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Analysis of Options by Context for Scaling Agroforestry in Northwest Vietnam

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By Nguyen Mai Phuong

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Analysis of options by context for scaling agroforestry in Northwest Vietnam

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ABSTRACT

Smallholder agricultural systems in Northwest Vietnam face a number of significant economic and ecological challenges. The move from shifting cultivation to more static farming methods, particularly maize farming, in this mountainous region has resulted in high levels of soil erosion. Agroforestry offers a potential mechanism to both stabilise these systems and to diversify production. The four chapters presented in this PhD thesis develop an integrated framework to scale up agroforestry options in Northwest Vietnam. Given the cultural and biophysical heterogeneity of this area it was assumed that there were no "one-size-fit-all" agroforestry solution. The concept of developing options that fitted, and were appropriate, to local contexts was used as a guiding principle. The framework was developed by mapping the extent and prevalence of soil degradation across the agricultural landscape and associating that with biophysical suitability mapping for different agroforestry options. Next the impact of social factors, including ethnicity and gender, were evaluated in terms of how they influence adoption of different agroforestry options. Finally the impact of social factors including ethnicity and gender affect adoption of different agroforestry options were assessed. Finally, shaded coffee agroforestry, an example of existing agroforestry system with potential for expansion, was explored as a case study to capture farmers' existing knowledge of the costs and benefits of integration of trees on farmland to identify opportunities for knowledge exchange.

The study provides the first systematic evaluation of soil erosion in the Northwest – showing that the area of cropland on erosion prone slopes has been underestimated (and is almost double the area identified by officially reported data). Agroforestry systems are an appropriate response option to this degradation as they have well established soil stabilisation benefits, particularly in contour planting patterns. Biophysical suitability analysis of different agroforestry options showed that 85 % of study site areas was viable for such agroforestry systems using high value tree species.

The study found that farmers' preferences for agroforestry adoption were highly influenced by social norms associated with different ethnic minorities who make up the majority of the farming population in this area (this study focused on the Kinh, Thai and H'mong groups). A case study looking at gender in H'mong communities found that H'mong men and women had very differentiated roles within the current agricultural systems and were subject to

different constraints and interests in relation to agroforestry adoption opportunities. These social norms currently limit H'mong women's full participation in agroforestry expansion.

In terms of design, tree selection for agroforestry was significantly influenced by the economic value to the tree (either as timber or fruit) and accessibility to market. Detailed analysis of farmers' understanding of the benefits of different trees in coffee systems explained why there were fewer native species in the areas with better road accessibility despite the farmers' own valuations of non-native tree species limited ecological benefits to coffee trees. The native leguminous tree *Leucaena leucocephala* and fruit tree *Dimocarpus longan* were identified by farmers as providing the broadest range of environmental benefits to coffee systems. However, *Leucaena leucocephala* had limited economic value and was primarily found only in the areas far away from roads and market. On the contrary, *Dimocarpus longan* had high market value, was found in more than 50% of surveyed farms, mostly near and medium distance to market. These results help local extension institutions understand current selection criteria of the 'right' tree species according to the local context

An integrated framework for scaling out agroforestry adoption is proposed and discussed in the synthesis chapter. It is tailored to a Vietnamese context through provision of greater detail on the context, options and actors involved in potential agroforestry systems in Northwest Vietnam.

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LIST OF ACRONYMS

ACIAR: Australian Centre for International Agricultural Research

AFLi: Agroforestry for Smallholder Farmers in Northwest Vietnam

AFLi-II: Developing and Promoting market-based agroforestry and forest rehabilitation options for Northwest Vietnam

AKT: Agroecological Knowledge Toolkit

ASTER: Advanced Spaceborne Thermal Emission and Reflection Radiometer

CANSEA: Agroecology Transition in South East Asia

CARE International: Cooperative for Assistance and Relief Everywhere

CGIAR: Consultative Group for International Agricultural Research

CIP: International Potato Center

CIRAD: French Agricultural Research Centre for International Development

CPC: Coffee Producers Cooperative

DANIDA: Danish International Development Agency

DARD: Provincial Department of Agriculture and Rural Development

DEM: Digital Elevation Model

FAO: Food and Agriculture Organization of the United Nations

FSCN: Forestry Science Centre for Northwest

FTA: Forest, Trees and Agroforestry

GIS: Geographic Information System

GPS: Global Positioning System

GHG: Green-house gas emissions

GSO: General Statistic Office

ICRAF: International Centre for Research in Agroforestry (Word Agroforestry)

ISDS: Institute for Social Development Studies

LANDSAT: Land Remote-Sensing Satellite

LDSF: Land degradation surveillance framework

MARD: Ministry of Agriculture and Rural Development

MOLISA: Ministry of Labour, Invalids and Social Affairs

MONRE: Ministry of Natural Resources and Environment

MPI: Multidimension poverty index

MUSCLE: Modified Universal Soil Loss Equation

NASA: National Aeronautics and Space Administration

NGOs: Non-Governmental Organisations

NOMAFSI: Northern Mountainous Agriculture and Forestry Science Institute

RUSLE: Revised Universal Soil Loss Equation

SATVI: Soil adjusted total vegetation index

SRA: Small Research Activity

SRF: Standardized surface reflectance

SFRI: Soils and Fertilizers Research Institute

STI: Space Technology Institute

TBU: Tay Bac University

VAC: Forest - garden – fishpond – livestock/ Garden – fishpond – livestock without forest

VAFS: Vietnam Academy of Forest Sciences

VND: Vietnamese Dong

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AUTHORSHIP INFORMATION

This PhD was developed out of the AFLi (Agroforestry for Smallholder Farmers in Northwest Vietnam) project administered by ICRAF Vietnam in collaboration with the Australian Centre for International Agricultural Research (ACIAR), the CGIAR Research Program on Forests, Trees & Agroforests and local partners. The study sites for each of the thesis chapters were selected from within AFLi project sites to contribute to the project.

I have prepared three chapters of the thesis for journal manuscript and one for a World Agroforestry (ICRAF) working paper. All the four chapters were presented as oral or poster presentations at international/regional academic conferences. I am the first author for all manuscripts, but received additional support developing the manuscripts for publication from my supervisors and co-authors. In all cases I took the lead in research design, data collection, co-ordinating and conducting farmer interviews and any other aspect of primary data collection and analysis.

Chapter 1:

Authors: Nguyen Mai Phuong, Tor Vagen, Tim Pagella, La Nguyen, Delia Catacutan, Leigh Winowiecki, Fergus Sinclair. Identification of potential domain for agroforestry expansion in Northwest Vietnam.

I designed the study with support from Fergus Sinclair, Delia Catacutan and La Nguyen. I collected field data following the Land Degradation Surveillance Framework methodology (with training and technical support from Leigh Winowiecki). Tor Vagen was responsible for the Random Forest modelling component. I wrote the manuscript which was edited and reviewed by Tim Pagella and Fergus Sinclair. This work was presented at the FLARE (Forests & Livelihoods: Assessment, Research, and Engagement) Conference in Edinburgh (Nguyen et al., 2016) as oral presentation, and at the ACIAR Research Symposium (Nguyen et al., 2017) as a poster. This manuscript is in preparation for submission to the journal Agriculture, Ecosystem and Environment.

Chapter 2: Nguyen Mai Phuong, Tim Pagella, La Nguyen, Fergus Sinclair. The impact of social and ethnic dimension on agroforestry adoption for indigenous people in Northwest Vietnam.

I primarily designed the first survey as the household survey for AFLi project with the contribution from other colleagues from ICRAF. I designed the second study with Tim Pagella. I managed the interview process with ICRAF colleagues. I wrote the manuscript with additional editing from Tim Pagella and Fergus Sinclair. This was presented as an oral presentation at Sustainability and Development Conference in Michigan (Nguyen et al., 2018). This manuscript is in preparation for submission to the journal Agroforestry Systems.

Chapter 3: Nguyen Mai Phuong, Nguyen Thi Van Anh, Le Thi Hong Giang, Vu Xuan Thai, Do Van Hung, Pham Huu Thuong, Vu Thi Hanh, Nguyen Van Thach, Tran Ha My, Nozomi Kawarazuka, La Nguyen, Tim Pagella. Exploring agroforestry opportunities and challenges in H'mong communities through a gender lens.

The study was jointly designed with Nozomi Kawarazuka, Nguyen Thi Van Anh, Le Thi Hong Giang and La Nguyen. I led the field work the field work team which included Nguyen Thi Van Anh, Le Thi Hong Giang, Vu Xuan Thai, Do Van Hung, Pham Huu Thuong, Vu Thi Hanh, Nguyen Van Thach, Tran Ha My. All co-authors contributed to the writing of a report for ICRAF. I was responsible for drafting the context and results section and contributed to Introduction and Discussion. I rewrote the draft to aim for a Working Paper and this was reviewed by Tim Pagella and Ingrid Oborn. This was then re-written for the PhD. This study was presented at The ACIAR Regional Gender Workshop on integrating gender into agricultural value-chain research in Vietnam (Nguyen, 2018).

Chapter 4: Nguyen Mai Phuong, Philippe Vaast, Tim Pagella, Fergus Sinclair. Potential to expand coffee agroforestry systems in Northwest Vietnam.

I designed this study with Philippe Vaast and other colleagues at ICRAF Vietnam. The two surveys were conducted with ICRAF colleagues, partners and interns. I did statistical analysis under the guidance of Clement Rigal. I wrote the manuscript which was edited and reviewed by Tim Pagella, Fergus Sinclair and Philippe Vaast. The result of this study was presented at Regional Forum on Agroecology in Cambodia (2018) and World Agroforestry Congress in France (Nguyen et al., 2019). This is aimed for submission to Experimental Agriculture.

COMPLIANCE WITH ETHICAL STANDARDS

All the research for this thesis fell under the AFLi (Agroforestry for Smallholder Farmers in Northwest Vietnam) and AFLi-II (Developing and Promoting Market-based Agroforestry and Forest Rehabilitation Options for Northwest Vietnam) projects administered by ICRAF Vietnam.

This study was conducted according to all prevailing national and international regulations and conventions. As such, scientific ethical practices regarding the involvement of people have been respected and the study was approved by Bangor University Ethical Review Committee and follows World Agroforestry's guidance on Research Ethics Policy (ICRAF, 2014)

The selection of human subjects also met all the requirements of current World Agroforestry guidelines. In particular all participation in research was voluntary, and all information, including any confidential personal data, was captured without identifying data and stored in appropriately secure facilities – following current World Agroforestry protocols.

I. INTRODUCTION

The introduction is divided into three main sections. The first section sets out a broad definition of what agroforestry is and why it is potentially important for the future development of small holding farming systems both globally and in the specific context of Vietnam. In this section the ‘Options by Context’ approach which has been adopted by World Agroforestry (ICRAF) and that underpins this work is presented. The initial section also provides an overview of agroforestry in Vietnam and identifies key issues associated with capturing the extent of, and for upscaling, agroforestry in upland areas of Northwest Vietnam. The final sections then set out the problem statement and then describes the structure of the thesis.

1.1 The importance of agroforestry in small holder farming systems

Very broadly, agroforestry is a management practice where trees are integrated into the same unit of land as either arable systems (such as maize) or livestock or combinations of the two and where the resulting interaction results in direct economic and/or ecological gains to the faming system (Lundgren and Raintree, 1982; Nair, 1993). As such ‘agroforestry’ is an umbrella term used to describe a very broad range of land practices (de Foresta et al., 2013). At its simplest agroforestry is a set of practices that combine woody components and agricultural crops and/or livestock however it often involves quite complex interaction between people and trees requiring more complex systems analysis (Sinclair, 1999).

The most classic and common form of agroforestry classification is based on vegetation structure (see Nair, 1985). This results in three broad groupings: Silvoarable or agrisilviculture (where crops are combined with trees), silvopastoral (where livestock are combined with trees either in a pasture or woodland setting) and agrosilvopastoral (combinations of both crops, livestock and trees). Somarriba et al. (1998) suggested that there could be a other options such as where trees are integrated in apiculture or aquaculture systems. Examples of agrisilviculture are: shade trees in perennial crops like coffee; alley farming; taungya systems, windbreaks and contour planting. Silvopastoral systems can involve: live fences; shade trees in pasture; fodder banks (see Somarriba et al., 1998; Sinclair, 1999). Agroforestry can also be classified by functions of woody vegetation in the systems such as production, habitat, regulation and cultural functions (McAdam et al., 2009). Based on spatial and temporal arrangements, agroforestry systems are defined as either simultaneous or sequential systems. In the former group, all components are intercropped at the same time while system components occupy land in different time in the later groups (Sánchez et al., 1994). Sequential systems have varying degrees of overlap between the crop and tree component. Concomitant systems overlap in the beginning (such as in taungya systems) and superimposed systems have overlaps between components only at certain times (such as temporary grazing of orchards) (Somarriba et al., 1998).

For smallholder farming to keep pace with global demand for food without further damaging the environmental resources there is a fundamental need to change the way farming is conducted (Pretty and Bharucha, 2014). One of the principal reasons why agroforestry is interesting in this context relates to the broad set of enhanced regulating benefits that agroforestry systems can provide at both plot and landscape levels, in contrast to existing systems. These include better soil stabilisation, increased fertility and increases to both above and below ground biodiversity (Khanh et al., 2009). The potential combination of these benefits are likely to be important for the improvement the resilience of small holder systems. Trees also provide economic benefits either directly, through provision of fruit or timber products, or indirectly through better shade and shelter provision and limiting damage to crops or livestock. The addition of shade trees in Vietnamese coffee systems is an example of how agroforestry can provide significant returns for some commercial crops (Binh, 2005).

Collectively these benefits are often referred to as ecosystem services. The Millennium Ecosystem Assessment (MEA) (2005), categorised ecosystems services into four groups: supporting services (which included soil formation, long term nutrient cycling, primary production); provisioning services (the supply of food, fresh water, fuelwood, fibre, biochemicals and genetic resources); regulating services (which included climate regulation, disease regulation, water regulation and water purification); and finally cultural services (which captured the spiritual and religious, recreation and ecotourism, aesthetic, inspirational, educational, sense of place and cultural heritage values associated with ecosystems). A number of studies have captured the many different ways that agroforestry systems contribute to the enhanced provision of ecosystem services. Some examples of this are set out below:

- The addition of trees into agroecosystems is an important tool for addressing climate change, not least by slowing deforestation (see, for example, MEA, 2005, Swinton et al., 2007; Palacios Bucheli and Bokelmann, 2017). Shaded agroforestry systems are a good example, with a number of studies highlighting their value as an adaptation mechanism for climate change (Philpott et al., 2008a; Lin, 2011).

Significant levels of carbon sequestration (4.38 tC ha^{-1} yr^{-1}) can be achieved through conversion of grassland to silvopastoral systems in tropical regions (Feliciano et al, 2018).

- Agroforestry provides fundamental benefits to soil health by increasing soil biodiversity, increasing the supply of nurients and limiting soil loss compared to other agricultural and forestry systems (Nerlich et al., 2013; Torralba et al., 2016; Hernandez-Morcillo et al., 2018). Agroforestry can also contribute to increased resilience. For example, in the Pacific dry sub-humid region, intercropping trees with crops improved soil water infiltration and improved drought coping strategies. Contour-based cropping systems reduce soil loss 30-60 % in first year and up to 72-98 % by the third year in Thai Lan (Hilger et al., 2012).
- Agroforestry has been proven as a technology for restoring of forest and degraded lands (Appanah et al., 2015; Rahman et al., 2015). Planting trees on degraded land in Uzbekistan provided superior biomass growth, up to 11.0 t ha^{-1} of utilizable aboveground dry matter (Khamzina et al., 2006).
- Agroforestry can provide food security through provision of fodder, fruit and through the use of fertilizer trees (Kiptot et al., 2014), or planting trees on farm in multi-layered and intercropping systems (Mbow et al., 2014). Agroforestry plays an important role in improving food quantity and nutrient provision by diversifying food products (Place et al., 2009; Maliki et al., 2012). Positive correlation between nutrition for children and tree cover has been found by Ickowitz et al., (2014). Krishnamurthy (2017) found that silvopastoral systems with legume trees such as Prosopis spp. and Leucaena spp. were important for improving animal production in semi-arid regions. The trees build resilience by contributing to increased forage productivity and reduction in heat stress in the animals.

Globally increasing awareness of these benefits provides a strong basis for considering agroforestry as a significant option to address the many significant environmental problems associated with smallholder farming systems (Mowo et al., 2012). Historical intensification of smallholder systems has led to significant land degradation, habitat decline, water pollution, and feeds in climate change (Firbank et al., 2007; Brawn, 2017; Edenhofer, 2015). Agroforestry offers a potential adaptation mechanism that could be integrated into more conventional practices such as shifting cultivation or intensive monoculture to address these issues. Indeed well-designed agroforestry systems have been demonstrated to provide more sustainable ecological, economic and social benefits (Nair, 1993; Sinclair, 1999; Mosquera-Losada et al., 2009, Kalaba et al., 2010; de Foresta et al., 2013). For example, one study suggests that adding trees on farm contributes to climate change mitigation by providing 200 million tons of carbon annually to global agricultural lands (Zomer et al., 2016). As the evidence base expands around these environmental benefits agroforestry is increasingly seen as a promising option for achieving many of the United Nations Sustainable Development Goals (Waldron et al., 2017).

1.1.1 The shift to an 'Options by Context' approach for agroforestry

Despite acknowledgement of these benefits agroforestry adoption lags somewhat behind the rhetoric (Coe et al, 2014; Coe et al., 2019). Recent research suggests that the performance of many agroforestry systems varies hugely across areas where it has been implemented (Vanlauwe et al., 2019). This variation is driven, in part, by the heterogeneity of farmer circumstances i.e. variation in their social, economic and ecological context (Smith-Dumont et al., 2019). The lack of understanding of how these contextual variables influence adoption has been identified as a critical knowledge gap in agroforestry development.

World Agroforestry has been at the forefront of developing methodologies that both support farmer innovation associated with agroforestry and that result in appropriate recommendations for large areas and numbers of farmers (Sinclair and Coe, 2019). This has led to the development of the 'option by context' (OxC) methodology which is behind a fundamental rethink of how agroforestry systems that address food security are designed and developed.

At the core of the approach is the acknowledgement that agroforestry is context specific. What works on one farm might turn be less effective on a neighbouring farm. An analysis of agroforestry adoption led to the development of a novel 'research in development' (RinD) approach to address fine scale variation in farmer context constraining spread of innovations (Coe et al, 2014).

1.1.1 The case for agroforestry in Vietnam

Smallholder farms play an important role in food production in Vietnam, providing more than 70% of the food production but at the same time suffer from food insecurity and are subject to rapid change in their context (Ricciardi et al., 2018). Economic, social, environmental and political conditions for smallholder farmers are increasingly under pressure from climate change, urbanisation and population increase (Andersson, 2018).

These conditions have channelled many smallholder farming systems into patterns of more intensive monocropping. In many parts of Vietnam this has resulted in land degradation, biodiversity decline and reduced yields. Similarly, other practices, such as burning crop residue and over application of fertilizer, have caused increasing green-house gas emissions (GHG) and poor soil fertility (Mukul and Herbohn, 2016; Hung et al., 2017.).

In Southeast Asia, upland areas contribute to 19 % of the total land area and 27 % of agricultural production takes place in these areas (Dixon et al., 2001). Smallholder systems have suffered from the negative environmental impacts of agricultural expansion and intensification on areas with steep slopes. In addition, Southeast Asia is known for very high rates of deforestation; approximately 1.2% of forest cover is removed annually (Brown and Zarin, 2013). In Vietnam forest covered approximately 14.3 million hectares or 43 % of the total land area in 1943. By 1990 it had dropped to 9.1 million hectares or 27 % of the total area. Over the past forty-seven years, almost 36 % of forest areas (5.2 million hectares) have been destroyed (Sam, 1994; Ministry of Natural Resources and Environment (MONRE), 2010). The main drivers for this were complex and varied across different eco-regions in Vietnam. The primary causes were the recent conflicts in Vietnam, continued logging and an increase in State Enterprises activities (Gomiero et al., 2000) combined with different levels shifting agricultural practices by ethnic minority groups, agricultural expansion, forest product collection and illegal logging (de Koninck, 1999). This practice covered 3.5 million hectares in Vietnam's mountainous provinces in 1989 including the area selected for this study. After 1992, forest cover rapidly recovered up 13.78 million hectares (equivalent to 41.6 % of total land area) in 2018 (Ministry of Agriculture and Rural Development - MARD, 2019) thanks to reforestation programs, forest plantation and forest protection for natural regeneration (Food and Agriculture Organization of the United Nations - FAO, 2015). A recent report by MONRE (2010), attributes approximately 50% of forest loss to shifting cultivation.

Shifting cultivation in Vietnam was a common practice before 2000 primarily practiced by ethnic minority groups. The biggest group practicing shifting cultivation is the H'mong with 523,420 people in 1989 (Sam, 1994). They are mainly located in the Northwest region which also accounts for about 50% of shifting cultivation area of the country (Vien, 2001). Although shifting cultivation practices provided the main source of food for these communities it was also thought to be responsible for serious environmental impacts including high levels of soil erosion (Sam, 1994).

Forest policy in Vietnam has looked at ways of reducing shifting cultivation to restore forest land and improve biodiversity in upland areas. This has been difficult due to a number of reasons: working in upland areas is difficult due to barriers associated with overcoming traditional forms of cultivation practice; low educational levels among many ethnic people, and rural population increase. All these problems forced policy to rethink about to modify cultivation practices to find more sustainable alternatives. A small number of studies have shown how innovation associated with upland agroforestry systems can contribute to smallholder livelihoods while improving carbon storage, water and soil quality and controlling soil erosion (Joshi et al., 2003; Tata et al., 2008; Roshetko et al., 2017). A number of alternative solutions for smallholders were provided by adding trees in the landscapes such as farm – based plantation (Sandewall et al., 2010), or tree-based farming systems (Hoang et al., 2017, Hung et al., 2017) with the aim to improve vegetation cover and enhance livelihood income. These offer a potential pathway with agroforestry to meet the challenges faced by farmers in Northwest Vietnam.

1.1.3 The current extent of Agroforestry in Vietnam

Whilst it is likely that agroforestry has been present in Vietnam for a very long time it has not been systematically assessed at all (Binh, 2005; Khoa et al., 2006). Khanh et al., (2009) used the ICRAF definition of agroforestry (Nair, 1993) to begin describing the various types of agroforestry systems found within Vietnam. The classification was primarily at the national and provincial scale with limited detail provided at the sub-provincial levels. The woody components of reported agroforestry systems were limited to timber trees, coconut and bamboo. One example is annual crops intercropped with timber trees in forest land. At national level, agroforestry systems were classified by ecological zones including coastal regions, river deltas and mountainous regions. The extent of agroforestry was estimated by the percentage of tree-based areas over the agricultural areas of the eco-regions (Khoa et al., 2006).

The history of agroforestry development in Viet Nam was described in a recent study by Hoa and Catacutan (2012). The study showed that from 1960 to 1990 using landscape scale assessments that agroforestry had been practiced widely across the country. This fell into distinct categories:

- Under traditional models of forest - garden – fishpond – livestock or garden – fish pond – livestock without forest (VAC) in the lowland.

- At field level, home garden with fruit trees, perennial tree-based alley cropping systems were very popular.

Between 2000 and 2004 there has been an expansion of forest gardens with the support of reforestation programs in the north and taungya system of annual crops and fruit or timber trees in central Vietnam. After 2004, taungya and alley cropping systems were expanded to other regions of the country as an objective of afforestation programs. Hoang et al. (2013) highlighted that short-term intercropping agroforestry had become more popular in the mountainous areas where maize or cassava was mixed with perennial crops.

The agroforestry database maintained by ICRAF Vietnam online database (ICRAF, 2014), identifies eight tree-based systems that are relatively common across the country. These eight agroforestry systems were promoted by the Vietnamese government for a long time and provide both environmental and economic benefits. Each system is built up around a different tree species including *Acacia spp*. (*Acacia mangium* and *Acacia hybrid*), rubber (*Hevea brasiliensis*), coffee (*Coffea arabica* and *Coffea robusta*), cashew (*Anacardium occidentale*), tea (*Camellia sinensis*), macadamia (*Macadamia integrifolia*), melaleuca (*Melaleuca cajuputi*) and mangrove (*Rhizophora spp.*)

The economic benefits of Vietnamese agroforestry systems have been captured in a few studies (Khoa et al, 2006). For example, taungya systems which combine woodlots on hilltops with upland rice in the middle and fruit garden in the foothills provided 90 - 110 USD/ha/year from the sale of wood, 1-2 ton of rice/year and 60 - 180 USD/ha/year from the sale of fruits and livestock. In lowland systems, forest gardens can provide income from bamboo (600-800 trees/ha), cassava (20 ton/ha/year) and beans (250 kg/ha/year). In wetland agroforestry systems in the Mekong River Delta, agroforestry based on combinations of mangrove and shrimps provide 650- 770 USD/ha/year (after twelve years). These demonstrate that well designed agroforestry systems can provide real livelihood benefits. Based on these findings a number of development projects and studies have been implemented to promote agroforestry. Examples include the agroforestry project in Quang Nam (FAO, 2008), a DANIDA-funded project implementing cardamom under forest canopy and taungya system with eucalyptus with soybean and groundnuts in Dien Bien (Simelton et al., 2015). Coffee agroforests with avocado, pepper and durian in Central Highlands doubled income compared to coffee monoculture (Phuong, Hoa and Phong, 2017).

Despite these advances there remain some significant gaps in knowledge associated with characterising agroforestry systems more generally in Vietnam. For example, a recent study by Khoa et al. (2006) attempted to identify the state and current presence of agroforestry but was only able to summarize the areas of potential land uses for agroforestry development. These land use types were annual crops, shifting cultivation, home garden, perennial crops, grazing land and aquaculture. Similarly, other studies (Khoa et al., 2006; Khanh et al., 2009) were only able to successfully characterise the types of agroforestry practices and outline their economic benefits but were unable to identify their accurate location, areas and changes by time.

The reasons for this are complex. Agroforestry classification is not an agreed science and a number of different classification systems exist (Lundgren and Raintree 1982; Nair, 1993; Sinclair, 1999; den Herder et al., 2017). In addition, whilst the concepts of agroforestry are often familiar to farmers and 'agroforestry' is practiced by smallholder farmers over the world as part of shifting cultivation systems, home garden or in multi-layered intercropping systems the term itself is not generally well understood by many farmers (Simelton et al., 2015). The broad range of classification systems available, combined with farmer confusion about the term can make it hard to define what agroforestry is clearly enough to map its extent within a specified context let alone to identify potential areas for further adoption. Indeed, there is very limited data on the extent of agroforestry systems available globally. The FAO land use database have been used to estimate agroforestry coverage in tropical and sub-tropical countries (Hall, 2001). Kumar et al. (2014) quantified the practices and distribution of agroforestry globally based on literature review using the definition and classification of Sinclair (1999). Another attempt is mapping tree outside forest (de Foresta et al., 2013) using statistical land use data to identify the areas of tree outside forests which are much similar to agroforestry practices based on its classification. Zomer et al. (2009 and 2014) used remote sensing data at 1km x 1km resolution to identify the presence of trees on agricultural land. Although the resolution is low, the study highlights the agricultural areas with tree cover in the global. At finer resolution the AGFORWARD project quantified and mapped the area of agroforestry at a European scale using the geo-referenced LUCAS (Land Use and Land Cover) dataset (den Herder et al., 2017). Most, if not all, of these studies are based on statistical data with different classifications of agroforestry and lack of accurate location of existing agroforestry practices. In other words, the results are not geo-referenced and do not provide information of system components.

Different definitions and classifications have made the overlap in estimating agroforestry areas because some systems can be found in other types. The results of the studies at different scales are difficult to compare due to the different classification. There is a need to develop mapping protocols that provides strategic assessments of existing and potential agroforestry systems in Vietnam over a range of operational scales.

1.2 Agroforestry for livelihoods of smallholder famers in Northwest Vietnam (AFLi)

This PhD research is embedded within the ICRAF led Agroforestry for livelihoods of smallholder famers in Northwest Vietnam (AFLi) project. The overall objectives of the project were to improve the performance of smallholder farming systems in northwest Viet Nam through agroforestry. The project is administered by ICRAF Viet Nam, with support from the Australian Centre for International Agricultural Research (ACIAR) working with local partners in the Northwest region.

In the first phase of the project (2012 - 2016) agroforestry trials were established in collaboration with farmers, researcher & extension workers. Within the first phase project brief are the following specific objectives:

- To develop best-practice agroforestry systems for three agro-ecological zones (< 600 m, 600 - 800 m and > 800 m).
- To improve the availability of high-quality germplasm to enable the expansion of agroforestry systems.
- To enhance market access and opportunities for adding value to agroforestry products.
- To improve extension methods and policy dialogues for successful dissemination of agroforestry systems

The phase II of the project "Developing and Promoting Market-based Agroforestry and Forest Rehabilitation Options for Northwest Vietnam – AFLI-II" (2017 - 2021) targets the following objectives:

- Quantify and evaluate generic agroforestry options and tree species to promote investment agroforestry.
- Understand the suitability of different agroforestry options to different contexts and develop markets and policy to scale up adoption.
- Understand the ecological and economic values of degraded forests and co-develop forest rehabilitation methods with local communities to enhance them.

- Understand drivers of land use change and develop cross-sector planning approaches for landscapes that integrate forest and agroforestry land uses; and
- Develop local capacity for agroforestry, forest rehabilitation and integrated landscape management.

The project hoped to broaden the knowledge on agroforestry. It will bring new insights about how smallholder farmers make decisions on tree planting and adopting new production systems. Alongside recommendations for soil erosion (a primary focus of this PhD), research has been conducted on water and agro-biodiversity conservation, conservation of indigenous species and establishment of methods to minimize landscape fragmentation.

Project national partners:

In Vietnam the project was administered and run by World Agroforestry (ICRAF) in direct partnership with Department of Agriculture and Rural Development in Son La, Dien Bien and Yen Bai provinces (DARD). In AFLi I (2012- 2016), the Forestry Science Centre for Northwest (FSCN) and Tay Bac University (TBU) were in charge of implementing agroforestry trials and collecting soil loss data. In AFLi II (2017 - 2021), DARDs continued providing support on transferring techniques to farmers through their strong network of extension workers. Southern Cross University (SCU) provided support on forest rehabilitation activities and development of agroforestry curriculum within TBU. Northern Mountainous Agriculture and Forestry Science Institute (NOMAFSI), Soils and Fertilizers Research Institute (SFRI) and Vietnam Academy of Forest Sciences (VAFS) and the Forestry Science Centre for Northwest (FSCN) were responsible for implementing and maintaining agroforestry exemplar landscapes while Vietnamese Academy of Forest Sciences (VAFS) was in charge of integrated landscape management.

1.3 Problem statement

Integrating multifunctional agroforestry systems into degraded landscapes has the potential to build more resilient livelihood systems. Developing agroforestry capacity in Vietnam requires a base line understanding of what agroforestry systems exist, what their primary benefits are and areas where these benefits can be transferred easily to other systems to meet specific livelihood needs. Some agroforestry practices exist for short periods of time i.e. before the trees' canopy close. Similarly, some types of agroforestry are present only during the early stage of industrial crop plantation or planted forests. Because of its diversity and complexity, agroforestry is often invisible in the official land use maps and hence, it is almost impossible to identify the potential areas for agroforestry development based on available data sources. Therefore, there is an urgent need to map the potential expansion space for promising agroforestry options in degraded areas (in particular in the Northwest region of Vietnam which is subject to very high levels of erosion associated with deforestation). The resulting outputs would be useful for policy makers, researchers and farmers who needs a reliable source of knowledge to underpin agricultural development (including agroforestry expansion) in Vietnam in Vietnam.

A major challenge towards achieving this practice is the associated problems of mapping the extent of agroforestry systems (as outlined above). Although agroforestry has a long history and exists in a wide range of practices in Vietnam, there is little documentation available on the spatial and temporal extent of smallholder agroforestry systems in Vietnam **(**Huy and Hung, 2012**)** – and thus all studies look at potential expansion have no baseline. This is not only a challenge for agroforestry research in Vietnam but also a gap in global agroforestry knowledge since most of global and national land use statistical data do not include agroforestry. Some types of agroforestry, such as taungya systems, are primarily found in forested areas whereas others, such as alley cropping, are primarily found in agriculture areas. (Rudebjer et al., 2005**).** Moreover, there is a gap in agroforestry planning since agroforestry has been applied as a replacement of existing land uses which were less productive instead of finding suitable locations (Huy and Hung, 2012). In order to scale up agroforestry practices successfully, a context should be assessed at a wide range of social, economic and ecological factors. Farmer are being considered the central factor for agroforestry adoption (Roshetko et al., 2017). Farmers' preference, knowledge and culture are important factors in the adoption process while gender plays an important role in decision making process on agroforestry adoption. Gender influences the evaluation of risk in new technologies (Villamor et al., 2014). Studies have highlight different priorities between men and woman for example Kiptot and Franzel, (2011) showed that women's concerns were primarily about soil conservation and food for the households while men considered financial implications first when considering adopting new agroforestry options. Beside a few limited studies from ICRAF Vietnam on gender such as Villamor et al., (2014), and Catacutan and Naz (2015), the understanding on the role of gender in agriculture and agroforestry adoption for ethnic smallholder farmers in the Northwest is still limited.

Once other areas of current existing agroforestry are identified, context mapping can be used to further identify potential domains for agroforestry expansion as an alternative option to improve eroded and degraded land. In addition, tree suitability mapping can help to define the most suitable species for development of context appropriate agroforestry designs. A critical component of this is appropriate assessment of ‘context’(Coe et al 2014) which should be assessed across a wide range of social, economic and ecological factors.

1.4 Research study site

This PhD is embedded in the “Agroforestry for Livelihoods of smallholder farmers in Northwest Vietnam” (AFLi) project delivered by ICRAF Vietnam (see section 1.5). Both the wider project, and the PhD specifically were implemented in three provinces in the Northwest region: Dien Bien, Son La and Yen Bai (See Figure 1.1).

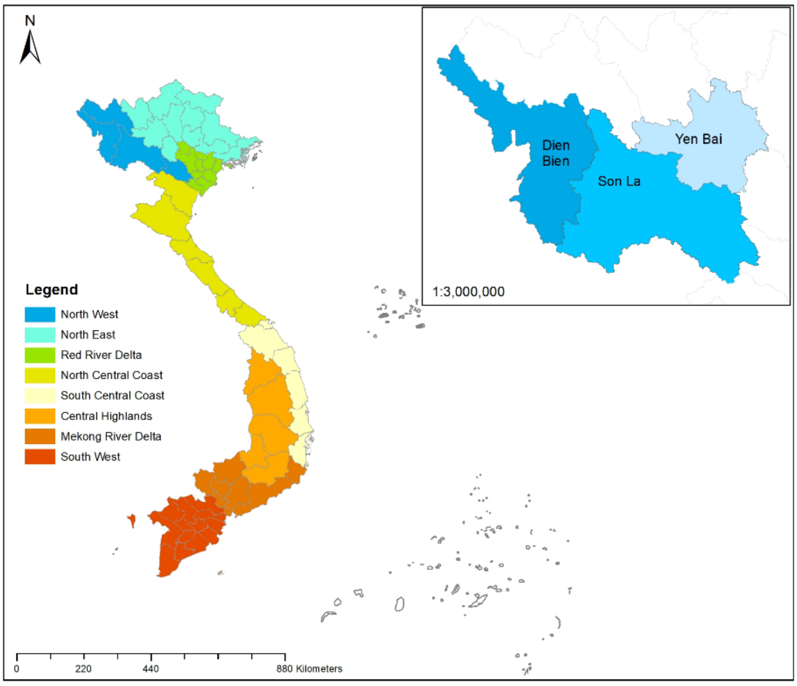


Figure 1. 1: Map showing the eight ecoregions of Vietnam with the inset map showing the location of the principal study areas of the thesis in the Northwest region of Vietnam

The northwest of Vietnam (21^{o}–23^{o}N and 103^{o}–105^{o}E) is one of eight eco-regions in Vietnam. It includes the provinces of Son La, Dien Bien, Lai Chau, Hoa Binh and Yen Bai. It is the most mountainous, remote and poorest area of Vietnam. According to Ministry of Labour, Invalids and Social Affairs (MOLISA) (2019), the rate of poor households was nearly five times as high as the national average with 24.25 % and 5.23 %, respectively. The Northwest holds about 15% of the total population which includes 3.4 million people belonging to 30 ethnic groups. These include the Thai, Kinh, H'mong, Muong and Dao ethnic groups (General Statistic Office -GSO, 2009). Official records suggest that forest cover accounts for more than half of the area, although the eco-region is subject to severe deforestation, land degradation and soil erosion. In addition, the region is prone to extreme weather such as landslide, drought, frost, and hailstorms which significantly affect agricultural production and economic development (World Bank, 2010).

1.4.1 Detailed site characteristics

The study sites were located across seven districts in three provinces of Northwest Vietnam, specifically Tua Chua district and Tuan Giao district in Dien Bien province, Thuan Chau district, Bac Yen district, and Mai Son district in Son La province and Van Chan district, and Tram Tau district in Yen Bai province. These districts cover all the elevation ranges, land use types which are utilised by the three main ethnic minority groups of the region.

Dien Bien province is a mountainous and frontier border area in the Northwest, has natural area of 9,526 sq.km of which more than 50% is located at over 1,000 m. Dien Bien has a monsoon climate with two seasons. The dry season lasts from October of current year to March next year, while wet season is from April to October. Average annual rainfall is 1,600-2,000 mm. Total provincial population is 587,000 (GSO, 2017). Within 21 ethnic groups, Thai is the majority which accounts for 42.2% of total provincial population, followed by H'mong 27.2%, and Kinh 19%. Dien Bien is famous for some agricultural and forestry products such as upland rice (*Oryza sativa),* maize (*Zea mays*), soybean (*Glycine max*), *Shan tea* (*Camellia sinesis*), Arabica coffee (*Coffea arabica)*, longan (*Dimocarpus longan*), plum (*Prunus salicina)*, peach (*Prunus persica*), H'mong apple - *son tra* (*Docynia indica*).

Son La province has an altitudinal range of 100 to 2,900 m above sea level. The topography is quite extreme with average slopes ranging from 25 to 30^o. The biggest plateau in Son La is Moc Chau where the climate is suitable for temperate vegetables and fruits. Average annual rainfall is 1,000-2,000 mm which is lower than Dien Bien and Yen Bai. With a typical tropical monsoon climate, Son La has dry and rainy seasons. The dry season lasts from November to April next year while the rainy season is from April – October. 80% of rainfall is from May to August. Son La is the second largest province of Vietnam with a total area of 14,100 sq.km. Son la has population of 1.195 million with 12 ethnic groups: Thai (55%), Kinh (18%), H'mong (12%), Muong (8,4%) and so on (GSO, 2017). Common agricultural and forestry products in Son La are timber (particularly teak wood (*Tectona grandis*), perennial crops (Arabica coffee (*Coffea arabica)*, sugarcane (*Saccharum barberi*) and *Shan tea* (*Camellia sinesis*), fruits including plum (*Prunus salicina)*, peach (*Prunus persica*), *son* *tra* (*Docynia indica*), mango (*Mangifera indica)* and other annual crops. Maize is the dominant crops on sloping areas.

Yen Bai province lies between the Northwest and Northeast region of Vietnam. The western part (also known as the highlands) of Yen Bai has characteristics similar to other Northwest provinces while the eastern part (the lowland) is more similar to the Northeast region. The highlands are typically above 600 m with steep slopes while the lowlands range from 0 to 600 m. Yen Bai has average annual rainfall is 1,600 – 2,100 mm, which is unevenly distributed during the year and between locations. The rainy season lasts from April to October and dry season lasts from November to March. There are significant differences in rainfall level between western and eastern areas of the province, meaning the western part has much less rainfall than the eastern. Total natural area of Yen Bai is 688,600 ha. Total population is 807,287 people (GSO, 2017), divided into 30 ethnic groups. The major ethnic groups are Kinh (40%), Tay (20%), Dao (7%) and H'mong (8%). Tram Tau district, which has typical characteristics of Northwest region, is home of H'mong people in the high elevations, Thai in the middle and Kinh in the lowland or the town. Van Chan district, which is locating on the eastern part, has higher rainfall level, lower elevation and more dominated by Kinh group due to the immigration policy from the River delta to the upland in 1976. Key agricultural and forestry products of Yen Bai are upland annual crops (mostly rice, maize, cassava (*Manihot esculenta*)), tea (*Camellia sinesis)*, orange (*Citrus sinensis*), acacia (*Acacia mangium)* and pine (*Pinus spp*.)

1.5 Research objectives and thesis structure

ICRAF's overarching goal in Northwest Vietnam is to integrate multifunctional agroforestry systems into the degraded landscapes to help build more resilient livelihood systems. Within this the aim of this study was to identify the potential for scaling out agroforestry options in relation to the local natural, socio-economic contexts of Northwest Vietnam with an explicit consideration of the social norms associated with ethnicity and gender. An underlying objective of the study was to provide a comprehensive analysis of key agro-ecological contexts and agroforestry options for smallholder farmers in the Northwest region. In particular the study sought to identify suitable agroforestry options that addressed soil erosion, reduced climate change and reduced poverty for local communities.

To meet this aim the PhD had four key objectives:

1. To map the potential domain for adoption of novel agroforestry systems faced by hill tribe populations and increased erosion threats associated and to identify suitable areas for agroforestry adoptions based on biophysical requirements.
2. To characterise the social dimension for pathway of agroforestry adoption for three main ethnicities in Northwest Vietnam
3. To provide an understanding on gender role in agroforestry adoption with a case study of H'mong community
4. To document local tree knowledge in coffees agroforestry and the potential for expansion.

The thesis structure is summarised in Table 1.1 below.

The central hypothesis proposed here is that using an 'options by context' approach will identify agroforestry systems that are both scalable and appropriate for addressing degradation and meeting livelihood needs in the agroecological systems of Northwest Vietnam

Table 1. 1: Thesis structure by chapters and objectives of the PhD

Chapter	Objectives	Principal methods deployed
1. Introduction	To review the current evidence base associated with agroforestry in Vietnam	Literature review
2. Mapping biophysical potential domains for agroforestry scaling up at North West region	To map the potential domain for adoption of novel agroforestry systems faced by hill tribe populations and increased erosion threats associated and to identify suitable areas for agroforestry adoptions based on biophysical requirements. This includes: • Mapping the extent of degraded areas • Mapping soil erosion risk within annual crop areas • Development of landscape suitability maps for agroforestry	Random forest modelling of cropland on slopes, soil erosion prevalence mapping using LANDSAT imagery and Land degradation surveillance framework (LDSF)
3. The impact of social and ethnic dimension on the pathway of agroforestry adoption for indigenous people in Northwest Vietnam	To characterise the social dimension for pathway of agroforestry adoption for three main ethnicities in Northwest Vietnam. This consisted of: • Characterising agroforestry adopters and non-adopters (with particular regard to ethnicity) • Capturing local perceptions on agroforestry adoption • Identifying constraints and opportunities on agroforestry adoption	Household survey tools, Agroecological Knowledge Tool (AKT)
4. Exploring opportunities and challenges in agroforestry adoption through the gender lens	To provide understanding on gender role in agroforestry adoption with a case study of H'mong community • Gender norms, roles and relationships and the differences between men and women, as well as the young and the old in the perceived challenges and opportunities in agricultural activities. • Recommendation to enhance the participation and contribution of women for the success of agroforestry adoption.	Gender-responsive participatory approaches

Chapter	Objectives	Principal methods deployed
5. Case study: Potential for coffee agroforestry system expansion in Northwest Vietnam	To document local tree knowledge in coffee agroforestry system and the potential for expansion of agroforestry systems with a case study: Coffee agroforestry systems in Northwest Vietnam • Characterisation of coffee agroforestry systems • Tree inventory in coffee agroforestry systems • Documenting ecosystem services and disservices that rural communities are associating with tree species • Ranking of tree species for different services in coffee agroforestry systems by different ethnic groups and gender	Household survey, pairwise ranking
6. Synthesis	• Overall discussion • Proposed integrated framework for scaling out adoption	

II. IDENTIFICATION OF POTENTIAL DOMAIN FOR AGROFORESTRY EXPANSION IN NORTHWEST VIETNAM

Abstract

Annual crop cultivation provides the most significant source of food for people living in the mountainous areas of Northwest Vietnam. This practice has caused serious erosion on sloping land which cover 75% total area of the region. Integrating agroforestry systems into these degraded landscapes has the potential to build more resilient livelihood systems. There are challenges with estimating the actual areas of land cultivated on slopes using existing land use data. This study used LANDSAT 8 satellite imagery, GPS ground truth points and Random forest classification algorithm to identify the probability of annual crops being present on sloping land in the study site as well as soil erosion prevalence. Suitability maps were then developed for a range of potential agroforestry options. Tree species were selected from existing high value timber and fruit species including H'mong apple – *son tra* (*Docynia indica*), *Shan tea* (*Camellia sinesis*), plum (*Prunus salicina),* macadamia (*Macadamia integrifolia)*, Arabica coffee (*Coffea arabica)*, teak (*Tectona grandis*), acacia (*Acacia mangium)*, mango (*Mangifera indica)* and longan (*Dimocarpus longan*). The results doubled existing estimates of cropland on steep slopes (above 25^{o}) in comparison with official reported data by Ministry of Natural Resources and Environment (MONRE) in 2010. Our study also suggests that 30% of cropland lies within land currently designated as forest. This result suggests that forest cover is currently being over-estimated by 15%. The biophysical suitability analysis shows agroforestry would be viable across approximately 85% of cropland areas where slopes are above 15^{o}. This suggest significant potential for expansion of agroforestry.

2.1 Introduction

The recent decades witnessed a growing concern over land degradation and its impacts on small holder livelihoods in Southeast Asia. Attempts have been made to assess the rate of soil erosion, change in soil organic carbon, nutrient imbalance (Food and Agriculture Organization, 2015), loss of biodiversity (Edwards et al., 2010) and understand the causes of land degradation (Douglas, 2006). One of the major causes of land degradation was the intensive cultivation of commercial crops (Fox, 2000). Agricultural expansion is also considered as the driver of deforestation in Southeast Asia (De Koninck, 1996). In many countries, traditional shifting cultivation has been transformed to permanent cultivation of cash crops due to the pressure of population growth and the provision of land ownership (Rasul and Thapa, 2003). Intensive permanent cultivation of cash crops on the same pieces of land without time for soil recovery has created significant levels of land degradation over the region. In these degraded areas, farmers have begun to find alternative options such as hedgerow planting and vegetative barriers (Fahlén, 2002) to reduce soil loss and improve soil quality and crop yield. There are also examples where trees and crops have been introduced in agroforestry practices driven by policy recommendation or driven by farmer experimentation (Nguyen et al., 2013).

Northwest Vietnam has high levels of rural poverty. The region is heavily focused on agricultural production. Levels of poverty in the region are high. This was assessed using the multidimension poverty index (MPI), which measures the percentage of households who cannot meet over a third of their five basic needs (specifically living conditions, income levels, access to education and health care, information, insurance and social assistance). For example, MPI scores of 37% were measured in Dien Bien and 25% in Son La in 2018, which is significantly higher than the national average of 5.2% (Ministry of Labor – Invalids and Social Affairs, 2019). The region is home to 3.4 million people and includes a broad number of ethnic groups including Thai, Kinh, H'mong, Muong and Dao (General Statistic Office, 2009). In Northwest Vietnam, pressure from a rapid increase in population between 1999 - 2010 (from which rose rapidly from 2.9 million in 1999 to 3.4 million people in 2009 (GSO, 1999 and GSO, 2009) and a government policy which banned rotational shifting cultivation led to static and more intensive crop monoculture systems. In upland areas where shifting cultivation still exists rotations have also been shortened to three years or less (compared with much longer rotations in the past). All these factors have combined to make soil erosion a significant (but seldom measured) issue in the region. Estimates of soil erosion on slash and burn areas of upland rice at 15-25^{o} of slope suggest figures of between 200-300 ton/ha were being lost per year and the thickness of soil layer had decreased by 1.5-3 cm/year (Bui 1990). Cropland on steep slopes in the Northwest are also highly prone to erosion and degradation. Cultivating maize on slopes under traditional practice (slashing, burning and ploughing) have caused soil loss up to 174 tons ha^{-1} yr^{-1} (Tuan et al., 2014). In comparison, reported annual soil loss in terraced paddy fields ranged from 0.163 to 1.722 tons ha^{-1} yr^{-1} (Mai et al., 2013).

Farmers have been growing maize and upland rice in the Northwest region for decades (Devendra and Thomas, 2002). Maize is critical to meet household level food demand. The official land use maps produced by MONRE currently capture only crop areas which lie outside any designated forest boundary. Hence, the actual areas of cropland, especially maize and rice on slopes, are likely to be greater than the official figures. Current uncertainty about current cropping areas makes it difficult to estimate the risk of environmental impacts and costs of tree restoration. Moreover, there is no widely used functional definition of “sloping land” which determines the gradient at which land is considered at risk.

