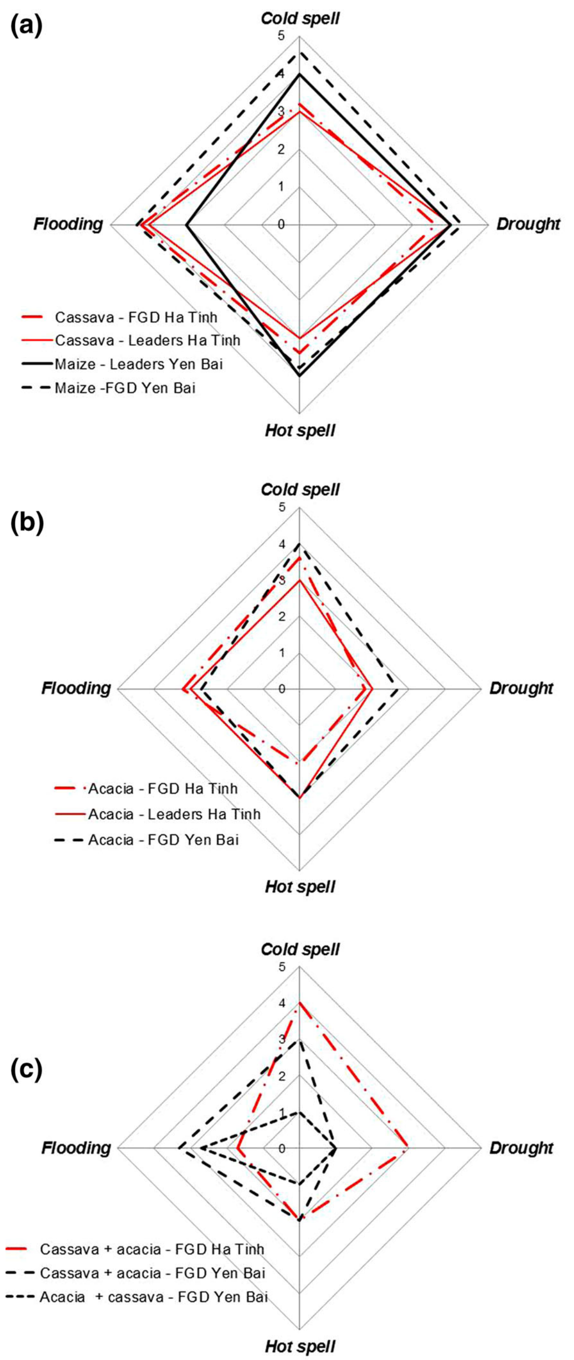


Fig. 3 Examples of perceived temperature and water tolerance for monocultures **a** cassava and maize, **b** acacia, and **c** intercropped as taungya system selected by farmer focus groups (FGD) and leaders in Ha Tinh (*red lines*) and Yen Bai (*black lines*). (Color figure online)

(Table 3). The climatic suitability can further be contrasted with the economic roles. Leaders in Lam Thuong ranked maize as the second most economically important agricultural product in 2013 and expecting it to become the most important by 2030s, while in Ky Son maize ranked seventh and was anticipated to drop in importance (Table 5). In both communes, farmers instead rated cassava and peanuts, both common for intercropping with annual and perennial species, as the economically most important annual crops (Fig. 3; Table 3).

Specifically, among the tree species leaders in Lam Thuong anticipated that bodhi, *Melia* and mai bamboo would increase in economic value although they ranked bodhi and *Manglietia* as more sensitive than farmers did. In Ky Son, both farmers and leaders appreciated acacia for its economic and environmental benefits, although sensitivity to cold spells was frequently brought up by farmers.

