Food and Agriculture Organization of the United Nations

OCTOBER 2014

# Evidence and Knowledge Gaps on Climate-Smart Agriculture in Vietnam

A Review on the Potential of Agroforestry and Sustainable Land Management in the Northern Mountainous Region

# Evidence and Knowledge Gaps on Climate Smart Agriculture in Vietnam:

## A Review on the Potential of Agroforestry and Sustainable Land Management in the Northern Mountainous Region

*Aslihan Arslan, Jian Ju, Leslie Lipper and Tran The Tuong*[1]

**Abstract**

Agricultural production in northern mountainous region (NMR) of Vietnam faces multiple pressures from soil degradation, poverty, food security, and climate change. A close look at agricultural practices that could potentially capture the synergies between food security and climate adaptation and mitigation may help outline a sustainable solution to the multifaceted problems of this region. This paper reviews the site-specific research in the published literature on the economic and climate impacts as well as the barriers to the adoption of agroforestry and sustainable land management in the NMR, and aims to identify knowledge gaps that need to be addressed for an evidence-based agricultural development policy in the region.

**Keywords**: Climate smart agriculture; sustainable land management; agroforestry; Northern Mountainous Region, Vietnam

**JEL codes**: Q1; O13

**FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS**
**Rome, 2014**

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[1] Aslihan Arslan is Natural Resource Economist at the Agricultural Development Economics Division (ESA) of the Food and Agriculture Organization (FAO) of the United Nations; Jian Ju, is candidate at Masters in Development Practice of the University of California, Berkeley and was an intern with the ESA EPIC Programme during the summer of 2013; Leslie Lipper is Senior Economist and the EPIC Programme Director at the ESA Division of FAO; Tran The Tuong is a Senior Official at the Department of Crop Production, Ministry of Agriculture and Rural Development (MARD) and PhD student at the Department of Economics of Tuscia University.

**Recommended citation**

**Arslan, A., *et.al.*** 2014, Evidence and Knowledge Gaps on Climate Smart Agriculture in Vietnam: A Review on the Potential of Agroforestry and Sustainable Land Management in the Northern Mountainous Region, Rome, FAO



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# Table of Contents

## Acknowledgements

This paper was prepared as background research in support of the FAO-EU project *"Climate-Smart Agriculture: capturing the synergies between mitigation, adaptation and food security".* The authors wish to thank all members of the FAO–EPIC Programme, the staff of the Northern Mountainous Agriculture and Forestry Science Institute (NOMAFSI) and FAO-VN for their continuing support to the project. Any views expressed or remaining errors and omissions are solely the responsibility of the authors.

# 1. Introduction

Vietnam has achieved remarkable economic growth since the reforms towards a socialist–oriented market economy in the 1980s (Fortier 2012). From 1988 to 2012, the country experienced an average growth rate of roughly 7 percent per annum in the whole economy and around 4 percent per annum in the agriculture sector (Wezel *et al.* 2002a; World Bank 2013). Per capita income rose from US$ 220 in 1994 to US$1,600 in 2012, while the poverty headcount ratio decreased from 85% in 1993 to around 43% in 2008 based on the $2 a day poverty line (World Bank 2013). Empirical evidence also indicates that households in Vietnam have become more food secure as measured by both calorie intake and dietary diversity during the 1990s (Molini 2006).

Despite the nationwide boom, the northern mountainous region (NMR)- located in the northwestern part of the country–is lagging behind in terms of both economic growth and poverty alleviation (Tran Duc Vien *et al.* 2006). Nationwide income inequality measured by the Gini coefficient remained stable around 0.35 since 1993 (World Bank 2013). 75% of the Vietnam's minority population lives in the Northern and Central Highlands, and the NMR remains among the poorest areas, with the deepest impoverishment in upland areas where 94–100% of residents belong to ethnic minority groups (World Bank 2001; World Bank 2009). Food insecurity is also a challenge in the area, as most of the increases in food security occurred amongst higher income strata of the population (Molini 2006; Hoan Thi Le Thao *et al.* 2013).