Developing accurate maps for this type of environment is challenging. Remote sensing is increasingly the preferred approach for inventorying areas covered by annual crops such as maize, rice, cassava (Pittman et al. 2010). There are different methods to that can be used to classify satellite imagery including the ‘supervised method’ (including Maximum Likelihood (Hagner and Reese, 2007) and Principal Components Analysis (Richards, 1984)) which use training areas taken from the field to classify pixels into different objects. Unsupervised methods generate clusters of pixels into the set number of classes and then the classes are assigned to different land cover classes. Among those classification methods, Maximum Likelihood is the most commonly used method. Recently a new method (Random Forest) has been developed (Lee, 2015). The advantage of Random Forest model is that it is good for hyperspectral remote sensing data, working with individual data channels in the classification. (Gislason et al., 2006). The Random Forest algorithm has been proven as a good classification model for cropland and soil erosion prevalence in several studies in Africa (Vågen, et al., 2013; Vågen and Winowiecki, 2019) especially when compared with traditional equations such as Universal Soil Loss Equation (Wischmeier & Smith, 1962) and Revised Universal Soil Loss Equation (Renard & Ferreira, 1993) or Modified Universal Soil Loss Equation (Smith et al., 1984). The Land degradation Surveillance Framework (Vagen and Winowiecki, 2018) was developed by ICRAF in response to the need for consistent field methods and indicator frameworks to assess land health in landscapes. The framework utilises the Random Forest model and was developed as a response to a lack of methods for systematic landscape-level assessment of soil and ecosystem health. The methodology is designed to provide a biophysical baseline at landscape level, and a monitoring and evaluation framework for assessing processes of land degradation and the effectiveness of rehabilitation measures (recovery) over time. The framework has been applied in various projects across the global tropics and is currently one of the largest land health databases globally with more than 30,000 observations, shared at http://landscapeportal.org.

The Land Degradation Surveillance Framework provides an opportunity to capture the extent of soil degradation across the study area. This output can then be combined with biophysical suitability analysis to identify potential tree planting areas within high risk cropland areas.

The main objectives of this study were:

1. To provide more accurate maps of cropland on slopes in Northwest Vietnam,
2. To estimate soil erosion prevalence and
3. To develop suitability areas of for tree-based options.

2.2 Materials and method

2.2.1 Study sites

The study took place across three provinces (Dien Bien, Son La and Yen Bai) all located in Northwest Vietnam (21^{o}–23^{o}N and 103^{o}–105^{o}E), accounts for approximately 3 million hectares - see section 1.4.1.

Official figures for the three provinces show that forests, including natural forest and planted forest, occupy approximately half of this area. In 2018, estimations of forest cover in Dien Bien, Son La and Yen Bai were 40%, 43% and 63%, respectively (MARD, 2019). Official figures suggest that agricultural land, specifically annual crops, fruit trees, cash crops and grazing areas, accounted for 13 % of total area. The main food crops were hill rice, paddy rice, maize and cassava. The major cash crop in Son La is sugarcane. There is one maize crop in Son La and Dien Bien while farmers can do two maize crops in Yen Bai due to higher rainfall amount. Approximately 75% of all agricultural activities occur on sloping land (Siem, 1994). The remaining area (25%) consisted of settlement areas, infrastructure and water bodies.

The study sites consisted of seven districts across the three provinces, specifically Tua Chua, Tuan Giao in Dien Bien province, Thuan Chau, Bac Yen, Mai Son in Son La province and Van Chan, Tram Tau in Yen Bai province. These districts cover all the elevation ranges, land use types with three main ethnic minority groups of the region. The location of the seven districts are presented in Figure 2.1.

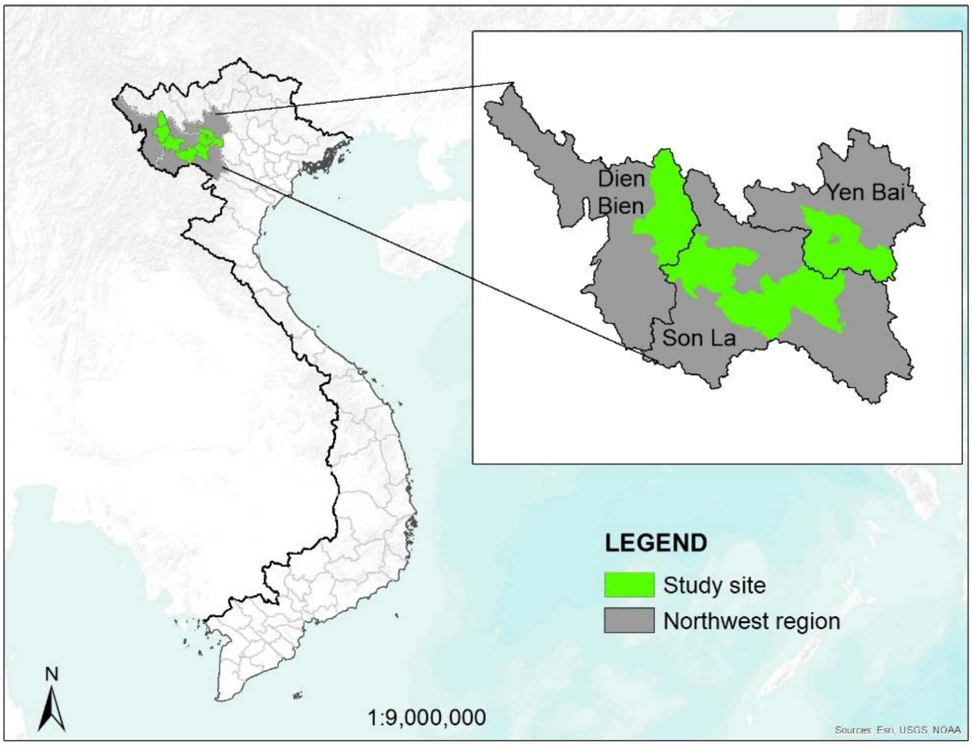


Figure 2. 1 Map of study area (Son La, Yen Bai and Dien Bien province)

2.2.2 Defining sloping area

According to FAO guidelines (2006) on soil description, land is considered 'sloping' at gradients between 10% to 30% (equivalent to 5^o - 15^o) and land is considered 'steep' above 30% (equivalent to values greater than 15^o). Khoa et al. (2006) and Thu (2010) have characterized and proposed agricultural interventions for sloping areas which is above 10^o and 8^o, respectively. In practice, farmers still cultivate up to 35 ^{o}. In this study four classes of sloping land were identified: i) Below 15 ^{o}; i) 15 ^{o} - 25^o; iii) 25 ^{o} - 35 ^{o} and iv) Above 35^o.

2.2.3 Mapping of annual crops on slopes

Cropland areas on slopes were identified using the Random Forest algorithm, adopted from Vågen et al. (2013). Whilst hill rice, maize, cassava are all grown in the study area this study focused on maize because it is the main food crop cultivated on sloping land.

2.2.3.1 Data collection

Maize data collection

Field sampling design was based on random stratified sampling within AFLi sites. First, 300 points were randomly selected from across the approximately 800,000 ha which made up the AFLi sites (see section 1.5). Road networks, river networks and settlement layers were used to remove points located at difficult to access areas which were either too far from settlement areas or roads or located in streams or rivers. We used field data for validating the classification model i.e. information on point coordinates, elevation and land cover were collected during field trips. Extra points of maize were collected close to the designed sample points to increase the accuracy of field data. The final number of field points was 434 GPS points which represented "maize area" (see **Error! Reference source not found.**).

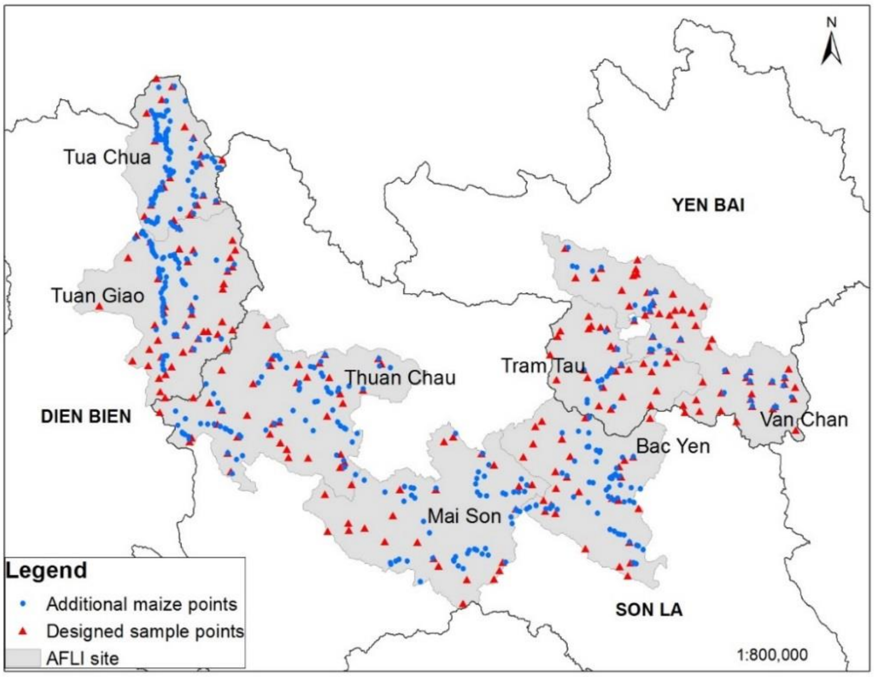


Figure 2. 2: Map of collected random field points of annual crops. The points in blue are the randomly designed sample points while the red points are the additional collected points

Additional crop data for model calibration and validation

The Land Degradation Surveillance Framework (LSDF) database was used to calibrate and validate the prediction model of annual crop mapping for Northwest Vietnam. The data was surveyed at 38 sites in Africa in the period 2009 to 2012 using the LDSF methodology

(Vågen et al., 2010; Vågen et al., 2012). 11,746 point of cropland extracted from LDSF database were combined with field data from Northwest Vietnam to make up the cropland dataset (N =12,222) which was used to train the classification algorithm to predict the presence of cropland.

Spatial data for model development

Landsat 8 is an America Earth observation satellite launched from 2013 with a mission to provide seasonal observation of the earth coverage at 30 m resolution for most of the bands, 100 m for thermal and 15 m for panchromatic band (NASA and United State Geological Survey, 2012). Landsat 8 satellite images acquired in February/March 2014 were used to extract the ground reflectance values for each point from cropland dataset as an input for the classification model. The output map was then compared to official land use map published by MONRE in 2010 at different slope classes for discussion. Slope classes was produced based on the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Digital Elevation Model (DEM) (Abrams and Crippen, 2019) (see Table 2. 1: Spatial data used for mapping annual crops).

Table 2. 1: Spatial data used for mapping annual crops

Data	Source	Date	Resolution
Landsat 8	NASA Landsat Program	February/March 2014	30 m x 30 m
Land use map	MONRE	2010	1:100,000 (resampled to 30 m x 30 m)
Slope	ASTER Global Digital Elevation Model (DEM)	2011	30 m x 30 m

2.2.3.2 Spatial prediction model of cropland presence

The classification model was developed in R studio and based on the training dataset of field data from LDSF global dataset (N= 12,222) and then related to satellite image reflectance. Independent training and test data were generated by randomly selecting 70% of the original data for model training and using the remaining independent random subset of 30% for validation. Field data from Northwest Vietnam are included in the validation dataset.

Satellite digital numbers (DNs) of each satellite image were converted to ground reflectance through radiometric calibration, atmospheric correction, solar radiance and solar zenith correction and then generate an archive of standardized surface reflectance (SRF) image. Input data for the model are reflectance values of band 4, band 6 and band 7 of LANDSAT 8 imagery to calculate the Soil Adjusted Total Vegetation Index (SATVI). SATVI is well known for recognizing both green and dead vegetation cover (Hagen, 2012; Torbick, 2016), therefore, it is more sensitive to maize in the Northwest Vietnam where maize residue is left on the field at the acquisition time of the image (in March). For Landsat 88, band 4, band 6 and band 7 are Red, SWIR 1 and SWIR 2, respectively. SATVI is calculated based on the below equation (Marsett et al. 2006).

$$SATVI = ((B6 - B4) / (B6 + B4 + 0.5))*1.5 - (B7/2)$$

Classification model used to predict annual crop prevalence was Random Forest classification models (Breiman, 2001; Svetnik et al., 2003) based on Landsat ETM + image reflectance bands. The calculation was implemented in R studio using Random Forest package.

Radiometric calibration, atmospheric correction, solar radiance and solar zenith correction were applied as the preparation of satellite data. After pre-processing steps, the cropland model was used to produce the probability of cropland prevalence. We took 80% as the threshold to identify cropland and non-cropland pixels. The pixels with probability values of cropland prevalence greater than 80% were assigned as "annual crops" in order to produce the final map of annual crops.

2.2.4 Soil erosion prevalence mapping

2.2.4.1 LDSF field data collection

The LDSF methodology was applied for field data collection in Mai Son district, Son La province in March 2018. In total, 10 clusters including 160 plots were sampled. There are 10 plots per cluster. Of those plots, seven were specifically within AFLi project activities with agroforestry systems being trialed from 1 – 5 years. The collected data have been uploaded to the ICRAF LDSF database. Sampling plots were designed following sampling method of LDSF field guide 2018. Data collected includes topography, visible soil erosion, vegetation structure and land use, cultivation method, tree and shrub diversity and soil samples. Soil samples were collected at two vertical depths (0–20 and 20–50 cm) at each subplot (n = 4) using a soil auger. Impact from ecosystem such as agriculture, grazing, fire and tree cutting were scored for each plot, based on methods adapted from Moat and Smith (2007) Soil samples are being preprocessed in Ha Noi and will be shipped to Nairobi, Kenya for laboratory analysis.

2.2.4.2 Prediction model for soil erosion prevalence mapping

Random Forest classification model and gradient boosting techniques were applied to classify land gradation risks with the inputs of Landsat ETM + image reflectance bands as predictors using SATVI index (See more details in 2.2.3.3). The model has been used to predict soil erosion prevalence in Africa with high accuracy (around 89% for detection) and high overall precision (Area under precision = 0.97) (Tor, 2019). 70% of plots from LDSF global dataset was used for model training. The remaining 30% of the dataset including field data from Vietnam was used for model testing and validating.

2.2.5 Biophysical suitability mapping

The biophysical suitability analysis was based on tree species being trialled in these districts as part of the wider AFLi project (ACIAR, 2016). The trees species were a) timber species including teak (*Tectona grandis*), acacia (*Acacia mangium*), b) cash crops including macadamia (*Macadamia integrifolia*), coffee arabica (*Coffea arabica*), Shan tea (*Camellia sinensis*), and c) fruit trees with plum (*Prunus salicina*), son tra (*Donycia. indica*), mango (*Mangifera indica*), and longan (*Dirmocapus longan*). Details of current biophysical conditions at the agroforestry trial sites under AFLi project are in Appendix 2.1.

2.2.5.1 Data collection

Biophysical suitability analysis requires two type of input data. The first set of data is six biophysical variables that can be mapped and available as presented in Table 2.2 below.

Table 2. 2: Variables and dataset used for biophysical suitability analysis

Variables	Source	Date	Resolution
Annual average temperature (ºC)	World Climate	1950-2000	1 km x 1 km (resampled to 30 x 30 m)
Annual average precipitation (mm)	World Climate	1950-2000	1 km x 1 km (resampled to 30 x 30 m)
Elevation (m)	ASTER	2000	30 m x 30 m
Slope (º)	ASTER	2000	30 m x 30 m
Soil map (FAO standard) *	Vietnam National Institute of Agricultural Planning and Projection (NIAPP)	2010	1:1,000,000 (resampled to 30 x 30 m)
Soil layer thickness (m) in three levels: 0-50 cm; 50-100 cm; Above 100 cm	NIAPP	2010	1:1,000,000 (resampled to 30 x 30 m)

* *Based on soil map, there are six soil types including Ferrasols, Humic Ferrasols, Rhodic Ferrasols, Acrisols, Gleysols and Arenosols.*

The second data input is the biophysical requirement for selected tree species specifically teak, acacia, macadamia, coffee, Shan tea, plum, son tra, mango and longan. The details of biophysical requirement and data sources are provided in Appendix 2.2

2.2.5.2 Multiple variable analysis

The analysis has been conducted using multiple variable suitability analysis in ArcGIS 10.2 software following method from Malczewski (1999), Kalogirou (2002). The suitability ranking was adapted from FAO method (1976). In this study, we assumed that the above six variables have the same weight. After overlaying six layers of variables in ArcGIS software, the suitability classes are set out in Table 2.3.

Table 2. 3: Classification of suitability ranking adapted from FAO (1976)

Suitability ranking	**Condition**
Suitable	All variables meet the most suitable condition or moderate suitable condition None of them belong to not suitable condition
Not suitable	Any of six variables belongs to not suitable condition

The suitability areas were then combined with the cropland map to identify the potential expansion domain of tree-based options in degraded land. The results are presented by elevation zones. Because elevation is the key variable of tree species suitability, the AFLi project sites were divided into five elevation zones including 0-300 m, 300-600 m, 600 - 800 m, 800 - 1000 m and above 1000 m. The zoning was the combination of elevation threshold for tree suitability and distribution of three ethnicities including Kinh (below 600 m), Thai (300-800 m) and H'mong (above 800 m).

2.3 Results

2.3.1 Mapping of annual crops prevalence

Based on the result of satellite image classification, we have selected the areas of annual crops (mostly maize) with the probability of cropland prevalence higher than 80%. Due to the unavailability of satellite images, the annual crop map covers 96% of total area of study site. Figure 2.3 shows the spatial extent of annual crops. Most of cropland areas were located in Son La and Dien Bien.

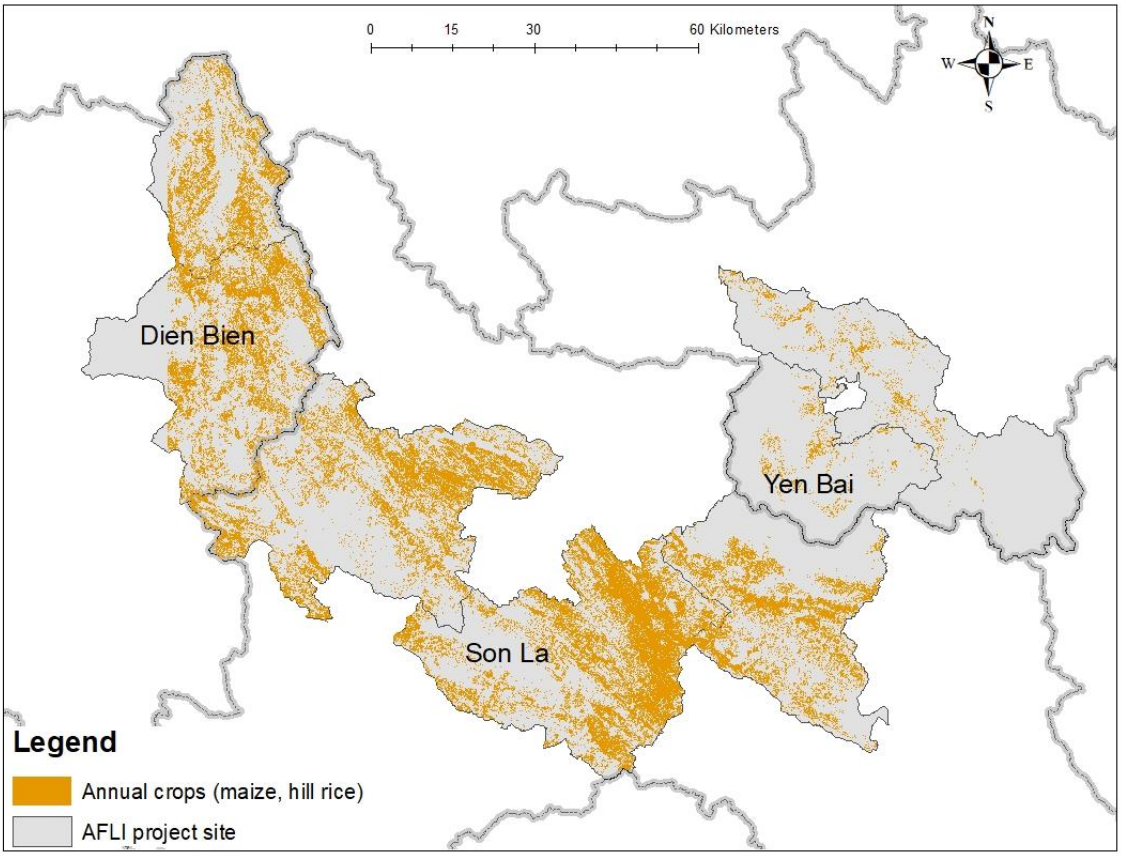


Figure 2. 3: Map of annual crops classified from Landsat 8 imagery in the AFLi project sites

Annual crops on slopes

On average, annual crops cover 25% of total area. Sloping land (above 15◦) accounts for 70% of total land area in Northwest Vietnam by calculation from Digital elevation model (DEM). More than half of study site falls in slope gradients from 15° – 35°. **Error! Reference source not found.** shows the distribution of annual crops among four slope classes including 0 - 15°, 15 - 25°, 25 - 35°, and above 35°. Annual crops (primarily maize) covers 23% of sloping land (above 15°) (approximately 130,000 ha) which are likely to be very prone to erosion. As the slopes increase, the cultivated cropland decreases. This is a significant increase from official map produced by the MONRE (2010) which states that cropland accounts for 14% of sloping land. Especially, the result shows the increase of nearly 10,000 ha of cropland on very steep slopes above 35° (See Table 2.4).

The analysis goes on to show that as slope increases, the similarity between the Landsat-based annual crop maps decreases. This explains the weak relationship of the two maps. On very steep slopping (land at above 35°), only 25% of cropland is identified as being at the same location as the MONRE maps compared with higher similarities (45%) on flatter land (0°-15°).

The Landsat data was generated in 2015 and the most updated available MONRE land use map was 2010 – this may also account for some variation.

Table 2. 4: Areas of Landsat-based cropland calculated from Random Forest model (2014), in comparison with official cropland from MONRE (2010)

Slope class (degree)	Study area (ha)	Area of Landsat-based annual crops (ha)	Percent of Landsat-based annual crops/study area (%)	Area of MONRE annual crops (ha)	Percent of MONRE annual crops/study area (%)
0-15	208,840	66,669	32	75,953	36
15-25	264,669	72,128	27	60,303	23
25-35	214,524	46,621	22	24,072	11
Above 35	104,492	13,983	13	4,762	5
All slope classes	**792,525**	**199,401**	**25**	**165,090**	**21**

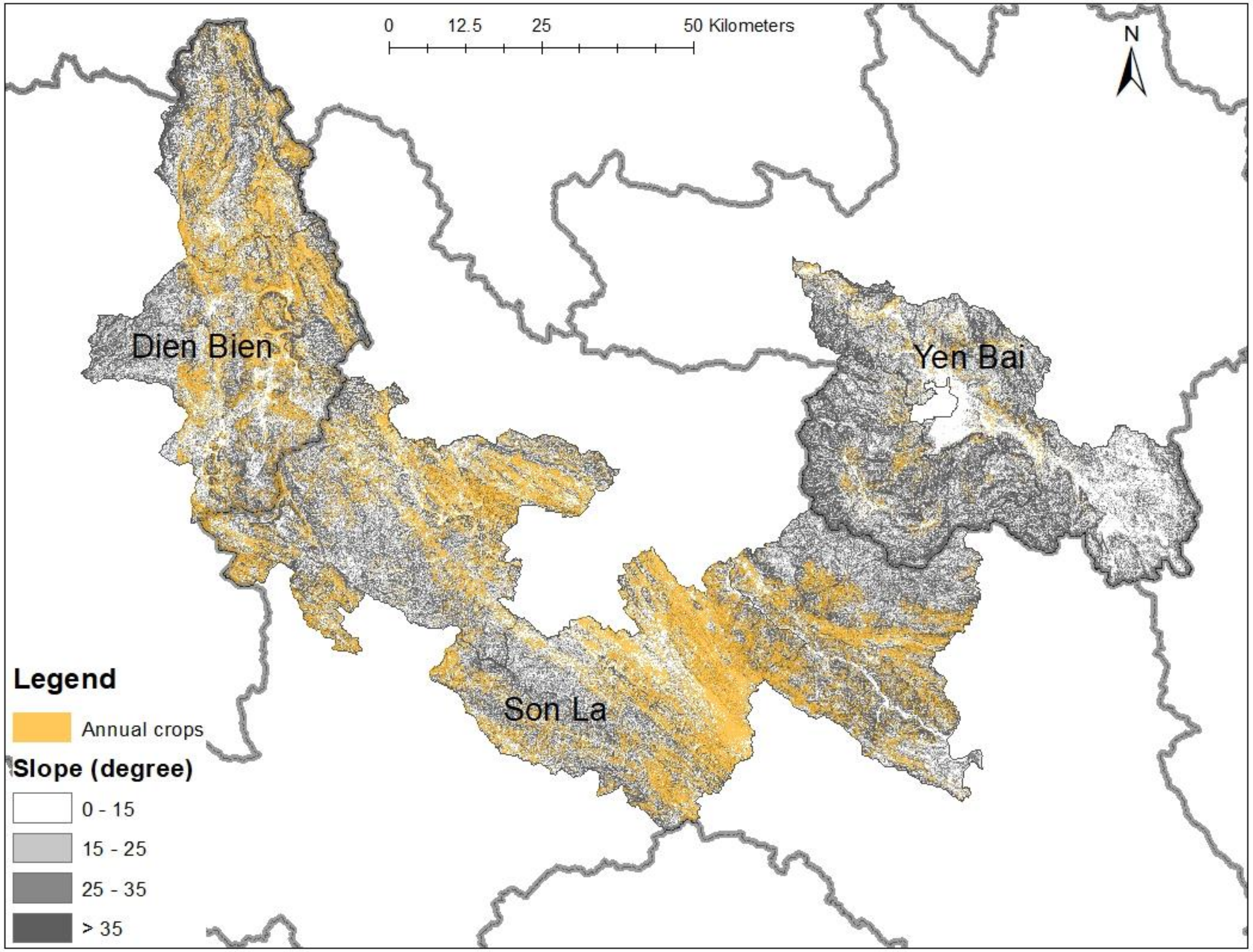


Figure 2. 4: Map of annual crops by slope class

Annual crops in forest land

Figure 2.5 shows the spatial extent of forests including natural forest and planted forest in 2010 from official land use map (MONRE, 2010). There was 30 % of cropland (equivalent to 63,000 ha) which lies within the forest designation defined in the MONRE land use map, meaning that the actual forest cover also included these cropland areas.

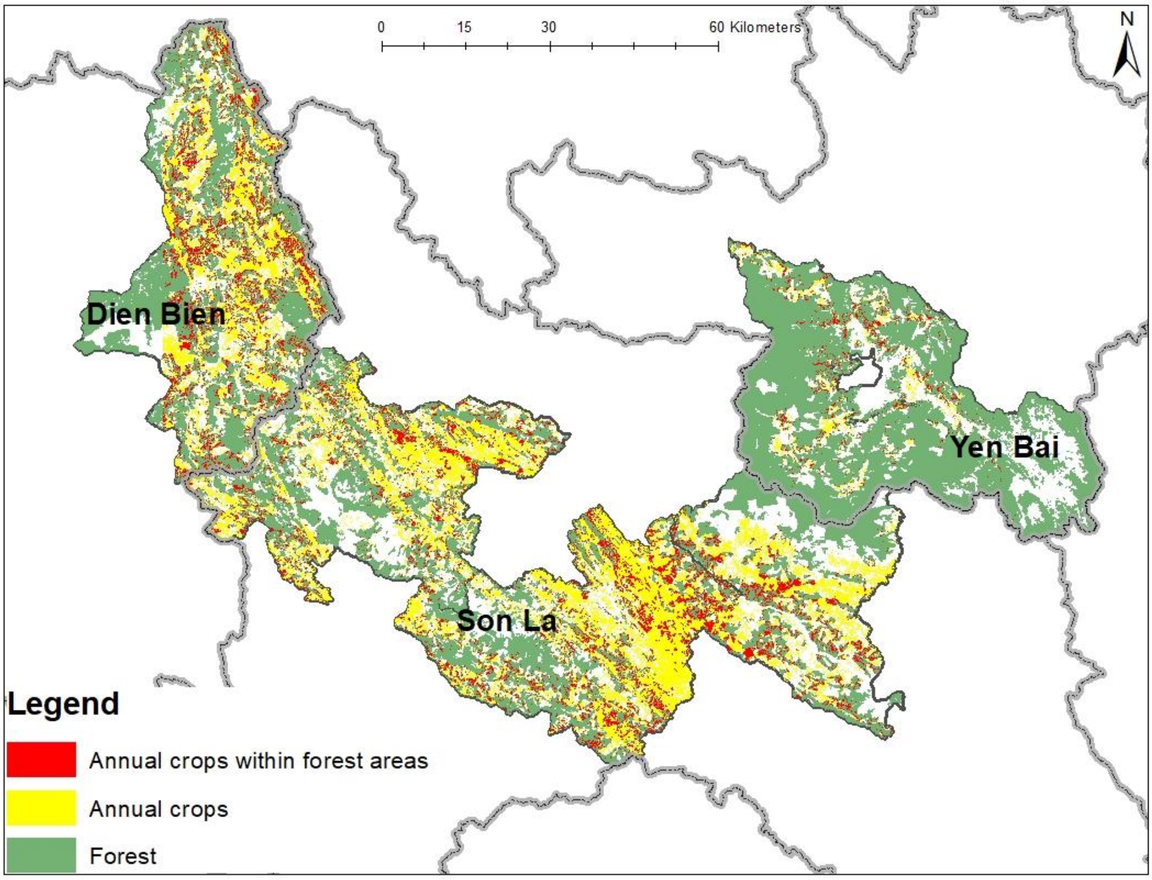


Figure 2. 5: Area of annual crops that are currently located in land officially classifies as forest land

2.3.2 Mapping of soil erosion prevalence

The majority land cover was identified as annual crops (85%) with the remaining plots classified as shrubland (8%) and bushland (7%). Visible erosion was recorded for 70% of sampled plots, all of them were annual crops on steep or medium slopes. Only 32% of the sampled plots had soil water conservation measures, indicating an opportunity for improved on-farm soil management interventions. Most of the LDSF clusters were located on sloping lands. Each cluster had ten plots and each plot consisted of four sub-plots. Only cluster number 8, 9 and 16 were on flat land, either in settlement areas or along the main roads. The recorded visible soil erosion in those clusters was much lower in comparison to the other plots. Severe soil erosion in the forms of sheet or gully erosion was present in all clusters except cluster number 8,9, and 16 (see **Error! Reference source not found.**). On average, soil erosion was recorded at 67% of plots across sixteen clusters in the site with 67% of these plots being subject to severe erosion). These data indicate that measures to curb soil erosion are needed. The most common form of soil erosion is sheet and gully. Another form of degradation is soil compaction.

Figure 2. 6: Visible erosion recorded by cluster (10 plots per cluster).

As a key indicator of land degradation, soil erosion prevalence was mapped using prediction model based on Landsat satellite imagery and LDSF data for seven districts of Northwest region. Initial result reveals that 2% of project site (16,500 ha) was under the highest threat of soil erosion (75%- 100%) while 27% of the area (215,500 ha) falls into the medium level of soil erosion prevalence (50% - 74%) (See **Error! Reference source not found.**)

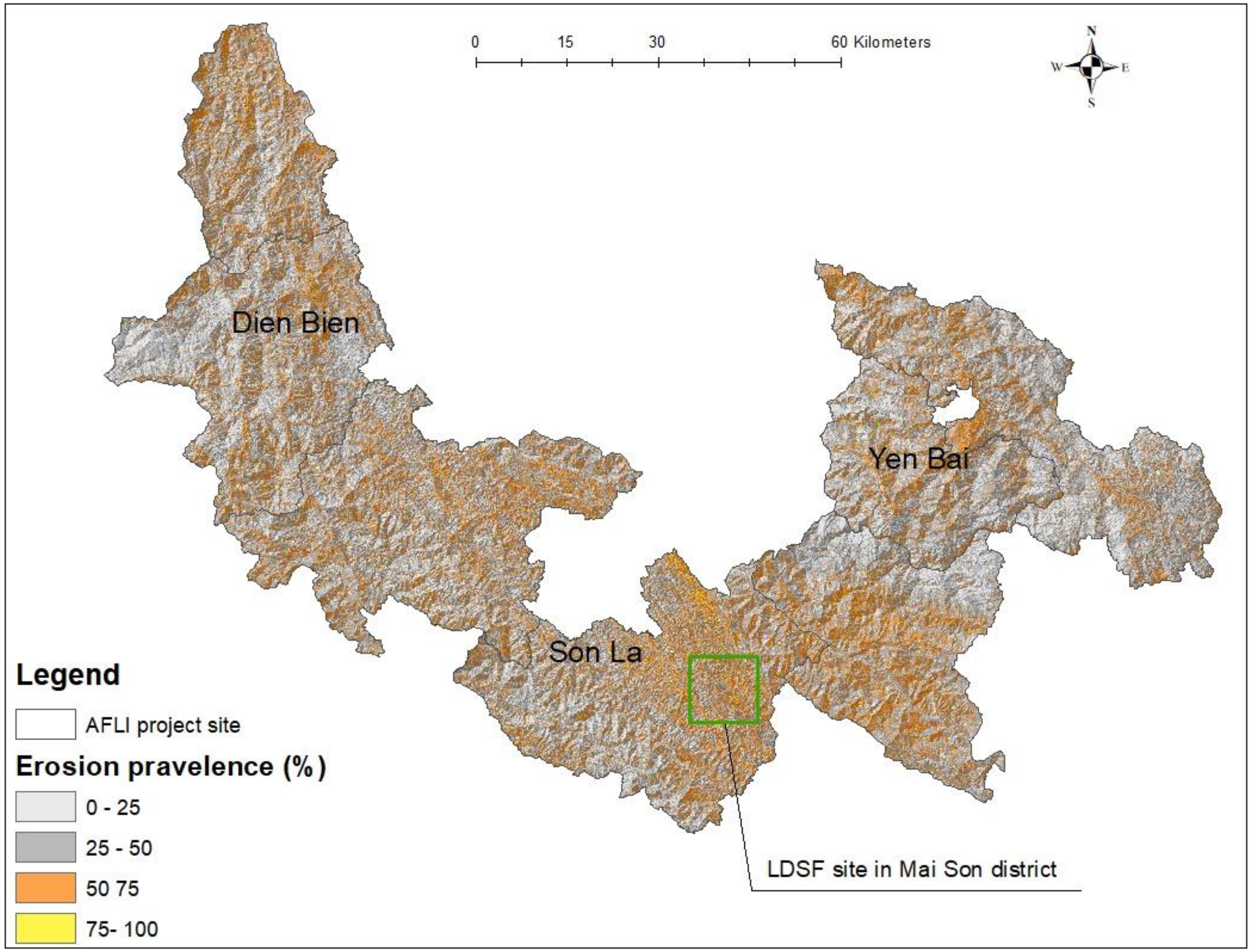


Figure 2. 7: Soil erosion prevalence in AFLi project sites in 2018

2.3.3 Tree suitability mapping combined with cropland on slopes

The potential expansion areas and tree-based options were identified by overlaying the biophysical suitability results with annual crops. In general, the suitable areas for integrating selected tree species as agroforestry options accounts for 85 % % of total cropland area on slopes (above 15o) over all slope classes. Table 2.5 provides suitable areas of possible options for integrating trees together as system with different species together are being promoted by local government and tested by AFLi project. Suitability areas of each species were combined to show the possibility for intercropping. For example, suitable area for growing only acacia and teak in Zone 1 were 420 ha, while the suitable areas for either acacia, teak, mango, longan or all four species in Zone 1 were 2,116 ha. It reveals the potential for intercropping in the overlap suitability areas. Zone 1 as the low land is suitable to only four species. Zone 2, at 300 - 600 m, has more tree options as macadamia and coffee grows from 300 m and 500 m above sea level, respectively. The largest suitable areas for agroforestry fall in middle elevation of zone 3 (600 – 800 m) and followed by zone 4 (800 – 1,000 m) and zone 5 (above 1,000 m). 600-800 m is also the area of Thai ethnic minority and above 800 m is the realm of H'mong group. The areas below 600 m are more suitable with commercial high value fruits including longan (*D. longan*) and mango (*M. indica*) while the areas above 600 m are more suitable with cash crops such as macadamia, coffee, Shan tea.

Table 2. 5: Suitability areas of tree-based options and tree combination possibilities and potential suitability areas in annual crop areas in sloping land by elevation zone, in combination with ethnic groups based on elevation ranges (in 7 districts of AFLi project sites)

Tree-based options	Suitability areas on maize sloping land (>15^o) (ha)	Ethnic group (T = Thai, K= Kinh and HM= Hmong)
Zone 1: 0-300 m	**2,536**	
Acacia- Teak	420	K
Acacia-Teak- Longan- Mango	2,116	K
Zone 2: 300-600 m	**19,046**	
Longan- Mango	**1,782**	**K, T**
Acacia- Teak	8,104	K, T
Acacia-Teak- Longan-Mango	7,000	K, T
Acacia-Teak- Longan-Mango-Macadamia	1,376	K, T
Acacia-Teak-Longan-Mango-Macadamia-Coffee	784	K, T
Zone 3: 600-800 m	**34,031**	
Longan	8,291	K, T
Acacia-Longan	17,250	K, T
Acacia-Teak	5,413	K, T
Acacia-Teak- Longan-Macadamia-Coffee	2,334	T
Longan-Macadamia-Coffee	743	T
Zone 4: 800-1,000 m	**27,829**	
Teak	2,462	T, HM
Teak-Macadamia-Coffee	1,170	T, HM
Plum	2,707	T, HM
Plum-Teak	2,530	T, HM
Plum-Macadamia-Coffee	2,849	T, HM
Plum-Teak-Macadamia-Coffee	2,881	T, HM
Shan tea-Plum	5,321	T, HM
Shan tea-Plum-Teak	5,076	T, HM
Shan tea-Plum-Macadamia-Coffee	733	T, HM
Shan tea-Plum-Teak-Macadamia-Coffee	2,100	T, HM
Zone 5: Above 1,000 m	**21,863**	
Plum	1,068	HM
Plum-Macadamia-Coffee	512	HM
Son tra	6,826	HM
Son tra-Shan tea-Plum	9,124	HM
Son tra-Shan tea-Plum-Coffee	2,696	HM
Son tra-Shan tea-Plum-Macadamia-Coffee	1,637	HM

Figure 2.8 presents the suitability areas for different tree species with agroforestry potential varied across the study area. This shows the total suitability areas of each species in crop land on slopes across all elevation zones. Acacia has the largest potential suitability area and was present in zones 1, 2 and 3 although it has low economic benefit. In the same areas, there are other choices with higher economic values such as teak, mango and longan in zone 1, macadamia and coffee in both zone 2 and zone 3. At higher elevations (zone 4 and zone 5) *Shan tea*, plum macadamia, coffee and son tra have greater potential. Of the timber species teak appears in three zones and has the second largest potential areas on cropland. Among those species, *son tra*, *Shan tea* and plum are indigenous species of H'mong farmers. Coffee was introduced in the region 30 years ago. Macadamia is even more recent having only been introduced in the last five years.

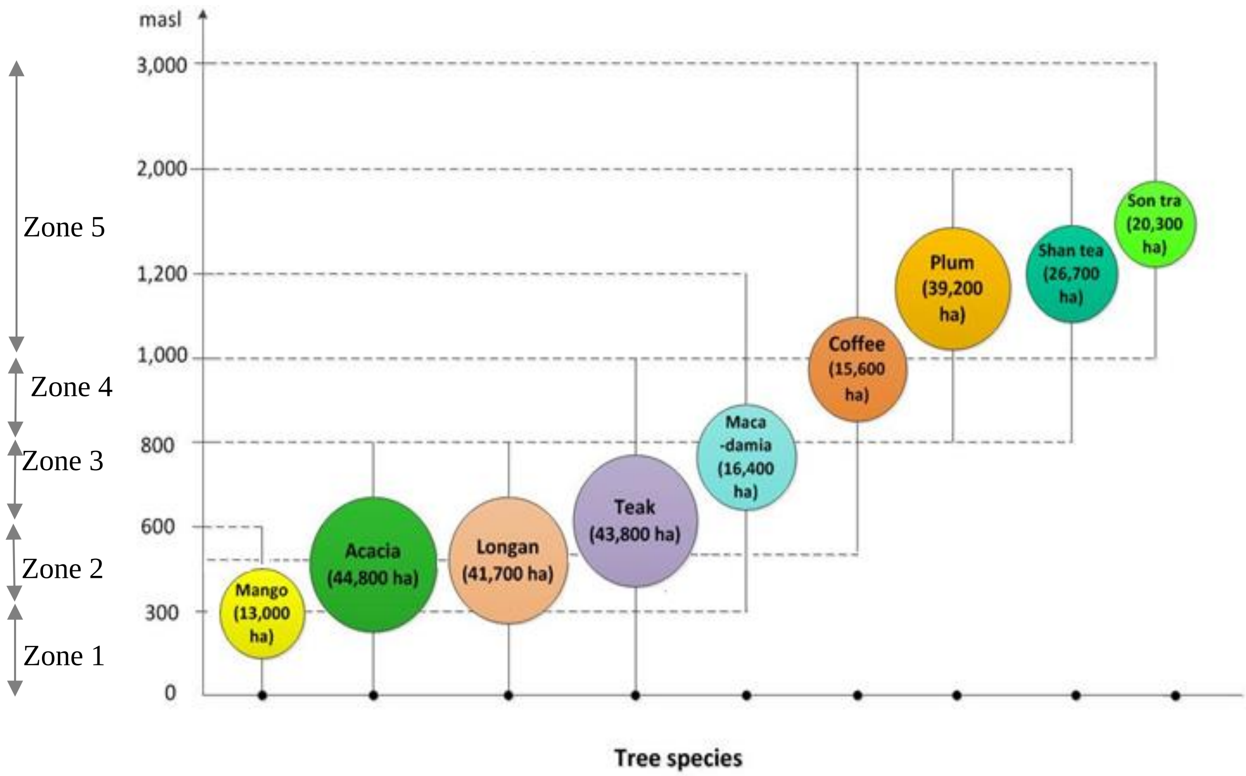


Figure 2. 8: Total suitability areas for different tree species with agroforestry potential in annual crop areas in sloping land by species

2.4. Discussion

2.4.1 Overestimation of forest cover

Using remote sensing technology and satellite imagery is an effective way to monitor and classify land cover at large scale (Waser and Schwarz, 2006; Kozak et al., 2008). This technique has enabled more robust forest and land cover maps to be produced which identified an overestimation of forest cover. This maps more closely to what was known anecdotally on the ground; farmers expanded their crop cultivation in forest areas from the post war period. The practice has continued to the present day. It is difficult to encourage farmers to convert from food crops to tree plantation because maize is their only income source and it is still quite profitable. Cultivating annual crops in those forest areas is not legal but accepted as traditional practice. Forest areas are often located on steep slopes (greater than 25^o), therefore, however the reality is significant areas of this sloping land is under annual crop cultivation leads to high erosion and land degradation which was effectively invisible until these maps were produced. These updated forest designation shows that there is an overestimation of forest cover in Northwest region.

2.4.2. Improvement of mapping methods using crop phenology and time series satellite imagery

There are different types of uncertainties which can affect the accuracy of cropland mapping. First, some vegetation types which look like annual crops from satellite images such as sugarcane in Son La can be classified as annual crops. Sugarcane is planted at large scale on slopes and valley but maize is harvested in September - October while sugarcane harvest season is until January. Second, there are two maize crops in Yen Bai where maize can be planted earlier in March while the planting season in Dien Bien and Son La is May. This leads to different vegetation cover of maize field from Landsat satellite image obtained in March. Third, fallow land with high herbs and grass could have similar pattern as food crop from Landsat satellite image because of low resolution. However, fallow land has the same vegetation structure over years while maize grow only from May to October. Using crop phenology of maize, hill rice and cassava, with time series Landsat imagery can improve the accuracy of the annual crop mapping result. The impact of tree-based systems on soil erosion and land degradation can be estimated by running prediction model for soil erosion prevalence for time series Landsat imagery in 2014 (before the system was implemented) and 2019. This could provide more concrete evidence of restoration functions of agroforestry to land degradation over the period of 5 years.

2.4.3 Estimating soil erosion prevalence using satellite imagery and field data

The provision of accurate detail land degradation maps was fundamental to underpin the development of agroforestry 'options'. Despite being a critically important contextual variable there was a number of problems with existing datasets such as lack of soil erosion data systematically collected at large scale across different land use types. Nguyen and Pham (2018) used soil loss data from two experimental plots in Son La province to map soil erosion for the whole province. This necessitated the use of earth observation data (particularly Landsat satellite imagery) which has the capacity to map the extent of soil erosion prevalence at large scale (Vågen, 2019) with enough accuracy to provide operational guidance an where interventions might be best placed to address them.

The process of developing these data in this environment was challenging due to difficult terrain, steep slopes and limited road network. The field survey should be conducted in dry season to be able to access the plots and avoid flash flood.

One element worth reflecting on was the training data used for this work. The use of the LDSF methodology has focused on Africa with limited but increasing use of the method in Southeast Asia (with 4 sites now having data). This had implications for this study as lack of more localised dataset required the use training sets were derived from African studies, which influences the accuracy of soil erosion predicting model. It is hoped that greater application of this method in Vietnam (and across the region) will enable further improvements in accuracy. In addition, soil samples needed to be sent back to Nairobi for laboratory analysis which slowed the progress.

However, the process of running the method combined with rigorous ground truthing produced outputs that significantly improved of existing datasets and provided hugely valuable insights both to land degradation and forest cover datasets. We recognise that one LDSF site in Son La province was potentially not representative enough for all the AFLi study sites as the landscapes in Dien Bien and Yen Bai province are quite different. Two more LDSF sites will be conducted in two other provinces to cover the dynamic of topography and land cover, contributing to model calibration and validation and improve the accuracy of soil erosion prevalence mapping.

2.4.4 Potential of agroforestry adoption for soil conservation

The outputs produced by this study show that significant areas of the study sites were suitable for a range of different agroforestry options based simply on the biophysical requirements of the tree component. Although tree biophysical suitability suggests a high potential for some form of agroforestry on the majority of sloping cropland, further research needs to be done at finer scales to identify suitable agroforestry design. This would include explicit consideration of other important biophysical variables such as soil pH, hours of sunlight, maximum and minimum temperature and frost season which were not considered at the wider landscape scale. Better understanding of how these parameters manifest at the farm scale is likely to further constrain these models.

Adoption of agroforestry is a decision-making process, in which farmers play a central role. There are a range of socio-ecological parameters beyond the biophysical which will affect how farmers think about tree integration in their traditional food crop systems. In particular robust characterisation of the potential economic consequences and labour requirements of moving over to are crucial factors to be considered. Studies in Ethiopia showed that other factors such as infrastructure, proximity to road and market also influence the adoption rate (Kassie, 2018). Northwest Vietnam is home of to many ethnic minorities with potentially diverse value systems in relation to their agronomic practice. Scaling out agroforestry also requires moving beyond these tree-based models to better fit them to their socio-economic context. Since the poverty index is very high in this region, especially amongst the H'mong group, trade-offs between agroforestry and traditional food crop systems need to be considered.

2.5. Conclusion

Integrating agroforestry systems into degraded landscapes has the potential to build more resilient livelihood systems. The study showed that sloping land (above 15^o) accounts for 70% of total land area in Northwest Vietnam by calculating slope areas from DEM. Using Random Forest classification (RFC) method and Landsat data, cropland (primarily maize) covers 23% of study site area. This doubled existing estimates of cropland on steep slopes (above 25^o) in comparison with official reported data by Ministry of Natural Resources and Environment (MONRE) in 2010. There is 30% of actual cropland lies within forest designation suggesting forest cover was over. The biophysical suitability analysis shows that the suitability areas cover approximately 85% of total area of croplands on slopes (above 15^o), presenting significant potential for tree integration and expansion of existing systems.

Trade-off between economic and environmental impacts should be considered when short term crops on sloping lands is converted to tree-based options at household and landscape level. To put these ideas into practice, communication with policy makers, land use planners, scientists and small holders is required through workshops and focus group discussions at provincial and local levels. Understanding farmers' local knowledge and perception towards agroforestry is necessary to scale out the adoption at landscape level.

III. THE IMPACT OF SOCIAL AND ETHNIC DIMENSIONS ON AGROFORESTRY ADOPTION FOR INDIGENOUS PEOPLE IN NORTHWEST VIETNAM

Abstract

During the 1980s, ethnic groups living in the mountainous areas of Northwest Vietnam were discouraged from practicing shifting cultivation and their livelihood systems shifted to more settled farming systems which revolve around annual crop cultivation. As their farming systems primarily occur on sloping land covering 75% total area, this transformation has resulted in very high levels of soil erosion and recent declines in productivity. Integrating agroforestry systems into these degraded landscapes has the potential to address this degradation process and improve local livelihoods. Moreover, those ethnic minorities have unique social and cultural norms. Agricultural intervention in this region requires understanding the real needs and interests grounded in socio-cultural contexts. This study applied local-knowledge-based methodologies with sixty farmers from six villages of Kinh, Thai and H'mong people across three provinces to understand local opportunities, preferences and constraints for adopting agroforestry systems. Our results showed that whilst farmers from all groups were aware of benefits of using trees in soil conservation, they had different perceptions on the benefits of agroforestry systems, which was likely to influence their types of agroforestry system adopted. All groups stated that it was important that the agroforestry systems had some provisioning function relating to income generation but had differing needs in relation to regulating functions. More than half of H'mong farmers were interested in increased land, labor and fertilizer utilization, the Thai people highlighted soil erosion reduction and the Kinh people were motivated by soil fertility improvement. This study suggests that farmer's specific social circumstances influence their aspiration and constraints for agroforestry intervention. Perceived behavioural controls to adopting agroforestry systems varied among those ethnic groups. Policies supporting agroforestry need to be tailored for different groups in order to build resilient livelihoods and ensure future environment benefits.