Designing adapted farming systems

Drawing on the anticipated future climate scenarios (Table 1), suitability ranking (Table 3) as well as hazard mapping and coping and adaptation strategies, women and men in six villages in Lam Thuong and Ky Son communes were facilitated in separate groups to design agroforestry systems, i.e. combinations of species and/or planting technologies that they expected would increase their incomes, enhance environmental values and resilience to extreme weather events. Table 4 shows that overall women selected more indigenous species and applied multistory functions from home gardens. Understory with ginger and/or lemon grass were often added to existing taungya-systems, such as acacia and cassava intercropped with peanuts (Ha Tinh), or (ii) *Melia* and bodhi intercropped with maize (Yen Bai). Wind breakers, typically bamboo in adjacent field boundaries, were mostly proposed by the women's groups in Ha Tinh but the men's groups in Yen Bai. Due to limited forestland and restricted paddy land-use, Lam Thuong farmers focused on increasing values of home gardens. The Ky Son farmers took a different approach and first determined a minimum annual benefit that any improved system must exceed (USD900 ha^{-1}).

Table 4 Recommended species by function adapted intercropped/agroforestry systems for sloping uplands by gender-divided focus groups and leaders in two communes

Commune, province	Village focus group	Timber trees	Fruit trees	Annual crops	Cash crop	Under story	Wind break	Erosion control
Ky Son, Ha Tinh	Men A	Acacia		Cassava, peanut, soybean		Ginger, lemon grass		Grass strip
	Women A	Acacia		Cassava, peanut, soybean		Ginger, lemon grass		Pine apple
	Men B		Jackfruit, papaya, banana			Ginger, lemon grass	Bamboo	
	Women B	Acacia, aquillaria	Jack fruit	Cassava, peanut				
	Men C			Cassava, peanut	Tea		Bamboo	Tea
	Women C	Acacia	Fruit trees	Cassava, peanut, soybean	Rubber			
	Leaders 1	Acacia		Cassava, peanut				
	Leaders 2	Acacia		Peanut, soybean, winter vegetables			Bamboo	
Lam Thuong, Yen Bai	Men D		Lime, orange	Maize		Ginger, lemon grass		
	Women D	Melia	Banana	Maize		Ginger, lemon grass	Bamboo	
	Men E		Orange, guava					
	Women E	Vernicia, Camellia spp, Canarium		Maize, cassava		Ginger	Bamboo	
	Men F	Bodhi, Manglietia		Maize		Ginger		
	Women F	Mangletia, Acacia	Banana	Cassava, maize		Ginger, taro		
	Leaders	Vernicia, Bodhi		Maize, peanut		Ginger, lemon grass	Bamboo	

The six villages are denoted from A to F, and leaders in Ha Tinh mentioned two systems

In between identifying areas with high hazard risk and priority agroforestry systems, leaders ranked their top ten most valuable trees and crops and projected how their importance would change by 2030s (Table 5). Firstly, following the climate and socioeconomic scenarios the leaders judged that low-impact damages, in particular reducing damages related to droughts and hot spells had more potential to be effectively addressed through cover crops (peanuts), intercropping or multistory agroforestry, than trying to reduce impacts of storms. The focus on fruit trees in Yen Bai was on par with the farmers, and leaders considered exchanging spring rice with maize to reduce cold spell and spring drought impacts on rice. Leaders in both provinces predicted that cassava would become less important, in line with its poor climatic ranking while peanuts would become more important. Second, the rankings highlight some disparities between projected future economic roles and climatic suitability. In Ky Son peanuts were expected to become the most important crop (Table 5), which contradicted the weather suitability ranking (Table 3). Similarly they also assessed that higher-value species would gain importance, such as agarwood, black pepper and tea (Table 5). In this case farmers had ranked agarwood and black pepper as overall sensitive except to droughts and hot spells respectively while leaders ranked agarwood as suitable and said that due to its location on upland plains, black pepper was not exposed to floods. In Yen Bai leaders had no cash crop among the top ten most important species primarily because of poorly developed nearby markets. Instead, they expected that a local orange variety would gain importance. They ranked citrus, longan and mango as less affected while the farmers rated most fruit trees as sensitive to weather extremes and pest infestation due to degenerated genetic material. Specifically, guava was promoted as intercropping for biological control of citrus greening disease, and suitable for the weather including drought tolerance (Orwa et al. 2010).