In addition to these challenges, the NMR has a particularly fragile ecosystem due to the terrain characterized by steep slopes, severe soil erosion increasing population pressure, land scarcity, and widespread use of environmentally damaging agricultural practices, such as burning of organic residues, deforestation, free grazing, and ploughing on slopes (Wezel *et al.* 2002a; Valentin *et al.* 2008). Climate change is expected to disturb the already fragile environment even more in the NMR and exacerbate the instability of food production in the area. The Intergovernmental Panel on Climate Change (IPCC) lists Vietnam as one of the countries most vulnerable to climate change (IPCC 2007). Vulnerability stems from sensitivity of socioeconomic structures to climate change and low adaptation capacity as well as exposure to natural forces (Nelson *et al.* 2007). Region-specific evidence for NMR is still scarce in terms of the extent of such vulnerability to climate change and the expected food security implications.

It is therefore pertinent to examine the impacts of different agricultural practices in the context of climate change in this region, to improve our understanding of their adaptation and mitigation impacts and potential to contribute to food security under the specific climate, agro-ecological and socio-economic conditions of the NMR. A better understanding of the region and its agriculture has broader significance as well, since nearly 74.1% of the total land in Vietnam is sloping land, subject to soil erosion and degradation, and the potential for expanding cultivated area in the flat delta regions has almost been exhausted (Wezel *et al.* 2002b; Doanh and Tiem 2001). An increasing understanding of sustainable development paths in the sloping areas is therefore essential for national food security in general (Doanh and Tiem 2001).

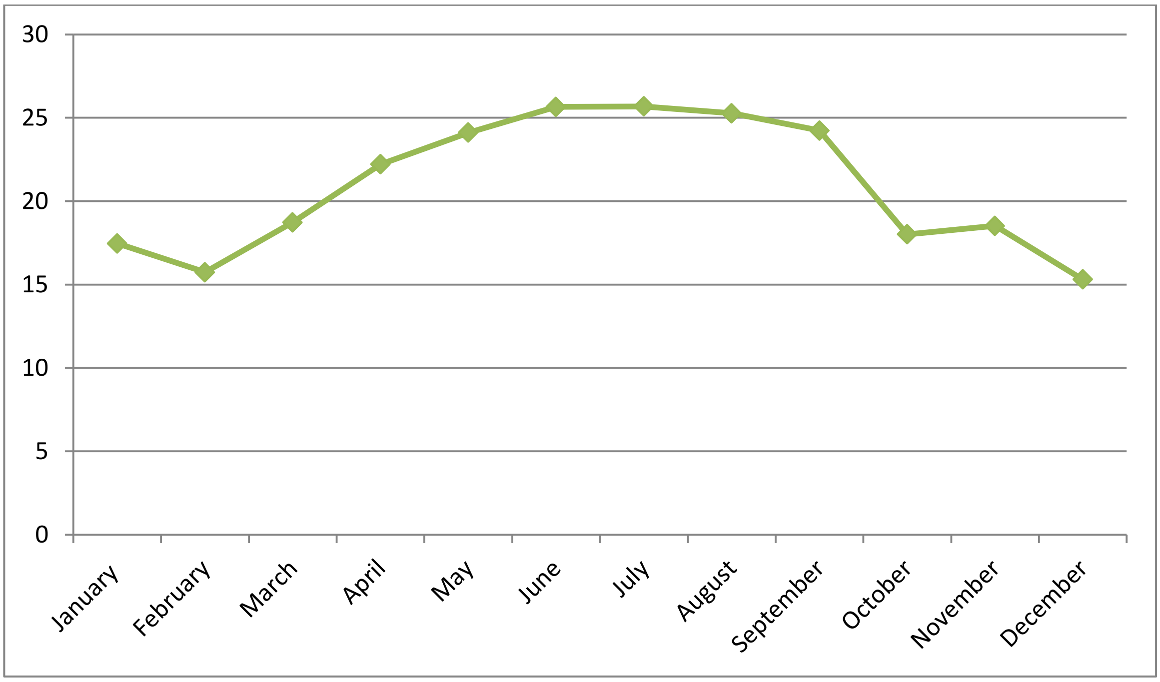
In an attempt to pave the way for more site-specific, evidence-based research on climate-smart agriculture (CSA) an agricultural development path that captures the synergies between food security, adaptation to, and mitigation of, climate change, this paper starts with an introduction of the geographical, agricultural and climatic structures in the region in Section II, and goes on with Section III to (a) discuss two sets of agricultural practices in NMR that have the potential to be climate-smart, i.e. agroforestry and sustainable land management, (b) evaluate the impact of these practices on yields and climate change, and (c) map out factors that affect people's adoption decisions. In Section IV, the paper finishes up with concluding remarks about potential areas for future research and policy implications.