3.1 Introduction

About 3.4 million people live in the Northwest provinces of Vietnam in culturally diverse communities made up of 30 ethnic groups (GSO, 1999). In this region there is a strong link between ethnicity and topography (Roche and Michaud, 2000) with different ethnic groups associated with different elevations. According to national household census in 2009, the main ethnicity occupying low land areas (below around 600 m) is the Kinh. This is the most common ethnic group in Vietnam making up 88% of Vietnamese population, but Kinh is the second largest group in the Northwest (26% of population). The Thai group is the third most common ethnic minority of the country (accounting for about 2% of the total population) but the largest group in the Northwest (28% of population). Thai groups in this region generally live in the middle altitudinal zone (around 600-800 m). The Hmong are the third common ethnic minorities in the Northwest (14% of population), and generally live at higher altitudes (above 800 m).

There are significant environmental problems in Northwest Vietnam. Expanding populations and government policy that stabilisised what were traditionally shifting cultivation ethnic minorities led to rapid deforestation and the expansion of agricultural monoculture systems. Given that much of this agriculture occurs on steeply sloping land (which accounts for about 70% of the area of the Northwest region) this generated a number of significant environmental problems associated with intensive food crop cultivation on steep slopes. There was significant erosion (see previous chapter) combined with declines in soil quality and loss of biodiversity (Wezel et al., 2002; Schweizer et al., 2017). In Northwest Vietnam, the maize mono-cropping remains the predominant farming system and trees are relatively rare on steep hillsides. Many of these smallholder farming systems now face economic uncertainty as increasing costs for fertilizer and seedlings may force farmers to reconsider their cultivation practices to find more sustainable options.

In Vietnam, agroforestry systems have been present for a long time (see section 1.1.3), however, its widespread adoption remains limited. There are many different forms across the country ranging from forms of silvopasture in the lowland to silvoarable systems in the uplands (Hoa and Catacutan, 2012). Given the need for effective soil stabilization in the Northwest agricultural systems, the integration of trees using agroforestry has significant potential. However, realizing this potential requires moving beyond understanding the biophysical pre-requisites for agroforestry expansion (see Chapter 1) the to incorporate better understanding of the key social factors that may influence adoption (Irshad et al. 2011).

For the AFLi project smallholder farmers were seen as the primary target for agroforestry adoption as they were the main providers of key commodities and significant contributors to critical ecosystem services (Roshetko, 2017). Agroforestry adoption is not just a “copy and paste” process but is highly dependent on the biophysical, socio-economic context of the households (Kiptot, et al., 2007). Farmers will primarily adopt tree species based on their own needs (Scherr, 1995). Understanding farmers’ interests and challenges is essential in order to provide appropriate support that meets their actual needs and capacities.

To address this issue, participatory approaches were developed in the 1990s (see, for example, Chambers, 1994). These approaches were viewed as a paradigm shift in research and development, providing tools to capture the views of local people (and moving away from the so called ‘top down’ proscriptions. Earlier participatory approaches were, however, often applied without critically thinking about the issues of social barriers to farmers' decision-making process. Several theories have been applied to understand farmers behaviours. For example the ‘Diffusion of innovation’ theory (Rogers, 2003) looks into how and why a technology is adopted and spread. Value-belief-norm theory (Stern et al., 1999) provides an approach to analyse social supports for environmental movement. To date, the theory of planned behaviour (Ajzen, 1991) has been proven as the most popular conceptual framework to explore the social dimension of technology acceptance and adoption (Rodriguez et al., 2009; Läpple & Kelley, 2013; Lalani et al., 2016; Daxini et al., 2018).

3.1.1 Key aspects of the theory of planned behaviour

The theory of planned behaviour forms the basis for the methods deployed here. In this section aspects of the theory are explained

3.1.2 Social norms

More recently more attention has been paid the role of social norms. Social norms are the expectations from a community on individuals to perform a behaviour in a specific situation. Social norms together with social relationship are influenced by, for example, their neighbours’ adoption patterns, social expectation and pressure or social status they may achieve as a result of activity (Liu et al., 2018). Current recommendations suggest that analysis of these norms should be incorporated in best practice adoption studies (Liu et al., 2018). Agricultural intervention should be adjusted to socio-cultural factors to improve farmers' value and motivation towards the innovation (Warren et al., 2016). Therefore, developing agroforestry capacity requires a local understanding of what their primary benefits are and areas where these benefits can be transferred easily to other systems to meet specific livelihood needs.

3.1.3 Farmer capacity to adopt

Farmer capacity to adopt agroforestry is defined by both biophysical and socio-economic conditions. Biophysical condition are derived from understanding of the ecological conditions of the farm, including characteristics such as soil type, slope (see Mercer & Pattanayak, 2003), farm size (see Vanslembrouck et al., 2002) or the geographical condition of the plots (Wilson & Hart, 2001). On the other hand socio-economic factors include: market incentives, household preferences (Mercer & Pattanayak, 2003), economic benefits (Kiptot et al., 2007), land tenure and available time (Nyaga et al., 2015), the amount of social capital, and human capital (i.e. knowledge systems) and the influence of local and national policies (Ajayi, 2006).

Applying the theory of planned behaviour (Ajzen, 1991), willingness to adopt is influenced by personal beliefs/attitude, social norms and perceived behavioural controls. Farmers' attitude describes personal belief on behaviour, which can be negative, positive or neutral. Farmers' attitude towards adoption is strongly correlated with farmers' perceived behavioural control (level of difficulty) and their self-belief of capacity to adopt or maintain the systems (McGinty, 2008). For example, farmers' attitudes towards agroforestry was strongly related to the level of access to information and extension support in Bangladesh (Ghosh et al., 2019).

3.1.4 Farmer perceptions

Farmers' perception towards agroforestry is influenced by the degree of difficulty associated with acquiring accurate information about the benefits of the innovation (Ajayi, 2006; Rodriguez et al., 2009), and perceptions of risks and barriers associated with tree planting (Pontara, 2019) or knowledge of agroforestry techniques (Oduro et al., 2018). Selection of tree species for agroforestry adoption highly depends on farmers' attitude or knowledge concerning the impact of trees on food, soil, water and crops from their experiences and observation (Tadesse, 2019).

3.1.5 Perceived behavioural controls

Perceived behavioural control describes a personal perception on the difficulty to perform a behaviour (Ajzen, 1991). High financial cost and lack of knowledge on tree management techniques are farmers' challenge of planting trees on farm (Oduro et al., 2018). Limited skills and techniques are highlighted in other studies in Pakistan (Nouman et al., 2008) together with capital and quality seed in Rwanda (Kiyani et al., 2017).

These above factors from theory of planned behaviour are associated with culture, social values which remarkably affect farm and household characteristics. Social and culture hold a strong link with ethnicity as different ethnic groups have their own religious, belief, values resources and influence their attitude, social norms and behaviour controls toward agricultural innovation (Inwood, 2013). If the communities were viewed as a homogenous group, resulting in reflecting the voices of a small number of powerful people, and designing interventions, which are rather harmful to those who were supposed to be empowered (e.g. Cooke and Kothari, 2001).

This study contributes to the existing global literature in understanding cultural and ethnicity aspects of local ecological knowledge on agroforestry and other land uses (Madge, 1995; Xu et al., 2005; Weber et al., 2007; Ayantunde et al., 2008). Scaling up agroforestry adoption need to be adapted to fine-scale variation in ecological and social context including local needs (Coe et al., 2014). Adoption is more likely to happen when farmers have knowledge, labour, secure land tenure (Adesina & Chianu, 2002; Bannister & Nair, 2003). Social factors including farmers' preferences, attitude, cultural or social constraints and local knowledge strongly influence farmers' decision (Meijer et al., 2015). Those adoption factors can be categorised as farmers' capacity to adopt and farmers' willingness to adopt (Mills et al., 2017).

Figure 3.1 shows farmers' capacity and willingess as two key elements for agroforestry adoption, based on theory of planned behaviour (Ajzen, 1991) and adapted from Mills et al. (2017). This study hypothesizes that agroforestry adoption will occur when farmers have both capacity and willingness to adopt agroforestry.

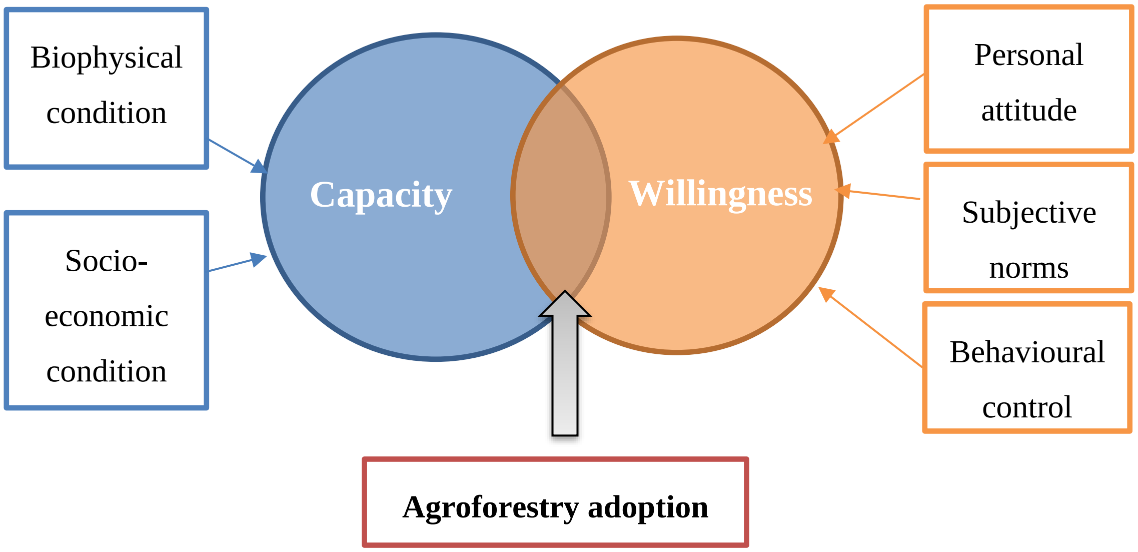


Figure 3. 1: Farmer’s capacity and willingness for pathway towards agroforestry adoption (adapted from Mills et al. (2017) and Ajzen (1991))

In this study, we explore how social factors influence pathways to adoption for agroforestry systems (designed to stabilize soils systems and support local livelihoods) of different ethnic groups in Northwest Vietnam. This includes:

- Identifying and understanding the social factors including personal attitude, subjective norms and behavioural controls towards farmers' willingness to adopt agroforestry (and whether this varies with ethnicity),
- Recording preferences for different forms of agroforestry systems and
- Identifying potential constraints to adoption of agroforestry from three main ethnic groups including Kinh, Thai and H'mong.

3.2 Methods

3.2.1 Study site

The study was conducted in the AFLi project sites in Yen Bai, Son La and Dien Bien of Northwest region (see Figure 3.2 and section 1.4.1).

To make the study consistent with other chapters the research was co-located on AFLi project sites, Six villages within project sites were selected with two villages per each ethnic group. These six villages are described below and shown in Figure 3.2.

- Kinh ethnic group: Van Thi 3 village in Van Chan district, Yen Bai and Tan Que village in Co Noi commune, Mai Son district, Son La
- Thai ethnic group: Na Ban village in Mai Son district, Son La and Giang village in Tuan Giao district, Dien Bien
- H'mong ethnic group: Hua Xa A village in Tuan Giao district, Dien Bien and Sang Pao village in Tram Tau district, Yen Bai

3.2.2 Data acquisition methods

Data was collected from two surveys (the first in 2016 and the second in 2017). These are described briefly below:

Survey 1: Adaption capacity survey

The first survey explored agroforestry adoption preferences with farmers. This involved a purposive sample of current adopters and non-adopters of agroforestry. The first group consisted of two sup groups 1) Farmers who were signed up to the AFLi project so called ‘project adopters (n=162) and if they had adopted agroforestry but were not involved in AFLi project, they were grouped into spontaneous adopters (n=7). If farmers had not adopted agroforestry, they were classified as current non-adopters (n = 56). Questions in the first survey were designed to understand the capacity of farmers to adopt agroforestry and included questions about their perceptions of the degree to which their biophysical context (elevation, cultivation, traditional practice) and social-economic condition (finance, labour, knowledge) affect their capacity to adopt agroforestry systems (for non-adopters) or expand these systems (for adopters) (A copy of the survey form is included in Appendix 3.1).

Survey 2: In-depth household surveys

The second survey was an in-depth household survey which focused on acquiring farmers' local ecological knowledge regarding tree planting following an approach developed by Sinclair and Joshi (2000). Because indigenous knowledge is cultural specific (Sillitoe, 1998), this survey looked at how their local knowledge was shaped by their attitudes and perceptions, their behavioural controls towards agroforestry adoption and their preferences with regard to potential agroforestry options and the degree to which these were influenced by their ethnicity, (i.e. the specific cultural and social context). The second survey used key informant interviews of six commune representatives, combined with farmer focus group discussions and semi-structured interviews. One focus group discussion was conducted for one village with the same farmers participated in the semi-structured interviews

Key informant interviews were designed to understand the overall context of the communes including the distribution of ethnic groups across elevations, socio-economic context of three ethnic groups, supporting policies of tree planting and agroforestry development.

Farmer focus group discussions aimed to understand village history, culture, tradition, cultivation practices, agroforestry opportunities and constraints using village map sketching, history mapping, faming calendar, Strength - Opportunity - Weakness - Threats analysis (SWOT) (Humphrey, 2005) on agroforestry adoption (N=??). Questions for focus group discussion are presented in Appendix 3.2.

Finally, semi-structured interviews were used to explore farmers knowledge on agroforestry management and get deeper understanding on agroforestry management, values of trees, social norms related to tree planting, farmers' attitude on benefits of agroforestry and preferences on agroforestry adoption. The interview was conducted together with farm visits. Farmers were again purposively selected for these interviews. All interviewees were agroforestry adopters who were currently not involved in the AFLi project (to avoid the influence from project training). The total number of farmers participating in the study was 58 with 9-10 farmers per village (this was gender balanced so equal numbers of men and women were interviewed). Two villages were selected for each ethnic group (Kinh, Thai and H'mong), amounting to six villages in total (see Figure 3.2).

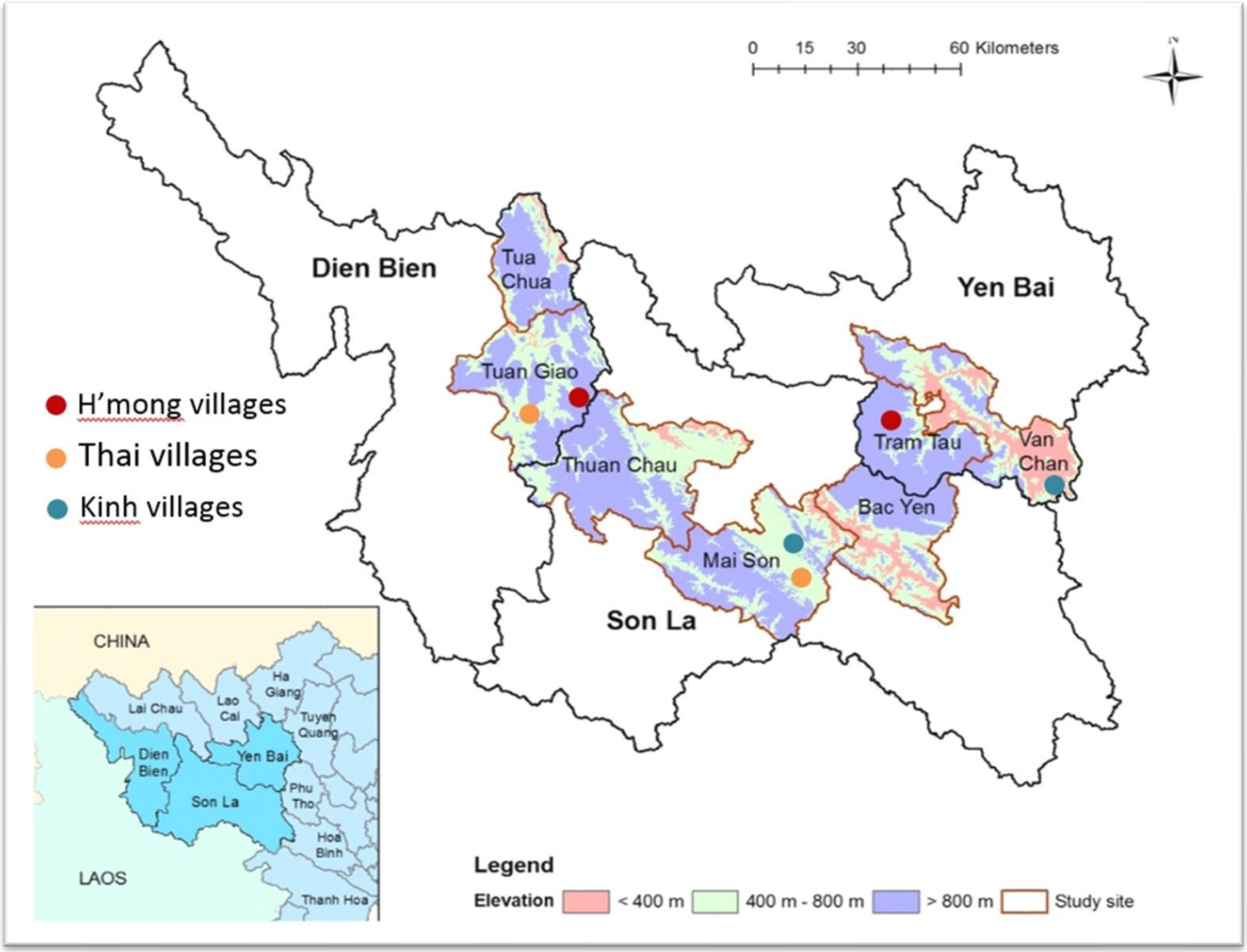


Figure 3. 2: Map of the study site within AFLi project site in Northwest Vietnam

3.3 Results

3.3.1 Farmer capacity to adopt agroforestry

3.3.1.1 Farmers perceptions of biophysical conditions required for agroforestry expansion

The interviews revealed that 'elevation' was considered the key criteria, and in part explains variation in preferred agroforestry options across the ethnic groups in northwest Vietnam. The initial survey revealed how farming practices and choice of tree-crops differed by elevation (which closely matched ethnicity - see Table 3. 1). The Kinh normally live in the lower land, the Thai is in the middle and the H'mong live at the high elevations. In some areas, they are mixed in the same communes but separated in different villages. The H'mong villages are always at highest altitudes. The information in table 3.1 were summarized from household survey 1.

Table 3. 1: Farming characteristics of three ethnic groups

Ethnic group	Range of elevation (m)	Traditional cultivation techniques	Suitable and preferred tree crops
Kinh	0 - 600	Intensive cultivation, Intercropping	• Tea • Longan, mango, plum, pomelo
Thai	400-800	Partly shifting cultivation	• Coffee, macadamia • Plum, mango, longan • Manglietia, melia
H'mong	> 800	Shifting cultivation	• Shan tea, coffee • Son tra • Pine

3.3.1.2 Socio-economic conditions

Socio-economic condition affecting agroforestry adoption was based primarily on variables for establishing, maintaining and selling the products from these systems. The important factors were farm size, access to market, education, agronomic knowledge and awareness of techniques (similar to Ajayi, 2006, Vanslembrouck et al., 2002, Mercer & Pattanayak, 2003). The data from survey 1 showed the main variables which varies by ethnic groups includes poverty condition (low, medium or high), accessibility to market (distance to the market), distance to the field, educational level and average land holding. The survey revealed that the available land resource was very different among three ethnic groups (see Table 3.2).

Market access refers here to proximity of the field to market. This has significant influence on potential designs as farmers who live far from their fields, they often preferred to grow timber trees and annual crops which do not require lots of management. On the other hand, the more valuable fruit trees seedlings were expensive, and fruits were reportedly often stolen in the harvesting season, which meant farmers would prefer to plant fruit trees near their houses. Because farmers sell fruits and other products on the main road, the road, itself represents the 'market' and distance to road was a proxy for distance to market.

In the study sites the Kinh were largely forcibly relocated migrants from lowland areas. They always live in the lower altitude areas (under 600 m), and had a market advantage they were main ethnic group in Vietnam, (and were most able to access t science, technology and gathered market information more efficiently. Thai people lived at medium elevation from 400 – 800 m. Thai generally had access to quite good soil and were able to speak Kinh language. This allowed them to access to science and technology, information in similar ways to the Kinh. On the other hands, because their settlements were at the highest altitudes (above 800 m), and there was a language barrier combined with relatively poor infrastructure, the H'mong people had considerably lower access to external information. This was particularly true for H'mong women who were not able to attend any school after primary. At present, some H'mong households were still doing shifting cultivation and have fallow land, others possessing less land have shifted to permanent farming.

As a result of the survey the ranges in values of key social-economic factors that could influence adoption were captured (see Table 3.2) This collates date from both household surveys (n= 176).

The survey revealed that factors could be scaled up to the village scale – and this also allowed patterns for the different ethnicities to be established All these factors influence agroforestry adoption in different ways and had different ramifications for these groups. Poverty condition shows their financial status (which affects their capacity to create the new infrastructure) whereas degree of education influenced farmers' capacity to learn the new techniques. For both these variables the Kinh scored highest and the H'mong score lowest. The variation in size of land holding was used as an indicator of farmer capacity to scale out agroforestry. Distance to market was identified as a critical determinant of what trees could be adopted at different locations. Finally, the degree to which different groups had been exposed to agroforestry (for example some forms of agroforestry were identified as traditional Kinh practices) was identified as being a likely signifier or their appetite for this form of technology. Exposure to agroforestry was lowest for the H'mong.

Table 3. 2: Typical social characteristics of three main ethnic groups in Northwest Vietnam (summarized from household survey 1).

Ethnic group	Poverty	Distance to market	Distance to the field*	Education	Average land holding
Kinh	Low	0-2 km	< 1 km	High school, university	< 1 ha
Thai	Medium	0-3 km	1-3 km	High school	1-3 ha
H'mong	High	5-10 km	3-6 km	Primary school	2-5 ha

* distance to field represents the distance from the homestead to their fields

3.3.2 Typology of agroforestry adopters and non-adopters

Based on framework in Figure 3.1, farmers were characterized into four types (see Table 3.3: Farmer characterization based on capacity and willingness to adopt/scale out agroforestry). The difference among three ethnic groups was explored for each type – and the degree to which this, in turn, affected decisions to adopt agroforestry or scale out agroforestry.

Table 3.3: Farmer characterization based on capacity and willingness to adopt/scale out agroforestry

Capacity to adopt/scale out agroforestry	**Willingness to adopt/scale out agroforestry**	
	Unwilling	**Willing**
Positive capacity	**Type 3:** • Have available land, labour, finance, techniques • Do not like to adopt agroforestry (for non-adopter farmers) or only want to maintain current agroforestry adoption (for adopter farmers)	**Type 1:** • Have available land, labour, finance, techniques • Have positive attitude towards agroforestry, willing to adopt (for non-adopter farmers) or expand agroforestry (for adopter farmers)
Negative capacity	**Type 4:** • Lack of available land, labour, finance, techniques • Do not like to adopt agroforestry (for non-adopter farmers) or only want to maintain current agroforestry adoption (for adopter farmers)	**Type 2:** • Lack of available land, labour, finance, techniques • Have positive attitude towards agroforestry, willing to adopt (for non-adopter farmers) or expand agroforestry (for adopter farmers)

Using this characterization for non-adopter farmers, these types are illustrated in Figure 3. 3: Characterization of non-adopter farmers based on their capacity and willingness to scale out agroforestry options with actual number of farmers (n = 56) below. The size of the circle represents the actual number of interviewed farmers.

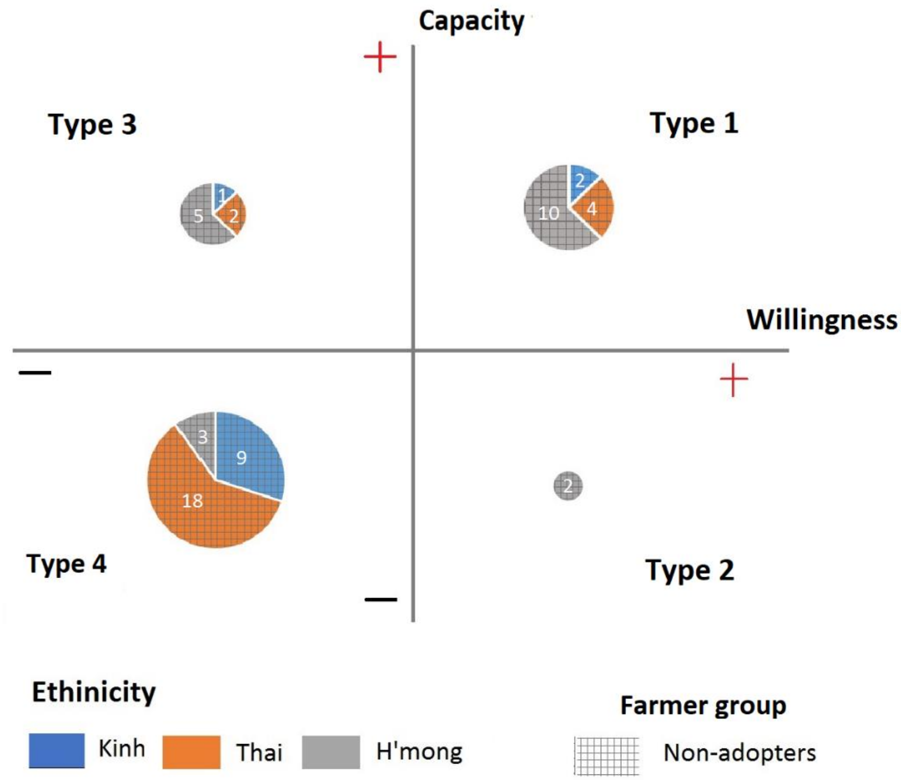


Figure 3. 3: Characterization of non-adopter farmers based on their capacity and willingness to scale out agroforestry options with actual number of farmers (n = 56)

30% of non-adopter farmers had resources and were willing to adopt agroforestry on their farms. Most of these were H'mong farmers as they saw the benefits of agroforestry from project adopters. One of the techniques they wanted to adopt was planting fruit trees together with grass so that they had more food for cattle in the winter. Cows and buffalos play an important role in H'mong livelihoods because they help farmer with ploughing and carrythe materials to the farms (which are far from home and have high slope gradients). Two H'mong farmers did not have enough land but they were interested in doing agroforestry and willing to adopt the technique. None of Kinh or Thai farmers who lacked land wanted to adopt agroforestry.

The majority of the non-adopters (53 %) did not want to adopt agroforestry because of perceived lack of capacity. Most of these were Thai and Kinh farmers. Only a few H'mong farmers were in this group primarily because they lacked cultivatable land (which, in this context, meant land that was fertile and less than 10 km from their home. For the Kinh and Thai farmers, they stated that they did not have spare land for agroforestry.

Of those that were unwilling but had capacity (Type 3: 14 %) a large proportion were H'mong the reasons given were lack of knowledge about agroforestry. For the Kinh and Thai, they have not yet seen the benefits, so they were not willing to adopt agroforestry at present.

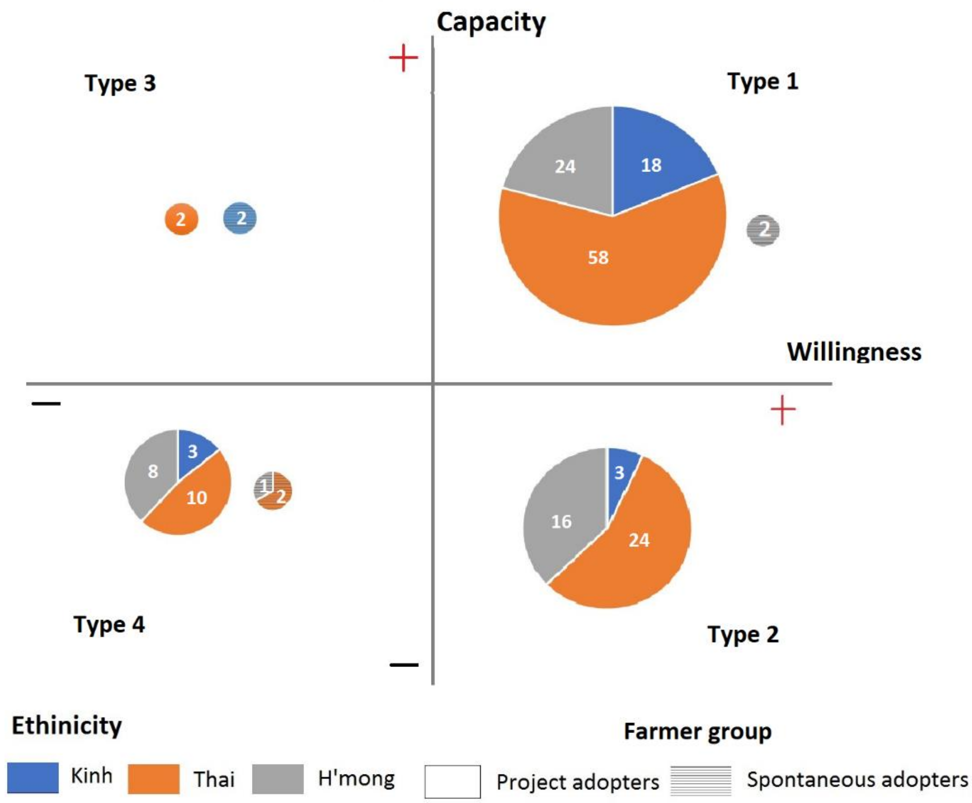


Figure 3. 4: Characterization of adopter farmers based on their capacity and willingness to scale out agroforestry options with actual number of farmers (Project adopters: n = 162; Spontaneous farmers: n = 7)

In the adopter groups, all farmers wanted to maintain their existing agroforestry systems. The results showed that 60% of project adopter farmers had resources and wanted to expand agroforestry on their other plots (see Figure 3.4). 26% of the farmers who had adopted agroforestry were unable to expand because they felt they did not have more capacity (particularly land, labour) to expand. In all types, the number and percentage per sample size of Thai farmers accounts for the most, followed by Hmong and Kinh farmers. Most of spontaneous adopter do not want to expand agroforestry to other plots due to their limited spare land and difficult intercropping techniques (but the sample size is very small).

There were different patterns in ethnicity between adopters and non-adopters farmers in group 1 – i.e. farmers with capacity and willingness to adopt/expand agroforestry (Figure 3. 3: Characterization of non-adopter farmers based on their capacity and willingness to scale out agroforestry options with actual number of farmers (n = 56) and Figure 3. 4: Characterization of adopter farmers based on their capacity and willingness to scale out agroforestry options with actual number of farmers (Project adopters: n = 162; Spontaneous farmers: n = 7)). A higher percentage of H'mong non-adopter farmers had capacity and were interested in adopting agroforestry techniques while Thai ethnicity accounts for large proportion in Group 1 of adopter farmers. These results suggest that there is high potential to expand agroforestry from the project adopter group; it also suggests that increasing agroforestry adoption from current non-adopter groups or expanding agroforestry from spontaneous adopters is much lower. The main reasons were related to limited capacity. While lack of capacity was clear (i.e. farmers could easily explain how lack of land, labour, finance or limited understanding of technique limited their uptake) For the second variable, willingness to adopt agroforestry, the responses were often less clear including vague responses such “I do not like agroforestry”, “I don’t know” or “I’m not sure”. This fed into the second survey which was conducted to understand in more detail the farmers’ drivers and their challenges associated with agroforestry adoption.

3.3.3 Farmer’s attitude on benefit of agroforestry adoption

Individual perceptions of agroforestry benefits were recorded from survey 2. Based on data from the in-depth survey on farmer perception on agroforestry adoption, all three ethnic groups thought that agroforestry delivered many benefits; including contributing to income, generation a long-term profits and providing a second income stream for first few years from crops. Furthermore, each ethnic group emphasised the different benefits of agroforestry that they consider as a motivation for them to practice agroforestry (see Figure 3.5).

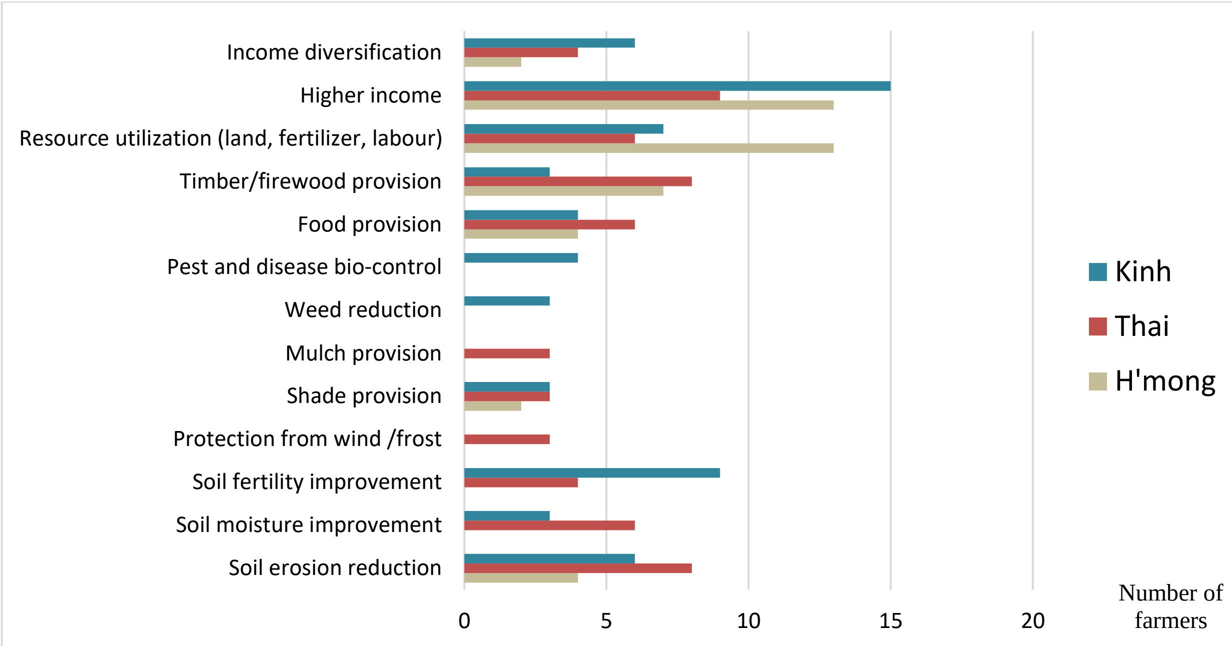


Figure 3. 5: Benefits of agroforestry adoption as identified by H'mong, Kinh and Thai groups (n =58)

The H'mong people living in the uplands of Dien Bien, Yen Bai emphasised the advantages of land, labour and fertilizer interactions when cultivating multiple species in the same plot. In addition they valued having access to both firewood and timber from perennial trees. This was very consistent with living condition of the H'mong people since their land is mainly far from home and they are facing labour shortages, although they have a lot of land plots. In addition, they used firewood as the main source of energy for cooking and harvest wood from the forest for house building. Thus, localised supply of wood and timber play an important role in the lives of H'mong people.

Thai farmers also believed that wood and firewood were critical products from agroforestry, but also highlighted the possibility of providing food for humans and cattle (buffalo and cow) and soil regulation benefits. Most of Thai households had livestock, but unlike H'mong people, they kept animals in stalls, so intercropped grass was quite useful (although, interestingly tree species were not immediately identified as a source of fodder).

The Kinh farmers primarily saw agroforestry as a mechanism to make fuller use of resources because their land area was generally much smaller than that of the others. The Kinh were generally more technical and had access to more technical information. This meant they had knowledge on which species were better for intercropping, especially in home gardens. As an example they were aware that intercropping peanuts and beans with perennial trees improved soil fertility (increasing the overall productivity of land).

3.3.4 Subjective norms towards forest protection, tree values and agroforestry adoption

Subjective norms were explored for three areas: Forestry protection, tree values and agroforestry. These are described as below:

Farmers from the different ethnic groups held different norms in relation to forest protection.in particular in relation to expectations of their behaviours regarding forest protection. Government Programs 327 and 661 (Five million ha-reforestation) supported the establishment of new forest plantations, and natural forest regeneration and protection (De Jong et al., 2006). In these programmes, production forest lands was allocated to farmers to grow timber trees such as acacia (*Acacia spp)*, melia (*Melia azedarach*), *manglietia conifera*, pine (*Pinus spp.), son tra (Donycia indica)*—in turn, households and communities were expected to protect the forest. In Thai villages however, cultural norms existed wherein community forests were considered 'ghost forests' or burial grounds that families come to visit every year. The Thai group also believed they had to protect the old wild trees in their village as they were holy and revered in ceremonies since time immemorial.

As the indigenous group living at high elevations, the H'mong people are expected to protect the forests on top of the mountains and limit their shifting cultivation practice. Like the Thai group, by participating in program 327 and 661, the H'mong recieved support on timber tree species such as *pinus spp* and *son tra (Donycia indica)*. For the cultural value of the trees, only two H'mong farmers (out of 19) said that they protected an old tree as the holy tree in the village.

When the Kinh group migrated to the uplands, they were expected to retain forest patches on hill tops while annual crops, fruit trees or cash crops were to be planted in the mid-lower portions of the hill, rendering a forest-garden-fishpond-livestock system. This comes from a traditional farming design called VAC, which is the combination of vegetable garden, fishpond and livestock recommended by the government extension program ((Khoa et al., 2006). Kinh farmers believed they were expected to adopt the modified VAC practice to help reduce soil erosion and prevent flash flooding. All Kinh farmers concurred that they learnt fruit tree management techniques and bought seedlings from their hometown to grow in their new upland environment, 26% of Kinh correspondents indicated that intercropping was a traditional technique to address limitations on land size.

3.3.4 Behavioural controls on agroforestry adoption among three ethnic groups

Common problems perceived by all three ethnic groups were lack of land, labour and finance. H'mong farmers were particularly concerned about technical management of the systems because they do not have good access to training, accentuated by a language barrier. Although all the ethnic groups had problems with land availability, it had different implications for each group. Kinh people had very small land area, therefore they do not have actual land to expand agroforestry. Thai people and H'mong people had larger areas of land holding but they only wanted to do agroforestry on the plots near their house and with fertile soil. Thai people earned significant income from maize monoculture, so they always compared profit from tree-based systems with monoculture maize and they felt reluctant to grow trees because the perceived income was smaller in the first four to five years.

Kinh behavioural controls

Kinh groups in Yen Bai were largely recent immigrants from their home town provinces in Red River Delta to the upland in Son La and Yen Bai. They brought with them fruit seedlings and tree management techniques which enable them to establish fruit tree systems. They were generally the highest educated of the three groups and had good market access (combined with high social capital to traders in their original hometown areas). Kinh communities were generally located near the main road and commune centre and access to market was not considered a constraint for agroforestry adoption in Kinh villages. In comparison the Kinh farmers in Son La had smaller land holding but lived even closer to the main road. These groups were already implementing many fruit-based agroforestry systems to take advantage of this. They also liked to plant timber trees on top of the hill to keep the soil firm (whereas Kinh farmer in Yen Bai do not prefer timber trees due to difficulty in transporting timber to the road). Both groups were interested in receiving more support on intercropping techniques and system design because they were concerned about tree-tree or tree-crop interaction in the systems).

Thai behavioural controls

Thai farmers in Son La and Dien Bien shared the same characteristics about traditional shifting cultivation practices. They both did slash and burn in the past to expand their annual crops areas. After land was allocated to households, they had a greater interest in adopting agroforestry. Although their average land holding was 2 ha /household, they maintained some rice and maize plots for family consumption and had begun to convert sugarcane/maize areas over to fruit trees. Although having the same cultural tradition of cultivation, Thai people in Son La had more advantages in terms of access to main road and market. Therefore, they did not have general concerns about market access, except for macadamia because the tree had been newly introduced in the area by Macadamia Association – and as a result there was some associated uncertainty. In contrast, Thai farmers in Giang village, Dien Bien had significant concerns about market and transportation for timber because they lived further away from the commune centre.

Hmong behavioural controls

H'mong farmers have the largest land holdings when compared to Kinh and Thai groups but live very far from main road or markets. They were not good at speaking Vietnamese, especially the H'mong women, which was another disadvantage for them. The H'mong people were slower in learning new techniques and the language barrier also limited connection to their markets. Although fallowing was still their traditional way to recover soil quality, due to limited land resources, there are more H'mong farmers willing to adopt agroforestry. Because H'mong farmers were very aware of soil erosion and degradation in their land, they were more willing to apply agroforestry on bare land or in degraded areas with low productivity maize. The H'mong farmers in Dien Bien, had more advantages that the H'mong group in Yen Bai - as they were closer to main road and market. They also spoke Vietnamese better. Hence, they have better connection to market and learn new techniques faster. They had learnt to grow coffee by themselves and were more active in producing seedlings as well as selling the products.

Behavioural controls and gender

Behavioural controls were also gender specific, meaning that male and female farmers had different constraints towards agroforestry adoption (this is explored in more detail in the next chapter). However, most of the concerns about fruit market from Thai group were from female respondents while only H'mong men had concerns about market. In relation to potential future adoption of agroforestry there were no obvious differences - both male and female farmers from all ethnic groups wanted to know about tree management and tree-crop interactions.

3.3.5 Preferred agroforestry options for three ethnic groups

Based on the understanding of capacity, willingness and motivation on agroforestry adoption, farmers were able to identify suitable tree-based options which fit their local ecological-social context and that were economically viable. Fruit tree intercropping systems were the common interest of all groups as fruits had high selling prices. The other systems were identified based partly on individual farmer motivation for agroforestry. For example, H'mong farmers tended to want to have an annual crop component in their systems to provide food. In contrast Thai farmers liked to have grass for livestock and Kinh farmers wanted to improve soil by growing peanut/soybean (see Table 3.4).

Table 3. 4: Preferred agroforestry options identified by three ethnic groups and local contexts

<table>
<tr><th colspan="2"></th><th>H'mong</th><th>Thai</th><th colspan="2">Kinh</th></tr>
<tr><td colspan="2">Common system</td><td colspan="4">Mixed fruits (Peach, Plum, Mango) – Lime/ Maize</td></tr>
<tr><td colspan="2">By elevation</td><td>High
(Above 800 m)</td><td>Medium
(500 m – 800 m)</td><td>Medium
(500 m- 800 m)</td><td>Low
(Below 500 m)</td></tr>
<tr><td rowspan="9">By location</td><td rowspan="3">Dien Bien</td><td>Son tra - Rice/ Maize/ Cassava</td><td>Cassia - Vernicia montana - Grass</td><td colspan="2" rowspan="3">N/A</td></tr>
<tr><td>Coffee - Leucaena/ Mixed fruits</td><td rowspan="2">Coffee - Cassia/ Leucaena/ Longan</td></tr>
<tr><td>Coffee - Maize</td></tr>
<tr><td rowspan="2">Son La</td><td rowspan="2">N/A</td><td>Fruit trees – Cana/ Maize/ Soybean/ Cucumber/ Pumkin</td><td rowspan="2">N/A</td><td>Mixed fruit trees - Arachis pintoi/ Peanut/ Bean</td></tr>
<tr><td>Macadamia - Coffee/ Fruit trees - Grass - Amomum</td><td>Pomelo - Guava</td></tr>
<tr><td rowspan="4">Yen Bai</td><td rowspan="4">Shan tea - Rice/ Maize/ Cassava
Son tra - Rice/ Maize/ Cassava</td><td rowspan="4">N/A</td><td>Melia/ Vernicia montana - Tea</td><td rowspan="4">N/A</td></tr>
<tr><td>Manglietia - Melia - Vernicia montana</td></tr>
<tr><td>Plum - Pineappe/ Bean/ Peanut</td></tr>
<tr><td>Tea - Maize</td></tr>
</table>

(N/A: not available)

Understanding local preferences and motivation to adopt agroforestry helps project teams to modify the trials and make them fit with the local interest. For example, the grass component was removed from systems for H'mong farmers while peanut/pineapple was added into the systems for Kinh farmers. Grass was still maintained in the systems for Thai group.

3.4 Discussion

3.4.1 Ethnicity and agroforestry adoption

Results of this study clearly demonstrate that ethnicity associated with specific contexts highly influenced agroforestry adoption and potential designs available. The results suggest that the Thai ethnic group had the highest potential for adopting agroforestry and for expanding their current systems in the near future. This is a combination of the advantage of living at medium elevations which were suitable for more tree species and they had moderate access to market, seedlings and information. The Kinh group were more technologically advanced advance and had good access to market but their land size was restricted. The H'mong group were more isolated and have the most difficult agricultural conditions although they have largest land holding area.

Comparing figures 3.2 and 3.3, suggests that the number of non-adopters in group 4 (i.e. those with no capacity and unwillingness to adopt) was much smaller than the number from the adopter group. Adopter farmers had received training by the project teams on agroforestry benefits. This is consistent with the findings from Gamboa et al. (2010) which suggested that low access to information could lead to low rate of adoption. Unlike the finding from Nyaga et al. (2015) which suggested that farmers with more resources were more likely to adopt resources tend to adopt agroforestry, these results suggested that a higher percentage of H'mong farmers were willing to adopt agroforestry compared to Kinh and Thai group although their capacity was most limited. However, only H'mong farmers from spontaneous adopter group wanted to expand their agroforestry systems on farms (Figure 3. 3: Characterization of non-adopter farmers based on their capacity and willingness to scale out agroforestry options with actual number of farmers (n = 56) and Figure 3. 4: Characterization of adopter farmers based on their capacity and willingness to scale out agroforestry options with actual number of farmers (Project adopters: n = 162; Spontaneous farmers: n = 7)). Because famers' positive perception towards agroforestry is important for adoption (Neupane et al., 2002), this bring up a high potential for scaling out agroforestry adoption for H'mong group. This ethnic group is particularly well known for poverty, climate change vulnerable, shifting cultivation and degraded landscapes.

People's attitudes to future agroforestry options was also heavily context and ethnic specific. For example, H'mong farmers in two provinces Dien Bien and Yen Bai have different preferred options. This can be explained by variations in their access to the highway (i.e. a context variable rather than an ethnic variable). The options that farmers wanted to have in table 2.5 is consistent with their motivation to adopt agroforestry in Figure 3. 5: Benefits of agroforestry adoption as identified by H'mong, Kinh and Thai groups

(n =58) and also fits with their context. H'mong famers preferred cash crops or fruit trees with short term crops for food and high income in acceptable time period (3- 4 years). Thai farmers wanted to have fodder grass for their livestock and Kinh farmers want to have legume plants in their systems. However, it is clear that market factors played an overwhelmingly important role in the choice of farmers and likelihood of change over the short term (Bacon et al., 2012). Except for Thai group in Dien Bien and H'mong group in Yen Bai where fruit trees do not grow well, all three ethnic groups in other areas like to grow fruit trees and the species are decided by market availability.

3.4.2 How farmers move from non-adopters to agroforestry adopters?

According to Kiptot et al, 2007, adopters can be "real adopters", "testers" or "pseudo adopters". Farmers have benefited from projects socially or materially, therefore, the adopters might adopt the techniques just because of the incentives from project. In this study, current farmers in project adopter group might be not the real adopters even 61% of them expressed the capacity and willingness to adopt agroforestry. On the other hand, non-adopter farmers who want to adopt agroforestry might be more committed because they are willing to do it on their own without any support. This requires further research in longer time for the whole cycle of one agroforestry systems, or at least post project to have the complete assessment of adoption.

The social condition that enables the scaling out of diversified farming systems needs the changes in people's aspiration and actions (Kloppenburg et al. 2000). In order to scale out agroforestry adoption, farmers should move from other types into type 1 (have capacity and willingness to adopt) from both adopter and non-adopters. Moving from type 2 to type 1 needs to improve their capacity such as labour, finance or land which are quite difficult and dependent on external support. The most feasible option is to increase their access to social capital in order to hire more labour or rent more land. Moving from type 3 to type 1 requires the change in farmers' attitudes, perceptions and address some behavioral controls towards agroforestry adoption. Farmers can change by themselves if they see the success from project agroforestry trials, or learn from neighbors, friends and social media. This is more sustainable because farmers will combine the new information with their indigenous knowledge into practice. This is also the observation of farmers adopting agroforestry in Malawi by Thangata and Alavalapati (2003). Successful agroforestry trials should be promoted widely through different channels so that farmers can be easily access. Regarding type 4, the rate of farmers in type 4 from agroforestry adopters is much smaller compared to this from non-adopters, meaning that more farmers want to continue adopting after some time working with project

3.4.3 Implication for scaling out agroforestry adoption

First, understanding different ethnic group's motivation for agroforestry adoption and their preferred options help policy makers or development project design best fit agroforestry systems in their specific context. If the option does not fit with their existing practices, farmers are not willing to adopt it (Kabwe, 2010). Second, during the interview, men and women appeared to have different concerns towards agroforestry adoption such as Thai women concerned about market for fruits and H'mong men wanted to learn more techniques. Further research on gender would help the scaling out of agroforestry adoption. Third, addressing perceived behavior controls enable the condition for farmers to adopt agroforestry. McGinty et al. (2008) found out that there was a strong correlation between farmers' intention to adopt or maintain agroforestry and their behavioral controls. However, behavioral controls vary by different ethnic groups and related to their contexts which differs from one community to others (Rai et al., 2006). Therefore, governmental policies or development projects should be tailored for different ethnicities in different location and combined in respect of their local knowledge and practices.