The spider diagrams (Fig. 3) further highlight the disparities regarding the perceived tolerance of three key species to temperature and water extremes. The outer line represents high risk and the preferred species to diversify the risks are those that dominate the inner circles (low risk) or can compensate a species with high risk. Weighting in the frequency or intensity of the climatic exposure into this calculation, the priority in Yen Bai would be to find short-term solutions for farming systems with low tolerance (rank “4” or “5”) to cold spells. Overall, intercropping and taungya agroforestry was considered to ameliorate temperature and water stress compared to monocultures by farmers and leaders in both provinces.

Discussion

The discussion draws on three key findings relating to local experiences with trees and agroforestry on farms for coping with extreme weather events.

First, over the past decade at least 70 % of the interviewed households had experienced cold spells and droughts, or impacts thereof. The evidence

Table 5 The economic importance of top-ten crops in 2013 ranked by local leaders, with arrows indicating projected trends towards 2030s

District, province	Timber trees	Fruit trees	Annual crops	Cash crop	Wind break
Ky Son,	1. Acacia ↓		2. Peanut ↑	3. Tea ↑	
Ha Tinh	9. Agarwood ↑		4. Cassava ↓	8. Black pepper ↑	
			5. Rice↑		
			6. Soybean ↓		
			7. Maize ↓		
			10. Sesame ↑		
Lam Thuong,	6. Melia →	7. Lime/orange ↑	1. Rice ↓		5. Bamboo ↑
Yen Bai	10. Manglietia/Bodhi ↑	8. Mango ↓	2. Maize ↑		
		9. Longan ↓	3. Peanut ↑		
			4. Cassava ↓		

presented here should be viewed against the lack of objective measures and local definitions of the extreme weather events, which means that the degree of harm, or impact, is likely to define the exposure (Simelton et al. 2013a). Yet, for farmers every impact counts.

Second, the study showed that trees on farms shortened the period required for economic recovery after droughts, floods and storms—because trees reduced impacts and/or farming system sensitivity. In addition, stands with mixed ages can diversify risks if individual trees can be sold (prematurely) when in need of cash or for recovering from frequent (low-impact) disasters that otherwise act as a constant drain on the household economy. Agroforestry has been found to generate similar positive economic cycles elsewhere, by spreading the harvests and diversifying risks (Thorlaksen and Neufeldt 2012).

Third, only 20 % of the interviewed households in this study had agroforestry systems. This number is likely underestimated as taungya systems were common during early reforestation stages while farmers not necessarily considered this as agroforestry. Despite that our results gave evidence for monoculture being associated with high climatic risk, provokes the question 'why were not more suitable trees and crops planted'?

Uptake and scaling up agroforestry systems requires a combination of local 'options that improve food security, nutrition, livelihood and environment', 'effective delivery mechanisms' and 'an enabling policy and institutional environment' (Coe et al. 2014). In addition, the utilisation of trees is associated with personal, community and policy-infused incentives and risk perceptions (Eakin 2005; Hay 2007).

Local and farm-level contexts

Agroforestry was more common on larger sized and/or better-off farms, typically the farmers who are the early adopters of new farming systems and may lead the way for the poorer ones (Stigter et al. 2007). Similar to other provinces in Viet Nam (Simelton and Dam 2014) more diverse land uses corresponded with long-term land tenure, larger acreage and household food security. This suggests a need to find viable integrated options for poorer households and smaller farms.