## 2. Geography, Agriculture and Climate in the NMR

Vietnam has a monsoon tropical climate. It is situated completely in the interior tropical zone of the Northern hemisphere and heavily influenced by the East Sea (UNEP 2009). The NMR is almost exclusively highland (Nguyen Quang Tin *et al.* 2014). Mountains over 2,500 masl are most concentrated in the north-western part of country (UNEP 2009). The NMR region is characterized by a wide variety of topography, climate, biodiversity, agricultural systems, and ethnic groups (Tran Duc Vien 2003).

The NMR has a hot rainy summer and a dry cold winter. The average temperature in January in Vietnam ranges from 2 - 26°C, and decreases gradually from the South to the North, and from the low lands to the high lands. The average temperature in July ranges from 10 - 30°C, (UNEP 2009). Satellite data from the European Centre for Medium-Range Weather Forecasts (ECMWF)[2] shows that in 2010, the temperature in January ranged from 14 - 21°C, and in July from 22 - 30°C in the NMR. The long-term monthly average temperatures of the region from 1989 to 2010 are shown in Figure 1.

**Figure 1. Long term average temperatures in NMR (°C)**




*Source:* Authors' calculations based on ECMWF data.

[2] ECMWF Re-analysis data available for the period of 1989-2010 was processed by Giulio Marchi (Geospatial Analyst at FAO) to create a communal level data base on rainfall and temperature in the NMR. For more details on the raw data:
www.ecmwf.int/research/era/do/get/Reanalysis_ECMWF

The normal annual average relative humidity in Vietnam is about 80 - 85%, reaching 86 - 87% in high mountainous areas in the North. Annual rainfall in Vietnam usually ranges from about 1,400 - 2,400 mm, but in general, rainfall in the north much exceeds that in the south (UNEP 2009). Our calculations based on the communal level ECMWF data show that the annual rainfall in the NMR from 1989 to 2010 ranged from 930 - 2,900mm and averaged at about 1,800mm. Analyses of observed weather trends show that while winter temperatures in the North were rising at faster rates than the country average, the annual rainfall has decreased between 1958 and 2007 (MONRE 2010).

The local geographical conditions coupled with socio-economic factors shape Vietnam's agriculture, which has always been a cornerstone of the national economy. Agriculture provides livelihoods to 60 percent of the population and generates about a quarter of Vietnam's GDP, down from around 70% in the 1980s (Carew-Reid 2008; World Bank 2013). It also plays a central role in food security, poverty reduction, and foreign exchange earnings in Vietnam (Bingxin Yu *et al.* 2012). Throughout the nation, households are increasingly growing crops on permanent fields for subsistence needs as well as for sales (Lamers *et al.* 2013). Agriculture in the NMR predominantly involves mono-culture of staple crops on sloping lands (Hoang Thi Lua *et al.* 2013). The process of agricultural intensification and commercialization has been accompanied by a change in the types of crops grown and the cultivation methods used, with a greater reliance on external inputs such as fertilizers and pesticides (Pingali 2001; Lamers *et al.* 2013).