3.5 Conclusion

The study identified the social context for agroforestry adoption from three ethnic groups Kinh, Thai and H'mong. Non-adopter and adopter farmers were categorized in four groups with different level of capacity and willingness to adopt agroforestry. Farmers' behavioral controls for adopting agroforestry vary among those three ethnic groups due to their location of origin, accessibility to market, and different cultivation tradition. Most of farmers are lack of high quality tree seedlings and connection to market. Kinh and Thai farmers in lowland concerned about climate change and high cost to manage systems because they prefer high value fruit trees. H'mong people concerned about utilizing resources such as fertilizer and labour and financial support to buy seedlings and fertilizers.

This also contributes to provide the potential agroforestry interventions for different ethnic groups and supporting policies to enable the condition for adoption. The findings of this study give insights into issues and variables to be considered at the micro level implementation of policies or programs.

This suggests that farmers' specific social circumstances linked with their culture influence their preferences for agroforestry intervention and ignoring these elements is likely to adversely affect adoption.

IV. EXPLORING OPPORTUNITIES AND CHALLENGES IN AGRICULTURAL ACTIVITIES THROUGH GENDER LENS

Abstract

The H'mong ethnic group living in the highest altitude (above 8000 m) of Northern mountain areas in Vietnam have unique social and cultural norms and values in relation to gender. We used gender-responsive participatory methods to explore 1) gender norms and relations, 2) information and knowledge sharing systems, and 3) challenges and opportunities for the development of agriculture and forestry within H'mong communities. Particular attention was paid to differences in gender and inter-generational dimensions associated with decision making. The findings show that agricultural activities were highly gendered, with men and women playing very specific roles and having clearly different constraints and interests. There was evidence of changes to these norms; young women were becoming less restricted in interactions between their husbands and their in-laws and had fewer language and cultural barriers compared to their parents' generation. Of critical importance was the finding that men and woman have different communication channels when it comes to learning about forestry and agriculture practices. Men had both formal and informal learning channels, whilst women were generally more reliant on informal information from their female peers. This suggests that current modes of agricultural extension services were not reaching H'mong women effectively.

A wide range of agricultural challenges were raised by both male and female farmers. Some technological issues such as fertilisers, pests and diseases were common for both men and women, while others were gender specific. Women had higher time constraints and were interested in labour-saving technologies. Culturally men were responsible for major household decisions and they indicated needs for greater information on investment and market strategies. Overcoming these gender roles, and empowering woman to feed into and even make major household decisions, is likely to be a significant challenge for H'mong communities in the Northwest.

4.1 Introduction

Poverty, deforestation and land degradation are key socio-ecological challenges in the northwest regions of Vietnam. Nearly 3.5 million people from 30 ethnic groups live in this area. People are generally quite poor with the poverty rate was 24.23% compared to 5.23% of the Vietnamese nationwide in 2019 (Ministry of Labor – Invalids and Social Affairs, 2019). In recent years, the cropping systems in this region have moved to monoculture food crops with significant areas of land being converted to small holder farming systems. This new farmland is often located on the steep slopes which cover more than 70% of the total area. Recent studies have demonstrated that cultivating short term crops on slopes leads to very severe soil erosion (Chapter 2, Van De et al., 2008; Tuan et al., 2014). Agricultural activities in mountainous areas are often key drivers of deforestation and soil erosion (Sam, 1994).

In common with many other countries, agriculture in Vietnam is underperforming. This is, in part, due to a lack the resources and opportunities for women. Woman generally face more severe constraints than men in accessing productive resources, markets and services (FAO, 2011). Women have less access to a range of resources, reduced land rights and are less likely to receive a good education. This inequality in assets and support results in women being unable to produce the same yields as male farmers despite equal ability. In addition, women are often culturally excluded from 'major' decision making. This "gender gap" reduces productivity and creates a significant barrier to meeting their livelihood needs. If agroforestry interventions are to succeed in Northwest Vietnam, then is it critical that we explore how different actors will be affected by the new technologies and to seek to make any benefits derived from these systems as equitable as possible. In line with increasing interest in gender and agriculture at the global scale (see, for example, Kiptot et al., 2014; Akter et al., 2017), recent research in Vietnam has paid attention to gender (Catacutan and Naz, 2015; Villamor et al., 2017).

Understanding men and women farmers' interests and challenges is essential in order to provide appropriate support that meets their actual needs and capacities. To address this issue, participatory approaches were developed in the 1990s (Chambers, 1994). They were viewed as a paradigm shift in research and development, providing tools to capture the voices of the poor. Earlier participatory approaches were, however, applied without critical thinking about the issues of power hierarchy within the community among the poor people and between men and women. As such, the community was viewed as a homogenous group, resulting in reflecting the voices of a small number of powerful people, and designing interventions, which are rather harmful to those who were supposed to be empowered (e.g. Cooke and Kothari, 2001).

A group of significant interest in relation to gender is the H'mong. The H'mong community live at the higher elevations (generally above 800 m). The communities generally have lower access to road networks, electricity, education, information in comparison with other ethnic minorities. As such the H'mong group are the poorest ethnic group (index=58 percent) in the country (Le et al., 2014). Efforts have been made through land allocation, government subsidy, cash and food incentives and extension activities to assist H'mong farmers. However, if proposed interventions (particularly agroforestry) do not fit with gender expectations, then the expectation is that adoption levels will be low. The focus of this study was to enhance the understanding of social norms, gender-based constraints, interests and challenges for women and men in H'mong communities in agriculture and agroforestry in particular. In this study, we carefully consider the dynamics in household power structure based on gender, ethnicity and age. This information can then be used to suggest suitable approaches to encourage greater participation in agricultural activity amongst H'mong women.

4. 2. Materials and methods

4.2.1 Study site

The study was conducted at Hua Sa A village in the Toa Tinh commune, Tuan Giao district of Dien Bien province. A number of activities from AFLi and AFLi-II have been implemented in this commune, such as agroforestry trials with *son tra* and grass, agroforestry landscape with fruit trees. The general context of the commune and village are described in detail below.

Toa Tinh commune

Toa Tinh commune was established in November 20, 1952 and it consists of seven villages with more than 2,000 people belonging to 400 households (see Figure 4.1). The residents in Toa Tinh commune are all from the H'mong ethnic group. Electricity has only been available for two years; and television has increasingly become a main source of information. In common with many H'mong villages lack of good transport infrastructure is a key issue. The roads connecting villages to the commune centre were dirt roads, traffic conditions were very difficult during the rainy season. Both men and women used motorbikes to carry maize, coffee and rice from the field to home or to the market.

Rice and maize are the most important crops for the Toa Tinh people, mostly used for family consumption and feeding livestock. Livestock numbers are quite limited and consisted of buffalo, cows, goats, pigs, chickens, and ducks. The main household income are from agricultural products, mainly from *son tra* (*Docynia indica*) -a local apple of the H'mong people, also known as "Tao Meo" in Vietnamese, coffee and medicinal plant (*Amomum villosum*). *Son tra* is considered the most important fruit tree in terms of trading activity and commercial expansion. *Son tra* is transported by motorbikes from fields to the small market.

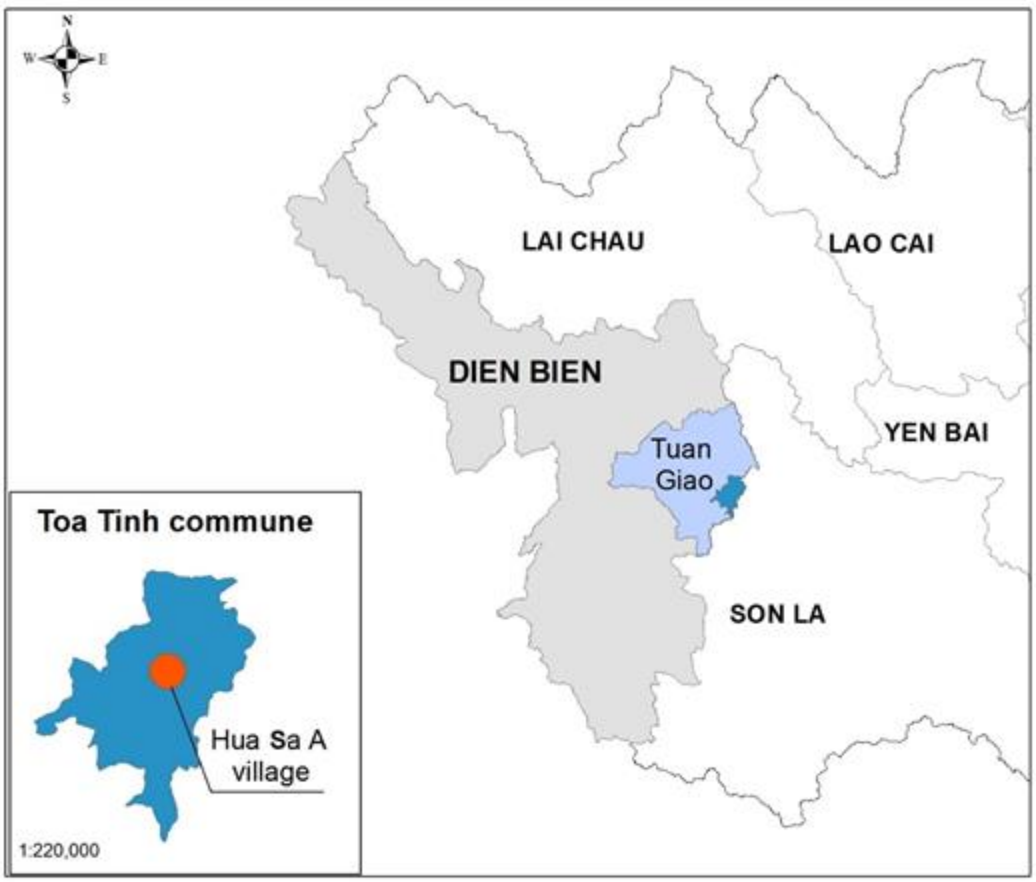


Figure 4. 1: Map of the study site at Hua Sa A village and Toa Tinh commune in Dien Bien province

Hua Sa village

The Hua Sa village was established before the war in 1954 when the Toa Tinh commune was split from the Pu Nhung commune. In 1984 the Hua Sa village was divided into Hua Sa A and Hua Sa B because of its high population. All households have a land certificate for their farms and forest land. In addition to this, they still cultivate in bare land without land tenure. According to secondary data from Toa Tinh People's Committee, 30% of villagers have finished their primary education and young people having completed high school in most cases. There are 103 households in the village. The average household members are 4-5 people with 62% of the households being 'poor' or 'nearly poor'. The average land holding is 3.3 ha/household and the total village area is 693 ha, of which agricultural land accounts for 337 ha. In addition to Son tra, other major fruit trees grown are peach, plum and local pear. There are limited amounts of coffee grown.

4.2.2 Methodology

The subjectivity of the researchers influences the way the research is designed and the way in which data are interpreted. Critically considering researchers' own subjectivity is essential for qualitative research to maintain its objectivity. H'mong men and women were likely to have different concepts of wealth from outsiders (including the research team). In this study questions were formulated that were open to new information emerging from the respondents, whose subjectivity is different to the researcher's (English, 1994).

Reflexivity is another challenge in obtaining information, as the researcher is viewed as a gendered person and treated according to local gender ideologies (Callaway, 1992). For example, H'mong young female farmers would not openly talk to male researchers and/or female researchers who were older than them, as this was prohibited by current social norms. Furthermore, many H'mong farmers may feel shy when talking to researchers because of language barriers and cultural differences. In order to limit these appropriate facilitators based on respondents' gender and age. Ice breaking activities were also critically important to build rapport with the farmers.

The subjectivity and reflexivity of translators were as important as those of researchers. In this study, two H'mong women were used as translators. Working with a local female translator enabled better understanding of the local context. However, her social position and her relationships with each respondent could also affect the answers of the respondents. Another translator from outside the village was also used. Translators had a short training session about methods including the issues of subjectivity and reflexivity.

4.2.3 Data collection

Field work was conducted in the Hua Sa A village, Toa Tinh commune in December 2017. An initial focus group discussion was held with key informants (n =7) including commune officers such as leaders of farmers' unions, women's unions and youth unions and agricultural extension workers at Commune People's Committee to collect information on the context and social background of the commune and village.

In addition, three further activities were conducted in the village. The main activities were ice breaking games (1/2 day) to warm up the atmosphere with farmers; focus group discussions to explore gender norms and relations with each group above (1.5 days). The last activity was a photo activity to understand gender- and age-based challenges in agriculture and information sharing systems (1 day). In all cases Farmers are divided into four groups based on gender and age. There were ten farmers in each group. The groups consisted of a) young women (15-25 years old), b) old women (25 – 60 years old), c) young men (15-25 years old) and d) old men (25 – 60 years old).

Ice breaking activities were based on the Social Analysis and Action approach developed by CARE International (CARE, 2017). Focus group discussions for male and female farmers were based on GENNOVATE methods (Petesch et al., 2018) and other research tools used in the participatory approaches such as power and freedom ladder, 24-hour time allocations, gender divisions of labour and decision-making.

This study employed the ladder of power and freedom framework using GENNOVATE methodology (Petesch et al., 2018, Table 4.1) for understanding women's and men's subjective power positions within the family. This was aiming at visualizing women's perceptions of their own status as an entry point of analysis. Participants were asked to vote privately for their perceived subjective positions at current and past (five years ago) respectively.

Table 4. 1: The ladder of power and freedom adapted from GENNOVATE Methodology

Step 5	Power and freedom to make most all major life decisions
Step 4	Power and freedom to make many major life decisions
Step 3	Power and freedom to make some major life decisions
Step 2	Only a small amount of power and freedom
Step 1	Almost no power or freedom to make decisions

The photo activity was an approach which enabled farmers to visualise their perceptions and opinions. Four to five volunteer farmers were selected per group. Seven key guiding questions were developed and volunteer farmers answered the questions by taking photos and explaining the reasons to the researcher (detailed questions and images are presented in Appendix 4.2). A photo exhibition event was held. This event helped farmers to recognise differences in opinions according to gender and generation. It also plays the role of a validation meeting, and participants exchanged their opinions on photos and shared their feelings of participating in the research. Further details on the methods used in this study are described in ICRAF Guide for Facilitators (ICRAF-The Gender SRA, 2017).

4.3 Results

4.3.1 Social context of the village

According to the discussion with commune officers and village leaders, the social background of the village was figured out to set up the context for the study.

In the study site, women were primarily responsible for the household and raising children as well as participating in farm work. Men were responsible for building the house, buying property, earning income for the family. In general, both husband and wife made decisions together as to which products to sell at which market prices. The husband decided which species to cultivate after consultation with the wife. The wife kept the money for the family. In a H'mong family, the husband was responsible for more laborious tasks, such as cutting wood – but also in some parental activity, including guiding children's behaviour. Women were responsible for cooking and washing. Husband and wife shared the same responsibilities in terms of dealing with their relatives and engaging in social activities. The husband took care of government-related work (paperwork) in the community.

H'mong families often consist of two to three generations living together. The head of the household in the family is usually the husband. But in some cases, when men work outside the commune or pass away, women can also be household heads (4% of total households in Hua Sa A). Normally, the age of marriage for boys was 20 years and 18 years for girls. This rule is regulated by law and followed by the people in the Toa Tinh commune. However, if girls had an unplanned pregnancy (as young as at 13 years of age), they can still get married and complete the registration later when they reach the officially allowed age of marriage. The costs of a H'mong wedding depend on the economic status of the two families. The lowest amount should be enough to organise the wedding such as 70 kg of pork, 20 L of alcohol, no less than two million Vietnamese Dong and the costs for a party (paid by the groom's family), the costs for a weeding party (paid by the bride's family) and dowry such as clothes and goods (optional). The total costs shared by the groom's and bride's families are similar.

Within a family, the person who is perceived as most knowledgeable plays an important role in making decisions, this person usually being the husband. The son is likely to replace his farther when he gets old. Household assets and land are inherited by sons. Daughters can share some but less than the sons, traditionally. Daughters-in-law are not considered for inheritance distributions because their husbands have an inheritance right.

According to the information from the commune officers, there are many changes regarding the role of women in the H'mong family compared to the past. They have much stronger voices and become more or less equal to men in some domains compared to the past, which was influenced by government policy on promoting women's rights. In theory, women have the right to participate in social activities, such as joining sport activities and entertainments. Furthermore, they can have meals together with men, which was not accepted in the past. In actual everyday lives, however, gender norms and prevailing patriarchal power relations persist.

4.3.2 Gender norms in the H'mong village

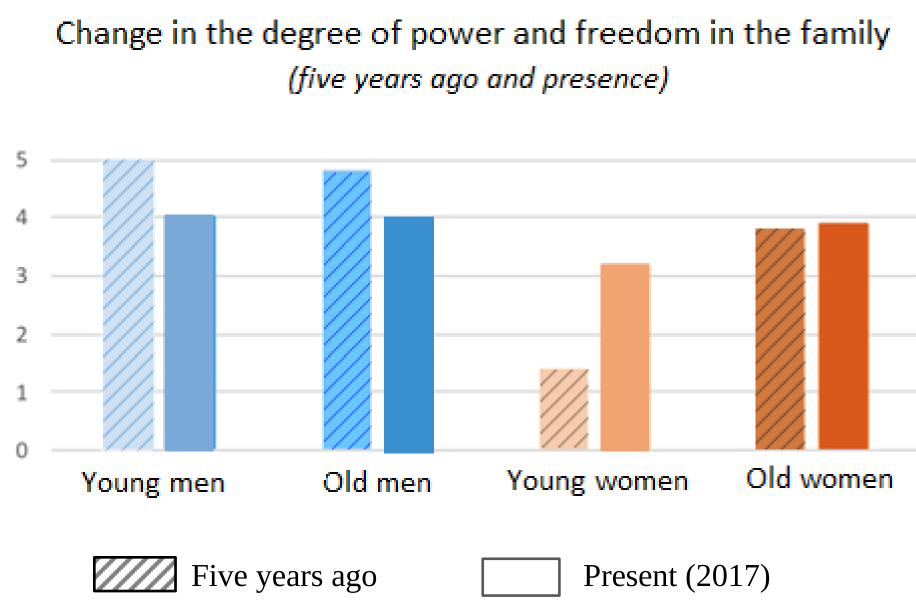
Gender norms refers to social expectations of roles, responsibilities, behaviours for male and females (Ridgeway and Correll 2004). Gender norms are highly influenced by culture and the changes in the social-economic context of the community.

4.3.2.1. Social expectations of men and women in farming activities

Social expectations for women and men in farming were also highly gendered. Men were expected to have a lot of current knowledge in new varieties, agricultural chemicals and pest and diseases. They were also expected to have business skills to sell agricultural produce at higher prices. There is a strong gender norm that household heads (mostly men) were always invited to meetings and trainings by ICRAF or extension centres. In fact, both men and women could attend the meetings and trainings, but it was usually men who did. Women were shy, and linguistically were less confident in speaking Vietnamese language, so they tended to rely on their husbands. On the other hand, women were expected to support their husbands, prepare agricultural tools before going to the field and manage to control pest and diseases on the field including having knowledge on pesticides and herbicides. Maintaining harmony in the community was highly valued as an important element for both men and women to be a good farmer, such as following the government policy and rules, protecting forests and water resources by carefully looking after their livestock and by not using too many agricultural chemicals, sharing new agricultural information and knowledge with neighbours.

4.3.2.2 Gendered power relationships within the family

The results from private voting from each group show that, in the study area, men's perceived subjective power was higher than that of women on average. This may be associated with a gender norm that men (household heads) were perceived as the final decision makers in the household. However, power relations have changed over the past five years and women’s subjective power in the family was perceived as increasing (See Figure 4.2). In Figure 4.2, value from 0 – 5 indicates the level of power and freedom with 0 is lowest value. In each men/women group, the bar on the left with light color shows the value of five years ago, the bar on the right shows the value at the present.



(5=Full of power and freedom, 0=No power and freedom)

Figure 4. 2: The change in perceived degree of power and freedom of themselves between 5 years ago and presence (private vote)

There were two women of the old women group (n = 10) who perceived their positions as higher compared to their husband because their husbands were almost absent in agriculture and everyday decision-making processes for various reasons such as working for the government, working far from home, being alcoholics or suffering from health problems.

Both men and women recognised changes in gender relations, in particular, women's increased power and freedom. There were some men who perceived that their wives had equal or more power than themselves. The reasons mentioned were the government's policy on gender equality, increased women's educational levels and increased access to information though TV and social media via the internet, in which H'mong men and women are more exposed to social values outside H'mong. Women's perceived positions of themselves in the family was closely associated with their relationships with their mother-in-law as well as their husband. Five out of nine young women positioned their power level of five years ago as step 1 (the lowest) because they had little decision-making power as a daughter-in-law who was new to the husband's family. Women also mention that relationships between the mother-in-law and daughter-in-law have been changing in the sense that the respect for daughters-in-law is increasing due to their higher education levels as opposed to women in the previous generation.

These findings show that while H'mong gender norms suggest that men are household heads and final decision makers, actual relations are more complex with family situations. At least at the perception level, women are gaining their power and freedom. At the same time, however, gender norms persist, making it difficult for women to change actual practices.

4.3.3 Gender division of on-farm and off-farm labour, access to and control over resources

4.3.3.1 Labour division of on-farm and off-farm labour

This study spent time to make gender norms visible and recognisable to participants before asking questions pertaining to the gender divisions of labour, access to and control over resources. Non-farm activities including domestic work were also taken into account.

There were a number of perceived gender divisions of labour described by participants (see Figure 4.3). This was summarized based on men and women group discussions. Actual practices varied depending on specific family situations. While heavy tasks were undertaken by men, some women managed to do them by themselves due to the absence of male labour in their families. Agroforestry activities were divided into small tasks such as carrying fertilizers and water to the field, purchasing herbicides and pesticides, receiving fertilizers from project, selling maize and coffee and so on.

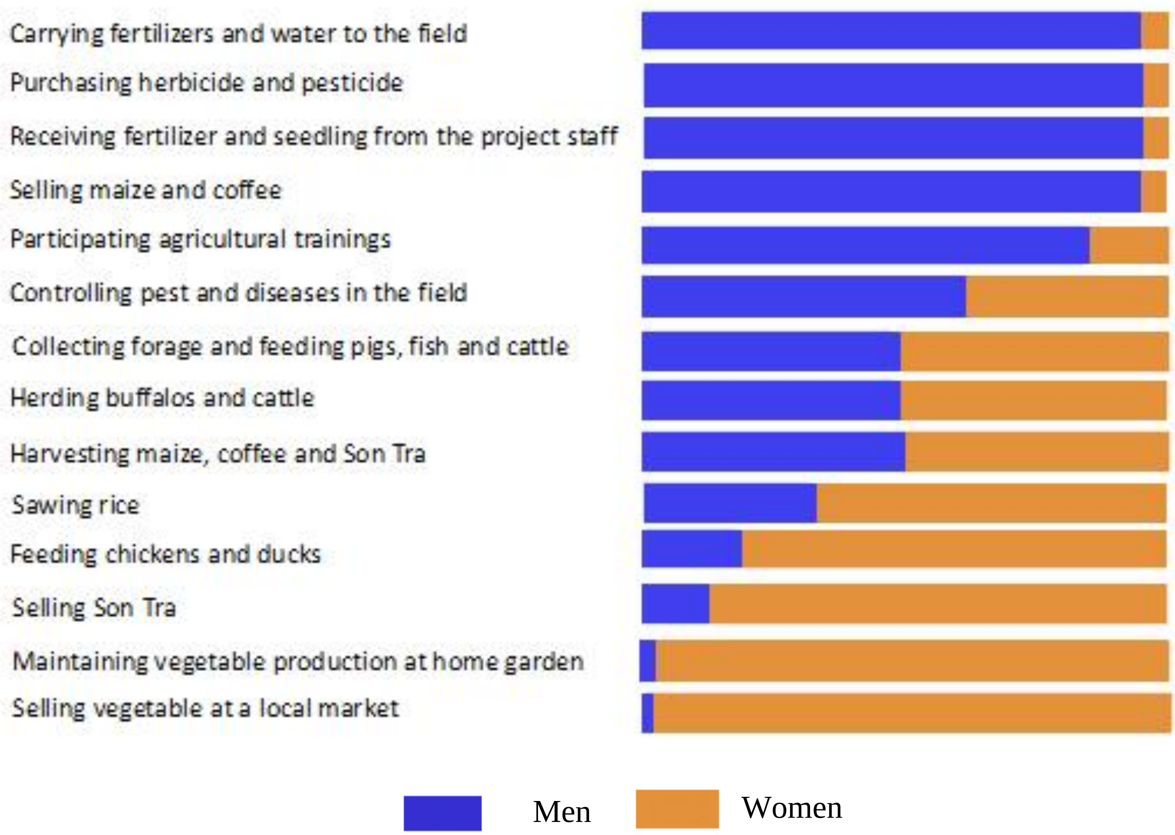


Figure 4. 3: Labour divisions in agricultural activities between men and women. The blue colour represents work under men's responsibility and the orange colour is for women's activities.

The findings show that some agricultural activities were conducted exclusively by men or women. For example, men more often carried heavy materials such as water, herbicide and pesticide by motorbike than women, and they were also in charge of the heavy labour activities on their farm. Men normally purchased agricultural chemicals and sold maize and coffee to traders because they could speak Vietnamese better. Some participants said that old H'mong women were very shy to talk with outsiders using the Vietnamese language, and had difficulties in calculating profits and bargaining with traders. Yet, the same women sold their vegetables and *son tra* in the market. An important finding was that women had specific autonomous domains such as selling *son tra*, vegetables (e.g. mustard, cucumber, lemon, and banana) and managing small livestock, such as chickens and ducks. *Son tra*, in particular, can be a great opportunity for women to expand their autonomy and gain confidence if production increases and if they can find better market channels within the areas where women can still handle by themselves.

Another important finding is that most agricultural tasks were shared by family members and the responsibilities therein depend on families. Women, for example, are also responsible for managing pest and diseases including spraying. However, attending trainings is considered to be a men's task according to current gender norms. This norm reinforces men's perceived power that they are more knowledgeable than their wife, and women perceived lower position that they learn from their husband. Providing knowledge and information to women can therefore not only lead to more effective agricultural management but also support strengthening women's power. If women obtain knowledge and information on *son tra* production, for example, it may help women to increase confidence compared to current practices in which they are taught by their husbands.

Time allocation for farming and domestic activities were identified by group discussion. Figure 4. 4 shows the summary of 24 hours' time allocation by gender as the mean values of young and old groups for women, and the same for men. Because these are average figures from young/old groups of men and young/old group of women, it is not possible to present the data statistically Detail of their daily activities for each group are presented in Appendix 4.1. Both men and women spend around 8-9 hours farming in the field. Women's sleeping time is 2 hours less than men's and they spend 4 hours more than men on domestic work. Women do not have leisure time, and resting time is only 1.6 hours as compared to 3.7 hours for men. Men often go to drink in the evening 3-4 times per week and come back home at around 21-22:00 p.m., which seems to be an integral part of social activities for men. Young men play sports in the evening from 4:30 p.m. – 6 p.m. after their back from the field. There were small differences between younger and older groups in time allocation and therefore the figure below shows an average from two groups, the old and the young.

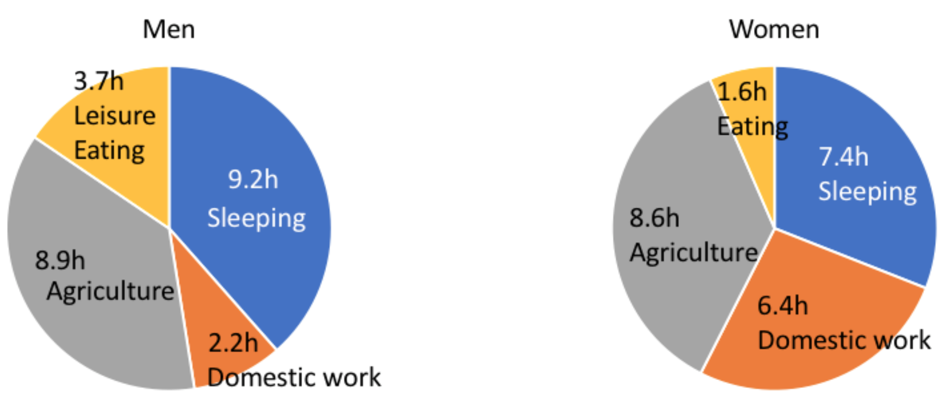


Figure 4. 4: 24 hours' time allocation of men and women in coffee harvesting season

During the harvesting season from August to December for rice, son tra, coffee, both men and women wake up earlier at around 4 a.m. but women always need to get up one hour earlier than men to do housework and feed livestock. They both spend more time on the field up to 11 hours and sleep 1-2 hours less compared to non-harvesting seasons. Women's over burden in domestic work and time constraints for agriculture are often overlooked in agricultural research. Women's lack of opportunities for attending agricultural trainings and accessing information and knowledge may be associated with their time constraints. Agroforestry interventions that require extra labour and time from women are less likely to be adopted. Also, without considering women's time constraints, simply inviting women to trainings will not be sufficient for women. Careful arrangements will be needed to facilitate women's participation in trainings, such as location, time and providing child caring services, as well as addressing language barriers.

4.3.3.2 Perceived ownership and the use of resources and assets by gender

What are the perceptions of men and women about the ownership of resources, such as land, livestock, agricultural machines and tools? Understanding their perceptions helps agricultural researchers think about innovation processes for men and women. If women have the ownership or at least perceived freedom to use equipment/machineries, proposed interventions for women can include some innovations by using those machineries. If women do not have the freedom to use specific resources/assets, those interventions' adoption rate remains low. In the study site, there were some assets related to agriculture in each household such as land, garden, ploughing machine, weeding machine and pesticide sprayers. Perceived ownerships varied with individuals but there was a tendency in perceptions that the husband was the owner of most of assets and women had equal access to use them. Young women, however, tended to perceive that they have joint ownership in many assets while young men still perceived that they hold the ownership in farmland, livestock and machines and equipment, indicating that the situation was contested (see Figure 4.5 below).

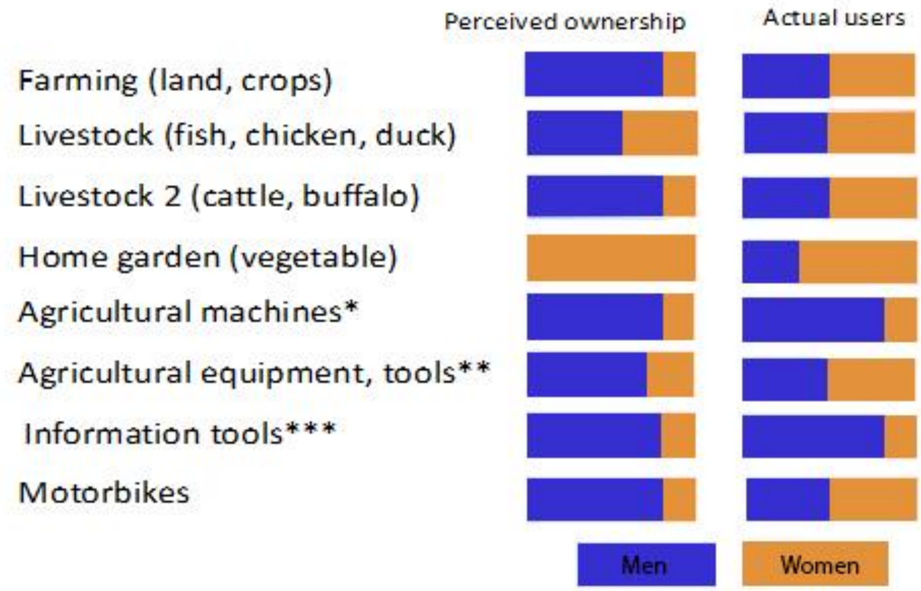


Figure 4. 5: Perceived ownership and actual uses of resources by gender.

(Note: *tractor, truck, sewing machines; ** grass chopping machines, spraying equipment, hoe; *** Radio, TV, phones, training materials, posters)

There were three key findings. First, although men may hold ownership, women had relative freedom to use some small equipment, such as grass chopping machines and spraying equipment, while large machines are owned and used by men only. As in many parts of the world, in the study site, mechanisation was primarily in men's domain only. Providing some small equipment for women could potentially help them to reduce time and labour in agricultural activities. Second, the greatest gender gap was in the use of information tools. While the community has many different information sources to deliver agricultural knowledge such as posters, training materials, radios and TVs, women have limited access to this type of information due to language gaps as well as a strongly persisting gender norm that men were in charge of communication with people outside the family and they are responsible for government-related paper work and activities. Although men were final decision makers and they control over most of household resources and assets, they discuss with their wives before buying new things such as seedlings and equipment. However, since women had little access to information and knowledge, they usually let men make decisions. There was therefore a need for providing information to women in the way both men and women feel comfortable. Third, although women had access to motorbikes and phones, it is often men who buy them first and women are often given the second-hand items from their husband. In this respect, access is not always equal, and it may take some time for women to get smart phones with some better applications that can be useful for agriculture.

4.3.3.3 Gendered knowledge and information sharing systems

Understanding how men and women access information and share knowledge and experiences was the first step for us to deliver knowledge and information in appropriate gender-responsible ways. The findings showed that there are clear differences in terms of the access to information by gender and generation. Conventional approaches to disseminate knowledge and information, such as training materials, posters and TV were only used by men, not women. In this context, many important items of information had not reached women. We need to provide women-friendly information delivery systems.

Photos that farmers taken from photo activities showed us some key things (See Appendix 4.2). First, men have a wide range of information sources and approaches through both informal and formal channels including trainings, media and relatives and friends thank to their advantage in speaking Vietnamese language. Also, H'mong men had broader network outside the village than women because they often go to the market or off-farm labour. Second, there were generation gaps in the approaches. Young men were increasingly using the internet, which old generations could not do. Agricultural interventions needed to be tailored to adapt to those technological changes and attract more young people. Also, in the study site, current female young generations studied at school and therefore they could read Vietnamese and learn from training materials. This was a big difference from the old generation who are less confident in many parts of their lives due to their language barriers. Third, women's information sources are mostly informal, learning from relatives and friends. They often had a role model in the village who is successful in agriculture through whom they learn and apply new practices. In this context, rather than bringing women to the formal learning systems, it might be better that agricultural extension services enter into those existing informal networks. Some key findings from their access to information are presented in table below.

Table 4. 2: Challenges related to current training materials

Groups	Challenges	Solutions and support required
Young men	Difficulty in understanding Vietnamese-written training materials with too many jargons	Convert training materials to video and combine with voices, guides, and practices
Old men	Low capacity to understand information Participating in training but no practicing afterwards	Learning especially from visual tools: e.g. television, documents to better understand More practicing and training at least 2 – 3 times
Young women	Lack of trusted information Currently we use mostly oral information	Training on how to identify trusted information More visual information
Old women	Training materials have too many steps and are in Vietnamese, so women cannot understand, there was no translator to explain	Translate into H'mong language or provide translator

4.3.4 Gendered challenges, interests and concerns in agricultural production and value-chain

During the photo activity session, a wide range of challenges and interests in agriculture were discussed. Both men and women have common concerns and gender-specific concerns (see Appendix 4.2). There are many concerns over agriculture, from production to selling. Both men and women clearly identify detailed issues and have a strong will to learn new technologies and change their practices. Some are common concerns between men and women, while others were gender-specific. The details of challenges and concerns are presented in Appendix 4.2 These issues included pest and diseases, soil qualities, soil erosion, low productivity, fertilizer, livestock, water resources, infrastructure, access to capital, marketing, machines and manual labour.

4.3.4.1 Common challenges and interests of men and women

Both men and women shared concerns about poor farming conditions such as pest and diseases, poor soil, water scarcity, poor road conditions and low quality fertilizer. Selling agricultural produce was also a common concern for both men and women. H'mong men and young men, as ethnic minorities, may have specific challenges in negotiating with Kinh traders. There was a scope for investigating opportunities for addressing marketing issues, such as using Information technologies.

Most of men's technical problems overlapped with the women's. There was no difference between men and women in their willingness to attend training or in relation to a desire to learn new things. There was, however, a big gender difference in the approaches to how different genders wanted to learn the new things (and the languages they might use). Therefore, it was considered valuable to provide some trainings specifically designed for women although the content of such trainings would largely be similar to those for men.

4.3.4.2 Women's challenges and interests

Women's interests were as diverse as men's, despite them having limited autonomy in decision-making. For example, women are keen on mechanisation. In the study site, women had many time and labour constraints as shown in the time allocation analysis. To create additional time and labour for improving agricultural production, introducing some small equipment, such as grass chopping machines, is essential so that women can create the time for other work. Young men, who might have already had experiences in using machines, expressed their concern in using machines effectively and fix them accordingly.

The finding also showed that women have a strong interest in livestock. This might be associated with their gender roles: women were often in charge of preparing fodder for animals and feeding them, and they often had decision-making power over selling or eating chicken and fish. Also, cattle and buffalos are very important for land preparation. While women looked after livestock more closely than men, men appeared to be responsible for disease control. Given young women's strong will to learn, the government could involve women as well as men in animal disease control.

Both men and women expressed their concerns about access to capital such as high interest rate when getting a loan or more complicated procedure but this issue was more dominant for women (only one issue raised by men while women raised seven issues related to financial problems).

Women particularly mentioned *son tra*, and its issues in production and selling. Young women had a strong will to learn new technologies and practices in *son tra*. Given that women were in charge of selling *son tra*, improving production and selling *son tra* could be a great opportunity for women to gain confidence and have more autonomy. Women's concerns were also closely related with food and water and infrastructure. If the water pipe was connected to their house, they can save a lot of time and labour. This was not directly related to agriculture, but it could create time for improving agriculture. This could be a specific recommendation to the government.

Figure 4. 6: H'mong women's aspirational agriculture system was a good coffee farm – because they had fewer pests and diseases and were generally located near a road

One surprising finding was that women were concerned about selling processes of maize and coffee, such as bargaining with traders particularly in relation to price fluctuations, despite men being largely responsible for these activities. Similarly, women also mentioned the loans of which their husbands had taken out. This indicates how those issues severely affect the everyday lives of women as it is women who have to manage to find food for family (i.e. they have to respond to poor decision making of their spouses). This suggests that women should be included in all processes of meetings, trainings, and introductions of new methods.

4.3.4.3 Men's challenges and interests

While women had many small practical concerns affecting their everyday agricultural activities, men are more interested in bigger-scale issues such as infrastructure, irrigation, big machines and markets. Young men, in particular, had a strong will to improve their agricultural conditions. As compared to women, young men showed strong interest in gaining new knowledge as well as practices. Figure 4.7 is one result of young men group showing their dreaming farming system. This was a coffee intercrop with shade trees (*L.leucocephala*) system like his neighbour's because coffee trees were very healthy, had more fruits and provide high income. In addition, shade trees could help protect coffee trees from frost in winter and heat in summer, reduced weed on the soil surface and reduced coffee leaves falling down. The shade trees were not indigenous species and a system like this was introduced by Son La coffee company many years ago. They could do this practice because of a lack of investment and techniques.

Figure 4. 7: Coffee – shade tree as the aspirational agroforestry system of the young men group

4.4 Discussion

Drawing from the insights of the key findings, five key messages are presented in this section as opportunities for providing gender-responsive interventions in agroforestry.

First, in the study site, the family was a core unit of agricultural production and development. Unlike agricultural business in urban areas where workers were viewed as individuals in isolation from their family positions, in the H'mong study village, individuals' family positions influenced their roles and capacities in engaging in agricultural production and selling. For example, women were often viewed as wives or as daughters-in-law and there are specific social expectations as to how they should behave. Within these norms, women and men had some specific domains in which they were more responsible than their wife/husband was. For example, H'mong gender norms mean that a husband is a household head and he is responsible for communicating with outsiders, including bargaining with traders and attending agricultural trainings. Without gender considerations, therefore, the trainings and agricultural extension services research to only men, while women, representing half of the population, are not included.

Second, there were certain domains where women can have relative autonomy in investment, risk taking and changing practices, such as vegetable production and selling, son tra fruit (local apple) selling, and small livestock production and selling. While another conducted research in four countries of Southeast Asia, included Vietnam but on Kinh group, women had equal access to most productive resources, this research on H'mong group is more similar to the finding from Kiptot and

Franzel (2011) about the importance of indigenous fruits selling to women. In these domains, women could easily decide to adopt new practices and take small risks for innovation, as compared to other domains of production where they need permission and/or labour support from their husband and in-laws. Therefore, trainings on *son tra* fruit classifying technique before selling will be more efficient if women can be invited to the trainings. This technique together with improving access market information for women could trigger profit from *son tra* and support the adoption of *son tra* -based systems.

Third, although both men and women shared a number of concerns there was often different emphasis between men and women, and between old and young groups. For example, regarding poor soil condition, women focused on specific aspects of soil condition such as factors affecting quality and the effects of soil erosion whilst the men worried about the higher costs associated with managing poor soil. Another example was tree management, where men were primarily concerned about techniques and low-quality seedlings while women were more concerned about issues such as climate impacts (like frost and flooding) on coffee. Old women, in comparison to young woman, showed stronger concerns with regard to accessing to capital, understanding high interest rate. Old women often did not know the potential solutions to these issues. This suggests that old H'mong women need more support on information and finance.

Fourth, men and women, the young and the old had different approaches to obtain information and learn new technologies. Similar to African men who attend more trainings (Kiptot and Franzel, 2011), H'mong men had various formal and informal channels through which information is updated. Formal channels include trainings from agricultural extension workers, discussions with a male village leader and learning from books, posters and training materials. Informal channels included learning from peer male farmers who were advanced in the village, observing agricultural practices of male relatives and friends, and collecting on-line information through internet. On the other hand, women’s access to formal learning channels was limited although young women have higher education and more access to internet compared to old women. Women are rather comfortable with learning through their relatives and friends. Findings have also shown that technical terms are difficult for not only women but also men to understand. There was often too much information in training materials, making it difficult for farmers to identify the relevant information. Some technologies were not applicable in their conditions or with their old varieties. Information should be updated. More visual methods could help not only women but also men to increase their levels of understanding. Also, organising trainings for women should remain more informal. Selecting a specific time and location is very important as women have limited time and many obligations at home. Interventions also need to engage men to help them understand the importance of women’s involvement.

Fifth, young men and women expressed their special interests to try new practices such as coffee and agroforestry while old men and women prefer incremental change based on traditional practices with improved working conditions (e.g. introducing new equipment or improving roads). The young generation were more open to new techniques and willing to apply them on their farms. Both young men and women even could explain about the agroforestry coffee system that they like, the reasons why they like it, tree interactions within the system. Young women, in particular, showed their great knowledge by presenting clearly and confidently in H'mong language about improving their current cultivating systems. Their knowledge is precious, and they show a great potential in adopting new techniques. Therefore, agricultural interventions should be designed to fit with their interest and integrated with their local knowledge and practices.

4.5 Conclusion

The study was initially developed through several discussions between ICRAF and the Gender SRA to provide better interventions that fit with H'mong people’s gendered interests. Research methods were designed for this study in the H'mong society where social values and communication norms are different from those of the Kinh ethnic majority in Vietnam. The study explored 1) gender norms and relations, 2) information and knowledge sharing systems, 3) challenges and opportunities for the development of agriculture and forestry. This can be applied for agricultural extensions by inviting farmers to participate in developing visual materials together.

This study employed a critical gender analysis in the participatory data collection methods. The study proves that this approach is very helpful to build rapport with H'mong famers and thereby collecting rich information on gender and social dimensions. Although there are some limitations in this approach to fully understand gender relations, it is a promising approach to design gender-responsive interventions. Further in-depth qualitative gender research may be very useful to informing gender-responsive agricultural interventions. The topics relevant for further studies are changing agency of young men and women, social dimensions of mechanisation and technological innovation, and ethnic minorities’ masculinities. Agricultural interventions should be carefully designed to empower men as well as women, women can also benefit from it. Understanding the complex gender relations thus helps agricultural researchers to identify the pathways in which men and women benefit from agricultural interventions.

V. CASE STUDY: POTENTIAL TO EXPAND COFFEE AGROFORESTRY SYSTEMS IN NORTHWEST VIETNAM

Abstract

Over the past decades in Northwest Vietnam, Arabica coffee systems have been developing in intensified, full sun monocultures that are not long-term sustainable and have negative environmental impacts. As the farming systems primarily occur on sloping land covering 75% total area, this has resulted in very high levels of soil erosion, loss of biodiversity and recent declines in agricultural productivity. There is a great need to accompany this rapid development by good agricultural practices, including agroforestry, to avoid deforestation and soil erosion on slopes. The association of trees on farm with monoculture is recognized to be part of an agro-ecological approach to address this degradation process and diversify household on-farm activities as well as improve local livelihoods. A survey of 124 farmers from three indigenous groups was conducted in Northwest Vietnam to document the characteristics of coffee agroforestry systems as well as ecosystem services and disservices that rural communities are associating with the different tree species. Trees were ranked according to the main ecosystem services and disservices selected as locally relevant by rural communities. Our results show that tree species richness in agroforestry coffee plots is much higher compared to non-coffee plots including annual crops, orchards, timber plantations. They also show that farmers have in-depth knowledge of the benefits of trees for coffee in their agroforestry systems. Most of them are aware of obvious ecosystem services such as reducing soil erosion, improving soil fertility, enhancing biodiversity, preventing damages from wind and frost, and providing shade and mulch. However, farmers have limited experience or knowledge on impact of trees on coffee quality and yield as well as on light and nutrient interactions between coffee and associated trees. Farmers ranked the leguminous shade tree species (*L.leucocephala*) as the best species based on the services provided by this species to coffee. Nonetheless, farmers' selection of tree species in their coffee agroforestry systems is very much influenced by economic benefits of intercropped trees and market access, particularly proximity of farms to main road. Hence, there are fewer native species and more commercial species in the areas with better road accessibility although those species were not considered highly beneficial to coffee trees. Consequently, leguminous tree (*L. leucocephala*) holding most of environmental services but having low economic benefit is maintained only in the areas far away from road and market. This

study helps local extension institutions and farmers in the selection of the right tree species according to the local context together with households' needs and constraints towards more sustainable and climate-smart coffee systems.

5.1 Introduction

Coffee is the one of the most important commodities globally, contributes to income of million smallholders. Approximately twenty-five million farmers grow coffee in sixty developing countries (Tucker, 2017). There are approximately 10,584,305 hectares of coffee around the world consisting of both Arabica (*Coffea arabica)* and Robusta (*Coffea robusta)* varieties (FAOSTAT, 2018). Vietnam is the second largest producer after Brazil (ICO, 2011). It is also the largest producer of Robusta coffee with a share of about 40 % of global Robusta production in the global market (Amarasinghe et al., 2015) accounting for 14.5% of total production.

Coffee was traditionally cultivated under moderate to heavy shade, and gradually changed to light share or full sun in order to improve the coffee yield, at least in short term. But shade reduction made coffee system more vulnerable to soil loss and water run-off (Perfecto et al., 1996), biodiversity loss (Philpott et al., 2008b), or soil erosion (Haggar et al., 2011). Shade coffee, which is a method of growing coffee naturally under tree canopy, is generally considered to be more environmentally benign. It generally has, increased biodiversity, higher levels of natural pollination, greater erosion control, and higher carbon sequestration (Somarriba et al., 2004; Philpott et al., 2008b; Jha et al., 2011). Coffee agroforestry system and boundary tree planting in coffee farms provided potential for climate mitigation and adaptation (Rahn et al., 2013).

Coffee was first introduced in Vietnam by the French in 1857. Between 1975 to 2010, the planting area of coffee in Vietnam increased from 134,000 ha to 513,000 ha. By 2016, the total area of coffee had reached 650,000 ha (MARD, 2017). Vietnam exports over 90% of its total production but the value remains low mainly because the beans rather than processed coffee are exported at low price. The annual export volume was approximately 1.8 million tons with the value of USD 3.5 billion in 2018 (Vietnam Customs, 2018).

Whilst Robusta is the most popular coffee variety in Vietnam it is mainly Arabica that is cultivated in the mountainous areas of Vietnam. Arabica prefers elevation above 600 m. Arabica only accounts for 6.5% of total coffee area of Vietnam. The estimated area of Arabica in Vietnam was 42,000 ha while Arabica area in Dien Bien and Son La was approximately 14,600 ha in year 2013-2014 (GSO, 2016).

Smallholder farmers have converted large areas of annual crops to coffee in Northwest Vietnam, which transformed their livelihoods from subsistence to commercial commodity (Nghiem et al., 2019). Most of the Arabica plantation in the Northwest is full sun monoculture on sloping land, which is not long-term sustainable. This has contributed to soil degradation. The long-term sustainability of unshaded coffee is likely to be limited given climate change and the less certain weather patterns associated with it. Increasing temperatures, uneven precipitation and unexpected extreme weather like storm, flood or frost may have negative impact on Arabica coffee production.