Farmers in this study stated that important aspects for adopting more risk-averse integrated farming systems were (1) that the new products were marketable and (2) that prices were stable, as farm prices normally vary considerably with weather. As long as achieving food security remains the main driver, long-term investments are perceived too risky. There were at least two interacting features to this. First, both farmers' and leaders' perceptions of risks were clearly influenced by their prioritisation of short-term incomes. Still they rated the suitability of trees and standard food crops differently. Many responses to the frequently repeated climatic exposures were short-term reactions that reduced neither the impact nor the farming system sensitivity. As result farmers were caught in a poverty trap of coping strategies. Second, both farmers' and leaders' criteria for adapted farming systems rendered immediate financial and market risks (i.e. 'options that improve food security and livelihoods') more critical than environmental factors. This suggests two sets of criteria for adoption. For immediate uptake, assess the system's ability to generate a minimum annual income, its temperature-water-wind tolerance and suitability with soils, ease to establish, input-demand (no or low additional labour, capital, agrochemical inputs), interference with the farming calendar of other crops (Matocha et al. 2012). As the systems take off economically, criteria for environmental services, and hence resilience and upscaleability, can be weight-adjusted to increase in importance over time.

Technical know-how and delivery mechanisms

The study documented experiences with indigenous and improved technologies using crops and trees for proactive adaptation strategies, such as multistory coastal agroforestry, species combinations acting as biological pest control and short-duration flexible plants. Incorporating trees into farming systems directly and indirectly reduced multiple risks, such as buffering the risks of production losses of nearby crops by giving shade, wind shield, reducing soil erosion, improving soil fertility and soil moisture. Such climatic and environmental co-benefits have been proven effective in reducing high-frequent (but often low-impact) risks, such as droughts (Eitzinger et al. 2007).

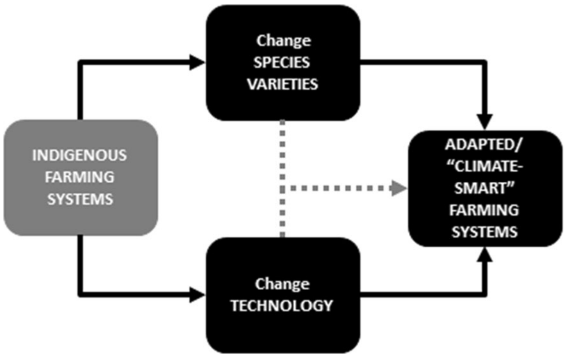


Fig. 4 Conceptual flowchart for strategies for a step-wise introduction of adapted/climate-smart agroforestry system, starting from what is known then either change plants or technology while keeping the other fairly constant may lead to an adapted system. While changing both species and technology, totally disrupts the existing system there is less conclusive evidence that this results in successful adoption of adapted systems

In contrast, when technology and know-how were underutilised, this was primarily due to unfamiliarity with integrated farming systems, sloping land technologies and impact-adaptation assessments rather than with the species. For example, the typical adaptation solution is breeding for more tolerant varieties, such as for rice (da Cruz et al. 2013). However, until such varieties have been tested and developed, temporary solutions such as adjusting timing and management may be considered (Mitin 2009).

Many underutilised functions of trees depended on beliefs and opinions. First, during our first meetings the prevailing view of farmers and leaders was that agroforestry was a one-time investment, rather than a process similar to those of natural forests or home gardens which evolves over time. Without strategies and good models for responding to extreme weather events and mechanisms to deliver alternatives, it is understandable that leaders resort to short-term familiar interventions in the field rather than at the landscape or watershed scale. A participatory policy review for northern Viet Nam found that differential support were suggested vital for a shift from short-rotation taungya systems to permanent agroforestry systems (Simelton et al. 2015). Second, overall we found surprisingly little documentation about (i) impact assessments of adverse weather impacts with losses reported to different authorities and other losses than rice were underreported, and (ii) the agroclimatic suitability for certain trees and crops in Viet Nam (see Table 3; Phạm and Nguyễn 2013). A search for online extension recommendations in Vietnamese returned a multitude of measures for reducing impacts of cold spells on rice and annual crops, while no recommendations were found for trees. For instance common frost injury prevention approaches in temperate climates for fruit trees are feasible also in the subtropics, e.g. wrapping, timing of pruning and adjusting soil water content (Snyder and de Melo-Abreu 2005). Several indigenous trees and crops were rated as "hardy and resilient", more systematic documentation about their interaction effects when integrated into systems (Mercado et al. 2009) is needed as alternatives to unsustainable short cycles of clear-felling and mono-plantations.