In the NMR, maize is one of the most important cash crops and in recent years has replaced rice on sloping lands as the dominant crop, due to the increasing demands for maize from the livestock feed industry (Pham Thi Sen *et al.* 2012), declining yields of upland rice associated with decreased soil fertility (Wezel *et al.* 2002a), and increasing yield and profitability of maize with improved varieties of maize (Wezel *et al.* 2002a; Doanh and Tiem 2001). Through an exploratory time-series analysis of the ideal rainfall and temperature conditions to cultivate maize in the uplands of Vietnam, we find that temperature during the maize growing season became more favourable for maize cultivation over the past two decades, whereas no significant changes were found in the idealness index for rainfall (See Appendix Table 1).[3]

Total maize production in the NMR was over 1.5 million tons in 2010 (>31% of the total production of maize in the country) (GSO 2011). Hoang Thi Lua *et al.* (2013) conducted a study of agroforestry in northwestern Vietnam and reported that 90% of the farmer participants grew maize, which was also the main income source for 82% of all farmer participants. Expansion of maize production has pushed cultivation to the tops of slopes

[3] Ideal rainfall and temperatures for maize growth during the growing season are defined based on Thanh *et al.* (2013) as documented in Appendix Table 2. The idealness scores are the weighted sum of number of dekads during the growing season of different idealness. The weights are set such that they increase from 1 to 5 for the categories of "not optimal," "moderately optimal," "average optimal," "optimal" and "very optimal," respectively.

with an inclination of over 25 degrees. This is despite government efforts to restrict the cultivation of annual crops to flatter lands at lower elevations, as annual crops are inappropriate for sustainable land use on sloping lands (Doanh and Tiem 2001; Pham Thi Sen *et al.* 2012) ). It has also been noted that intensive mono-cropping of maize is experiencing decreasing yields due to soil erosion and decreasing returns due to high fertilizer and labor costs (Hoang Thi Lua *et al.* 2012).

Other crops of particular interest in the NMR are Shan tea and coffee as cash crops (e.g. tea is the dominant cash crop in Yen Bai, and coffee is for Son La and Dien Bien). Regenerated forests of acacia and eucalyptus are not unusual at steep slopes at high altitudes, mostly at places where soil fertility is low, for their value in generating timber. Small scale agroforestry, such as home gardens, coffee planted under timber species, and *Amomum*[4] under forest canopy, are practiced as well, especially when there's a good market for the produce. Paddy rice is still common on the limited flat fields in the valleys or terraces of the NMR (Hoang Thi Lua *et al.* 2013).

Apart from pressures from human induced land-degradation (Quyet Manh Vu 2012; Doanh and Tiem 2001), recent effects of climate change bring additional challenges to agricultural production in NMR. Climate forecasts predict an increase in average temperature by around 0.5°C in 2020 and by 1.2-1.3°C in 2050 compared to the level in 1980-1999, and an increase in total rainfall by 1.4-1.6% in 2020 and by 3.6-3.8% in 2050 compared to the level in 1980-1999 in northwestern Vietnam, depending on different emission scenarios (FAO 2011). Our analysis of commune level climate data from 1989 to 2010 reveal a similar increasing trend in temperature, although the exact rate of change may vary from the forecast level (See Appendix Table 1).

Contrary to the forecasted trend for rainfall, we find a decreasing trend in observed rainfall for the period of 1989-2010, which is consistent with the trends presented by the Ministry of Natural Resources and the Environment (Appendix Table 1; MONRE 2009)[5]. Projections also include a decrease in rainfall during the dry season and an increase during the rainy season, hence increasing within-year rainfall variability (FAO 2011). Consistent with these expectations, we find significant increase in two indicators of within-year rainfall variability in the NMR, i.e. the coefficient of variation in rainfall and the seasonality index (Appendix Table 1)[6]. Studies show that increasing temperature and erratic rainfall, both of which are defining characteristics of climate change (UNEP 2009),

[4] *Amomum* is a genus of plant that includes several types of cardamom.

[5] It is important to note that in the forecasts of FAO (2011), a lot of emphasis has been given to model human intervention in climate. In our models, human intervention is treated as a time-invariant province-fixed unobservable variable and much more implicit. The authors also remarked that "Northern climate zones have seen a decrease in annual rainfall, in contrast to southern zones" during 1958-2007 period (FAO 2011), which is consistent with our model.