Expanding the area of shaded coffee systems in Northwest Vietnam offers a potential mechanism to provide a more stable crop, both economically and environmentally than either unshaded coffee or maize production (see Chapter 2). There has been an increased interest, globally, in shaded coffee systems given the sensitivity of coffee, particularly arabica, to climate change (Davis et al., 2012; Schroth et al., 2009). Coffee systems with between 20 %- 40 % shade have a more regulated microclimate which, in turn, leads to higher coffee yields (Vaast et al., 2005). This is not always the case and poorly designed shade systems can lead to low coffee productivity (Mancuso, 2013). Shade systems provide additional benefits beyond direct impacts on the coffee crops in the shape of a more balanced supply of ecosystem services (Meylan et al., 2017; Roupsard et al., 2017). These are critically important considerations when considering interventions in degraded systems, such as the Northwest, where expansion of coffee agroforestry systems potentially offers a livelihood option that is more resilient to climate change and protects farmers from price fluctuations by providing enhanced ecosystem service provision (particularly soil stabilization) and product diversification (Vaast et al., 2005). Shaded coffee systems offer a potential mechanism to increase the sustainability of cropping systems and the economic sustainability of households to agricultural price volatility through production and revenue diversification as well as to facilitate adaptation of rural communities to climate change via the adoption of more ‘climate-smart’ farming practices.

There have been a number of studies looking at Farmers’ knowledge of coffee systems (Cerdan et al., 2012; Valencia et al., 2015) but, to date, there have been no studies looking at farmers’ attitudes and knowledge associated with coffee systems in Northwest Vietnam. Understanding farmers knowledge of the benefits that trees potentially provide in shaded coffee systems (and any trade-offs or disservices) is critical for developing interventions that enable more resilient landscapes (Dumont et al, 2017) whilst reconciling production and conservation objectives. This is particularly important in this context given the broad spectrum of different ethnicities at play and the way in which factors such as gender feed into tree species selection (see Chapter 4).

To address this knowledge gap, this principal aim of this study was to explore farmer perceptions of the range of benefits associated with shade trees in coffee systems and then to use this information to customise a decision-support tool (the 'Shade Tree Advice tool' developed by ICRAF) to conditions in Vietnam. The original tool was developed using data from Uganda, Ghana and China http://www.shadetreeadvice.org (Van der Wolf et al., 2016; Rigal et al., 2018). The 'Shade Tree Advice' tool is aimed primarily at extension services, members of farmers' cooperatives and NGOs working in the Northwest region. Ideally the tool enables farmers to select the most appropriate tree species that are both adapted to local ecological conditions and meet households' needs and constraints.

5.2 Materials and method

5.2.1 Study sites

Son La and Dien Bien are the only two coffee planting provinces in Northwest Vietnam, of which Son La is the second biggest coffee producer of Vietnam. This study was conducted in seven communes of Son La and Dien Bien (see Figure 5.1). The communes were selected from known coffee planting communes (based on information provided by district extension centres). Households were selected from the Kinh, Thai and Hmong farmers who were actively involved coffee agroforestry. The Kinh are the majority ethnicity of Vietnam but only account for less than 30% of the population in the Northwest. Kinh people generally live in the lower areas (below 600 m) while Thai people generally are found at altitudes of 500 m to 800 m and H'mong people prefer to live in areas above 800 m. The selected communes in Son La are located along the national highway while the communes in Dien Bien are far away from the road (from 2-5 km) to compare the different characteristics of coffee agroforestry systems, perception on tree services and tree species ranking.

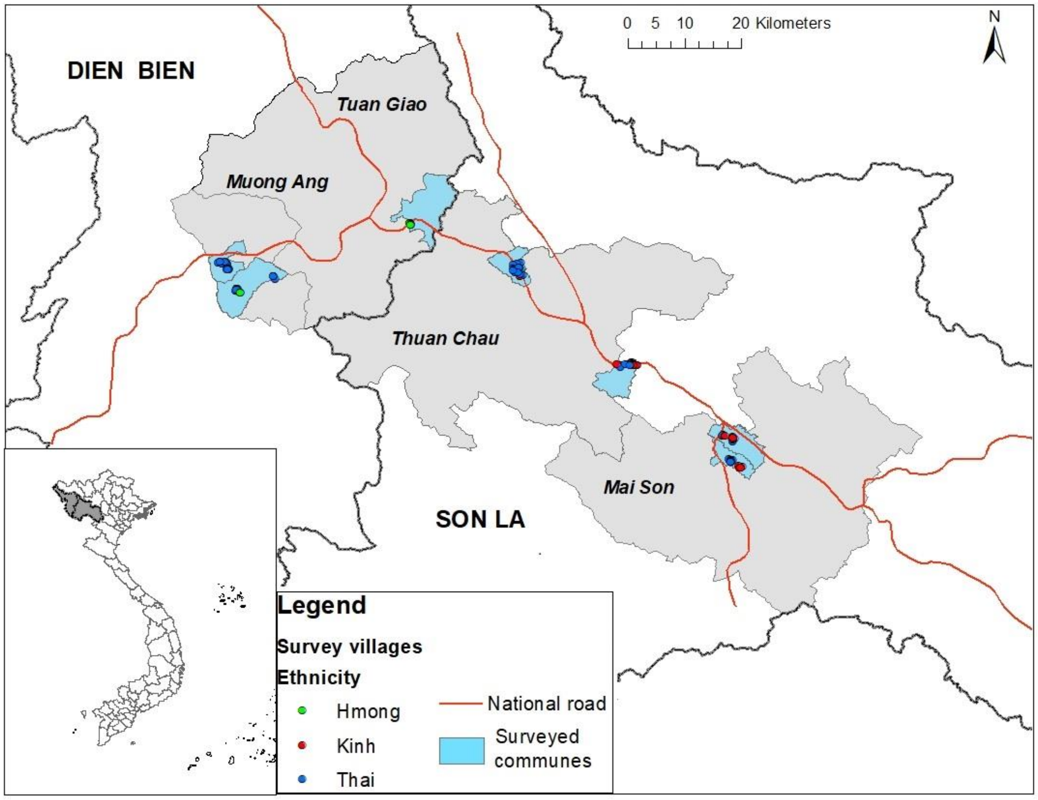


Figure 5. 1: Map of the study sites and the surveyed communes

Elevation of the study sites ranges from 300 to 2,000 m above sea level on 5 to 50 % slopes. Annual temperature ranges from 21 – 24^{o} C, annual precipitation ranges from 1,500 mm to 2,500 mm. Rainy season is from April to September. The main soil type is Ferrasols, average soil layer thickness ranges from 50 cm to 1 m. These natural conditions are favourable for arabica coffee. The upper limit Frost in winter is the most serious constraint for arabica coffee plantation at high elevations. Besides coffee, the main agricultural land uses are annual crops (upland rice (*Oryza sativa),* maize (*Zea mays*)), fruit tree plantations (longan (*Dimocarpus longan*), plum (*Prunus salicina),* mango *(Mangifera indica*)), planted forest, secondary natural forest and coffee plantations. The major ethnic groups are Kinh, Thai and H'mong.

5.2.2 Data collection

Data were collected through two rounds of survey between March to May 2018, following the methodology of van de Wolf et al (2016). The first survey was household interview and tree inventory at coffee agroforestry farms in March 2018. 124 households were surveyed; consisting of 16 H'mong farmers, 25 Kinh farmers and 83 Thai farmers (with those proportions largely representative of the distributions of ethnicities at the study sites). 68 men and 56 women participated in the interviews. A sub section of 50 farms were inventoried (providing a baseline of 47 tree ‘shade’ species in coffee agroforestry plots). The questionnaires were designed to capture social-economic characteristics, coffee plot descriptions including tree information in the agroforestry coffee plots and non-coffee plot, the benefits that trees provide to coffee in the plots and coffee management. Additional information was captured with group discussions, particularly relating to information on these ecosystem services and disservices and how perceptions potentially varied in relation to the age, ethnicity and gender of the farmer.

From the first survey, all the tree species on coffee farms were documented and the most dominant twenty five species were selected for the second survey in May 2018. Based on the initial discussions with farmers the effects of trees were grouped into eleven broad topic areas (which effectively act as proxies for ecosystem services). These topics were: Effects on coffee production; effects on soil moisture, effects on soil fertility, effects on soil erosion, effects on biodiversity, effects on climate regulation, wind control, frost control, the effects of and on shade provision, the value of mulch provision and effects on the use of fertilizer (which relates to soil fertility and GHG emission). The same farmers involved in the previous survey were invited for the second one. There were 118 farmers from three ethnic groups Kinh, Thai and H'mong, of which 64 men and 54 women, joined the second survey.

The second interview involved a ranking activity. Interviewees were asked to select up to ten preferred species to grow with coffee. They must be planting, or at least be familiar with these selected species. Pictures of both tree species and tree services were printed on cards. Then farmers ranked the performance of the trees to coffee for each topic area (stating whether their effect was positive or negative). Individual farmer ranking trees was then used to generate scores at the group level which were then recorded in the ranking sheet for later analysis. The smaller numbers indicate the higher ranking position of the species compared to the greater ones. During this exercise, farmers also provided the explanation for their rankings.

A final workshop was conducted in July 2018 in Mai Son district (Son La) and Muong Ang district (Dien Bien) with twenty five farmers to examine the result of the analysis, then present the results from the previous surveys to farmers and get their feedback.

5.2.3 Data analysis

Results of tree species inventory were analysed using the Biodiversity R packages in statistical software named R studio. Total species richness was presented with first order Jackknife formula (Kindt and Coe, 2005). Several species richness analyses were made for three ethnic groups, coffee farms and non-coffee farms to compare the biodiversity among Thai, H'mong, Kinh farms, coffee and non-coffee farms.

Following the ranking in the second survey, an analysis was undertaken via Bradley-Terry model in R studio (Turner and Firth, 2012). Ranking were converted into pairwise comparison as input data for the model. The model running was repeated for eleven tree services for three ethnic groups, three level of distance to road (near, medium and far), gender (male and female). Species that were ranked less than 10 times were excluded from the results. The scores reflect the comparison of performance rather than the absolute values. Scores were recalculated to the values between 0 and 1 with 1 is the maximum value for the best tree species. Ranking data was uploaded to the online database at www.shadetreeadvice.org. This study followed the same methods as other existing database from Gana (van de Wolf et al, 2016) and China (Rigal et al., 2018) to ensure that results are comparable.

5.3 Results

5.3.1 Farm characteristics of coffee agroforestry systems

All the interviewed farmers were from 25 to 50 years old with average age at 39. Among three ethnic groups, Kinh people had the highest average annual income while Thai farmers had middle level of average annual income. H'mong farmers had lowest average income which is approximately USD 1,762 per year. Average farm size was about 1.5 ha, Kinh farmers have smaller cultivation land compared to H'mong group. Coffee was cultivated on about two thirds of their land (approximately 1 ha in average) and the remaining areas were for annual crops for family and livestock consumption. Almost areas of their coffee plantation were ‘shaded’ coffee, i.e. coffee intercropped with trees such as fruit trees, timber trees, nut trees or *L. leucocephala* (See Table 5.1). Those were considered agroforestry coffee systems. Fruits were often sold at home or at the main road. Timber and coffee were collected by middlemen at home or sometimes at the local market on the road. All the Kinh villages were near the main road, at the distance of 0-2 km. Thai farmers typically lived at distances 0-5 km from the markets. H'mong farmers mostly lived far from the main road (5-7 km) except for the H'mong group in Toa Tinh district, Dien Bien province because of the newly built highway near their village.

Table 5. 1: Social and farm characteristics of coffee agroforestry (with statistical errors of the value)

Social and farm characteristics	Total population	Kinh	Thai	H'mong
Total number of respondents	124	25	83	16
Average agricultural income (USD/year)	4,571 ± 390	8,762 ± 1,286	3,810 ± 324	1,762 ± 276
Average farm area (ha)	1.5 ± 0.09	1.6 ± 0.26	1.3 ± 0.1	1.9 ± 0.3
Average number of coffee plots	2-3	2-3	2-3	2-3
Average area of coffee farm (ha)	1 ± 0.09	1.1 ± 0.16	1 ± 0.08	1.2 ± 0.2
Average area of agroforestry coffee plot (ha)	0.8 ± 0.06	1 ± 0.12	0.8 ± 0.07	1 ± 0.21
Average distance to main road/market	N/A	0- 2 km	0 – 5 km	0-3 km (Tuan Giao) or 5-7 km (Muong Ang)

5.3.2 Tree species inventory in coffee agroforestry systems

Forty-seven tree species were identified during the farm inventories. These included fruit trees, timber trees, nut trees, and shade trees. All inventoried farms were located from 580 - 1,000 m. Two native timber tree species were unidentified (have only local name). Half of them were native tree species. Table 5.2 present the names, scientific names, dominant functions, sources of origin (exotic or native). Related to tree biophysical requirement in chapter 1, *D. longan* is suitable with elevation lower than 800 m, plum (*Prunus salicina)* and *son tra (Donycia indica)* grows well at high elevation (higher than 800 m). Frequencies of tree species were calculated by the number of tree species appeared on surveyed farms by the total number of farm inventoried. Some trees were quite rare (with 37 % of tree species encountered on only 1% of the coffee farms. Another 37 % of tree species were found on 2 % - 10% of coffee farms). There are 26 % of tree species accounted for the most abundant species (which were found on 13 % - 46 % of total coffee farms) and most of them are commercial fruit trees. They were *L. leucocephala*, *Melia azedarach* and *Macadamia spp*.

There were 25 species out of 48 species are exotic. *D. longan* and mango are native species, however, only grafted hybrid varieties are being planted on farms.

Table 5. 2: Characterization of tree species mentioned by farmers as growing in their coffee farms and observed in coffee farms during farm inventory

No.	English name	Scientific name	Dominant function	Exotic/Native	Frequencies of species (%)
1	Longan	*Dimocarpus longan*	Commercial fruit	Exotic	46
2	Plum	*Prunus salicina*	Commercial fruit	Native	43
3	Mango	*Mangifera indica*	Commercial fruit	Exotic	42
4	Leucaena	*Leucaena leucocephala*	Shade	Exotic	23
5	Jackfruit	*Artocarpus heterophyllus*	Family consumption/ Commercial fruit	Native	22
6	Pomelo	*Citrus grandis*	Commercial fruit	Exotic	22
7	Melia	*Melia azedarach*	Commercial timber	Exotic	20
8	Peach	*Prunus persica*	Commercial fruit	Native	15
9	Macadamia	*Macadamia spp.*	Commercial nut	Exotic	15
10	Avocado	*Persea americana*	Commercial fruit	Exotic	13
11	Docynia indica	*Docynia indica*	Commercial fruit	Native	9
12	Guava	*Psidium guajava*	Commercial fruit	Native	8
13	Orange	*Citrus sinensis*	Commercial fruit	Exotic	6
14	Lime	*Citrus aurantifolia*	Family consumption	Native	6
15	Litchi	*Litchi chinensis*	Commercial fruit	Exotic	6
16	Eucalyptus	*Eucalyptus spp.*	Commercial timber	Exotic	6
17	Vernicia montana	*Vernicia montana*	Commercial timber	Native	6
18	Apricot	*Prunus mume*	Commercial fruit	Native	5
19	Tamarind	*Tamarindus indica*	Family consumption	Native	4
20	Chukrasia	*Chukrasia tabularis*	Commercial timber	Exotic	4
21	Dalbergia	*Dalbergia tonkinensis*	Commercial timber	Exotic	4
23	Manglietia	*Manglietia conifera*	Commercial timber	Exotic	3
22	Michelia	*Michelia mediocris*	Commercial timber	Exotic	3
24	Local pear	*Pyrus granulosa*	Family consumption	Native	2
25	Oroxylum indicum	*Oroxylum indicum*	Timber /Flowers	Native	2
26	Lucuma	*Pouteria lucuma*	Family consumption	Native	1
27	Fig	*Ficus auriculata*	Timber/fruit	Native	1
28	Baccaurea sapida	*Baccaurea sapida*	Timber /fruit	Native	1

No.	English name	Scientific name	Dominant function	Exotic/Native	Frequencies of species (%)
29	Bischofia javanica	*Bischofia javanica*	Timber	Native	1
30	Papaya	*Carica papaya*	Family consumption	Native	1
31	Star apple	*Chrysophyllum cainito*	Family consumption	Exotic	1
32	Star fruit	*Averrhoa carambola L.*	Family consumption	Exotic	1
33	Pomegranate	*Punica granatum*	Family consumption	Exotic	1
34	Indian Jujube	*Indian Jujube*	Family consumption	Native	1
35	Pine	*Pinus latteri*	Commercial timber/resin	Exotic	1
36	Styphnolobium japonicum	*Styphnolobium japonicum*	Timber	Native	1
37	Teak	*Tectona grandis*	Timber	Exotic	1
38	Alstonia scholaris	*Alstonia scholaris*	Timber	Exotic	1
39	Syzygium nervosum	*Syzygium nervosum*	Timber/leaf/flower	Exotic	1
40	Khaya senegalensis	*Khaya senegalensis*	Timber	Exotic	1
42	Dillenia Indica	*Dillenia Indica*	Timber	Exotic	1
43	Tea	*Camellia sinensis*	Leaf	Exotic	1
44	Zanthoxylum rhetsa	*Zanthoxylum rhetsa*	Seed/timber	Native	1
45	Agarwood	*Aquilaria malaccensis*	Timber/resin	Exotic	1
46	Schima wallichii	*Schima wallichii*	Timber	Native	1
47	Local timber tree (mý) *		Timber	Native	1
48	Local timber tree (thro) *		Timber	Native	1

* Scientific names of those species have not been identified yet

Trees were planted within the coffee plot in different settings such as in rows or scattered within the coffee plots, or along plot boundary. Coffee – tree intercropping was characterized into four common systems including coffee – fruit trees, coffee – timber trees, coffee – nut trees and coffee – *L. leucocephala*. In current practice, trees were planted at regular spacing in rows if there are one to two species being intercropped with coffee. Trees were planted at 5 m x 5 m for plum or mango, macadamia, Leucaena, and up to 10 m x 10 m for avocado. If more than three species are intercropped with coffee, farmers often planted them scattered in coffee plot between coffee rows or along the boundaries of the coffee plots. Most of coffee- multiple fruit tree systems were found in home gardens and coffee – native timber trees are far from home. Tree products in both cases were for family consumption. Coffee with commercial trees were planted at medium to close distance to home because it is easier for management, harvest and transport

5.3.3. Tree species richness in coffee farms

Figure 5.2a showed the difference in species richness from the coffee agroforestry plots and non-coffee plots (n = 124). Non-coffee plots are annual crops, other tree plantation such as timber or fruit trees. First order Jackknife asymptote shows the extrapolated value of total tree species richness was 48. All tree species encountered during the inventories also appeared in coffee agroforestry systems. Species richness from coffee agroforestry plots was almost double this from non-coffee plots.

Higher species richness was found on Thai farmers' coffee agroforestry plots compared to those of the Kinh and H'mong ethnic groups. First order Jackknife asymptotes from Kinh coffee plots was the same as this from H'mong coffee plots. This reflects the higher diversity in coffee plots of Thai group in comparison to other groups as the Thai people live in the middle elevation area which is suitable to the most species from table 5.2.

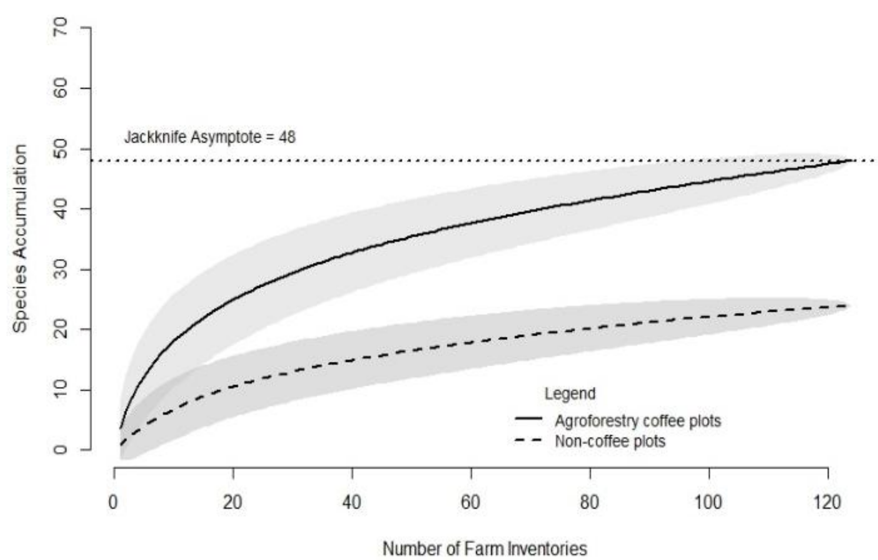
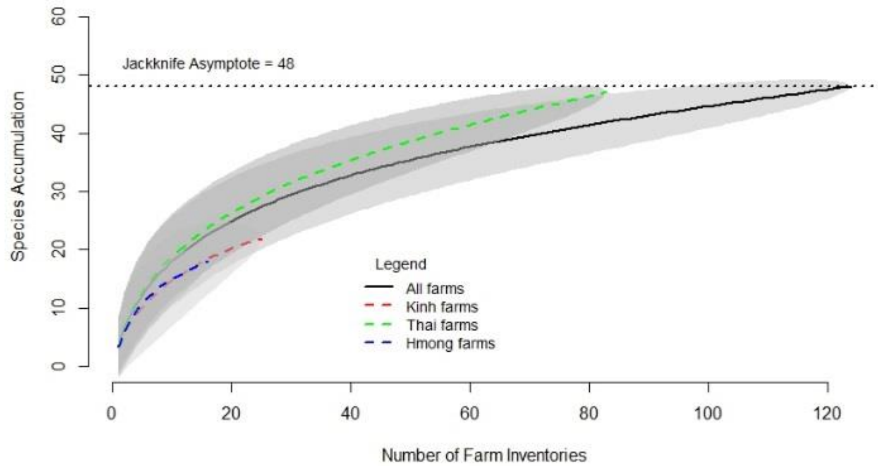


Figure 5. 2a: Species accumulation curves and 1st order Jackknife asymptotes from coffee agroforestry farms and non-coffee plots (orchards, annual crops, timbers) (n = 124)



(b)

Figure 5. 3b: Species accumulation curves and 1st order Jackknife asymptotes from all coffee agroforestry farms and Thai, H'mong and Kinh coffee plots (n = 124)

Tree species presence in coffee farms by proximity to road

When farmers select tree species to be intercropped with coffee in coffee agroforestry plots the critical factor that influences the selection is commercial – i.e. the ability to sell products such as fruits or timbers. There were a number of variables related to this factor including market price, proximity to market or proximity to main road because farmers usually sell fruits at the main road. Among three ethnic groups, the H'mong had lower access to road compared to the other two groups. The Kinh people had good road networks because they live in the lower altitudes. Proximity to road was identified as a critical factor for determining tree species selection of farmers in coffee farms (see Figure 5.4). Total number of investigated farms were 124, of which 52 farms in the communes near the main road (0-2 km), 54 farms in the communes at medium distance to main road (2-5 km) and 18 farms far from the main road (5-7 km). It is clear from Figure 5.4 that more commercial species (fruits and timers) associated with coffee if the farms are close or at medium distance to the main road/marke with the percentage of those were 77%, 55% and 46% of total tree species when farms were close, at medium and far from the main road, respectively. This was lower with 44% of commercial species if t. At further distance to the main road, more native timbers are intercropped. A leguminous species *L. leucocephala* were more present in the farms far from the main road.

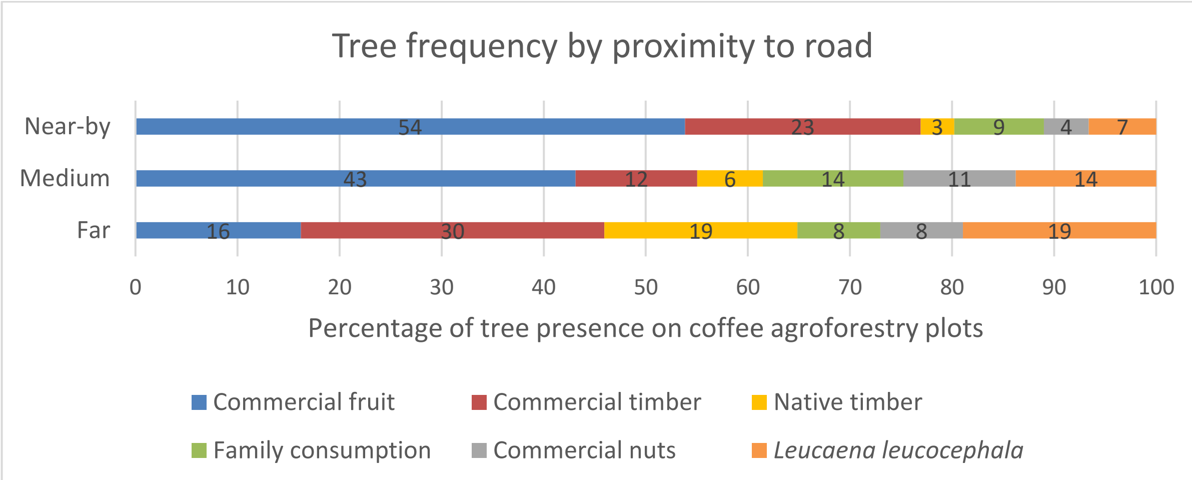


Figure 5.4: Percentage of tree species presence on coffee agroforestry plots by proximity to road *(Note: Number of farmers near the road was 52, medium to road was 54, far from road is 18)*

5.3.4 Farmer perspectives on ecosystem services associated with trees in coffee systems

Farmers had in-depth knowledge of the benefits of trees for coffee in their agroforestry systems. Most of them are aware of obvious ecosystem services such as reducing soil erosion, improving soil fertility, enhancing biodiversity, preventing damages from wind and frost, and providing shade and mulch.

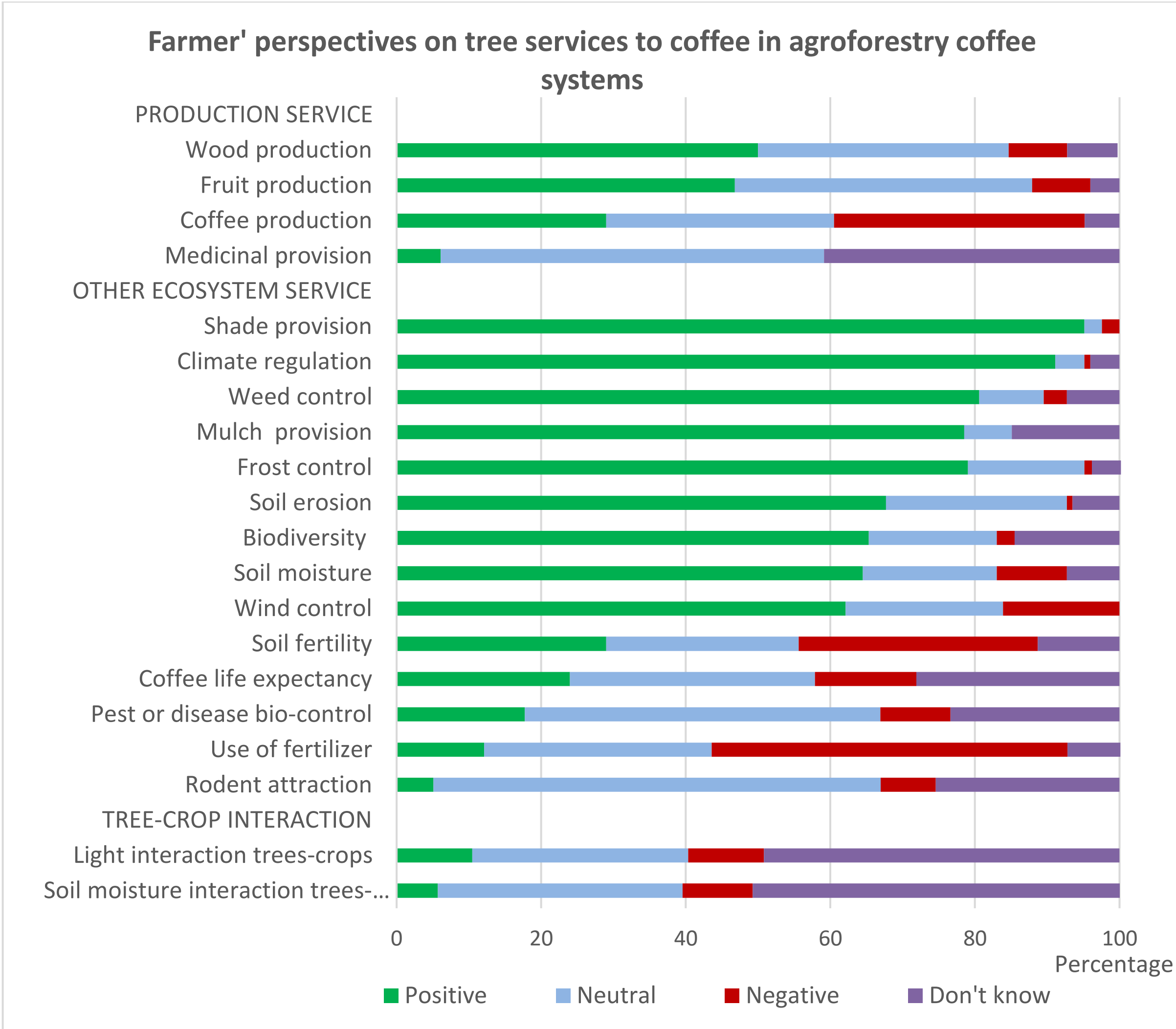


Figure 5. 5: Farmers' perspectives on tree services to coffee in coffee agroforestry systems

Some ecosystem services were highly linked to each other such as shade provision, mulch provision and soil moisture or frost control and wind control. Tree with big leaves and canopy were generally most associated with these benefits. Interestingly farmers had limited experience or knowledge on the effects of different trees on the quality of the coffee crop. In addition the responses suggest that farmers were less knowledgeable about light and nutrient interactions with more than half of their answers consisting of 'don't know' which can be considered as "knowledge gap" (see Figure 5.5).

If taking ethnicity into the analysis, the proportion of four answers were quite similar among three groups, except for coffee production, soil fertility, use of fertilizers (Kinh farmers were more negative about these), wood production (H'mong farmers were more positive about this), biodiversity (H'mong farmers were more negative about this), climate regulation (more Thai and Kinh farmers were more positive about this) (See Appendix 5.1)

5.3.5 Tree species pairwise ranking

Among 48 tree species encountered in coffee plots, only 25 species being intercropped in more than 2% of coffee farms were selected for tree pairwise ranking exercises. Accumulated values for each species are shown in Figure 5.6. It is clear from the figure that leguminous shade tree species (*L. leucocephala*) was the best species based on the services provided by this species to coffee. *Dirmocacpus longan* was the second best species because *D. longan* was intercropped in most common species across the coffee farm, followed by mango (*Mangifera indica*). Timber trees were not preferred as farmers said that timber trees compete for nutrient and water with coffee. Details on the ranking for each tree service was presented in Appendix 5.1.

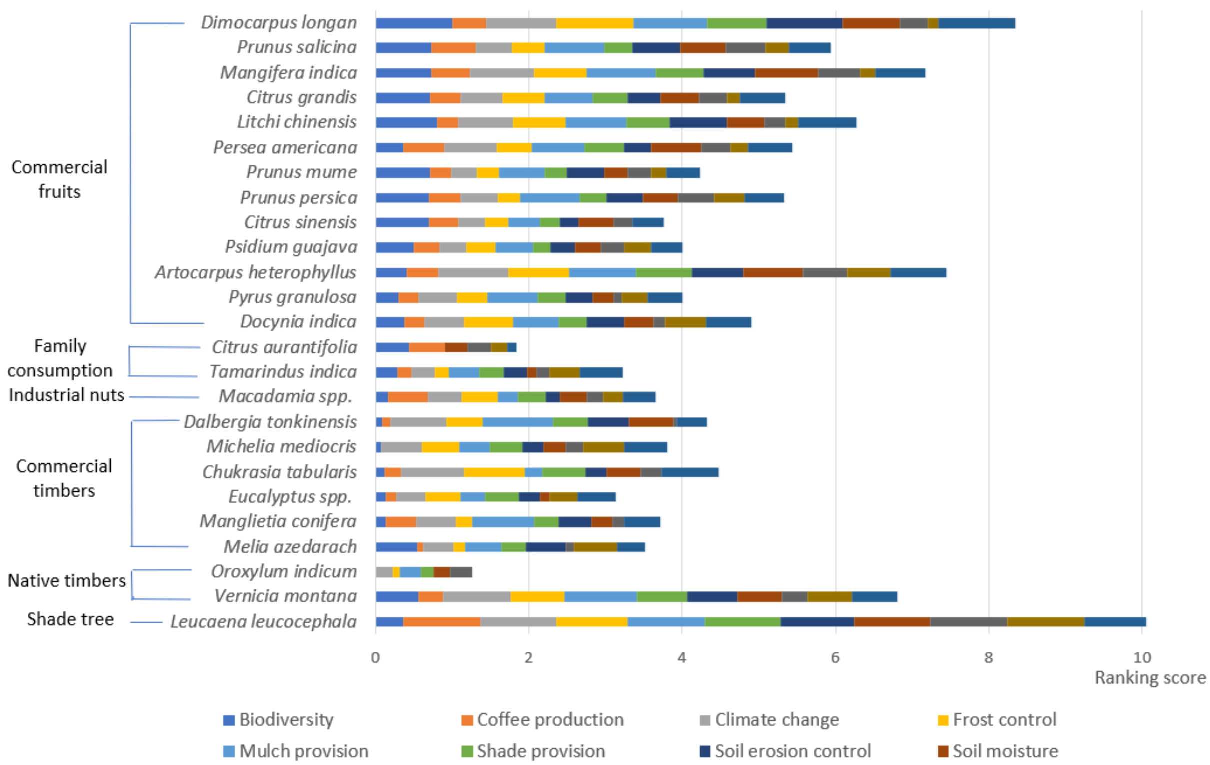


Figure 5. 6: Accumulated tree species ranking scores by different services from the whole farmer group

Since fruits are sold on the roadside, farmers living near main roads tend to plant more commercial fruit trees while farmers living far away plant more timber trees. The result from three group (near the road, medium distance to road and far from road) showed the difference in tree ranking for coffee production. The farmer group living near the main road ranked fruit trees such as plum

(*Prunus salicina*), longan (*D. longan)* as the best species for most of the services because the fruit selling price is high and it is easy to sell plum by the road. They also liked the shade from those trees for coffee. Most of the farmers from Thai and H'mong or at medium and far distance to road ranked *L. leucocephala* while the choices of Kinh and nearby group to the road preferred fruit trees with available. They explained that economic value of *L. leucocephala* was much lower compared to commercial fruit trees but the trees were good for coffee. Thefore, when their coffee farms were far from the main road, leading to difficult condition to carry fruits for selling, they would grow more *L. leucocephala* with coffee. Table 5.3 shows the best tree species for eleven services according to farmers ranking.

Results of pairwise comparison from men and women group did not show any significant difference with the overall ranking. Men and women had quite similar average ranking for the best tree species from all tree services. The main differences on their ranking were related to timber trees and happened with soil erosion, mulch provision, use of fertilizer and coffee production (See Appendix 5.3). On the other hand, rankings from three ethnic groups showed remarkable differences and mainly for timber trees and son tra (*Docynia indica*) (See Appendix 5.4)

Table 5. 3: Best tree species ranked by farmers for tree services to coffee in coffee agroforestry systems (grouped by ethnicity and proximity to main road)

Tree services	By ethnic group			By proximity to road			Overall ranking
	Kinh	Thai	H'mong	Nearby	Medium	Far	
Coffee production	Leucaena*	Leucaena	Leucaena	Plum	Leucaena	Leucaena	Leucaena
Soil fertility	Leucaena*	Leucaena	Leucaena	Leucaena	Leucaena	Leucaena	Leucaena
Shade provision	Longan	Leucaena	Leucaena	Longan	Leucaena	Leucaena	Leucaena
Climate regulation	Longan	Leucaena	Mango	Longan	Leucaena	Leucaena	Leucaena
Soil moisture	Longan	Leucaena	Leucaena	Jackfruit	Leucaena	Leucaena	Leucaena
Soil erosion	Longan	Longan	Longan	Longan	Longan	Longan	Longan
Wind control	Longan	Longan	Longan	Longan	Longan	Longan	Longan
Frost control	Longan	Leucaena	Longan	Longan	Leucaena	Longan	Longan
Mulch provision	Plum	Leucaena	Longan	Longan	Jackfruit	Leucaena	Longan
Biodiversity	Longan	Longan	Mango	Longan	Longan	Longan	Longan
Use of fertilizer	Jackfruit	Leucaena	Leucaena	Leucaena	Leucaena	Peach	Leucaena

(Note: Leucaena: *Leucaena leucocephala*, Longan: *Dirmocacpus longan*, Jackfruit: *Artocarpus heterophyllus*, Plum: *Prunus salicina*, Peach: *Prunus percia* Mango: *Mangifera indica*)

(*) indicates low level of confidence in ranking results.

L. leucocephala belongs to legume woody family. It was introduced in coffee plantation first by the French since they brought coffee to grow in Vietnam in 19th century. After the war, Leucaena was promoted to intercrop with coffee by Son La coffee company in Son La and Dien Bien. When the company was corrupted, farmers planted shade trees by themselves. Some of them keep Leucaena in their coffee garden, some replaced it by other fruit trees. Data from the survey shows that the current coffee farms in Dien Bien and few coffee farms in Son La have intercropping *L. leucocephala* since long time ago. Almost farmers in Son La have removed Leucaena in their coffee farms because this species had no economic benefit although they recognized the positive impacts of *L. leucocephala* to coffee (Figure 5.6). Farmers in Son La replaced *L. leucocephala* by fruit trees such as plum and longan which provide better income.

Ninety percent of *L. leucocephala* were found in Dien Bien province and grown by Thai farmers (n=29). A few H'mong farmers also plant *L. leucocephala* intercrop with coffee and other trees. Some H'mong farmers stated that they learned the technique and took the seedling from their friends in those Thai villages. Son La province is famous for fruit production while fruit trees have not well developed in some areas of Dien Bien province despite some fruit tree support programs from local government. Farmers in Dien Bien said that it was hard to manage fruit trees as young seedling and fruit in harvesting season often were stolen. Harsh weather like drought and frost were also their constraint in planting fruit trees. Most of fruits for domestic consumption in Dien Bien are imported from Son La and other provinces. Because farmers found difficult to grow fruit tree well in Dien Bien, and they are at medium or far from road (2 – 8 km), they decided to keep *L. leucocephala* in their coffee farms.

On the other hand, *D. longan* is highly popular fruit tree species in the Northwest. From the tree inventory, *D. longan* is the most abundant species since it appeared in 46% of surveyed farms. Only 9 farms in Dien Bien had *D. longan* while the rest 50 farms were in Son La. Most of *D. longan* trees were planted by Kinh and Thai farmers. Selling price of *D. longan* in 2017 was around USD 4/kg. Approximately *D. longan* was highly ranked for coffee agroforestry systems because of its good services to coffee such as providing shade, litterfall to keep the soil humidity, reducing wind and frost impact.

5.4 Discussion

5.4.1 Tree diversity in coffee agroforestry systems

Shaded coffee systems were well recognized for biodiversity enhancement. Tree species richness from agroforestry coffee plots was almost double than this from non-coffee plots, supporting the notion that shaded coffee systems have higher tree diversity in coffee agroforestry compared to other land uses (Vaast et al., 2005). The highest record of planting trees on coffee plots belong to Thai group (see Figure 5.3b), which can be explained by the favourable condition of their location for different tree species compared to other two groups. Thai is the group living at medium elevation from 600- 800 m and they are distributed near or at medium distance to the national highway. Because of geographical distribution of these ethnic groups, ethnicity was associated with two important variables including elevations and proximity to road.

Among 48 recorded species from the tree inventory, 10 species are the most abundant as being planted in more than 10 % of total inventoried coffee plots. This is relatively low compared to 162 tree species found from Yunnan, China (Rigal et al., 2018) or 165 tree species in Mount Kenya (Carsan, 2012). However, this finding was similar to the number of species found by Nyaga et al. (2015) in the Rift Valley in Kenya with 44 species (and 55% of recorded species were native). However, the primary functions of trees in Vietnam were commercial fruits with ready market while the most abundant species in Kenya were firewood and pulp species (Nyaga et al., 2015).

5.4.2 Tree ranking and farmer's perception on tree services or disservices

Farmers did not like planting timber trees with coffee. They only planted timbers when they had no other choices for fruits (either because of unsuitable condition or distant from the main road and market). Farmers' ranking on timber were always at the lowest places. This was consistent with the tree frequencies from table 5.2 where timber species appeared in less than 6 % of surveyed farms. Farmers were knowledgeable about benefits that trees can provide to coffee (Dumont et al. 2016; Soto-Pinto et al., 2007). In this study farmers could confidently describe the effects of trees on climate regulation, soil erosion, shade provision, mulch provision, frost and wind control.

Unlike the Central Highlands of Vietnam where coffee was blamed for deforestation (Meyfroidt et al., 2013) in the Northwest, most of coffee farms were established on annual crop land or fallow land (Nghiem et al., 2019). Therefore, farmers could explain clearly the benefits from integrating trees on their coffee farms on steep slopes such as soil become soft and moist, soil has dark brown color compared to yellow color in the past. For those services that farmers cannot observe directly from fields, most of their answers were do not know when they were asked about pest and disease bio-control or soil fertility, coffee life expectancy, interaction between coffee and trees for light and water. Coffee production under shade is still a question when they explained that too much shade made coffee bean take long time to ripe, coffee produced fewer cherries but the size of the cherries was bigger. Coffee quality remains a big gap because farmers do not taste coffee. These are the areas that knowledge through trainings or extension activities can be provided for farmers.

5.4.3 The relevance of tree knowledge and tree biophysical suitability

Nitrogen fixing species were common in many coffee regions such as *Erythrina* spp. and *Inga* spp in Central America although it has no timber values (Beer et al., 1998). *L. leucaena* was ranked as the best species for most of ecosystem services. As farmer observed, Leucaena was growing well with coffee and provides good shade as leaf size was not too small or too large. *L. Leucaena* leaves were soft, which was good for soil fertility. Despite the facts that *L. leucaena* was good for coffee, *L. leucaena* frequencies was only 23 % and it was planted mainly in Dien Bien where farmers thought the natural condition was not suitable for fruit trees. If the biophysical condition was suitable for fruit trees, farmers preferred fruit species for additional values. Moreover, although legume species is good for coffee, this also depends on the management of legume trees on farm (Haggar et al., 2011), farmers in Dien Bien expressed their concern about too much shade from Leucaena trees.

Fruit trees in coffee farms are also popular thank to its high profit. Farmers in Yunan ranked fruit trees including *D. longan* quite high (Rigal et al., 2018). *D. longan* has restricted elevation up to 600 m while arabica coffee is suitable with elevations at 500 m and above. Most of Kinh farmers live in lower land compared to Thai and H'mong groups. That was why they ranked *D. longan* as good species for coffee and explained that *D. longan* had good shade although its leaves were harder than *L. leucaena* leaves. However, Thai and H'mong farmer also ranked *D. longan* for some ecosystem services and they expressed the wish to expand coffee- *D. longan* systems if they have available land. This raises a concern about the biophysical suitability of *D. longan* at higher elevations and it may lead to the low productivity of the trees and the whole coffee- *D. longan* systems. Also farmers stated that *D. longan* has large canopy and wide root which can compete with coffee, their selection of tree species in coffee agroforestry systems was highly influenced by economic benefits of intercropped trees and market access, particularly proximity of farms to main road. It can raise a concern about oversupply of *D. longan* and market price drops in the near future. Moreover, farmers choice on trees were just a few species (*L. leucaena*, *D. longan*, peach, plum, jackfruit), low biodiversity of the coffee landscape can be foreseen.

While timber was also good for coffee, farmers ranked timber as the worst species for integrating with coffee. They explained timber trees often compete with coffee for water, nutrition and timber shade was not good for coffee. This is quite similar with Central America where timbers are also less common in coffee farms although it can provide additional values for farmers (Vaast et al., 2008). This suggests further studies to focus on economic benefits from coffee - legume trees, coffee-timber and coffee -fruit trees to provide evidences on the trade-off values of integrating different type of trees on coffee farms.

5.4.4 Gender, ethnicity and tree selection

Findings from the study shows that ethnicity influences farmers' perception on tree services to coffee in agroforestry systems (see Appendix 5.1) and farmer's ranking on tree species varied by ethnicity (see Appendix 5.4). However, average rankings of tree species between men and women from all services were not too different (see Appendix 5.3). The main differences were in a few services such as soil erosion, much provision, use of fertilizer, and mostly related to timber trees. Farmers from three ethnic group Kinh, Thai, H'mong, both men and women ranked *L. leucocephala* as the best tree species providing multiple services to coffee. Overall ranking shows that the most preferred options were *D. longan* or plum and jackfruit if the farms were close to the main road. *L. leucocephala* was preferred if the farms were further from the road. Thus, the underlying factor of the selection could be market drivers. Moreover, coffee was produced only for trade, farmers did not consume it themselves. In this commercial system, market factors seemed to be the most important consideration rather than ethnicity or tree knowledge.

5.5 Conclusion

This study suggests that integrating trees into unshaded coffee systems can bring multiple benefits to environment and livelihoods. From the field survey, most of smallholder coffee area was under agroforestry, but highly dependent on plot location, ecological suitability and market access. Tree diversity of coffee agroforestry farms were double those in non-coffee farming systems. There were observable differences between different ethnic groups. Thai farms had higher tree species richness in comparison with Kinh and H'mong groups – but it was not clear the degree to which this was driven by cultural rather than contextual factors (such as proximity to roads). Commercial fruit trees were more common when farmers lived near or at medium distance to main roads. Timber trees and legume tree - *L. leucocephala* were more common on coffee farms which were far from the road.

Farmers had knowledge on visible tree services such as soil erosion, mulch provision. However, they appeared to lack knowledge about the effects of shade trees on soil fertility, pest and disease control, and interestingly on the competition between coffee. This is where integrating local knowledge and scientific knowledge can provide advises farmers on selecting tree species for their coffee farms.

By uploading the data to the online tool http://shadetreeadvice.org, this information can help farmers, researchers and policy makers to choose suitable tree species according to preferred services. Further research on economic analysis of different coffee agroforestry systems can provide farmers on the profitability of the systems, therefore help them choose the most optimal options to enhance environment and improve their livelihoods.

VI. SYNTHESIS

6.1 Reflection of key findings of research chapters

The thesis aims to identify the potential of scaling out agroforestry options in relation to the local natural, socio-economic contexts of Northwest Vietnam with an explicit consideration of the social norms associated with ethnicity and gender.

To meet this aim the PhD had four key objectives:

1. To map the potential domain for adoption of novel agroforestry systems faced by hill tribe populations and increased erosion threats associated and to identify suitable areas for agroforestry adoptions based on biophysical requirements.
2. To characterise the social dimension of pathways for agroforestry adoption across the three main ethnicities in Northwest Vietnam
3. To provide an understanding on gender role in agroforestry adoption with a case study of H'mong community
4. To document local tree knowledge in coffees agroforestry and the potential for expansion.

6.1.1 Enhancement of understanding of erosion risk

Despite broad acknowledgement of a significant issues with erosion in Vietnam this work provides an important iteration in the systematic assessment of vulnerable cropping systems on sloping land and soil erosion prevalence in the Northwest region. There have been studies that have provided similar evidence of environmental impacts caused by continuous annual crop cultivation on steep slopes in Southeast Asia (Valentin et al., 2008), in the mountainous areas of Vietnam (Van De et al., 2008) and in Northwest region (Tuan et al., 2014; Wezel et al., 2014). However, there has been no published data on the spatial extent of the degradation area and its impacts at landscape scale. The findings from Chapter 1 provide data on the areas of cropland on slopes and the prediction of soil erosion in order to establish potential expansion domains for agroforestry. The areas of annual cropland on slopes were mapped using Landsat satellite imagery and Random Forest classification algorithm. The combination of the Landsat satellite imagery with the Random Forest classification algorithm suggests that the area of vulnerable cropland on steep slopes (> 25^{o}) was 35% of total area while the official reported cropland data by Ministry of Natural Resources and Environment (MONRE) in 2010 was only 16% of total area. This study reveals that large areas of vulnerable cropland lie within land designated as forest by MONRE, resulting in a current overestimation of tree cover. In addition, the soil erosion prevalence data shows a high probability of soil erosion within these areas. Agroforestry is one potential mechanism to address this issue. The biophysical suitability analysis carried out in Chapter 2 (using lower resolution Landsat data) revealed that 85 % of total area of vulnerable cropland was suitable for tree integration. At the higher elevations (above 1000 m) the number of potential agroforestry options available drops from nine to four tree-based options, limited mainly to coffee and indigenous trees such as son tra *(Docynia indica)* and plum (*Prunus salicina*.)

6.1.2 Opportunities and barriers to adoption

Having identified both a clear need and an opportunity space for agroforestry the second chapter explored the human dimensions that might impact on agroforestry adoption. The analysis of cultural factors that potentially influence agroforestry adoption of the three main ethnic groups (the Kinh, Thai and H'mong people) showed significant variation in attitudes to tree establishment. In particular the study revealed significant barriers to adoption amongst the Kinh despite having suitable land available. This information is critical as, to date, there have been almost no studies looking at ethnicity and cultural aspects of agroforestry in Vietnam apart from very broad ICRAF guidelines on how to engage ethnic minorities in general agricultural research (Hiwasaki et al., 2016). As such current recommendations concerning agroforestry options for Vietnamese upland systems are effectively generic. This study demonstrated that each ethnic group studied had their own context, characteristics and preferences in relation to tree expansion and revealed real limitations to adopting a 'one-size-fit-all' approach to agroforestry extension activity.