Scientists and agricultural advisories clearly need to better communicate benefits in terms of costs for not adapting versus adapting with trees. Examples from Africa and Asia show that quantifying the role of externalities can raise awareness on spill-over effects of agroforestry beyond the farm level compared to business-as-usual (Ajayi and Catacutan 2012). For farmers, extension workers, or leaders who are largely unfamiliar with agroforestry, such as in our case, our findings propose that rather than discussing both new species and new technologies at the same time, starting with what farmers already do and know, evaluating the roles of species and/or technologies that are familiar (Fig. 4) is a more efficient starting point. Focus should be to exploring multifunctional farming systems that can (i) withstand key multiple extreme events in the field and the landscape, (ii) provide continuous income and (iii) protect ecosystem functions. As a first move towards integrated systems, consider a stepwise approach where either new species are planted in a known way (e.g. adding understory plants that are grown in the garden), or familiar species are planted in a new fashion, e.g. along the contours.

In summary given the difficulties to find information in local languages, basic delivery of sustainable adaptation strategies seem to require (1) a database of impacts and good proven examples and capacity building of local advisories; (2) cost-and-benefit analyses to help decide whether adapting is worthwhile and can pay-off some investments by avoided damage; (3) crop models can be utilised to experiment with management options to optimise crop and farming calendars both in current and future climates (Eitzinger et al. 2007).

Enabling environments for agroforestry

In terms of policies, Dixon et al. (2014) argue that dependence on formal institutions can have a considerable role in deteriorating social and cultural institutions, or knowledge. When formal institutions are misinformed or lack capacity to inform, this may lead to maladaptation. In this case national food security policies and local land use plans instigate that paddy land is primarily for rice cultivation (Viet Nam Government 2012). This had consequences for incentives. For example, the national and provincial support programmes compensating rice and maize seedlings lost through (some) natural disasters appear at high cost on both public spending and farmers' unpaid labour time. Subsequently, the fate of nationally prioritised crops determine what other farm activities farmers have time for and therefore are able to invest in. The compensated seeds undoubtedly shortened households' economic recovery time. While some reports consider such relief as successful adaptation (see e.g. Stigter et al. 2007), the limited availability and diversity of affordable stress-tolerant species discouraged or prevented many farmers from experimenting to develop better adapted systems (Simelton et al. 2013b). In fact, our results point to that if farmers stood the entire risk and seedlings were available, they may choose to diversify with a combination of lower risk and higher value crops. Their wishes contrasted somewhat with findings from Mexico, where particularly poorer farmers prioritised minimising economic risks over climatic risks, such as maintaining subsistence maize production with high climatic risk over growing marketable crops (Eakin 2005).