[6] The seasonality index used is the one developed by Walsh and Lawler (1981).

can affect food security by altering farmers' production behaviour and the natural environment of crops (Bingxin Yu *et al.* 2012).

The current agricultural development model involving unsustainable forms of intensification raises concerns, especially in the context of climate change (Fortier 2011), where increased resource use efficiency and resilience are key to achieving agricultural systems that support food security. It is therefore important to explore agricultural development options with the potential to capture the synergies among food security, adaptation and mitigation. Given that the adoption of such options by farmers is usually subject to constraints, it is also imperative to have a thorough understanding of the socio-economic and institutional determinants of adoption in order to support an efficient agricultural policy targeting. We review the existing evidence in the literature on these issues in the next section.

# 3. Review of Agricultural Practices with CSA potential in NMR

There is no one agricultural practice or production system that can be considered CSA, but rather a set of possible options that under the specific climate change, socio-economic and agro-ecological conditions can increase agriculture's capacity to support food security. That is, the magnitude of the benefits and costs of varying practices, as well as the institutional environment necessary to support adoption vary widely across regions (FAO 2010). Site-specific research, therefore, is required to identify potential CSA practices in each region. A thorough understanding of the potential of a practice for CSA, requires an analysis of its contributions to household food security (productivity and income), adaptation (variability of income/productivity over time) and the potential for mitigation.

Site-specific research on potential CSA practices in NMR is very limited and mostly relies on grey literature (Nguyen Quang Tin *et al.*, 2014). Although a variety of potential CSA practices, such as sustainable land management practices, have been developed and promoted in the region in the past, adoption rates remain very low, bringing into question the suitability of these techniques to the local agro-ecological and socio-economic contexts.  Existing peer reviewed literature in English language is very much focused on reducing soil erosion and degradation while increasing land productivity and household income through agroforestry and sustainable land management (Doanh and Tiem 2001; Hoang Thi Lua *et al.* 2012; Hoang Thi Lua *et al.* 2013; Nguyen 2013; Thai Phien and Tran Thi Tam  2007). Both of these have the potential to increase household incomes and contribute to the adaptation and mitigation capacity of agricultural systems. Given the limited nature of the site-specific research on a wider set of potential CSA practices, this paper mainly tries to assess the CSA potential of these two practices in the following sections.

## i. Agroforestry

Agroforestry, defined as the deliberate use of forestry in the agricultural landscape, is a common practice in the tropical climate zones. Studies show that agroforestry practices such as multi-strata forest gardens, mixed tree crop systems, and home gardens, can reduce the vulnerability of the agricultural system to climate change, modulate water flows, store carbon, and provide food, fodder, and goods for cash (Kumar 2006; Verchot *et al.* 2007; Nguyen 2013).  While there is growing evidence worldwide that agroforestry can generate income for households, increase climate resilience of agricultural production, and decrease greenhouse gas (GHG) emissions, research specific to Vietnam to attest these features of agroforestry, is still relatively limited. Below we review the few papers on this topic that are available in the published literature in English.

## (a) Economic returns and climate resilience of agroforestry

Home gardens are a dominat type of agroforestry in the Northern Vietnam. Quan Nguyen *et al.* (2013) interviewed 42 farmers and organized village meetings in 2 villages in Cam My commune in Ha Tinh Province to learn about farmers' home garden practices. They identified a number of home garden species (e.g. rattan, jack fruit, aquilaria) that show potential for increasing climate resilience of the agricultural system to various negative shocks such as flooding, drought, pest/disease, hoarfrost, and cold, while providing additional economic benefits. The authors pointed out that while income from rice crops ranging from VND 30-38 million/ha seems to be larger than that from home gardens, which ranges from VND 6-27 million/ha (per year), the economic benefits from home gardens are likely to be underestimated. This is mainly due to lower labor costs of home gardens, the ignored economic value of home consumption of a large part of home garden produce, and insurance benefits of diversification in agriculture especially in times of harsh weather. Quan Nguyen *et al.* (2013), however, analyzed tree species separately from other crops and therefore cannot shed light on the potential interactions/synergies between crops and trees in the same system.