Chapter 2 also highlighted that farmers' preferences for agroforestry adoption were highly influenced by social norms. Ethnicity influenced the design of agroforestry systems in the way farmers want to have crop/tree components in their systems to fit with their available capacity. Based on their interests and knowledge of agroforestry, a limited number of farmers have developed suitable tree-based options which fit with their capacity (or socio-ecological context) and have high market values. Different ethnicities clearly had different needs, for example H'mong farmers always required an annual crop component in their systems to meet their subsistence food demand while Thai farmers were reliant on maintain a grass component for their livestock. There was also evidence of different knowledge systems in play, for example, Kinh farmers placed higher value on leguminous plants to improve soil fertility. This study contributes to the existing global literature in understanding cultural and ethnicity aspects of local ecological knowledge on agroforestry and other land uses (see, for example, Weber et al., 2007; Ayantunde et al., 2008; Xu et al., 2005; Madge, 1995). By recognizing these attributes this study can feed in appropriate methodologies that can inform the future design of culturally appropriate agroforestry interventions that are more likely to be accepted and adopted beyond a standard project cycle. This study sets out further research needs that more closely integrate local and scientific knowledge. This allows better design of agroforestry options for different ethnic groups and to expand this work to the other ethnic groups such as Muong, Tay which are more common in other provinces.

6.1.3 Building gender sensitivity into scaling out agroforestry – a case study with the H'mong

Gender issues associated with natural resource management remain an area of significant uncertainty (Kiptot et al., 2014; Catacutan and Naz, 2015; Villamor et al., 2017). To better understand any potential gender constraints and opportunities associated with expansion of agroforestry in Vietnam the third data chapter focused on gender issues amongst the H'mong. The study revealed that agricultural activities and agroforestry adoption were highly influenced by gender. Certain domains that women had more freedom in accessing to resource and decision-making included vegetable, fruit and small livestock production and selling. H'mong women had particular constraints in information access due to Vietnamese language barrier. Of particular interest was the variation between young and old male and female farmers perspectives and suitable approaches for each group to scale out agroforestry adoption. For instance, if too much information in training materials is provided by extension workers it makes it difficult for male farmers to identify relevant information and limits the transfer of knowledge to their wives. This is despite women play important role in farming activities, especially they are main labour in coffee and fruit harvesting. This study also highlighted the need to engage men to help them understand the importance of women's involvement in their livelihood systems. On a more positive note there were indications that the norms were changing, and that young women were less restricted now than in the past – particularly in regard to relations with their husbands and in-laws and there were fewer language and cultural barriers compared to their parents' generation.

Of particular relevance to this study were the different ways that men and women accessed information. Men have both formal and informal learning channels, whilst women were more reliant on informal information derived primarily from their female peers. This suggests that, certainly amongst the Hmong, current agricultural extension services were not directly reaching women. This is important as women also had specific needs, particularly associated with their increased time constraints and were, for example, more interested than their male peers in labour-saving technologies. There remain some more entrenched gender issues, particularly in relation to strategic decision-making responsibilities at household levels. Woman were not involved, for example, on investment and market strategy decisions.

Despite, and perhaps because of, being limited to a single village the gender work immediately highlighted the need for greater integration of gender focused research, particularly to expand the study to the Kinh and Thai communities. The study offers a possible explanation for why Kinh farmers are less likely to adopt agroforestry although they have capacity to adopt

6.1.4 Coffee – an opportunity for agroforestry expansion?

The final data chapter focused on opportunities to address erosion through expansion of coffee agroforestry systems. Coffee arabica is an important commercial crop not only for smallholders in Northwest Vietnam but also other countries in Southeast Asia, Africa and Latin America. This chapter built on research conducted exploring the broader ecosystem services derived from integrating 'shade trees' on coffee farms – see De Souza et al., 2012; Van Oijen et al., 2010; Méndez et al., 2007). The context for integrating trees in coffee systems is a little unusual in that trees are not primarily integrated for shade alone – and upland coffee systems often inegrate trees to provide income diversification options. To explore this the final chapter looked at how farmers ranked the different benefits provided by trees across the different ethnic groups involved in the study. As tree selection was strongly influenced by accessibility to market this was also integrated into the analysis. The results complemented for the result of the third chapter which explored ethnic perspectives on agroforestry adoption. Understanding how accessibility to market influences tree selection a critical factor for tree species selection of smallholder farmers is and thus for scaling out agroforestry options. At present the study was only able to provide a rough estimation of profitability of coffee agroforestry systems however it was clear that farmers' selection of tree species in their coffee agroforestry systems was highly influenced by the economic value of intercropped trees and market access, particularly proximity of farms to main roads (which was where produce was largely sold). In systems with lower access (i.e. with greater distance from the road) there were different priorities associated with which trees to intercrop with coffee). There was a limited cultural component to these choices

The study did reveal a number of interesting findings related to potentially expanding coffee systems to address erosion prevalence. In systems where farmers had already integrated agroforestry tree species richness was much higher compared to non-coffee plots including annual crops, orchards, timber plantations. Tree species richness in Thai farmers' coffee farms were higher than those of H'mong and Kinh groups. Because Thai group mostly live at medium elevations (400 – 800 m) which is suitable with various speices and have both low or medium access to market, all type of agroforestry coffee systems were found on their farm.

In all cases farmers were able to offer in-depth local knowledge of the benefits different trees in their coffee systems provided. The results explain why there were fewer native species and more commercial species in the areas with better road accessibility despite the farmers' own valuations of these species ecological benefits to coffee trees. The leguminous tree *L. leucocephala* and fruit tree *D. longan* were identified by farmers as providing the broadest range of environmental benefits to coffee systems. *L. leucocephala* with low economic benefits was mostly found in the areas far away from roads and market. On the contrary, *D. longan*, having high market value, was found in more than 50% of surveyed farms, mostly near and medium to market. Considering *D. longan* not suitable with elevation above 600 m, intercropping this species with arabica coffee could bring some risks for farmers. The results help local extension institutions and farmers in the selection of the 'right' tree species according to the local context together with households' needs and constraints towards more sustainable and climate-smart coffee systems. The tree knowledge from this study was integrated in the existing global online tool for shade tree advices (van der Wolf et al., 2016; Rigal et al., 2018).

6.2 The dynamics of agroforestry adoption in various contexts

Agroforestry adoption is not just a "copy and paste" process but it highly depends on the biophysical, socio-economic context of the households (Kiptot et al., 2007). Farmers adopt tree species and modify adoption based on their own needs (Scherr, 1995). There are a number of variations of agroforestry adoption observed from the survey such as planting one or double grass strips on farms, growing trees in different spacing and density, learning grafting techniques to apply on their farms. Trees can be planted along the boundary of plots, or in rows between other trees and crops. Maize, rice or vegetable are intercropped when trees are still small for Thai and H'mong farmers. Fruit trees are often planted near the house or the road while timber trees are planted at further distance. H'mong farmers chose to adopt agroforestry on their fallow plots while Kinh and Thai farmers intercropped trees with their existing annual crops. Kinh farmers do not prefer planting grass strips while Thai always to expand grass-tree-crop systems because Kinh farmers have small areas of cultivation land and they are afraid of the competition between trees, grass and crops. This is quite similar to the adoption pattern of farmers in Nepal (Neupane et al., 2002) where farmers in the lowland do not like fodder trees but upland farmers prefer trees for livestock. Unlike the farmers planting trees to improve soil fertility in Malawi (Coulibaly et al., 2017) or for fuel and timber in Ethiopia (Assefa and Rudolf Bork, 2014) , most of farmers in Northwest Vietnam adopt fruit trees in their agroforestry options provided that they are suitable for their biophysical condition and have high market values.

The complexity and diversity agroforestry adoption make it difficult to monitor the number of non-project adopters and the areas of adoption. The temporal aspect of agroforestry systems makes the monitoring process more challenging because farmers intercrop tree and crops for few years then the crops are removed to give more space for trees. The design and component of adoptions are changed when the context changes and farmers change their altitudes over time. In this study, we could only measure the types and components of agroforestry systems that farmers observed in their context at one point of time. The method to monitor adoption at large scale is still a limitation. Moreover, the monitor of adoption should be in long term since planting trees in few years only does not make any significant impacts to both environment and livelihoods.

6.3 Understanding the risks of agroforestry adoption

Agricultural production of smallholders contains various sources of risks which can be classified into production, marketing, financial, institutional and human (Hardaker, 2004). Risk is an important factor that reduce the rate of innovation adoption (Mercer & Pattanayak, 2003). Testing new species and technique in various context are even more risky for smallholder adopters although biophysical suitability has been done carefully. Production risks, which come from unpredictable extreme weather or uncertainty in tree and crop productivity. It is easy to happen if an intervention or option is promoted at large scale without considering the local context. For example. This is where local knowledge play an important role and integrating scientific and local knowledge can help reduce the risks.

There is always risk associated with market even though market demand can be estimated, and market trend can be researched. Adoption at large scale may lower market price because of the oversupply of the products. It is the reason why some non-project farmers are actually the observers and they wait to see the real benefits of agroforestry options before adopting.

Pattanayak et al. (2003) pointed out that training is one variable of risk for adoption. We also observed the low rate of training material usage and knowledge transfer of project farmers. From the gender study, we found out that most of the training participants are men although both men and women work on farm. Weak management of trees on farms were observed in the plots that the wives are in charge of managing the trees, dealing with pest and diseases but they did not know the techniques from their husbands who joined the trainings.

Another popular type of risk is farmer decision making towards agroforestry adoption and it always in the relation with other sources of risks and uncertainties. “Smallholders are profit maximizers and risk minimizers” (Schuren and Sneider, 2008). Farmers learn the technique very fast and they will plant trees in large areas if the profit is high. However, they always compare the profitability of tree-based options with monoculture cash crop (maize or rice) in the same piece of land (Mercer & Pattanayak, 2003). Farmers can change their mind very quickly. Their decisions are based on their personal feeling about the objects and activities rather than the information to help them make decision (FAO, 2008). Gender study reveals that men were willing to accept more risks than women. Understanding local culture, farmers preferences and constraints for different ethnic groups can help to understand better the risks for ethnic minorities. Among three ethnic groups, Kinh group is willing to take risk and invest on new options and H'mong is the most vulnerable group. The adoption process happens faster for Kinh group and it takes more time for H'mong group to consider all type of risks in adoption.

6.4 The importance of capturing feedback loops and farmer ‘option’ modification

At the end-line of the first phase of project, approximately 70 % of project farmers want to expand agroforestry systems on their farm. This is high adoption rate compared to the average 39 % of farmers who reject the techniques after trying it in Kenya (Kiptot et al., 2007) or 30 % for alley cropping in Ethiopia (Tafere and Nigussie, 2018). Although the rate of farmers adopting techniques and want to maintain the systems from project farmers are high, there are still some constraints from system design and components which did not work for farmers in some areas although tree species were selected by farmers in the beginning of project. Sustainable scaling out of agroforestry adoption requires a process of several steps which consist of testing the techniques at small scale to operational scale and then adoption. Following these steps can help reduce risks of adoption process (Scherr, 1995).

In this study, it is highlighted that techniques should be applied to test and then modified based on the preferences of household and biophysical context. For example, grass component of the introduced technique received both negative and positive feedbacks from farmers. Among three ethnic groups Thai households raise the largest number of cattle so they prefer to have grass in their systems. Other non-project Thai farmers also learn to plant grass for livestock on their farms, but they modified the technique to plant one grass strip instead of two strips as introduced by project design. On the contrary, H'mong farmers did not want to have grass because their tradition is herding cows and buffalos in the forest.

Indigenous species are always the most suitable species to the biophysical condition and local tradition. The promotion of *son tra* (*Docynia indica)* as the indigenous species for H'mong farmers above 800 m was definitely accepted by local farmers. When extreme weather occurred in Yen Bai province with snow fall (once in 40 years), only *son tra* trees survived while other exotic species died. It makes a great potential for son tra agroforestry to be the most resilient system under climate change among all tested agroforestry options under AFLi project.

6.5 Implication for future development of agroforestry at large scale

As a result of this work I here suggest an initial integrated framework that describes the process for scaling out agroforestry in a Northwest Vietnamese context see Figure 6.1). This is a marginal agroecosystem where a complex and historical socioecological system has been combined with rising food insecurity to create an acute land degradation problem. Whilst agroforestry offers a potential solution to these issues the biophysical and social heterogeneity limits the viability of standard or generic agroforestry proscriptions as the performance of these agroforestry options will vary hugely across the complex geographies of Northwest Vietnam. Instead the approach taken here was to focus on how both biophysical and social context varies across this system and to begin the process of fitting context appropriate agroforestry options (Smith-Dumont et al 2019). This approach utilises and adapts a framework of research developed by Coe et al. (2014) (and which is being tested within the AFLi and AFLi-II projects in Vietnam). This framework presented here is a locally adapted version which provides greater detail on a) locally specific factors that feed into context, b) detailed descriptions on potential options and c) a participatory assessment of suitability developed by analysis of the key socio-ecological variables that are likely to have the most influence on the adoption process. This is an inherently iterative process and this work reflects the first phase of a cyclic adoption process. Further monitoring of the process of how and why farmers adopt agroforestry options will allow increasing refinement of how specific conditions vary and and feed into a continuing process of modification to improve the ‘fit’ of these option to what is a complex socio-ecological landscape.

Within this framework the key shift is the focus on capturing ‘context’ variables. Context here is both the potential biophysical parameters that define the envelope in which defined agroforestry options can operate and the socio-economic variables that feed into local stakeholder prioritisation. The broad aim was to identify what might work (in relation to agroforestry options, and then use context parameters to both identify 'spatial envelopes' (i.e. the scaling out domain for each agroforestry option) and the degree to which local farmer 'appetite' for these options varied in response to their livedoid needs and cultural norms. The primary driver guiding this process was the need, recognised by policy in Vietnam, to reduce the very high levels of land degradation occurring across these upland landscapes (driven, in part, by the unstainable cultivation of annual crops on slopes). The key biophysical parameters analysed here were limited initially to soil type, soil thickness, average annual rainfall, average annual temperature, slope and elevation (data for which in most instances could be sourced remotely). In contrast, a participatory process identified an initial set of socio-economic conditions for scaling agroforestry options consisting of 'proximity to main road or market', social norms, farmers' local knowledge and attitudes towards agroforestry adoption, available market and appropriate communication products for different targets. The options that were initially promoted options are designed to be tested before adoption at small scales initially and then with larger scale trials. During the adoption process, options were modified based on farmers' need and preferences. Stakeholders in this process included farmers, government, NGO organisations, enterprises and buyers. All were involved in the process with farmers in the centre. The results show that farmers from different ethnic groups often had different attitudes, preferences and constraints with regard to the design of agroforestry systems, which were shaped by their different contexts (see Chapter 3). In addition, other factors were important in the manner in which they affect the uptake of these techniques such as gender (see Chapter 4). There are a number of agroforestry systems that already have begun in these systems, and coffee with shade trees has significant potential for scaling out. By working with farmers who manage these systems and those who are interested in adopting these systems the study captured key local knowledge about properties of these systems that both fed into future designs and highlighted gaps in farmer understanding (see Chapter 5,) The combination of this research effort provides the first platform to develop sustainable agroforestry systems that both meet local livelihood needs, that are sensitive to local contexts and the address sustainability needs.

This framework is scale neutral and can be applied to any efforts to scale out agroforestry from farm level to landscape level. It highlights the need to test the options in different farmer groups before adoption. During the process, options were refined to fit in the context with a set of farmer groups and will be tested again until they are adopted and scaled out. This process supports and recognises the immediate value of the process suggested by Coe et al (2014) by suggesting an initial set of potential agroforestry options tailored for different stakeholders. The second phase of this would be to conduct in situ planned comparisons. Coe et al (2014) This research demonstrates the value of this approach to underpin the adoption processes and reduce the risks in any scaling up processes. Suggestions below are for the implication of the framework for agroforestry adoption in the future.

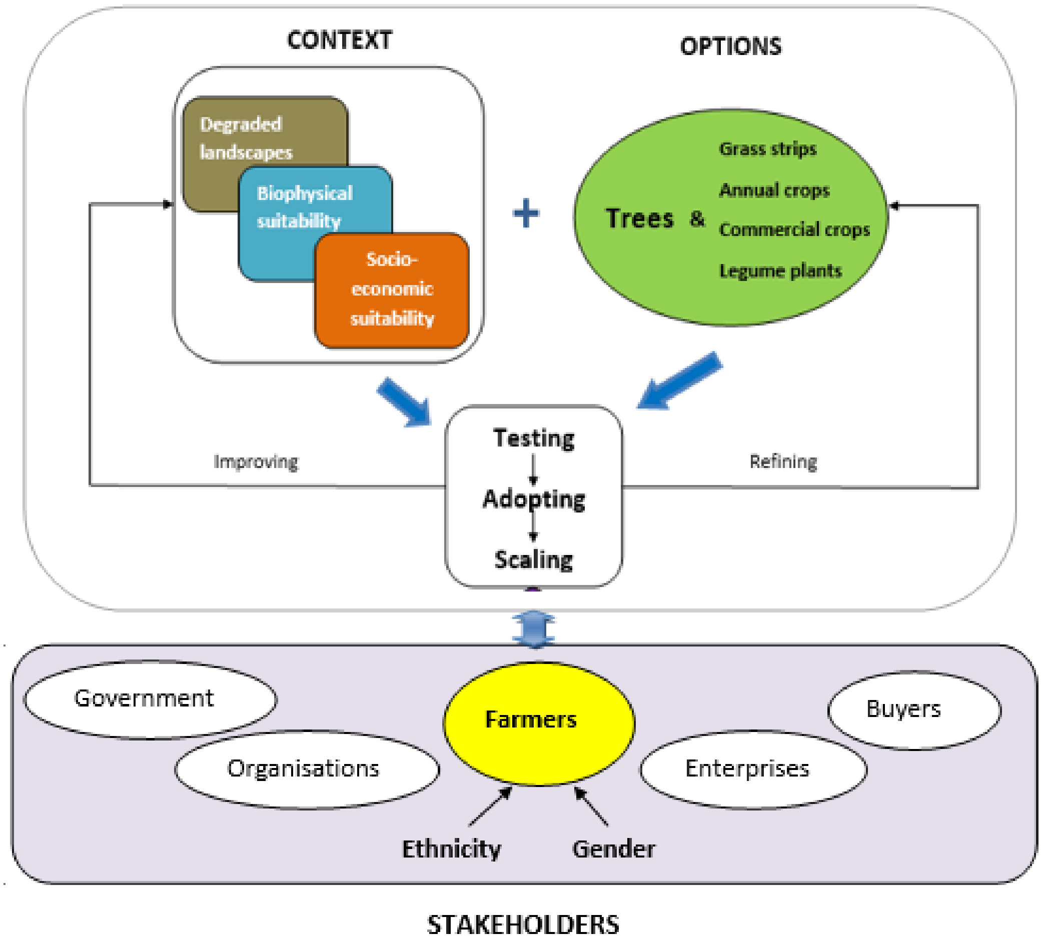


Figure 6. 1: Integrated framework of scaling out agroforestry adoption (adapted from Coe et al., (2014)

6.5.1 Market development strategies for different ethnic groups and gender

Scaling out tree-based options for smallholder farmers requires the development market because producing tree products at large scale are for sale. This is considered an essential step to ensure the long term adoption of agroforestry options. (Russel and Franzel, 2004; Gold et al., 2004). In a Vietnamese context, among timbers, fruits and other perennial crops such as tea, coffee, and macadamia, markets for coffee and some fruits like longan, plum, orange, mango already exist with relatively stable price over recent years. This is the motivation for farmers to adopt these tree-based options. For son tra - indigenous apple species, there is market but accessibility to market is still a challenge for H'mong farmers since they live in remote areas with bad road network. Therefore, market development should consider the improvement of physical accessibility and improved access to market for ethnic groups, such as the H'mong who live at higher altitudes. Similarly, there is need for better understanding of gender dimensions. The expansion of agroforestry options also needs thoroughly market demand and supply research, marketing strategy for specialty products and developing market linkage with enterprises for large volume consumption.

Diversification of agroforestry products is one strategy not only to improve biodiversity but more important to reduce the risks from market (Sherr, 1995). It appears that farmers in Northwest Vietnam often plant more tree species for diversification if the plots are near their home so that they can manage the trees easily. The diversification is much less if the plots are far from home. Farmers plant one to three species to minimize the management requirement.

6.5.2 Improvement of stakeholder engagement

Multiple stakeholders are involved in the process of scaling out agroforestry adoption. Improving the engagement of these actors would encourage the sustainable adoption at large scale. However, farmers should always be the centre actor of the stakeholders. The stakeholders mapped in Figure 6.1 include farmers, buyers, policy makers, extension workers, researchers. Different stakeholders have their own interest, needs, contexts which influence their preferences (Lazos-Chavero et al., 2016). Together with the analysis of context and options, stakeholders' preferences on options should be also mapped out. Dumont et al (2018) has found out a method of structured stakeholder engagement to come up with a wide range of agroforestry options addressing the needs of various stakeholders in different context.

6.5.3 Appropriate support for different farmer groups

In order to provide support for different stakeholders involved in agroforestry adoption scaling process, a number of support recommendation have been made. First, trainings should be in both Vietnamese and ethnic language, which makes it easier for ethnic people to follow. Farmers need more frequent trainings to improve skills and to remember the knowledge from the trainings. Ideally, trainings should target both husbands and wives, or at least equal number of men and women. Second, communication approach for ethnic minorities should be improved, such as big size calendar with photographs of successful agroforestry systems, less text and more visual graphics. Third, knowledge sharing workshops among researchers, extension workers and provincial policy makers should be conducted to increase knowledge sharing and learning. Fourth, tested agroforestry options should be maintained over long time enough (or one cycle) in order to generate significant impacts.

VII. CONCLUSION

Through the four data chapters, the high potential of agroforestry adoption in Northwest Vietnam was highlighted. This was demonstrated by the following findings: i) High biophysical suitability within the maize areas on steep slopes ii) Positive perception of three main ethnicities towards agroforestry benefits iii) Their willingness to adopt agroforestry despite their available capacity iv) Young H'mong men and women are particularly interested in agroforestry as the new innovation v) Integrating shade trees in coffee systems enhance tree species richness. Farmers were found to have good knowledge and perspective towards tree integrating on coffee farms. Their motivation for selecting tree species is either market accessibility or ecosystem services to coffee, depends on their biophysical and social context.

There are also specific challenges and concerns are associated with context. Most of farmers lack of tree management techniques and connection to market. Kinh and Thai farmers in lowland concerned about climate change and high cost to manage systems because they prefer high value fruit trees. H'mong people concerned about system management such as pests, diseases and financial support to buy seedlings and fertilizers. In H'mong group, men and women do have different concerns about agroforestry activities and adopting new technique. In general, farmers are knowledgeable about tree services, but some tree species having high market values and preferred by farmers might not be biophysically suitable in their areas. For example, *Dirmocapus longan* is highly ranked as good tree for intercropping with coffee by Thai and H'mong farmers, but this species is not favourable with high elevations above 600 m.

The integrated framework for scaling out agroforestry following “Context and Options” approach is suggested. Biophysical suitability is the foremost factor to be considered when promoting tree-based systems. Social dimension including ethnicity and social norms and behavioral controls need to be understood well. Agroforestry options are introduced and tested, then modified based on the preferences of household and biophysical context before scaling out at large scale. Farmer is the centre actor of the adoption process with the support from various stakeholder. Market access should be improved for H'mong and Thai group to enable the long term adoption. Supporting policies on agroforestry adoption should be tailored to fit with different context of ethnic groups.

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APPENDICES

Appendix 2.1 :Biophysical condition of existing agroforestry trials under AFLi project

Tree species	Agroforestry options	Elevation (m)	Slope (º)	Soil	Rainfall (mm)	Temperat-ure (º C)	Districts
Son tra (Donycia Indica)	Son tra-fodder grass/maize	782-1,514	8-33	Humic Ferralsols, Ferralsols	1,500-1,900	17-20	Tram Tau, Thuan Chau, Tuan giao
Shan tea (Camellia sinensis)	• Shan tea-fodder grass • Shan tea-soybean/hill rice	900-1,100	10-31	Humic Ferralsols, Ferralsols	1,700-1,900	18-20	Tua Chua
Coffee *(Coffea arabica)*	• Macadamia-coffee-short term crop • Acacia-longan-coffee-fodder grass-short term crop	570-784	2-25	Ferralsols	1,400-1,800	20-22	Mai Son, Tuan Giao
Macadamia *(Macadamia integrifolia)*	Macadamia-coffee-short term crop	573-800	2-12	Ferralsols	1,427-1,763	20-22	Mai Son
Plum *(Prunus salicina)* / Teak *(Tectona grandis)*	Teak-plum-fodder grass-short term crop	790-824	10-26	Ferralsols	1,437	20	Mai Son
Longan *(Dirmocapus longan)*	• Longan-fodder grass-maize • Acacia-longan-coffee-fodder grass-short term crop	370-766	5-18	Rhodic Ferralsols, Ferralsols	1,400-1,800	20-22	Tuan Giao, Van Chan
Mango (*Mangifera indica)*	Acacia-mango-fodder grass-short term crop	340-406	12-27	Ferralsols	1,563	22	Van Chan
Acacia *(Acacia mangium)*	• Acacia-longan-coffee-fodder grass-short term crop • Acacia-mango-fodder grass-short term crop	340-620	7-25	Rhodic Ferralsols, Ferralsols	1,500-1,800	22	Tuan Giao, Van Chan

Appendix 2.2: Biophysical requirements of tree species being tested under AFLi project.

1. Son tra (*Donycia Indica*)

Variables	Most suitable	Moderately suitable	Not suitable	References
Soil type	Ferrasols, Humic Ferralsols,Rhodic Ferralsols, Acrisols	Gleysols, Fluvisols, Arenosols	Rock, water	MARD, 2014
Soil layer thickness (m)	> 0.5	-	-	MARD, 2014
Slope (º)	15-25	0-15; 25-35	> 35	Bac Yen Project 661 Management Office, 2010
Elevation (m)	> 1,000	-	< 1,000	MARD, 2014
Rainfall (mm)	1,500 - 2,000	2,000 - 2,300	< 1,500	Bac Yen Project 661 Management Office, 2010
Temperature (ºC)	15-20	5-15; 20-30	< 5; > 30	Bac Yen Project 661 Management Office, 2010

2. Shan tea (*Camellia sinensis)*

Variables	Most suitable	Moderately suitable	Not suitable	References
Soil type	Ferrasols, Humic Ferralsols,Rhodic Ferralsols, Gleysols	Others	Rock, water	Agricultural publishing house, 2003
Soil layer thickness (m)	> 0.5	-	< 0.5	Agricultural publishing house. 2003
Slope (º)	15-25	0-15; 25-35	> 35	Lam Dong extension centre (a), 2020
Elevation (m)	> 600	-	< 600	Agricultural publishing house, 2003
Rainfall (mm)	1,500 - 2,000	> 2,000	< 1,500	Lam Dong extension centre
Temperature (ºC)	18-23	-	<18; > 23	MARD, 2001a

3. Plum *(Prunus salicina)*

Variables	Most suitable	Moderately suitable	Not suitable	References
Soil type	Ferrasols, Rhodic Ferrasols, Humic Ferralsols, Gleysols, Fluvisols, Acrisols	Arenosols	Rock, water	Agricultural publishing house, 2003
Soil layer thickness (m)	> 1	0.5-1	< 0.5	Agricultural publishing house, 2003
Slope (º)	15-25	0- 15; 25-35	> 35	Agricultural publishing house, 2003
Elevation (m)	> 800	-	< 800	Agricultural publishing house, 2003
Rainfall (mm)	1600-1700	>1700; 1400-1600	< 1600	Technical centre of plant varieties Dao Duc, 2018
Temperature (ºC)	18-24	<18	>24	Technical centre of plant varieties Dao Duc, 2018

4. Teak (*Tectona grandis*)

Variables	Most suitable	Moderately suitable	Not suitable	References
Soil type	Rhodic Ferrasols, Ferrasols, Humic Ferralsols, Acrisols	Fluvisols, Arenosols	Rock, water, Gleysols	Vietnam Academy of Forest Sciences, 2014a
Soil layer thickness (m)	> 1	< 1		Vietnam Academy of Forest Sciences, 2014a
Slope (º)	0-15	15-35	> 35	Vietnam Academy of Forest Sciences, 2014a
Elevation (m)	100-300	300-1000;	> 1000	Vietnam Academy of Forest Sciences, 2014a
Rainfall (mm)	> 2,500	1,200 - 2,500	< 1,200	Vietnam Academy of Forest Sciences, 2014a
Temperature (ºC)	20-27	-	< 20; > 27	Huy, 2014

5. Macadamia (*Macadamia integrifolia*)

Variables	Most suitable	Moderately suitable	Not suitable	References
Soil type	Rhodic Ferralsols, Humic Ferrasols, Ferralsols	Gleysols, Fluvisols, Acrisols, Arenosols	Rock, water	Vietnam Academy of Agricultural Sciences, 2015
Soil layer thickness (m)	> 1	0.5-1	< 0.5	Vietnam Academy of Agricultural Sciences, 2015
Slope (º)	0-20	-	>20	Vietnam Academy of Agricultural Sciences, 2015
Elevation (m)	300-1200	-	< 300; >1200	Centre for producing and providing seedlings Eakmat
Rainfall (mm)	1500-2000	1200-1500; > 2000	< 1200	Vietnam Academy of Agricultural Sciences, 2015
Temperature (ºC)	20-25	15-20	<15	Vietnam Academy of Agricultural Sciences, 2015; Orwa et al., 2009a

6. Coffee *(Coffea arabica)*

Variables	Most suitable	Moderately suitable	Not suitable	References
Soil type	Rhodic Ferralsols, Humic Ferrasols, Ferralsols	Gleysols, Fluvisols, Arenosols, Acrisols	Rock, water	MARD, 2002
Soil layer thickness (m)	>1	0.5-1	< 0.5	Lam Dong extension centre (b)
Slope (º)	0-8	8-20	>20	Lam Dong extension centre (b)
Elevation (m)	> 800	500 - 800	< 500	MARD, 2002
Rainfall (mm)	1500-2000	1200-1500	< 1200; >2000	Orwa et al., 2009b
Temperature (ºC)	15-24	5-15; 24-30	< 5; > 30	Orwa et al., 2009b;

				Lam Dong extension centre (b)

7. Longan (*Dimocarpus longan*)

Variables	**Most suitable**	**Moderately suitable**	**Not suitable**	**References**
Soil type	Ferrasols, Fluvisols, Humic Ferralsols, Arenosols, Rhodic Ferralsols, Acrisols	Gleysols, Arenosols	Rock, water	MARD, 2001b
Soil layer thickness (m)	>1	0.5-1	< 0.5	MARD, 2001b
Slope (º)	0-20	20-35	> 35	MARD, 2001b
Elevation (m)	0-450	450-800	> 800	Orwa et al., 2009c
Rainfall (mm)	1300-1600	1600-2000	> 2000	FAO, 2005
Temperature (ºC)	21-27	15-27; 27-35	< 8	MARD, 2001b

8. Mango *(Mangifera indica)*

Variables	**Most suitable**	**Moderately suitable**	**Not suitable**	**References**
Soil type	Ferrasols, Fluvisols, Humic Ferralsols, Arenosols, Rhodic Ferralsols, Acrisols, Gleysols	Arenosols	Rock, water	MARD, 2001b
Soil layer thickness (m)	>1	0.5 - 1	< 0.5	MARD, 2001b
Slope (o)	0 - 20	20 - 35	> 35	MARD, 2001b
Elevation (m)	0 - 600	-	> 600	MARD, 2001b
Rainfall (mm)	1,000 - 1,200	1,200 - 2,500	<1,200	MARD, 2001b; Orwa et al., 2009d
Temperature (ºC)	24-27	4-24, > 27	< 4	Minh et al., 2001; Orwa et al., 2009d

9. Acacia (*Acacia Mangium)*

Variables	Most suitable	Moderately suitable	Not suitable	References
Soil type	Ferrasols, Rhodic Ferrasols, Acrisols	Humic Ferralsols Gleysols, Fluvisols,	Rock, Water	Vietnam Academy of Forest Sciences, 2014b
Soil layer thickness (m)	> 1	< 1	-	Vietnam Academy of Forest Sciences, 2014b
Slope (º)	0-15	15-35	> 35	Vietnam Academy of Forest Sciences, 2014b
Elevation (m)	0-300	300-800	> 800	Vietnam Academy of Forest Sciences, 2014b
Rainfall (mm)	> 2,000	1,100 - 2,000	< 1,100	Thang and Que, 2008
Temperature (ºC)	22-27	20-22	< 20	Vietnam Academy of Forest Sciences, 2014b; Thang and Que, 2008)

Appendix 3.1 Household survey questionnaires for AFLi project farmers

A – Basic information (obtained from baseline questionnaires)

<u>Part I: Awareness and engagement in the AFLi project</u>

1. Where were you involved in any of the AFLi project activities in your village?

Type of activity (training, field visit, meeting, etc)	Was the activity useful for you? Y/N	Do you remember doing something in your farm as a result of the activity? If yes, what was it? If no, why not

2. Do you know any farmer(s) in your village who were involved in the AFLI project? Y/N Y/N If yes, how many are they? ____________________
3. Do you think these activities are important and useful to farmers in your village?
4. Yes [ ] No [ ]

   In what way these activities would help or has helped farmers in your village?

<u>Part II: Household profile and food security</u>

5. Do you own the following items?

Household appliances	No. owned	Farm implements	No. owned
Radio		Hoes	
Mobile phone		Machetes	
Television		Ox-plough	
Bicycle		Wheelbarrow	
Motorcycle		Milking cans	
Car		Granary	
Ox cart		Grain miller	
Water tank		Sprayer (hand/ ox/ tractor drawn)	
Others		Spade	
		Others	

Did these assets increased or decreased in the last four years? Yes [ ] No [ ]

6. What led to these changes?

6. Is annual farm production sufficient for the food needs of your family for the whole year?
   Yes [ ] No [ ]

7. If no, how many months do you experience food shortage from farm produce (months)?

8. Which months are lean periods?

7. Please rank the main reasons for food shortage in the farm (Starting from 1 for the most popular one)? Reasons:

7.1. Limited land [ ]
7.2. Low land productivity [ ]
7.3. Infertile Land [ ]
7.4. Poor agricultural water supply [ ]
7.5. No funds to buy inputs [ ]
7.6. No land [ ]
7.7. Big family size [ ]
7.8. No intention to produce food [ ]
7.9. Others: _________

8. How did you manage to meet your food needs during these months Starting from 1 for the most popular one? Please rank

8.1. Buying from market [ ]
8.2. Borrowing money to buy food [ ]
8.3. Borrowing grain [ ]
8.4. Eat fewer meals [ ]
8.5. Eat different food [ ]
8.6. Harvest wild plants [ ]
8.7. Migrate for work [ ]
8.8 Others:

9. Do you think your family's food security status has improved or worsened in the last four years, and why?

Part III: Farm characteristics and production (to be compared with baseline data)

10. Since 2012, have you applied measures to control soil erosion and improve soil fertility in your farm? Yes [ ] No [ ]

11.1 If Yes, list specific measures and estimated area of land under specific conservation measures

11.2 If No: What constrained adoption of soil conservation measures?

12. What farming practices did you carry out since 2012?

Activity/ Practice	1= Yes, 2= No	If yes, reasons for practicing	If no, reasons for not practicing	Source of information of technology
1. Intercropping food crops with				
1.a. Trees				
1.b. Commercial crops				
2. Reduced tillage				
3. Soil cover crops (such as Arachis pintoi) and mulching (such as dried grass...)				
4. Fertilizer application				
5. Pest management				
6. Weed control				
7. Soil fertility management (such as fallow, plantation of N-fixing crops...)				

8. Marketing (such as access to the market, looking for new markets...)				
9. Other practices:_______________				

13. Please provide information regarding crop production since 2015 (USE AVERAGES)

Parcel No.	Total size (m2)	Crops planted (Name)	Inputs																Yield/ season (Kg)	Quantity consumed (Kg)	Quantity sold (Kg)	Selling price
			Seeds/seedling			Fertilizer			Insecticides/ fungicides/ herbicides			Farming tools			Labor used							
			Source	Quantity (no/kg/cans)	Cost	Source	Quantity (kgs)	Cost	Source	Quantity	Cost	Cost of Tractor	Cost of Hand tools	Cost Animal	Family labor (man days)	Hired labor (Man day)	Total Man days	Wage rate per M day				

14. Please provide information on livestock production since 2013

Do you own/rare any of the animals below?				Fodder Information			
	If yes, No. of adults	If Yes, No. of young	Type of breed	Type of fodder used	Source of fodder	Cost of fodder	Cost of supplementary feed
Bulls							
Cows							
Goats							
Pigs							
Chicken							
Ducks							
Other							

15. Have you planted trees anywhere in your farm or property since 2013? If yes, kindly provide information.

Tree local name (List trees first)	Tree name	Main seed/ seedling source[b]	Cost per seedling	Where planted[c]	No. of trees for all the plots	Main use[a] of tree or purpose of planting	Tree secondary uses[a]	Any observed effects on crops?[d]

Notes: *a – Tree uses: 1 – Timber/ Poles; 2 – Fodder; 3 – Fruit; 4- Fuelwood; 5- Soil fertilization/ Erosion; 6 – Medicinal; 7 – Beauty; 8- Bee forage/ Honey; 9 – Water/ Hydrological cycle; 10 – Clean air/ Global warming; 11 – Shade; 12 – Carving; 13 - Other (specify)*

b – Source of seed/seedlings: 1 – natural regeneration in farm; 2 – group nursery; 3 – purchased from other nursery; 4 – collected seeds and raised own nursery; 5 – neighbor/relative; 6 – was present when I acquired farm and I don't know source; 7 – Other (specify)

c – Where planted: 1 – Scattered in crop farm; 2 – External boundary/ live fence; 3 – Hedges within farm; 4 – Woodlot or river line section; 5 – Home compound; 6- Fallow; 7- Other (specify)

d - Effects: 1 - Suppresses growth; 2 - Improves growth; 3 - Harmful shade; 4 - Beneficial shade; 5 - No effect

16. Main Production Problems:

16.1 List three main production problems you encounter in your farm (please rank)

1.a.____
__

1.b.____
__

1.c.____
__

16.2 List three main marketing problems you encounter in your farm (please rank)

1.a.____
__

1.b.____
__

1.c. ____
__

17. Sources of income in the last 3 years (2012-2015)

Off and non-farm income	**Average income in 2012**	**Average income in 2015**
Salary from employment		
Income from business		
Income from wage labor		
Remittances (family/relatives		
Income from leasing land		
Others		

On-farm income	Average income in 2012	Average income in 2015
Maize		
Rice		
Tea		
Coffee		
Sơn Tra		
Fruit trees		
Other trees		
Cow		
Buffalo		
Goat		
Pig		
Small poultry (chicken, duck...)		
Firewood		
Timber		
Fishing		
Charcoal		
Tree nurseries		
Others…………………..		

18. What are your sources of information on the following?

	Sources of Information (*)	
	Most important source	Other sources
General farming practices		
Erosion control		
Soil fertility management		
Water conservation techniques		
New crop cultivation techniques		
New seed		
Pest control		
Animal husbandry		
Market and market prices		
Conservation agriculture – Min. tillage, soil cover, crop rotation		
Farm tree planting and management		
Forest management / Watershed management (inquire term that local partners use – catchment area etc)		

(*) ***Access to information****: 1=own experience 2=other household members 3= neighbors/other farmers 4= school/NGO 5=government extension workers 6=private company extension workers 7=input dealers 8=radio/television 9=farmers' organization 10=newspaper/magazine/other print media 11=none 12 = others (specify)*

19. What do you think is the most effective promotion strategies of agroforestry and/ or conservation farming technologies? (*Multiple choices applicable – please rank – first get respondent to generate list then rank, 1 for the most important source*)

[ ] a. Farmer-to-farming sharing of knowledge during community meetings

[ ] b. Seminars/training

[ ] c. Radio broadcast/TV

[ ] d. Agriculture Fair/Farmers' Day

[ ] e. House-to-house/Field visit

[ ] f. Demonstration farm

[ ] g. Printed materials

[ ] h. Farmers exchange visits

[ ] i. Others, please specify__________________

Part IV. Aspirations / Quality Question

20. What are three important things that you aspire to achieve in your farm?

Issues	Priority level (Please check X)			
	No Priority	Low	Moderate	High
Soil fertility improvement and soil erosion prevention				
Reduced Weeds				
Reduce insect pest and diseases				
Diversification of Farm products				
Integrate trees on farm to improve farm nutrient				
Integrate trees in the farm to improve income				
Commercial crop cultivation to improve farm income				
Access to credit				
Security of land tenure				
Availability of labor				
Access to market				

Availability of inputs (seed, fertilizers, agrochemicals)				
Low and variability of crop prices				
Training on sustainable farm cultivation techniques				
Availability of technical information				
Adequate food year-round				
Adequate money for children's education				
Availability of off-farm jobs/wage labor				
Improved health and health care				
Others: -_________________________________				

Section B: Perceived and observed impacts of the AFLi project

Part I. Impact of smallholder nurseries

21. Information on nurseries

21.1 Do you involved in a nursery supported by AFLI project? Yes [ ] No [ ]

21.2. If Yes, since then?

21.3. For what purpose did you join a nursery?

21.4. Are you able to produce seeldings?

21.5. Are you able to graft seeldings?

21.6. From whom did you learn about establishing a nursery?

21.7. Do you transfer knowledge on nursery to other farmers? If Yes, who ?

21.8. Are you going to maintain your nursery? Yes [ ] No [ ]

If Yes, why ?

21.8. Please provide the following nursery information that you own, or you belong under suport of AFLI project.

Year nursery was established	Distance of nursery from home	Tree species grown (per year)	Total number of seedlings grown per specie (per year)	Number of seedlings planted on farm (per year)	Number of seedlings distributed to members in case of group nurseries (per year)	Number of seedlings sold (per year)	Amount of seedlings sold (per year)	Income from nursery (per year)

Note: Data for the most recent year

<u>Part II. Impact of trainings, farmer field day and study tours</u>

22. Did you or any member of your household attend any training, farmer field day or study tours over the last 3 years (organized by AFLI)? Yes [ ] No [ ]

If Yes, please answer the following:

Training information

Name of the training / workshop	Who organized the training?/who invited you?	Duration (days)	Who attended the training? 1= Male 2= Female	What was the training about? (Main theme)	Did you learn from the training? Yes= 1 No = 0	If Yes, did you/your family apply what you learned? Yes= 1 No = 0	If applied, what are the benefits from the training 1= Skill improved 2= Increased cash income 3= Family health improved

							4= Employment generated 5= Soil erosion prevented 6= Other (specify): ______
1.							
2.							
3.							
4.							
5.							

Training evaluation (Please rate on a scale of 1-5, with (1) indicating the lowest level and (5) indicating the highest level)

Criteria	Training 1	Training 2	Training 3	Training 4	Training 5	Other
Relevance to your daily work						
Use of training materials						
Knowledge application						
Application level						
Knowledge transferring to others						

23. Can you describe what training materials you have used, for what purpose?

24. Can you explain what knowledge you have learned?

25. Can you explain what did you apply from knowledge you have learned?

26. Can you describe what knowledge you transfer to others?

27. Any other reflection or comment on the trainings you have attended?

28. What other trainings would you like to attend in the future?

Part III. impacts of the AFLI trials

29. Water conservation

Do you believe that tree planting in your farm affect water quantity and quality

Yes [ ] No [ ]

If Yes, Did you learn this from the project or through other farmers/extension workers working with AFLI? Y/N

If not, how and where did you learn this from?

30. Soil quality enhancement

Are you aware of a tree in your farm that enhances soil fertility? Yes [ ] No [ ]
If Yes, did you learn it from the project or through other farmers/extension workers working with AFLI? Y/N

If not, how and where did you learn this from?

31. Soil erosion reduction

Are you aware of the problems caused by soil erosion in your farm? Yes [ ] No [ ]

What do you think is the effect of soil erosion on crop productivity and profitability?

Do you know what causes soil erosion?

Do you think tree planting reduces soil erosion? Yes [ ] No [ ]

If Yes, list the name of trees that help reduce surface runoff. Did you learn these from the project or through other farmers/extension workers working with AFLI? Y/N

If not, how and where did you learn this from?

If No, why?

32. Do you think you have sufficient knowledge and skills to adopt agroforestry Yes [ ] No [ ]

Did you acquire these skills through the project or through other farmers/extension workers working with AFLI? If not, with whom did you acquire these skills from?

Did you already apply these skills and knowledge in your farm? Yes [ ] No [ ]

33. Do you have market information on agroforestry products? Yes [ ] No [ ]

If Yes, can you describe? Did you learn this from the project or through other farmers/extension workers working with AFLI? If not, where did you learn this from?
If No, why?

34. Do other households in your village have knowledge on agroforestry Yes [ ] No [ ]

If Yes, do you think they learn it from the project or through other farmers/extension workers working with AFLI? If No, where do you think other farmers learn this knowledge from?

35. Are there any changes or benefits from the project that you observe? Yes [ ] No [ ]

If Yes, can you describe?

If you have adopted agroforestry or its components through the AFLI project, what do you observe or expect as impacts? Please rate on a scale of 1-5, with (1) indicating the lowest level and (5) indicating the highest level)

Ecological	**Score (1-5)**	**Ecological disadvantages**
Increased surface runoff		
Reduced soil loss		
Increased nutrient recycling		
Increased water provision		
Reduced natural hazard		

Increasing tree cover		
Increased biodiversity and species quality		
Others:		
Production	**Score (1-5)**	**Production disadvantages**
Increased wood production		
Increased product diversification		
Increased food supply		
Others		
Economic	**Score (1-5)**	**Economic disadvantages**
Increasing farm income		
Diversification of income source		
Increasing contribution to livelihood (increasing percent on-farm income/total income)		
Human capital	**Score (1-5)**	**Social-cultural disadvantages**
Enhanced skills in tree cultivation		
Improved sell-sufficiency		
Improved community knowledge of tree cultivation and market		
Improved landscape beauty		
Others:		
Acceptance/adoption		
Will you continue adopting agroforestry on your farm?		If not, why?
Expansion	**Score (1-5)**	

Will you expand your area with agroforestry?		If not, why?

Part IV: Adoption information

36. Have you observed new planting of trees in your village in the past 4 years?

Yes [ ] No [ ]

If yes, please answer the following group of questions for each system below

1. How many farmers in your village plant trees in this manner?
2. Why do you think farmers adopt this technique?
3. Where did the farmers learn from, or get the information?

Type of systems:

a. Monoculture

b. Together with crops

c. Around the plot

d. On top of the hill (while other crops are in the middle and hill foot)

e. In home garden

Part V. Agroforestry expansion

37. Do you plan to expand your agroforestry farm? Yes [ ] No [ ]

37.1. If yes, please provide the following information.

Tree species and crops to be planted	Expansion area (ha)	Location 1. In existing farms, intercropping with existing crops	Distance from home	Agroforestry type 1. Woodlot 2. Hedgerow	Rank according to priority (1-5)	Reason for ranking

		2. In bare land 3. Rent new land		3. Boundary 4. Parkland		

37.2. Why do you want to scale up agroforestry?

37.3. What benefits do you expect? For how long?

37.4. Where will you sell your products?

37.5. What support do you need to scale up agroforestry?

37.6. What are the risks of scaling up agroforestry?

Appendix 3.2 Focus group discussion guiding questions to understand village context, culture, cultivation, social norms towards agroforestry adoption

1. Village sketching with farm location
   - Average distance from farm to house/road
   - Where are different tree species positioned in the landscape and why?
   - Existing agroforestry systems in the village
2. Farming systems (types, components, species and location in the village map, highlight the areas with trees on the map)
   - Tree-crop systems
   - Tree-crop-livestock systems
   - Crop-livestock systems
   - Mono-cropping systems
3. Farming calendar: Time to plant tree species and manage their systems
4. Livelihood mapping with access to resources from men/women, adults/children/old people
   - To what extent do rural agricultural activities contribute to livelihoods of local

people?

  - What are factors affecting decisions of local people on income generating activities?
  - How does agroforestry contribute to income of households living in rural area in the Northwest?
  - How will different types of households change their livelihood activities if agroforestry is commonly practiced in the Northwest?
  - What are potential alternative income-generating activities in the region?

5. Market for agroforestry products

6. Agroforestry adoption: Benefits, opportunities, constraints (using SWOT)

  - What will be brought for local people if they largely apply agroforestry practices?
  - What were constraints and opportunities of local households when they apply agroforestry?
  - Support from government or NGOs to establish and implement agroforestry.

Appendix 3.3 Semi-structured questionnaires for non-AFLi project farmers to understand their perception, preferences and challenges on agroforestry adoption

1. Ask farmer to draw their farms: house, garden, paddy rice, upland plots (tree and crops), forest plots.
2. Trees on farms characterization
    - What are their existing tree species, Vietnamese names, local names of species?
    - Can you locate of trees on your farm sketch?
    - History of tree planting on farm:
        - When did you plant the trees?
        - Can you list the name of trees that are no longer in the area?
        - Can you list the name of trees that have been promoted in the area?
        - Can you list the name of and trees that farmers retain/plant on your farm?
3. Are you intercropping trees and crops on your farms?

   If yes, which species are you intercropping now?