Part of creating enabling environments is developing capacity. As to the previous section, the leaders were unfamiliar with adaptive planning and analysing adaptation versus non-adaptation options. Furthermore, although the leaders were not obliged to implement any of the agroforestry systems or land use plans that they developed during our scenario workshops, they remained in their comfort zone. Only when referring back to the potential "future" climatic impact risks, some considered dropping certain high risk species. One possible reason for the leaders' caution was that they did not anticipate any new local markets or factories for the products within the vision for the 2030 s (despite both districts being close to international borders, and a new highway opening to China in 2014). In contrast in the focus groups, farmers selected more components for their intercropped/agroforestry systems (Table 4) and considered a wider range of roles of trees, including subsistence, economic and environmental functions. In particular, they selected species that were not covered by state programmes for reforestation or natural disaster compensations, but instead reflected their interest in progressively building up a non-fixed term agroforestry systems in contrast to the popular cyclical reforestation/taungya and annual intercropping systems. While planned adoption can generate impact at scale, such as centralised reforestation programmes in China and Viet Nam, its qualities depend on how well farmers' priorities were considered (Zhen et al. 2007), and the examples of autonomous adoption reflect well the diversity of their needs (Schomers and Matzdorf 2013). As noted elsewhere, approaches that enable a diversity of flexible response strategies rather than locking people into specific behavioural patterns, are often heavy in socioeconomic capacity (Fazey et al. 2010). For example, agroforestry development is also affected by other sectors, such as subsidized seeds and fertilisers, calling for inclusion in multisectoral policy assessments. Similar to Indonesia, promoting export crops has disfavoured agroforestry over monoplantations and in contrast to India, bans on logging have not favoured agroforestry development (Ajayi and Place 2012) in Viet Nam. In this study, a promising observation was that the national program on Reduced Emissions from Deforestation and Forest Degradation was starting to filter down, leaders paying some attention to mitigating climate change, albeit more so in the above-ground carbon sequestration than below ground or emission reductions from land use. Ajayi and Place (2012) expect that the increasing attention on climate-smart agriculture may offer a potential for agroforestry as a no-regret option.

The findings of this study are a reminder that scaling of agroforestry and resilient 'climate-smart' systems require village level consultations to respond to the local variations in needs and capacity. The scenario discussions highlighted that adapted planning requires a way of thinking and planning that few leaders are used to[2]—therefore at the local levels this process will require time. Examples from other regions show that well-facilitated back-casting and future scenario planning offer an explorative environment that avoid leaders becoming defensive (Fazey et al. 2010; Vervoort et al. 2014). Furthermore, local participation in local planning can avoid conflicts between mitigation and adaptation objectives, for example leaders' preference to plant water-demanding fast-growing trees for mitigation when people are short of food (Matocha et al. 2012). The multiple purposes of agroforestry for utilising planting designs and tree-crop-soil interaction effects to reduce weather impacts also open opportunities for local stakeholders to engage in new means of funding adaptation and mitigation activities. Bird et al. (2013) suggest effective delivery of climate change financing requires institutional coordination, innovation and anchorage. This would involve a set of institutional and individual capacity development.

Conclusion

The study concludes that trees and/or agroforestry have been traditionally used by farmers to cope with various climate-related hazards in Viet Nam. Farmers reported that annual crops were generally more sensitive to weather-related risks than perennials. Integrating trees and crops reduced weather risks, and farms with trees had shorter recovery periods after most natural disasters. However, despite reported benefits, the use of trees and/or agroforestry to cope with climatic hazards remains limited due primarily to preference on immediate cash from crops over the longer-term benefits provided by trees and unfamiliarity with promising tree species. Interestingly, farmers opted for planting trees and more diversified systems than their leaders, indicating disconnects between farmers' needs and government priorities when it comes to climate change adaptation and coping mechanisms. Limited adoption of trees and/or agroforestry may likewise be due to the lack of support from local leaders to tree-based options.

The transition from dysfunctional coping strategies to more resilient land-uses require a set of actions: (1) institutionalised reporting systems of all weather-related impacts and costs, and a systematic database with physical suitability range of trees and crops with open access for extension and local land-use planners; (2) guidelines for commune level adaptive land use planning at landscape scales based on local risk assessments and cost and benefit assessments of current coping and response strategies. These should include village level consultations, where farmers and leaders understand the rationale and trade-offs for selecting certain species and land uses; and (3) create a portfolio of incentives and support for a transition to resilient, climate-smart farms and landscapes with different options suitable for variable farm sizes, making larger selection of crops and varieties available, combinations of species and/or technologies that are familiar to the user.

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[2] This was also evident through the FAO-EPIC Scenario Workshops organised in 2013–2014, see e.g. http://www.fao.org/fsnforum/forum/discussions/epic-vietnam.

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