ICRAF's project, "Diagnosis of Farming Systems in the Agroforestry for Livelihoods of Smallholder Farmers in Northwestern Vietnam," provides valuable insights into identifying agroforestry practices that generate the greatest economic value and proposes a strategy that combines staple crops for short-term needs, grass strips for soil protection, and trees for medium-to-long-term income (Hoang Thi Lua *et al.* 2013). After assessing current practices, including the sporadic small scale agroforestry practices with farmers' participation in 17 villages in Yen Bai, Son La, and Dien Bien at different elevations, Hoang Thi Lua *et al.* (2013) found that: (a) regardless of the agro-ecological zone or ethnicity, mono-cultivation of staple crops was the predominant practice; and (b) profits from different farming practices and crops were usually lower at higher elevations[7]. The low profits at high elevations could be explained by 3 factors: (i) areas at higher elevations suffered from more severe soil degradation; (ii) local varieties of maize and upland rice have degenerated; and (iii) farmers often have to resort to selling their grains and tubers at low and volatile prices due to limited access to a wider market.

About 70% of the farmer participants in the project had at least some trees on their farm. Most trees were planted, at a small scale, in home gardens or scattered around the farm: at the top of the hill, on foothills, or along the contours. Typical agroforestry practices included home gardens with fruit trees, and coffee under the shade of timber/fruit trees in Son La Province; cassava intercropped with shan tea in Yen Bai Province; and cardamom under forest canopy in Dien Bien Province. Few generated significant cash income for households. The authors interviewed farmers and made the list of species that could be

[7] The authors define high elevations as >800 masl, intermediate elevations 600-800 masl, low elevations <600 masl.

incorporated into agroforestry for income generation, home consumption of fruits and timber, or ecological reasons presented in Table 2 (Hoang Thi Lua *et al.* 2013).

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Coffee and shan tea were among the species that farmers preferred to gradually replace maize when soils degraded. Both generate returns after the third year if they are planted as seedlings. However, Hoang Thi Lua *et al.* (2013) did not give estimates of the economic returns for most of the different agroforestry species recommended in the table above in comparison to other crops.

The authors conclude that the most profitable current framing systems are shan tea intercropped with cassava at high elevations in Suoi Giang Commune, Van Chan District (VND 20 million/ha/year), coffee in intermediate elevations in Chieng Bom Commune, and (VND 15 million/ha/year), and tomato (VND 27 million ha/year) at low elevations[8]. In their attempt to identify the most profitable amongst current farming systems, the authors simply rank all individual farming systems found in each commune based on their profits without any statistical/econometric analysis. This report therefore provides suggestive evidence only, as it potentially confounds the impacts of other variables (e.g. particular village or household characteristics) with those of the farming systems analyzed.

[8] The Department of Science and Technology (DOST) and the Department of Agriculture and Rural Development (DARD) in Yen Bai are implementing a conservation and sustainable development plan in 2012 - 2015 for shan tea, including the development and registration of a trademark for Yen Bai - Suoi Giang Shan Tuyet Tea (MCG, 2014).

**Table 1.** Agroforestry species with income generation potential by elevation

| Elevation | Species | Reasons |
| --- | --- | --- |
| **<600 masl** | Hybrid eucalyptus, Acacia auriculiformis | In Son La and Dien Bien, these species are in demand for house construction because natural wood resources have been overexploited |
| | Late-fruiting longan | This variety gives high fruit quality and late harvesting season |
| | Orange | Traditionally grown in Yen Bai with relative good market price |
| **600—800 masl** | Coffee | Can give high economic returns but requires high investment for establishment and annual inputs. Many farmers have been successful with coffee plantations |
| | Macadamia | High potential for income generation if able to enter international market |
| | Canarium nigrum | Multipurpose native species gives high value nuts and timber |
| | Eucalyptus | In demand for local use (house construction) |
| **>800 masl** | Son tra | Native tree species, provides fruit for cash and home consumption, shade, soil protection and timber. It can be intercropped with timber species or crops. Good market opportunities |
| | Shan tea | Considered a good investment owing to long life (100+ years), high yield and good quality of tea (well-developed market locally and for export in Yen Bai) |
| | French peach | Can be grown at high elevations on sloping land |
| | Walnut | Grows well at high elevations (Co Ma), gives high yield, good market Opportunities |
| | Cunminghamia lanceolata Lamb ('sa moc') | Provides timber for house construction, can grow well at high elevation |
| | Amomum Cardamom | Planted under forest canopy, good market opportunities |