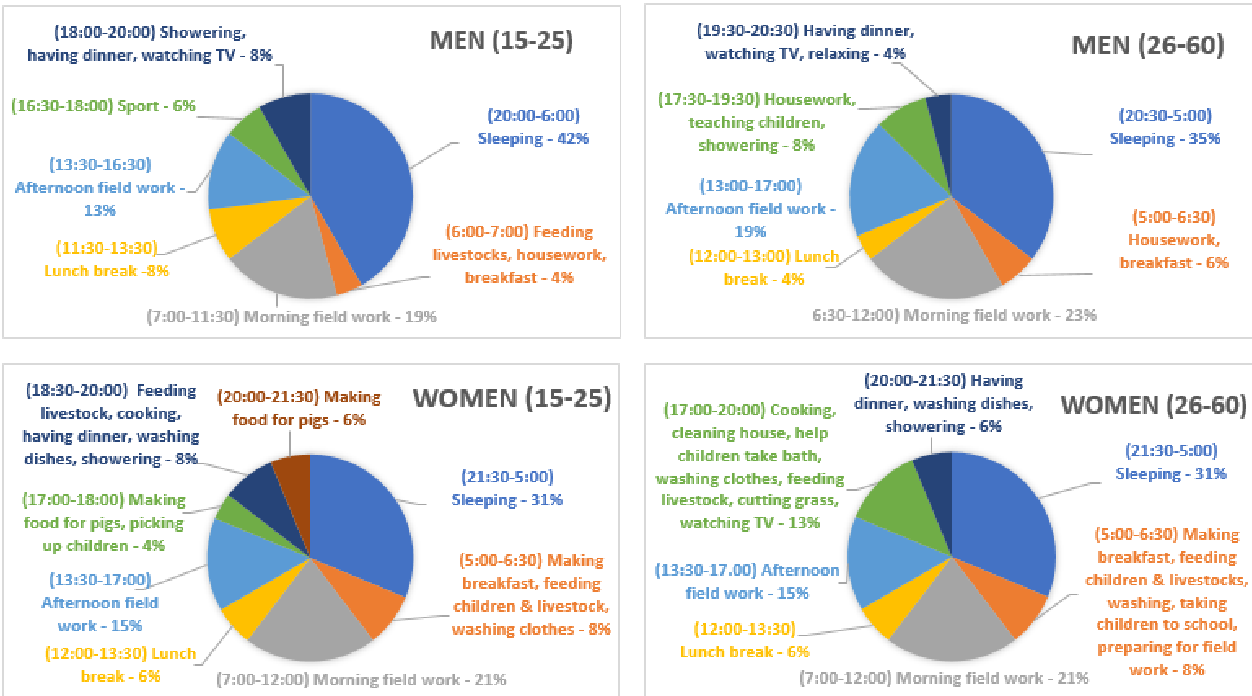
   Why do you intercrop those species on your farm?

   If no, why do
4. Knowledge on agroforestry practice:
    - Which crops to combine with tree species (good and bad for intercropping)

- How do farmers combine species in agroforestry system: time to intercropping, spacing?
- Natural regeneration or planted status of the tree specie
- How do farmers manage their trees, especially through natural disaster, extreme weather?
- Soil and water conservation measures taken in the area (if any)
- Tree-crops interaction: shading effect, competition for resources (soil, water, nutrients, rain, light), interact with livestock in the farming system

5. Knowledge on benefits of agroforestry (indirectly related to adoption rate)
    - Contribution of agroforestry in generating incomes
    - Diversified products including NTFP)
    - Soil fertility improvement
    - Soil and water conservation
    - Biodiversity conservation
    - Environmental protection
    - Climate change mitigation
6. Farmers' preferences on different option:
    - Tree-crop systems
    - Tree-crop-livestock systems
    - Crop-livestock systems
    - Mono-cropping systems
    - NTFP only (rely on forests)
7. Opportunities for agroforestry adoption in the future
    - Productive/non-productive areas of farmers' land – where is there potential for change
    - Motivation of tree planting: garden, upland fields, forest
    - Any support for tree planting
    - Preferred species and why
    - Market potential for agroforestry products
8. Constraints of agroforestry adoption

Appendix 4.1: Details of 24 hours' time allocation of H'mong farmers in coffee harvesting season by gender and age



Appendix 4.2: Challenges in agricultural activities of H'mong farmers by gender and age (results of focus group discussion by four groups: young men (15 - 25 years old), old men (25 - 60 years old), young women (15 - 25 years old), old women (25- 60 years old)

Topics	**Challenges**	**Proposed solutions or current solutions, if any**	**Groups proposed**
Pest and diseases	Yellow coffee leaves, stem borer in Son Tra influencing tree growth and reducing yields	Identifying type of pests/diseases and the right pesticides	Young men Old women
	Coffee and rice diseases	Applying pesticide/ insecticide but the effect is not higher than 70% because of low quality or pesticide.	Old men
	Tree diseases such as stem borer and leaf roller worm	Women often buy pesticide and spray for trees.	Young women
	Worms eating Son Tra leaves	No solutions	Old women
	Lack of information on pest and diseases on trees	No solutions	Old women
	Rice, maize, coffee pests	More pesticides are applied but it does not work for coffee.	Old women
Soil condition	Poor soil conditions lead to low yields, weak growth, a high investment in fertilisers is required	Applying more NPK fertilisers.	Young men
	Poor soil quality (dry and quite rocky)	No solutions	Young women
		More fertilisers are applied.	Old women

Topics	Challenges	Proposed solutions or current solutions, if any	Groups proposed
		It takes more effort to prepare before planting and farmer must carry rocks away	
	Heavy rain causes soil erosion and washes soil and rocks down to the plots at hill foot.	No solutions	Old women
	Lack of information on suitable trees for each soil type, e.g. jackfruit and longan are not suitable	No solutions	Old women
Tree management techniques	Lack of tree managing techniques Poor in planting and taking care of trees	Planting more trees Support required on techniques of planting trees to reduce landsides/erosion	Young men
		Better approach of training so that more farmers can apply the techniques to prevent soil erosion	Old men
		Planting grass strips can prevent soil erosion, but it requires replanting and grass competes with crops for nutrients. Thus, farmers need to replace crops by fruit trees if planting grass	Old men
Low productivity	Son Tra does not bear fruits this year	No solutions	Old women
	Coffee is damaged by frost and flood.	No solutions	Old women

Topics	Challenges	Proposed solutions or current solutions, if any	Groups proposed
	Low quality seedlings	Apply more fertiliser, spraying the stimulant for trees and managing weed more carefully	Old men
	Low quality seedlings	Support required on introducing quality seedlings suitable with local conditions	Young men
	Do not know which new seedling varieties are suitable to local conditions	Trainings required	Young men
	Cannot apply traditional techniques of old varieties to new varieties which need new and unknown techniques	.Relevant trainings required on new techniques	Young men
Fertiliser	Low quality of fertiliser	The higher nutrient fertiliser is very expensive, and farmers do not have enough money. They usually buy the cheap ones with a low nutrient percentage.	Old men
	Lack of technique to apply fertiliser correctly	Training on tree management (Son Tra and coffee)	Young women
Livestock	Animals get diseases	Men buy medicine and inject into animal body by themselves. Trainings on preventing and protecting animals from diseases.	Young women
	Impact of cold weather in winter on cattle	Farmers try to protect animals, but the death rate is still high.	Old men

Topics	Challenges	Proposed solutions or current solutions, if any	Groups proposed
	Lack of buffalo and cattle because they died after cold weather	No solutions	Old women
Water resources	Water shortage on farm, heavily dependent on rain water	No solutions	Old men
	Water shortage	Carrying water from home by motorbike to the fields or taking water from the stream and carrying up to the field on foot.	Old women
Infrastructure	Poor road conditions	Using support tool for motorbike wheel to travel on bad roads, for example putting chain around the outside of motorbike tyres	Old men
		Making it difficult to carry water to the field	Old women
Access to capital	High interest rate when getting a loan	Husband is the person to make decision on borrowing the loan	Young women
	Lack of funding to buy good seedlings and fertiliser.	No solutions	Young women
	Sources of capital are limited, complicated procedures with large amounts of money	Borrowing money from relatives and neighbours to get lower rate	Young men
	Lack of cash investment: The banks just lend farmers money for raising livestock. For cash loans, only several household are	Borrow money/fertiliser: Borrowing in January before planting season, paying back after harvesting in Sep-Oct with a	Old women

Topics	**Challenges**	**Proposed solutions or current solutions, if any**	**Groups proposed**
	selected by the banks and the procedure is complicated.	high interest rate (approximately 30-40 %)	
	Lack of funding and complicated lending process	Lower or subsidised interest rates	Young women
	Difficult procedure to get loans from the bank, some households cannot get loan books. Maximum credit is VND 30-50 million/time	No solutions	Old women
	Poor families must borrow fertiliser at higher price and pay back after harvest	No solutions	Old women
	Lack of money to buy maize seeds and coffee seedlings	.Borrow maize seeds and coffee seedlings (some households produce by themselves)	Old women
Selling agricultural products	Travelling far to buy seedlings Thuan Chau-Tuan Giao. It could take 2-3 trips to carry all home	No solutions	Old women
	Low selling price because product and market prices fluctuate	Support required for stable product output and higher selling price	Young men
	Unstable and manipulated price by traders	Trying their best to negotiate with traders but might resort to barter trade exchanging for maize crop	Old men

Topics	Challenges	Proposed solutions or current solutions, if any	Groups proposed
		Products sold at low price (coffee VND 6,000/kg, Son Tra at 7,000-10,000/kg), farm-gate from 4,000-5,000/kg. (Collected coffee is sold to middlemen from other villages).	Young women
	Fluctuating price of Son Tra, coffee and maize	Amount of agricultural product is still too small to attract large companies/traders	Old men
	Bargaining with large traders/companies Traders have market power	No solutions	Young women
	Lack of market information on price and trusted information source	No solutions	Young men
Machines, manual labour	Machines: lack of experience to use machines effectively and fix them accordingly	No solutions	Young men
	Lack of grass chopping machines	Do manually by hand	Old women
	Lack of ploughing machines	Use hoe or buffalo/cattle	Old women
	Difficulty in digging holes in hard, steep and rocky soil	No solutions	Old women
	Lack of rice threshing machines	Do manually by hand	Old women

Appendix 4.3: Information from photo activity to understand different points of view from men/women (young and old groups) on time spent, most valuable things/persons, sources of information, challenges in cultivation and desire farming systems.

1 Where do women/men spend much of their time? With whom? What do they do?

Young men

Young men spend much of their time to work on the field to do activities including havesting coffee, weeding, spraying herbicides/pesticides, planting coffee, rice, maize, fertilising, etc. with their family.

Old men

Family members are doing weeding together in the Son Tra plantation.

It took a long time to harvest tea. Farmers harvest tea every 2 weeks and usually exchange labour with 6 – 7 neighbours.

After the harvesting season, men and their wives usually go to the forest to collect fuelwood and store to use in the rain season next year.

It took farmers a long time to harvest agricultural products including coffee cherries.

The period from July to October is the time when farmers harvested Amomum (Sa Nhan). The fresh fruit price was 100.000 dong / 1 kg on average in 2017.

Young women

They spend most of their time in the field

Picking coffee consumes a lot time

Feeding chickens also takes quite a lot of time.

Old women

Mrs Thao and her husband are going to the fields with their grandchild

Mrs Thao and her husband do weeding in their coffee plot

Mrs Huong checks pests and diseases in coffee trees

Mrs Thao and Mrs Huong apply fertilisers to coffee trees

2: What are important and valuable things for women/men, and why

Young men

The house is important because it is the place for the whole family where they can take rest and relax with all family members

A motorbike is important because it is very convenient to travel and it can be used to carry goods

The phone is important because it is very convenient for communicating and entertainment

The television is important because it serves entertainment purposes and provides agricultural and technical information

Old men

The buffalo is an important asset because it is used for cultivation (ploughing) and it is valuable.

Land is a very important asset of the H'mong family because It brings products and cash for farmers through cultivation.

Farmers usually keep money and valuable assets in the safe (ket sat).

The house is the most important thing with Mong's family. It helps their lives remain stable then develops household livelihood.

A motorbike is an important asset for travelling and transporting agricultural products from the field to home or to the market.

Young women

A young farmer said she could not do land preparation without this buffalo! It gives birth many times and her family can sell the calves when they need cash.

Rice and grain are very important.

Good and fresh coffee seeds are very valuable to farmers.

Old women

1: A motorbike is the most important thing for May. Mrs Huong uses the motorbike to carry maize, rice, fertiliser, and water to the fields. She was the first one who owned a motorbike in the village. She bought it, after selling her horse 20-30 years ago. She bought a motorbike at that

2: A buffalo is the most important thing because she can't do ploughing or carry wood logs from farms to home without it.

3: The house is the most important thing for Mrs Thao because it is where she lives with her family.

time because there was a motorcycle road established in the village.

3. To whom/from what materials, you learn new things/technologies, and why? (materials, persons/innovators)

Young men

Learning new knowledge and techniques from neighbours because they are close and easy to contact

Learning new knowledge and techniques from the poster because it is easy to understand

Learning new knowledge and techniques from books/training materials because it can help to improve the knowledge and information in agriculture

Learning new knowledge and techniques through training/meeting, it can provide more information

Learning new knowledge and techniques from the teacher who can provide techniques during the study and easy to contact for getting agricultural techniques

Learning new knowledge and techniques through the internet - it is a way of learning agricultural techniques

Old men

A training course about raising livestock for farmers.

Farmers are reading technical guidelines.

TV is an information source for Mong famers to learn agricultural techniques in the Hua Sa A village.

Discussing and learning from neighbours improved farmers' knowledge to adopt and demonstrate the good modern and increase the farm's benefits.

Young women

TRƯỜNG ĐẠI HỌC TÂY BẮC
TRUNG TÂM NCKH& CHUYỂN GIAO CÔNG NGHỆ

TÀI LIỆU TẬP HUẤN

KỸ THUẬT GÂY TRỒNG CHĂM SÓC SƠN TRA

A training material indicating that a female farmer has learnt techniques and methods of tree management

Old women

1: The village head is the source of information for Mrs Tran about pesticides and fruit tree planting techniques

2: Cuc – Mrs Huong's neighbour – is the source of information about coffee planting and management. Mrs Ly is the first one who planted coffee in the village and she earns about 100 mil VND per year from coffee.

3: VT16 and VTV5 on television are the sources of information on new technologies and farming techniques.

4 What are challenges in farming, and why?

Young men

Bad soil: low fertility, the trees and crops have low yield, even trees and crop cannot growth lead to need for high fertilisers investment

Landside/erosion: affect trees and crops, destroy fields and roads

Landside/erosion influence on trees and crops growth, destroy fields and roads

Diseases affect coffee: yellow leaves, they affect the growth of trees and reduce yield

Diseases affect coffee: dry stem, branches and leaves, they affect the growth of trees and reduce yield

Stem borer affect Son Tra: stem, branches and fruit, they affect the growth of trees and reduce yield

Lack of money

Access to capital: sources of capital are limited, complicated procedures and cannot borrow with a large amount of money

Low price of selling product: because almost all products are retails and market price is fluctuating

Old men

Farmers' traveling and transporting agricultural products were encumbered by the bad road.

The prolonged drought resulted in a lack of water for tree crop growth and reduced crop yield.

The steep slope causes soil erosion and difficulty to cultivation and fertiliser application.

Pest affected peach tree and reduced fruit yield and farmer's benefit.

Lack of irrigation water caused difficulty to cultivation and reduced crop yield.

Young women

Coffee is destroyed by stem borer.

Fluctuated coffee price is always a concern to farmers

Sloping land is a challenge for farmers in agricultural cultivation.

Old women

Soil erosion forms small channels (or gullies) in the coffee plot. The channels become bigger in the rainy season. Top soil loss is about 40 cm deep per year. Surface runoff including soil and small

Fallow plot.

Land is abandoned for 5 years because the plot is far from home, no labour and the slope is too steep, seedlings ran off with the soil to the hill foot.

Dry soil, lots of gravels, poor quality, trees grow slowly rocks influence trees and crops in other plots.

Pests on plum leaves

Disease on coffee: coffee leaves dry and then tree dies.

Digging holes for planting coffee requires lots of labour because the hole is big, soil is hard and has small rocks.

Rice field

Farmers do manual rice threshing because they do not have threshing machines.

Farmers do not have money to buy fertiliser. It is the fertiliser shop where the farmer gets fertilisers before the season and pays after they harvest

The road is small and bad to travel or transport heavy things to the field using

Soil surface and small road make it difficult to carry water to the field by motorbike

Water is heavy but May has to carry water up to her coffee farms on the top of the hill to apply pesticide.

motorbikes. If it rains, they cannot go by motorbike.

Q5: What is your wish to improve their cultivating systems

Young men

Coffee intercrop with shade trees (*Leucaena leucocephala*) like the Sung A Tua household, because coffee trees are very healthy, have more fruits and provide high income. In addition, shade trees can help protect coffee trees from frost in winter time and sunlight in summer time, reduce weed on the soil surface and reduce coffee leaves falling down. The shade trees are not indigenous species and a system like this was introduced by a project many years ago. They cannot do this practice because of a lack of investment and techniques.

Son Tra field: Son Tra trees are planted with a tree distance of 6m x 6m like the Vang A Sua household. Because, with this planting distance, SonTra trees grow well.

Wishing to have Son Tra fields with a lot of trees and fruits.

Old men

Milling machine could help farmers reduce labour time for H'mong farmers. But this machine is very expensive (20 million dong) so farmers could not buy it. Currently, there is only one machine in the Hua Sa A village.

Terrace can prevent soil erosion, but building the terrace was very expensive because having to hire an excavator.

Agrimotor helps reduce time and labour for farmers. But it is very expensive, so farmers could not buy it.

Before using a spraying machine, it took farmers lots of time for weeding. But pesticides and herbicides are highly toxic. Currently, there was no safe pesticide and herbicide.

Young women

I want a coffee plant like this.

This is my dream house.

I wish my coffee plant will be good like this.

This coffee plant is very prolific because the soil here is fertilised and has fewer rocks.

I hope the coffee seeds quality will be better.

Archery is my favourite sport. I hope I could go for competitions at district and province level.

My dream is to have a good Son Tra field like this.

Old women

Good son tra field: not too steep, trees grow big, leaves are green, trees bear lots of fruits. Income is about 40-50 mil VND/7000 sq m/year/

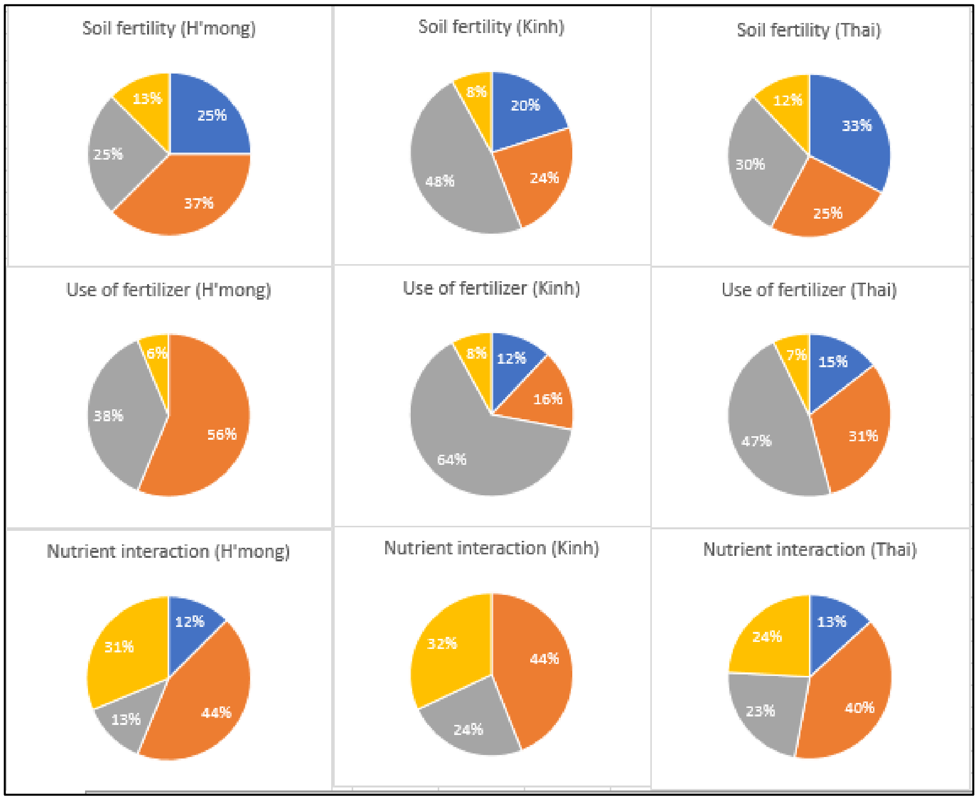
Paved road.

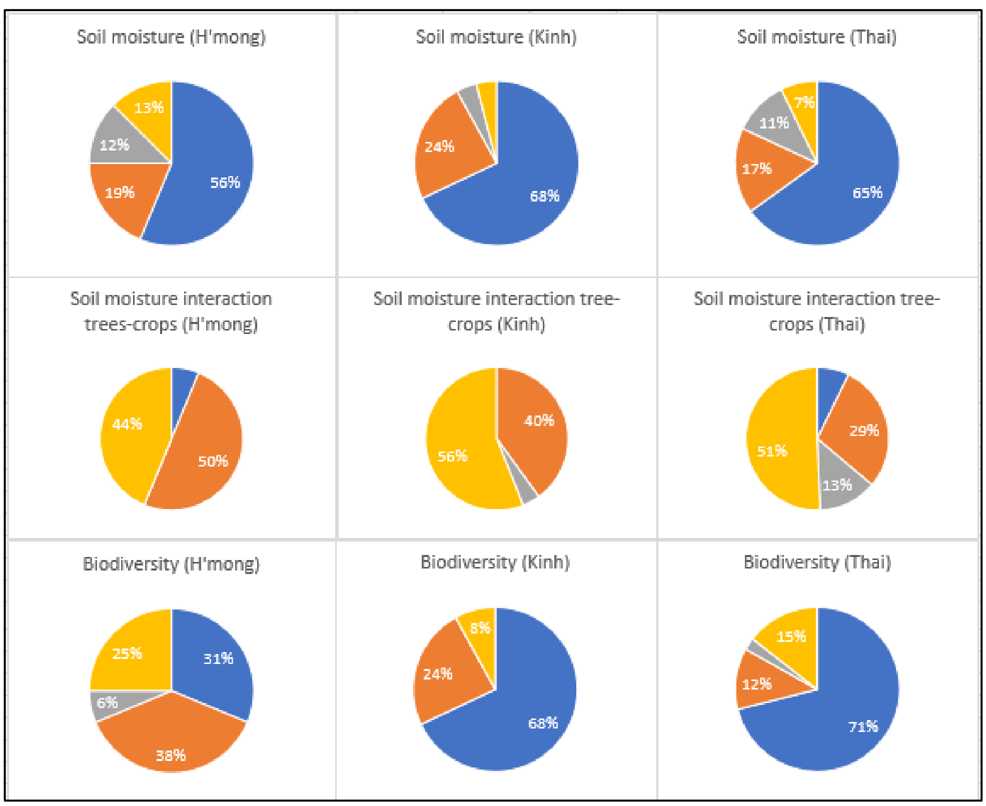
Good coffee farm – fewer pests and diseases, near the road.

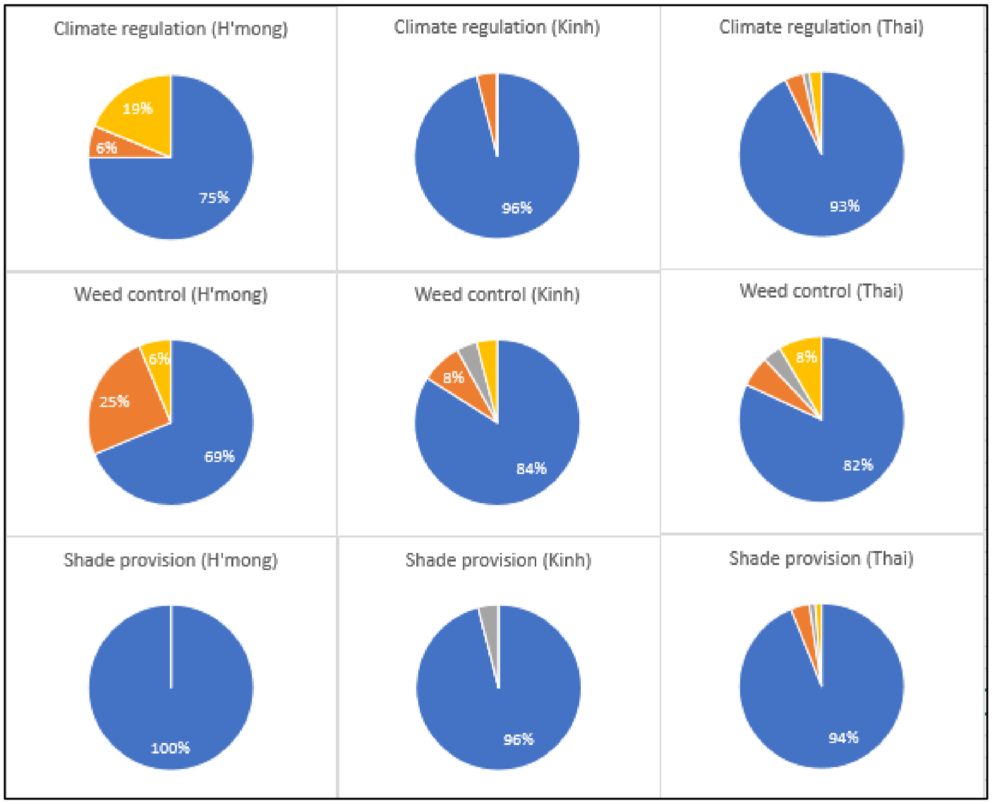
Nice wooden house, big and near the main road

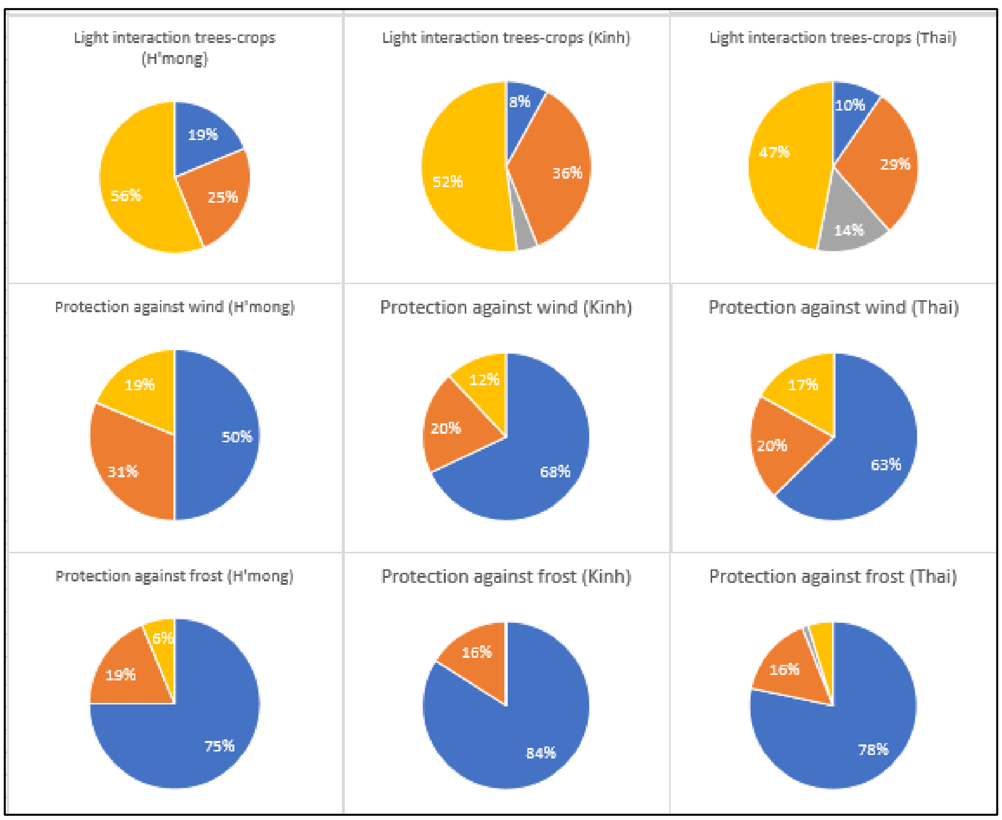
Running water pipe connected to the house.

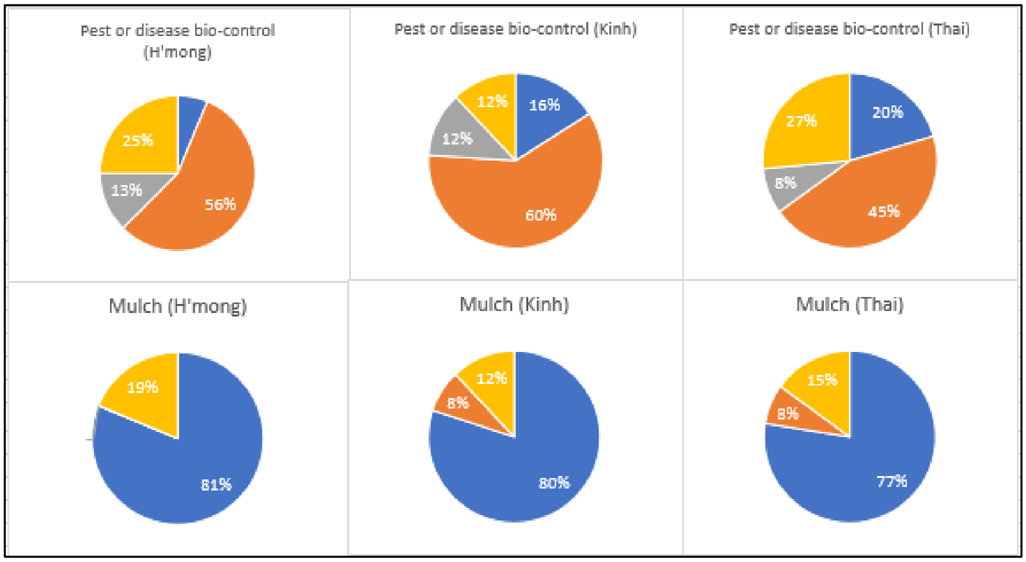
Appendix 5.1: Farmers' perception on tree services to coffee in coffee agroforestry systems by ethnicity


Soil fertility (H'mong)
13%
25%
25%
37%
Soil fertility (Kinh)
8%
20%
48%
24%
Soil fertility (Thai)
12%
33%
30%
25%
Use of fertilizer (H'mong)
6%
38%
56%
Use of fertilizer (Kinh)
8%
12%
16%
64%
Use of fertilizer (Thai)
7%
15%
47%
31%
Nutrient interaction (H'mong)
12%
31%
13%
44%
Nutrient interaction (Kinh)
32%
44%
24%
Nutrient interaction (Thai)
13%
24%
23%
40%


Soil moisture (H'mong)
13%
12%
19%
56%
Soil moisture (Kinh)
24%
68%
Soil moisture (Thai)
7%
11%
17%
65%
Soil moisture interaction trees-crops (H'mong)
44%
50%
Soil moisture interaction tree-crops (Kinh)
40%
56%
Soil moisture interaction tree-crops (Thai)
29%
51%
13%
Biodiversity (H'mong)
25%
31%
6%
38%
Biodiversity (Kinh)
8%
24%
68%
Biodiversity (Thai)
15%
12%
71%

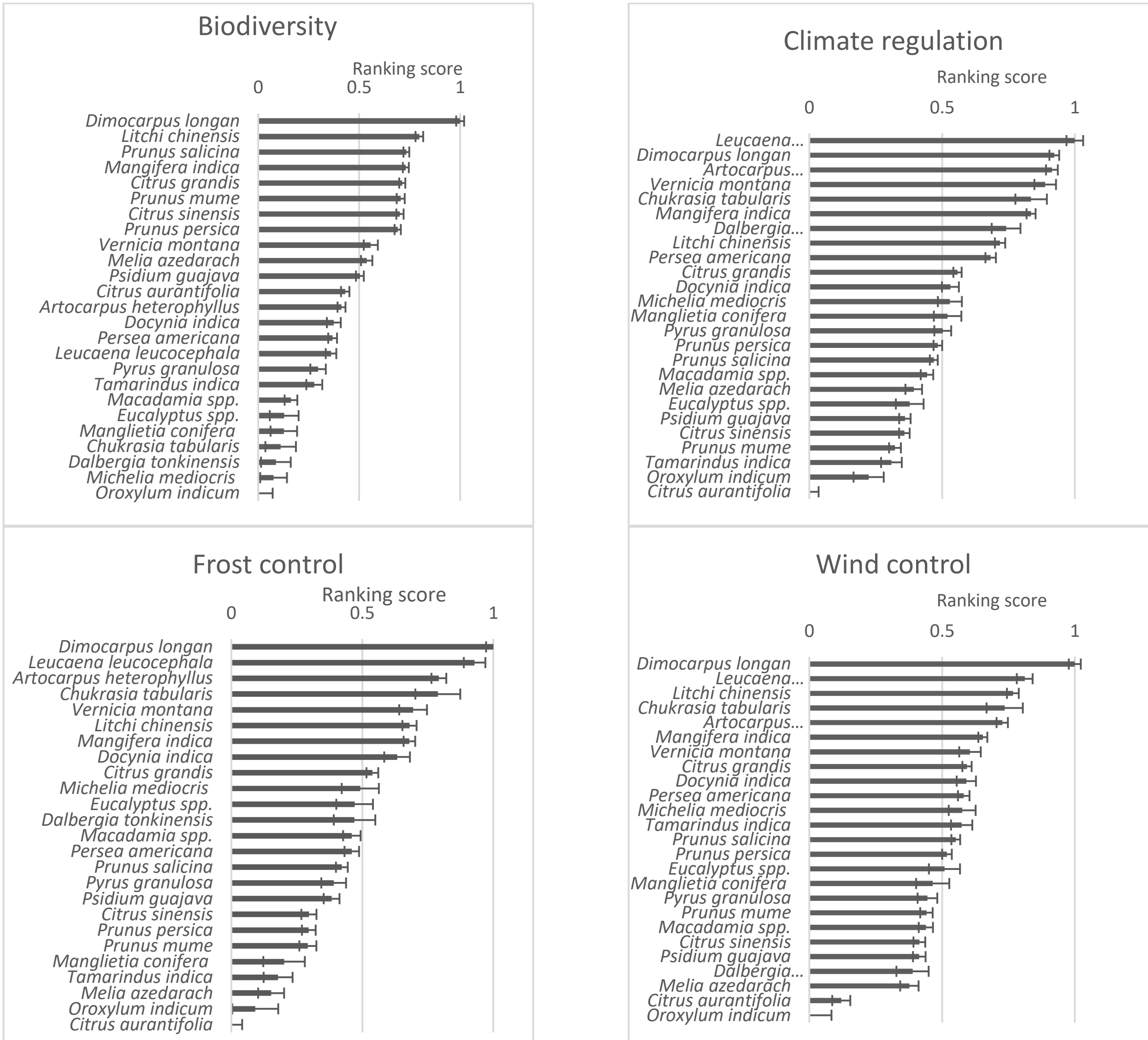

Climate regulation (H'mong)
19%
6%
75%
Climate regulation (Kinh)
96%
Climate regulation (Thai)
93%
Weed control (H'mong)
6%
25%
69%
Weed control (Kinh)
8%
84%
Weed control (Thai)
8%
82%
Shade provision (H'mong)
100%
Shade provision (Kinh)
96%
Shade provision (Thai)
94%

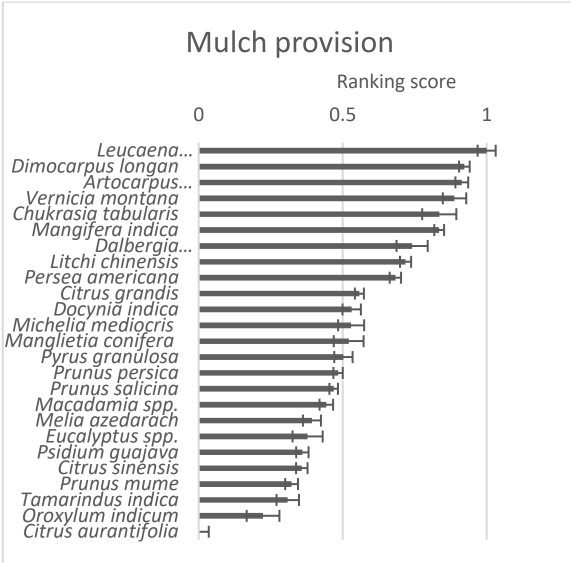

Light interaction trees-crops (H'mong)
19%
56%
25%
Light interaction trees-crops (Kinh)
8%
52%
36%
Light interaction trees-crops (Thai)
10%
47%
29%
14%
Protection against wind (H'mong)
19%
50%
31%
Protection against wind (Kinh)
12%
20%
68%
Protection against wind (Thai)
17%
20%
63%
Protection against frost (H'mong)
6%
19%
75%
Protection against frost (Kinh)
16%
84%
Protection against frost (Thai)
16%
78%

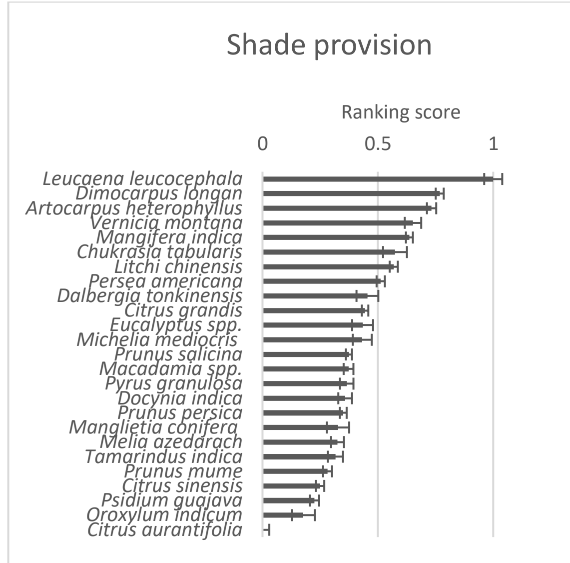


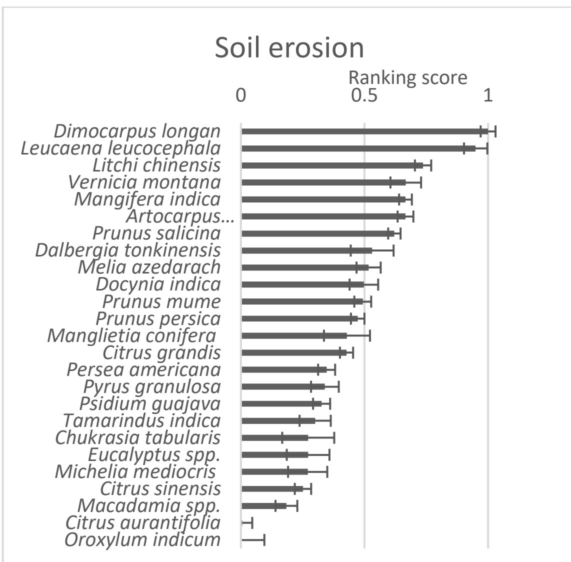
Pest or disease bio-control (H'mong)
25%
13%
56%
Pest or disease bio-control (Kinh)
12%
16%
12%
60%
Pest or disease bio-control (Thai)
27%
20%
8%
45%
Mulch (H'mong)
19%
81%
Mulch (Kinh)
12%
8%
80%
Mulch (Thai)
15%
8%
77%

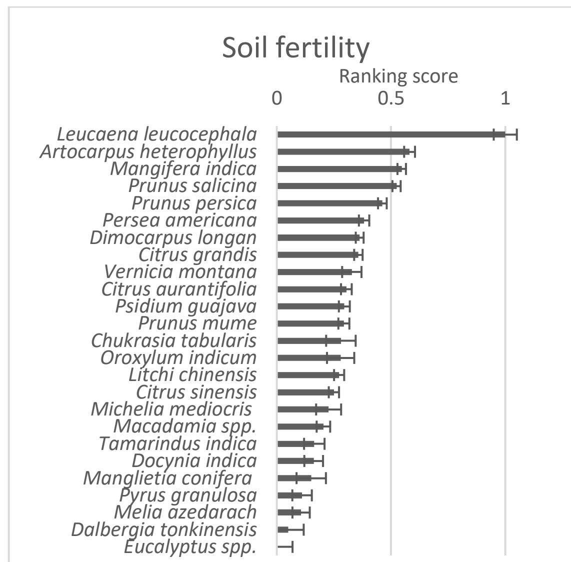
Appendix 5.2: Pairwise ranking of tree species contributing to different tree services in coffee agroforestry system by all groups

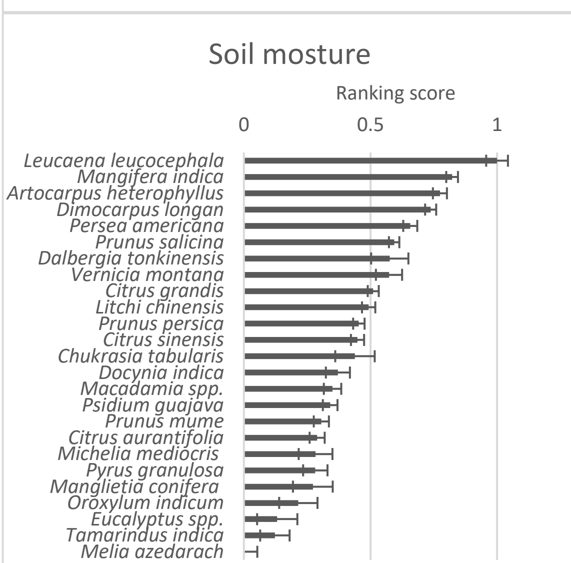


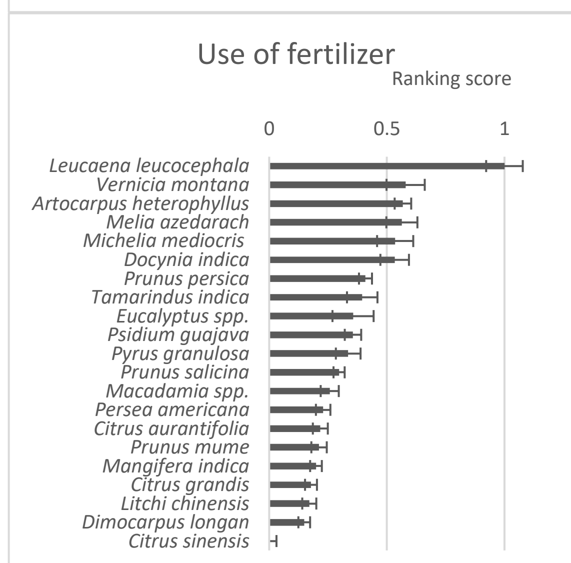

Mulch provision
Ranking score
0
0.5
1
Leucaena...
Dimocarpus longan
Artocarpus...
Vernicia montana
Chukrasia tabularis
Mangifera indica
Dalbergia...
Litchi chinensis
Persea americana
Citrus grandis
Docynia indica
Michelia mediocris
Manglietia conifera
Pyrus granulosa
Prunus persica
Prunus salicina
Macadamia spp.
Melia azedarach
Eucalyptus spp.
Psidium guajava
Citrus sinensis
Prunus mume
Tamarindus indica
Oroxylum indicum
Citrus aurantifolia

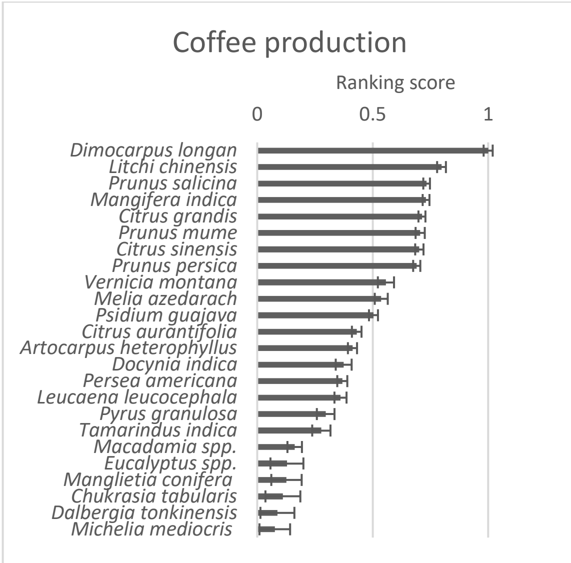

Shade provision
Ranking score
0
0.5
1
Leucaena leucocephala
Dimocarpus longan
Artocarpus heterophyllus
Vernicia montana
Mangifera indica
Chukrasia tabularis
Litchi chinensis
Persea americana
Dalbergia tonkinensis
Citrus grandis
Eucalyptus spp.
Michelia mediocris
Prunus salicina
Macadamia spp.
Pyrus granulosa
Docynia indica
Prunus persica
Manglietia conifera
Melia azedarach
Tamarindus indica
Prunus mume
Citrus sinensis
Psidium guajava
Oroxylum indicum
Citrus aurantifolia

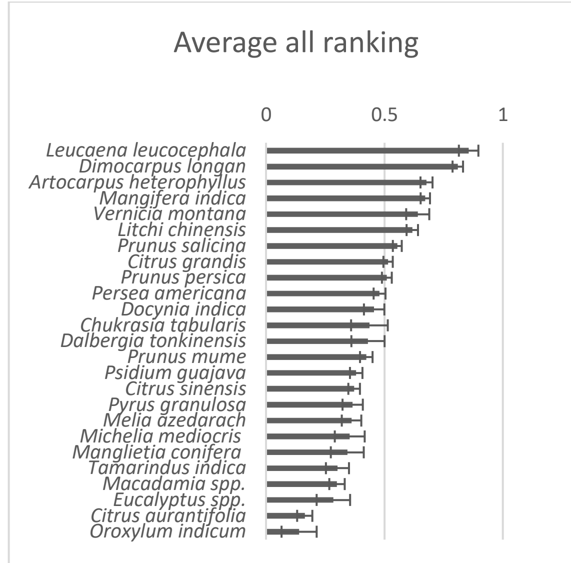

Soil erosion
Ranking score
0
0.5
1
Dimocarpus longan
Leucaena leucocephala
Litchi chinensis
Vernicia montana
Mangifera indica
Artocarpus...
Prunus salicina
Dalbergia tonkinensis
Melia azedarach
Docynia indica
Prunus mume
Prunus persica
Manglietia conifera
Citrus grandis
Persea americana
Pyrus granulosa
Psidium guajava
Tamarindus indica
Chukrasia tabularis
Eucalyptus spp.
Michelia mediocris
Citrus sinensis
Macadamia spp.
Citrus aurantifolia
Oroxylum indicum


Soil fertility
Ranking score
0
0.5
1
Leucaena leucocephala
Artocarpus heterophyllus
Mangifera indica
Prunus salicina
Prunus persica
Persea americana
Dimocarpus longan
Citrus grandis
Vernicia montana
Citrus aurantifolia
Psidium guajava
Prunus mume
Chukrasia tabularis
Oroxylum indicum
Litchi chinensis
Citrus sinensis
Michelia mediocris
Macadamia spp.
Tamarindus indica
Docynia indica
Manglietia conifera
Pyrus granulosa
Melia azedarach
Dalbergia tonkinensis
Eucalyptus spp.

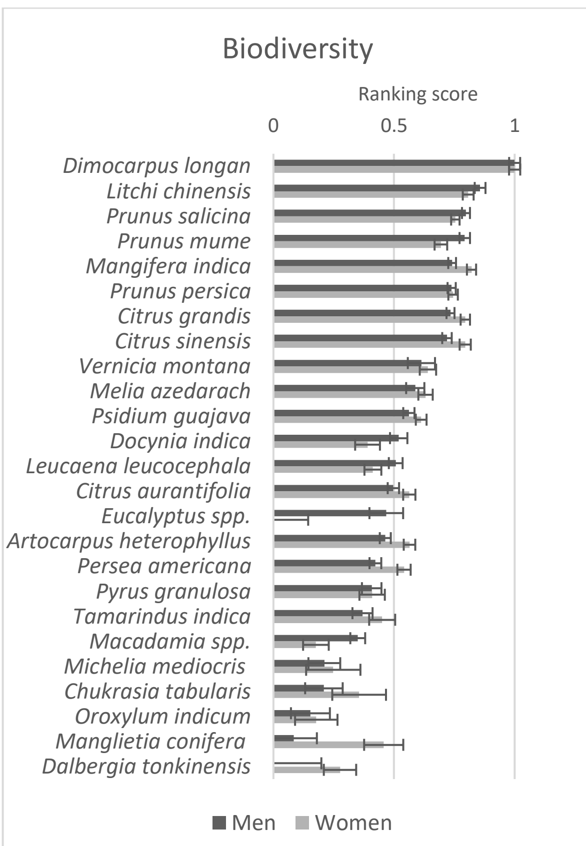

Soil mosture
Ranking score
0
0.5
1
Leucaena leucocephala
Mangifera indica
Artocarpus heterophyllus
Dimocarpus longan
Persea americana
Prunus salicina
Dalbergia tonkinensis
Vernicia montana
Citrus grandis
Litchi chinensis
Prunus persica
Citrus sinensis
Chukrasia tabularis
Docynia indica
Macadamia spp.
Psidium guajava
Prunus mume
Citrus aurantifolia
Michelia mediocris
Pyrus granulosa
Manglietia conifera
Oroxylum indicum
Eucalyptus spp.
Tamarindus indica
Melia azedarach

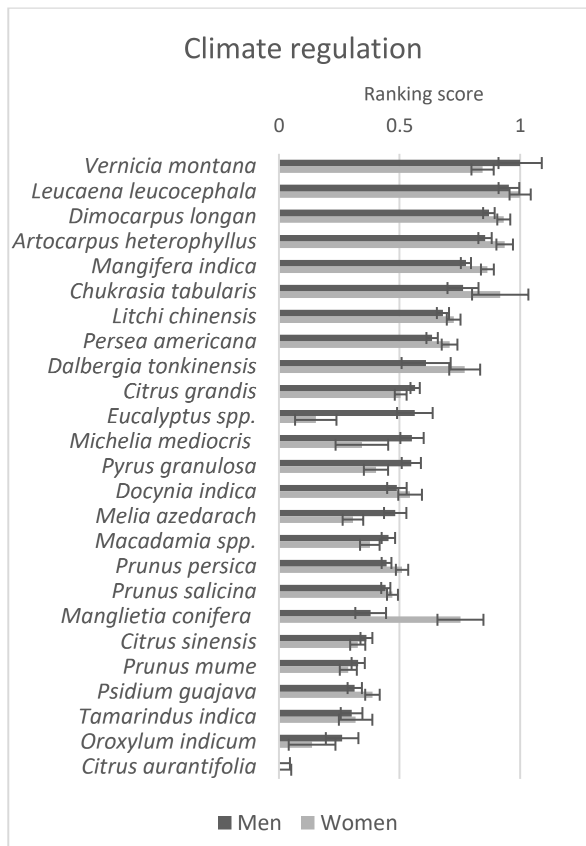

Use of fertilizer
Ranking score
0
0.5
1
Leucaena leucocephala
Vernicia montana
Artocarpus heterophyllus
Melia azedarach
Michelia mediocris
Docynia indica
Prunus persica
Tamarindus indica
Eucalyptus spp.
Psidium guajava
Pyrus granulosa
Prunus salicina
Macadamia spp.
Persea americana
Citrus aurantifolia
Prunus mume
Mangifera indica
Citrus grandis
Litchi chinensis
Dimocarpus longan
Citrus sinensis

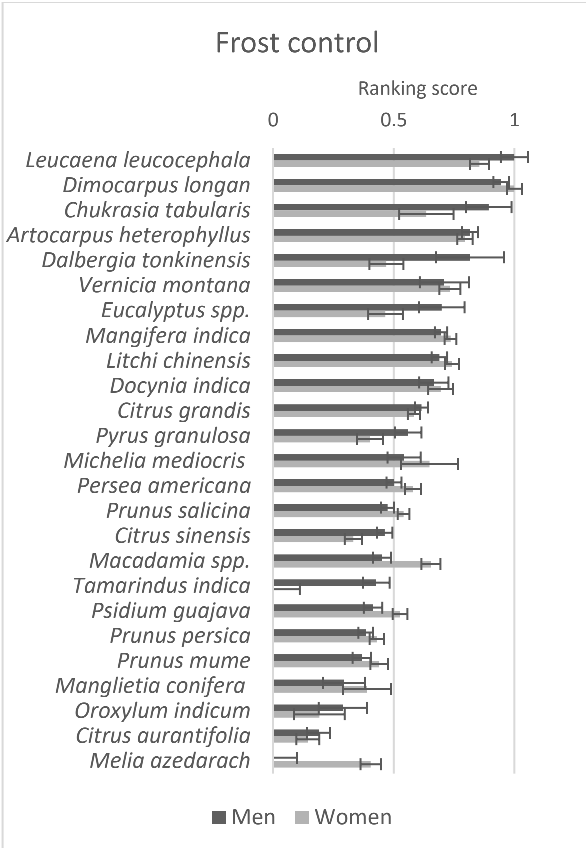


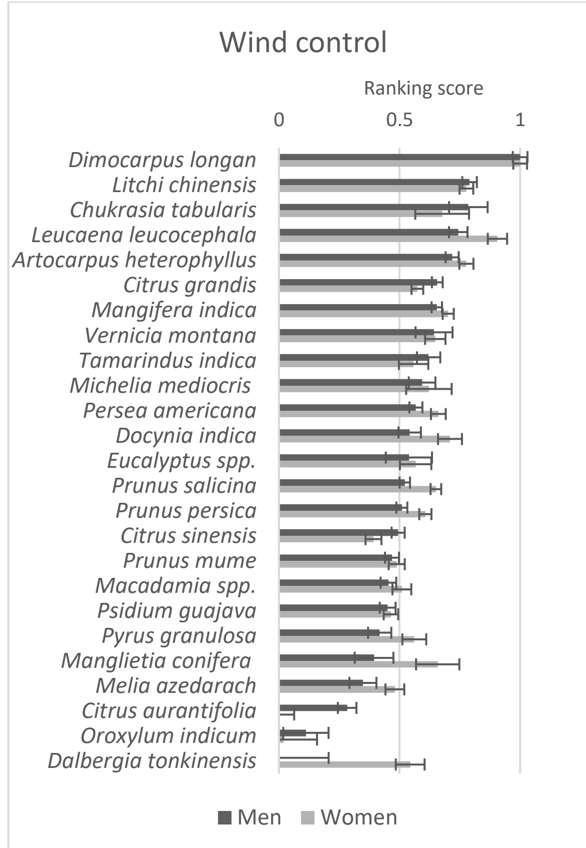


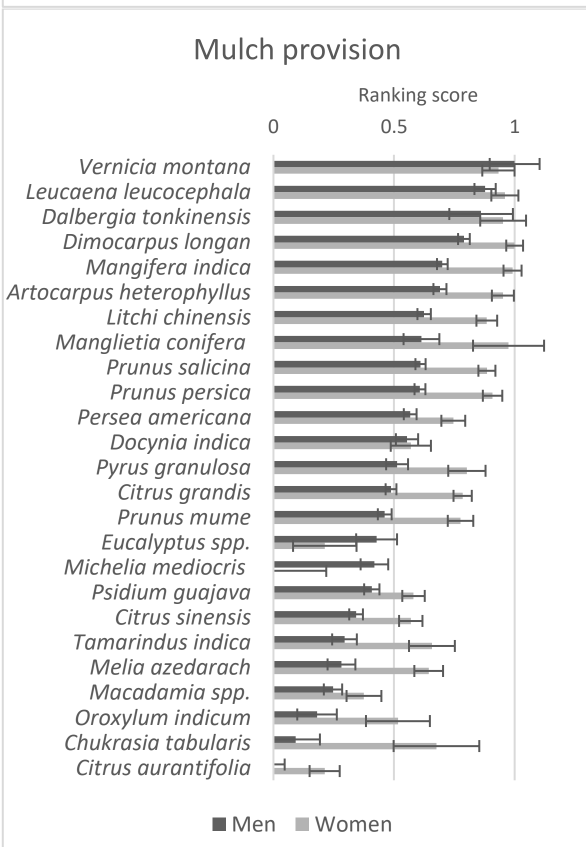
Appendix 5.3: Pairwise ranking of tree species contributing to different tree services in coffee agroforestry system by gender

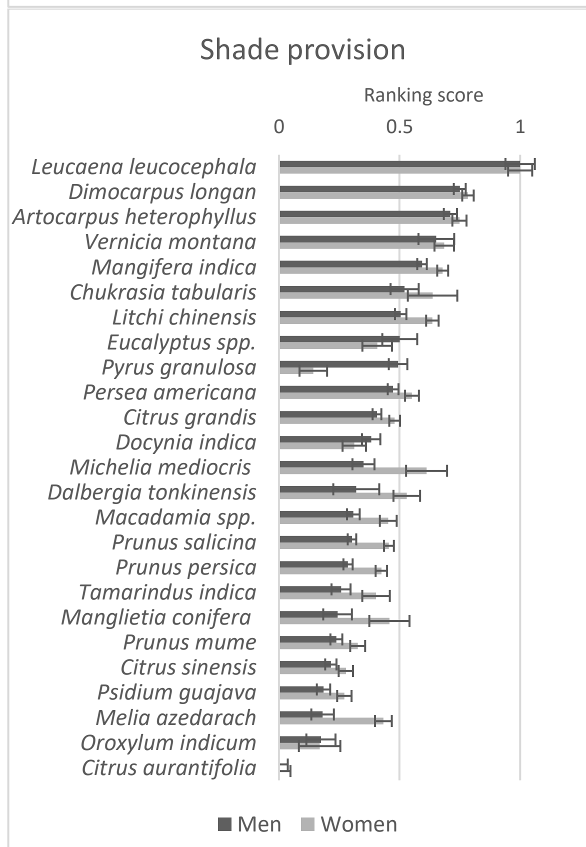


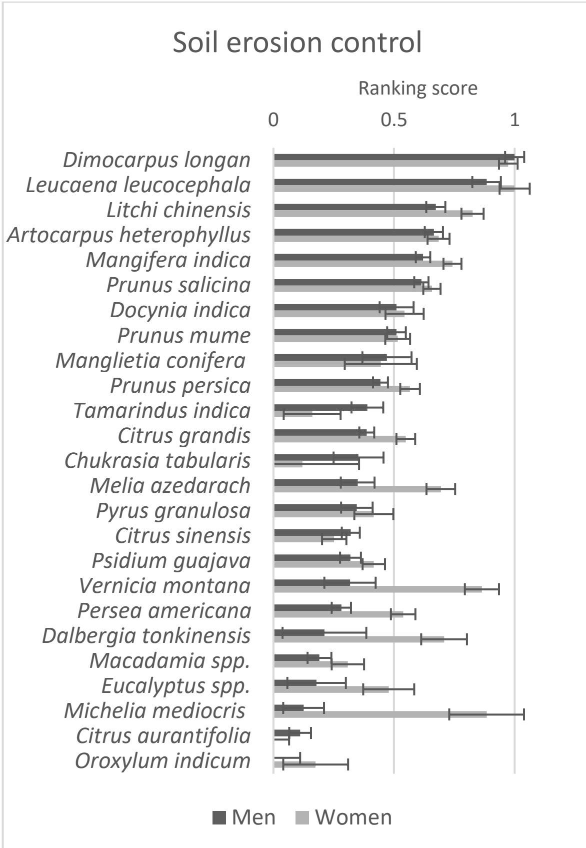


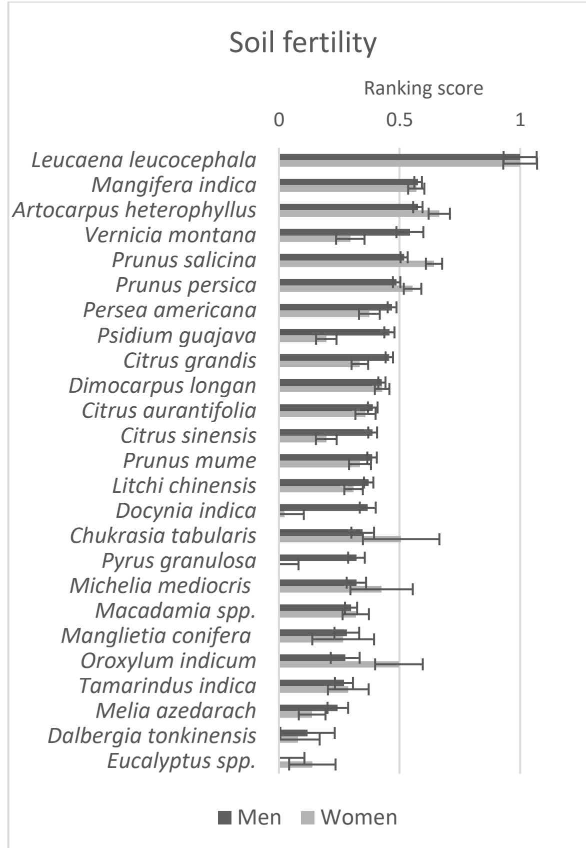

Frost control
Ranking score
0
0.5
1
Leucaena leucocephala
Dimocarpus longan
Chukrasia tabularis
Artocarpus heterophyllus
Dalbergia tonkinensis
Vernicia montana
Eucalyptus spp.
Mangifera indica
Litchi chinensis
Docynia indica
Citrus grandis
Pyrus granulosa
Michelia mediocris
Persea americana
Prunus salicina
Citrus sinensis
Macadamia spp.
Tamarindus indica
Psidium guajava
Prunus persica
Prunus mume
Manglietia conifera
Oroxylum indicum
Citrus aurantifolia
Melia azedarach
Men
Women

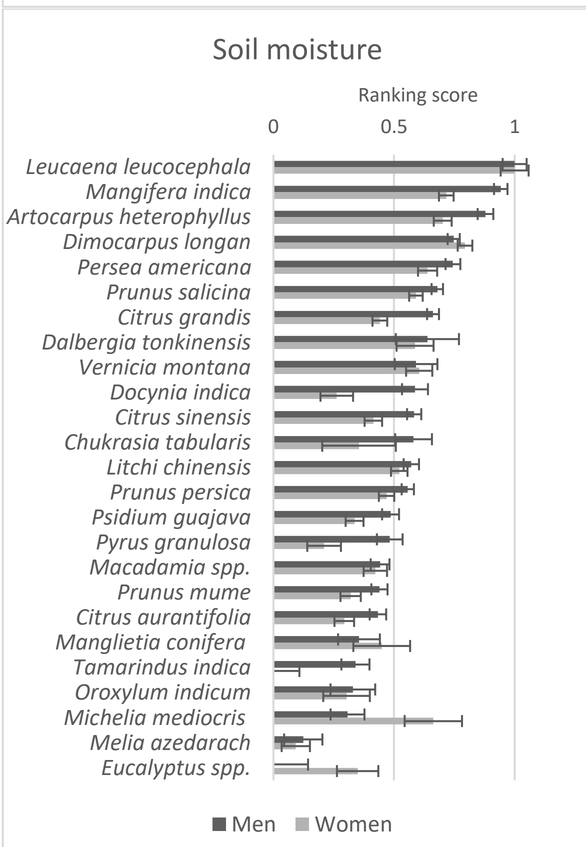

Wind control
Ranking score
0
0.5
1
Dimocarpus longan
Litchi chinensis
Chukrasia tabularis
Leucaena leucocephala
Artocarpus heterophyllus
Citrus grandis
Mangifera indica
Vernicia montana
Tamarindus indica
Michelia mediocris
Persea americana
Docynia indica
Eucalyptus spp.
Prunus salicina
Prunus persica
Citrus sinensis
Prunus mume
Macadamia spp.
Psidium guajava
Pyrus granulosa
Manglietia conifera
Melia azedarach
Citrus aurantifolia
Oroxylum indicum
Dalbergia tonkinensis
Men
Women

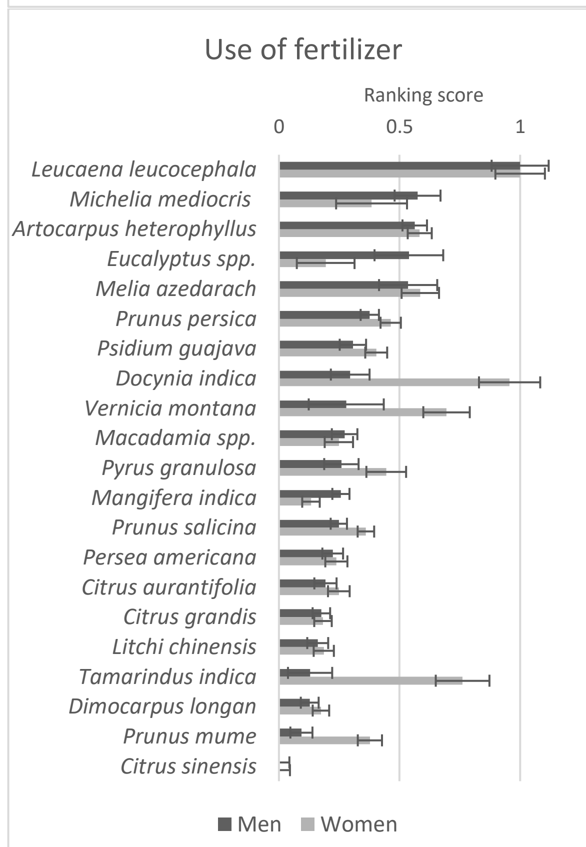

Mulch provision
Ranking score
0
0.5
1
Vernicia montana
Leucaena leucocephala
Dalbergia tonkinensis
Dimocarpus longan
Mangifera indica
Artocarpus heterophyllus
Litchi chinensis
Manglietia conifera
Prunus salicina
Prunus persica
Persea americana
Docynia indica
Pyrus granulosa
Citrus grandis
Prunus mume
Eucalyptus spp.
Michelia mediocris
Psidium guajava
Citrus sinensis
Tamarindus indica
Melia azedarach
Macadamia spp.
Oroxylum indicum
Chukrasia tabularis
Citrus aurantifolia
Men
Women

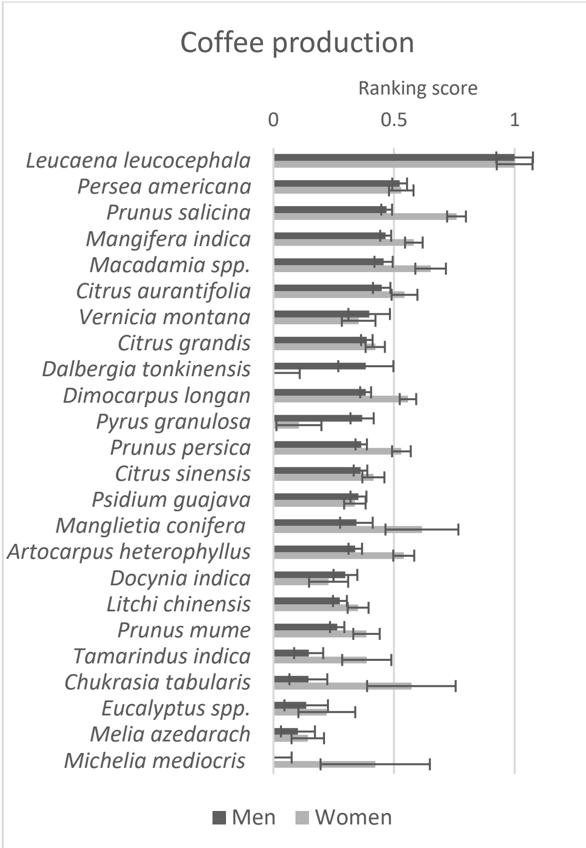

Shade provision
Ranking score
0
0.5
1
Leucaena leucocephala
Dimocarpus longan
Artocarpus heterophyllus
Vernicia montana
Mangifera indica
Chukrasia tabularis
Litchi chinensis
Eucalyptus spp.
Pyrus granulosa
Persea americana
Citrus grandis
Docynia indica
Michelia mediocris
Dalbergia tonkinensis
Macadamia spp.
Prunus salicina
Prunus persica
Tamarindus indica
Manglietia conifera
Prunus mume
Citrus sinensis
Psidium guajava
Melia azedarach
Oroxylum indicum
Citrus aurantifolia
Men
Women

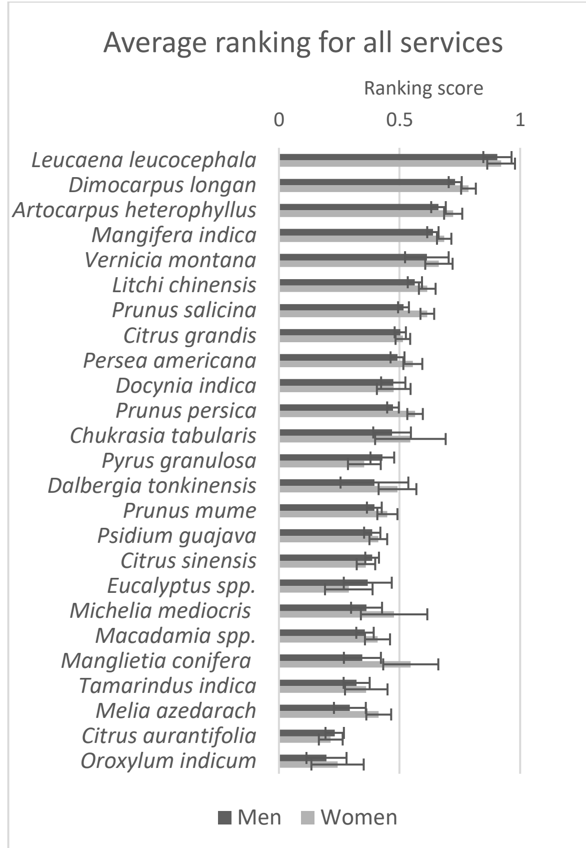

Soil erosion control
Ranking score
0
0.5
1
Dimocarpus longan
Leucaena leucocephala
Litchi chinensis
Artocarpus heterophyllus
Mangifera indica
Prunus salicina
Docynia indica
Prunus mume
Manglietia conifera
Prunus persica
Tamarindus indica
Citrus grandis
Chukrasia tabularis
Melia azedarach
Pyrus granulosa
Citrus sinensis
Psidium guajava
Vernicia montana
Persea americana
Dalbergia tonkinensis
Macadamia spp.
Eucalyptus spp.
Michelia mediocris
Citrus aurantifolia
Oroxylum indicum
Men
Women


Soil fertility
Ranking score
0
0.5
1
Leucaena leucocephala
Mangifera indica
Artocarpus heterophyllus
Vernicia montana
Prunus salicina
Prunus persica
Persea americana
Psidium guajava
Citrus grandis
Dimocarpus longan
Citrus aurantifolia
Citrus sinensis
Prunus mume
Litchi chinensis
Docynia indica
Chukrasia tabularis
Pyrus granulosa
Michelia mediocris
Macadamia spp.
Manglietia conifera
Oroxylum indicum
Tamarindus indica
Melia azedarach
Dalbergia tonkinensis
Eucalyptus spp.
Men
Women

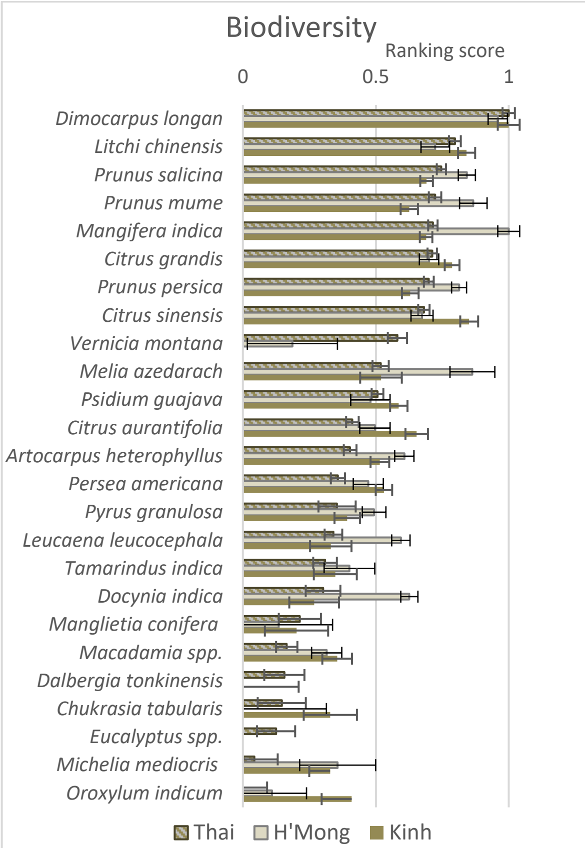

Soil moisture
Ranking score
0
0.5
1
Leucaena leucocephala
Mangifera indica
Artocarpus heterophyllus
Dimocarpus longan
Persea americana
Prunus salicina
Citrus grandis
Dalbergia tonkinensis
Vernicia montana
Docynia indica
Citrus sinensis
Chukrasia tabularis
Litchi chinensis
Prunus persica
Psidium guajava
Pyrus granulosa
Macadamia spp.
Prunus mume
Citrus aurantifolia
Manglietia conifera
Tamarindus indica
Oroxylum indicum
Michelia mediocris
Melia azedarach
Eucalyptus spp.
Men
Women

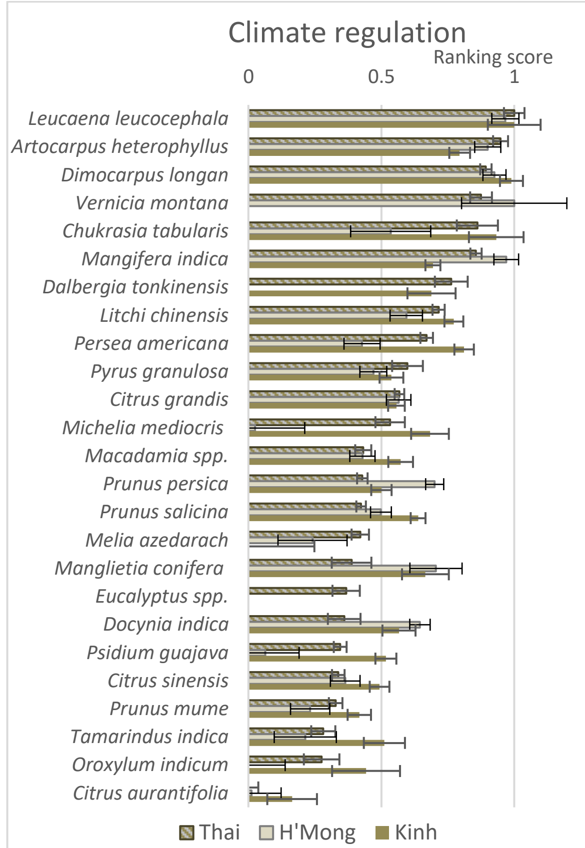

Use of fertilizer
Ranking score
0
0.5
1
Leucaena leucocephala
Michelia mediocris
Artocarpus heterophyllus
Eucalyptus spp.
Melia azedarach
Prunus persica
Psidium guajava
Docynia indica
Vernicia montana
Macadamia spp.
Pyrus granulosa
Mangifera indica
Prunus salicina
Persea americana
Citrus aurantifolia
Citrus grandis
Litchi chinensis
Tamarindus indica
Dimocarpus longan
Prunus mume
Citrus sinensis
Men
Women

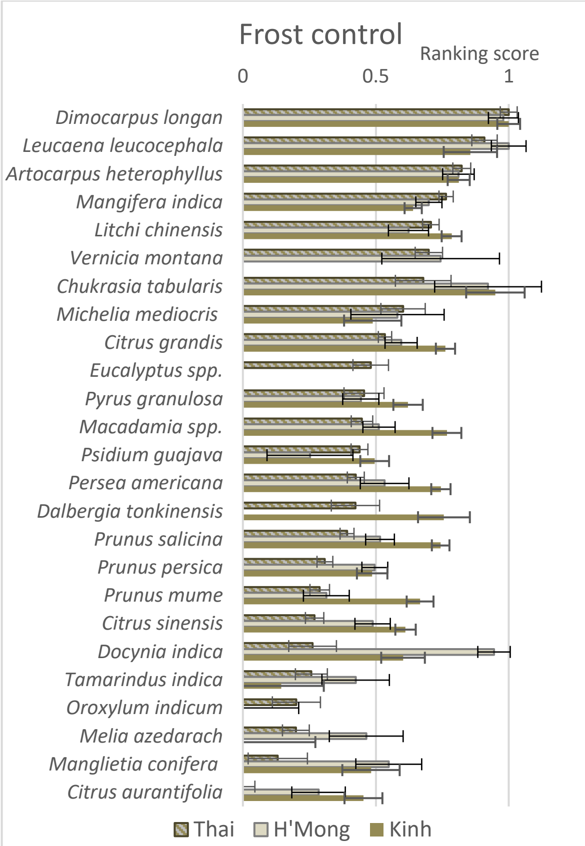

Coffee production
Ranking score
0
0.5
1
Leucaena leucocephala
Persea americana
Prunus salicina
Mangifera indica
Macadamia spp.
Citrus aurantifolia
Vernicia montana
Citrus grandis
Dalbergia tonkinensis
Dimocarpus longan
Pyrus granulosa
Prunus persica
Citrus sinensis
Psidium guajava
Manglietia conifera
Artocarpus heterophyllus
Docynia indica
Litchi chinensis
Prunus mume
Tamarindus indica
Chukrasia tabularis
Eucalyptus spp.
Melia azedarach
Michelia mediocris
Men
Women

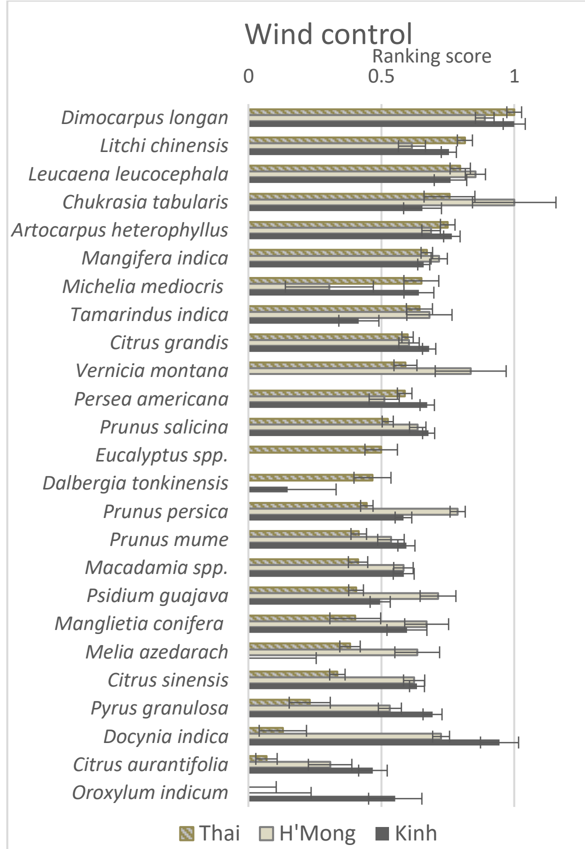

Average ranking for all services
Ranking score
0
0.5
1
Leucaena leucocephala
Dimocarpus longan
Artocarpus heterophyllus
Mangifera indica
Vernicia montana
Litchi chinensis
Prunus salicina
Citrus grandis
Persea americana
Docynia indica
Prunus persica
Chukrasia tabularis
Pyrus granulosa
Dalbergia tonkinensis
Prunus mume
Psidium guajava
Citrus sinensis
Eucalyptus spp.
Michelia mediocris
Macadamia spp.
Manglietia conifera
Tamarindus indica
Melia azedarach
Citrus aurantifolia
Oroxylum indicum
Men
Women

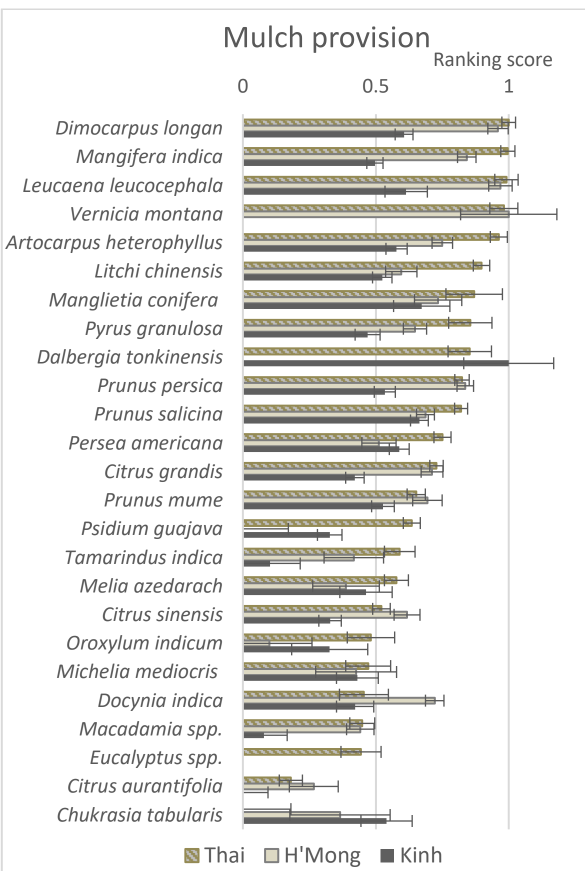
Appendix 5.4: Pairwise ranking of tree species in coffee agroforestry system by tree service and by ethnic group (Thai, H'Mong and Kinh)

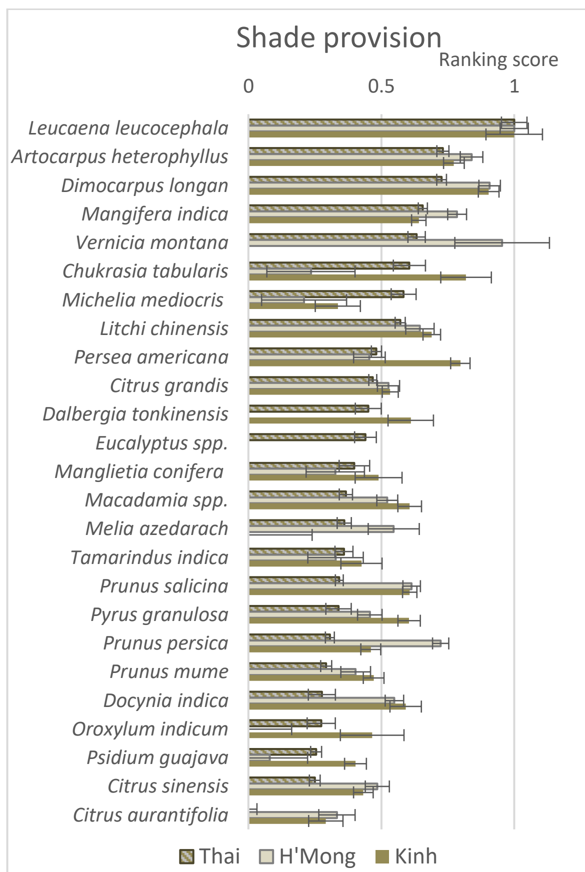


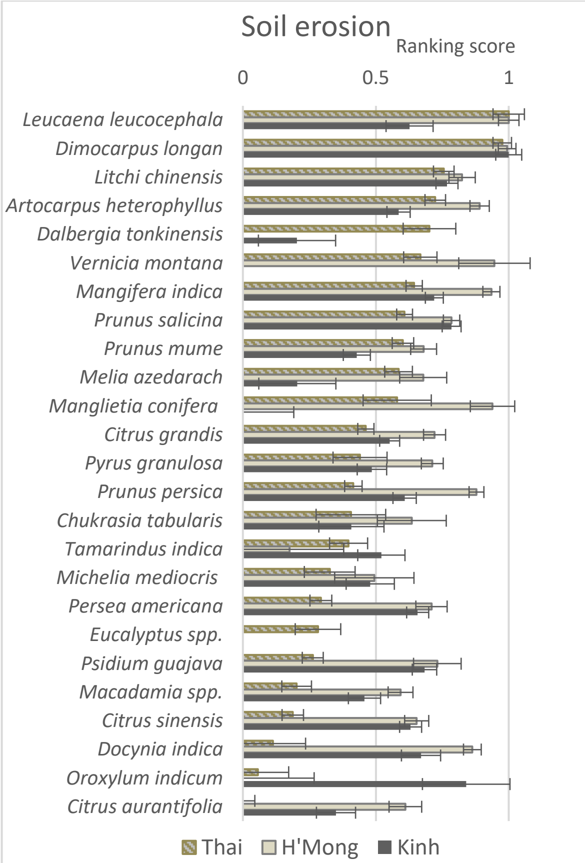


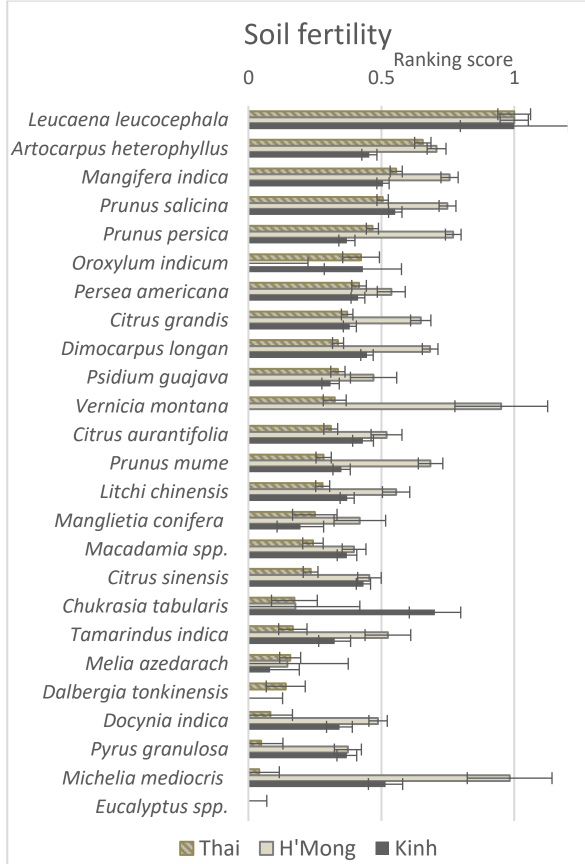

Frost control
Ranking score
0
0.5
1
Dimocarpus longan
Leucaena leucocephala
Artocarpus heterophyllus
Mangifera indica
Litchi chinensis
Vernicia montana
Chukrasia tabularis
Michelia mediocris
Citrus grandis
Eucalyptus spp.
Pyrus granulosa
Macadamia spp.
Psidium guajava
Persea americana
Dalbergia tonkinensis
Prunus salicina
Prunus persica
Prunus mume
Citrus sinensis
Docynia indica
Tamarindus indica
Oroxylum indicum
Melia azedarach
Manglietia conifera
Citrus aurantifolia
Thai
H'Mong
Kinh

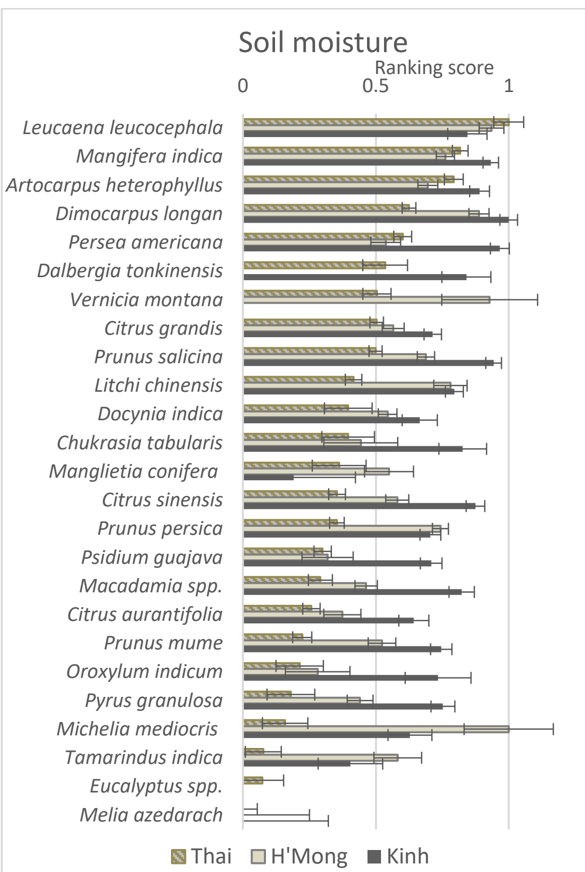

Wind control
Ranking score
0
0.5
1
Dimocarpus longan
Litchi chinensis
Leucaena leucocephala
Chukrasia tabularis
Artocarpus heterophyllus
Mangifera indica
Michelia mediocris
Tamarindus indica
Citrus grandis
Vernicia montana
Persea americana
Prunus salicina
Eucalyptus spp.
Dalbergia tonkinensis
Prunus persica
Prunus mume
Macadamia spp.
Psidium guajava
Manglietia conifera
Melia azedarach
Citrus sinensis
Pyrus granulosa
Docynia indica
Citrus aurantifolia
Oroxylum indicum
Thai
H'Mong
Kinh

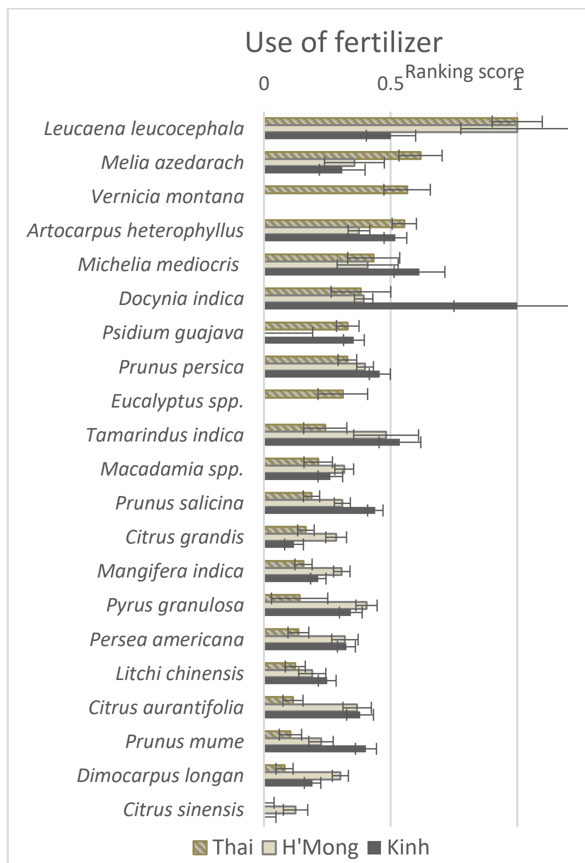

Mulch provision
Ranking score
0
0.5
1
Dimocarpus longan
Mangifera indica
Leucaena leucocephala
Vernicia montana
Artocarpus heterophyllus
Litchi chinensis
Manglietia conifera
Pyrus granulosa
Dalbergia tonkinensis
Prunus persica
Prunus salicina
Persea americana
Citrus grandis
Prunus mume
Psidium guajava
Tamarindus indica
Melia azedarach
Citrus sinensis
Oroxylum indicum
Michelia mediocris
Docynia indica
Macadamia spp.
Eucalyptus spp.
Citrus aurantifolia
Chukrasia tabularis
Thai
H'Mong
Kinh

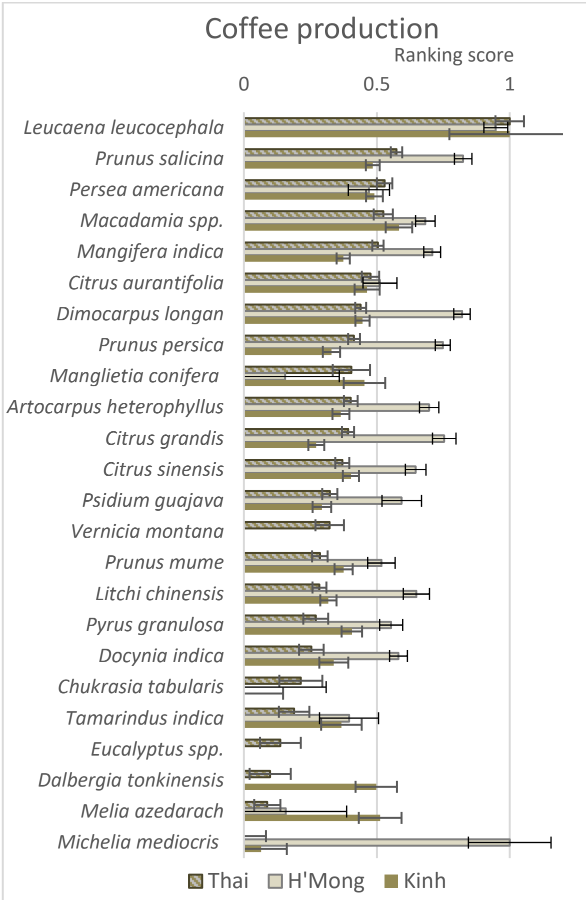

Shade provision
Ranking score
0
0.5
1
Leucaena leucocephala
Artocarpus heterophyllus
Dimocarpus longan
Mangifera indica
Vernicia montana
Chukrasia tabularis
Michelia mediocris
Litchi chinensis
Persea americana
Citrus grandis
Dalbergia tonkinensis
Eucalyptus spp.
Manglietia conifera
Macadamia spp.
Melia azedarach
Tamarindus indica
Prunus salicina
Pyrus granulosa
Prunus persica
Prunus mume
Docynia indica
Oroxylum indicum
Psidium guajava
Citrus sinensis
Citrus aurantifolia
Thai
H'Mong
Kinh

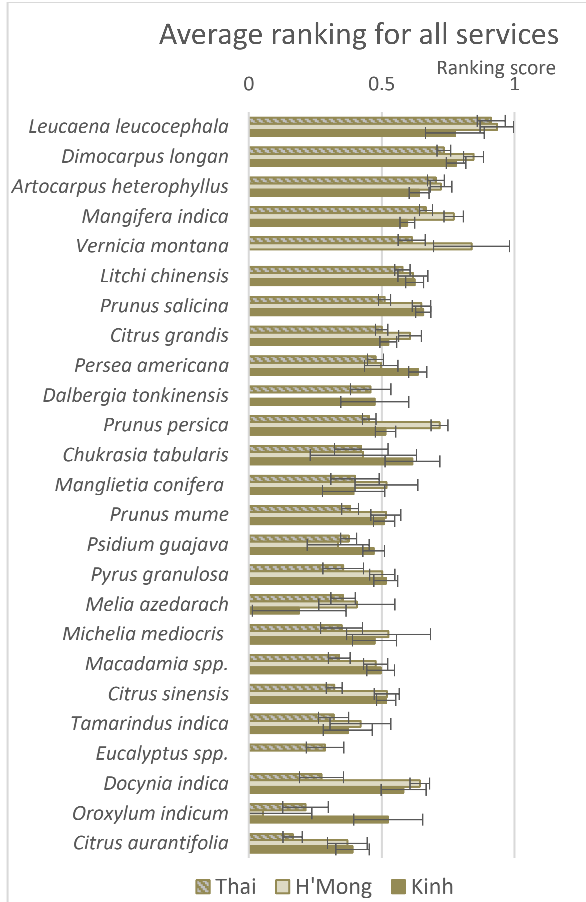

Soil erosion
Ranking score
0
0.5
1
Leucaena leucocephala
Dimocarpus longan
Litchi chinensis
Artocarpus heterophyllus
Dalbergia tonkinensis
Vernicia montana
Mangifera indica
Prunus salicina
Prunus mume
Melia azedarach
Manglietia conifera
Citrus grandis
Pyrus granulosa
Prunus persica
Chukrasia tabularis
Tamarindus indica
Michelia mediocris
Persea americana
Eucalyptus spp.
Psidium guajava
Macadamia spp.
Citrus sinensis
Docynia indica
Oroxylum indicum
Citrus aurantifolia
Thai
H'Mong
Kinh


Soil fertility
Ranking score
0
0.5
1
Leucaena leucocephala
Artocarpus heterophyllus
Mangifera indica
Prunus salicina
Prunus persica
Oroxylum indicum
Persea americana
Citrus grandis
Dimocarpus longan
Psidium guajava
Vernicia montana
Citrus aurantifolia
Prunus mume
Litchi chinensis
Manglietia conifera
Macadamia spp.
Citrus sinensis
Chukrasia tabularis
Tamarindus indica
Melia azedarach
Dalbergia tonkinensis
Docynia indica
Pyrus granulosa
Michelia mediocris
Eucalyptus spp.
Thai
H'Mong
Kinh


Soil moisture
Ranking score
0
0.5
1
Leucaena leucocephala
Mangifera indica
Artocarpus heterophyllus
Dimocarpus longan
Persea americana
Dalbergia tonkinensis
Vernicia montana
Citrus grandis
Prunus salicina
Litchi chinensis
Docynia indica
Chukrasia tabularis
Manglietia conifera
Citrus sinensis
Prunus persica
Psidium guajava
Macadamia spp.
Citrus aurantifolia
Prunus mume
Oroxylum indicum
Pyrus granulosa
Michelia mediocris
Tamarindus indica
Eucalyptus spp.
Melia azedarach
Thai
H'Mong
Kinh


Use of fertilizer
Ranking score
0
0.5
1
Leucaena leucocephala
Melia azedarach
Vernicia montana
Artocarpus heterophyllus
Michelia mediocris
Docynia indica
Psidium guajava
Prunus persica
Eucalyptus spp.
Tamarindus indica
Macadamia spp.
Prunus salicina
Citrus grandis
Mangifera indica
Pyrus granulosa
Persea americana
Litchi chinensis
Citrus aurantifolia
Prunus mume
Dimocarpus longan
Citrus sinensis
Thai
H'Mong
Kinh


Coffee production
Ranking score
0
0.5
1
Leucaena leucocephala
Prunus salicina
Persea americana
Macadamia spp.
Mangifera indica
Citrus aurantifolia
Dimocarpus longan
Prunus persica
Manglietia conifera
Artocarpus heterophyllus
Citrus grandis
Citrus sinensis
Psidium guajava
Vernicia montana
Prunus mume
Litchi chinensis
Pyrus granulosa
Docynia indica
Chukrasia tabularis
Tamarindus indica
Eucalyptus spp.
Dalbergia tonkinensis
Melia azedarach
Michelia mediocris
Thai
H'Mong
Kinh


Average ranking for all services
Ranking score
0
0.5
1
Leucaena leucocephala
Dimocarpus longan
Artocarpus heterophyllus
Mangifera indica
Vernicia montana
Litchi chinensis
Prunus salicina
Citrus grandis
Persea americana
Dalbergia tonkinensis
Prunus persica
Chukrasia tabularis
Manglietia conifera
Prunus mume
Psidium guajava
Pyrus granulosa
Melia azedarach
Michelia mediocris
Macadamia spp.
Citrus sinensis
Tamarindus indica
Eucalyptus spp.
Docynia indica
Oroxylum indicum
Citrus aurantifolia
Thai
H'Mong
Kinh