*Source: The table is taken directly from Lua et al. (2013).*

## (b) Mitigation effects of agroforestry

When it comes to the mitigation effects of different agroforestry practices, site-specific literature is even more scarce. Nguyen Viet Xuan *et al.* (2011) use Rapid Carbon Stock Appraisal to compare the carbon stock of 4 different agroforestry systems in the buffer zone of Ba Be National Park in Vietnam[9]. They also analyze the land use change in their short paper. Results are shown in Table 2 below.

**Table 2.** Carbon stocks and land use change related to agroforestry systems in Ba Be National Park, Vietnam

| Different systems | Secondary forest | Home garden | Fruit garden | Shifting agriculture |
|---|---|---|---|---|
| **Total carbon stock (Mg C ha$^{-1}$)** | 97.52 | 69.63 | 46.80 | 28.09 |
| **Below ground carbon as a percentage of total carbon stock (%)** | 51.20 | 69.90 | 69.99 | 84.50 |
| **Time-averaged carbon stock (Mg ha$^{-1}$)** | 47.55 | 21.59 | 14.10 | 4.35 |
| **Land use increase as a percentage from 1995 to 2008** | -14.73% | 274% | 19.14% | 263% |

*Source: Nguyen Viet Xuan et al. (2011)*

The authors estimate that if land use change is to continue at the rate observed from 1995 to 2008, carbon losses would reach 40,000 Mg C by 2020. The paper provides some evidence of the carbon sequestration benefits of agroforestry, but does not relate the climate benefits with economic returns, which is the priority for smallholders. Therefore, it cannot be used to assess the synergies or tradeoffs between income generation and climate mitigation in agroforestry. It is also arguable that the soil sampling was not deep enough to fully reflect the carbon sequestration effect of agroforestry. The mitigation capacity of agroforestry depends on the specific agro-ecological conditions and management practices (Nair *et al.* 2009a). The methodological difficulties in estimating and monitoring carbon sequestration of agroforestry and uncertainty of receiving income for environmental services make the comparison between agroforestry and other systems especially challenging (Nair *et al.* 2009b).

[9] In this appraisal, diameter at breast height (DBH) and height of trees with DBH bigger than 5 cm were measured to estimated aboveground carbon stock. Soil samples were collected at three depths (0-5cm, 5-10cm and 10-20cm) in the four agroforestry systems respectively: home garden, fruit garden, shifting agriculture, and secondary forest.

### (c) Determinants of agroforestry adoption

While agroforestry has long been recognized as a sustainable land-use model, its adoption is still very limited according to a farming system diagnosis survey based on focus group discussions in 14 villages and in-depth interviews of 45 farmers in Northwestern Vietnam (Hoang Thi Lua *et al.* 2012). Hoang Thi Lua *et al.* (2013), in a later report, find that the top three factors affecting the decision of which agricultural system and which crops to apply were output markets, land availability, and capital resources (listed by the frequency of being mentioned by the 45 farmer participants in the NMR). Among them, markets were considered especially important. In fact, very few households in the interviewed sample received any additional income from their forestland either by intercropping with food crops or non-timber forest plants, from payment for environmental services, or from selling the firewood. Potential reasons could include either that the scale of household farmland was too small to generate additional income after self-consumption, or that these type of market opportunities remained inaccessible to the households.

Land size and property rights are another major concern of the farmers. 82% of the farmer participants have less than 4 ha of land (Hoang Thi Lua *et al.* 2013). Smallholders also tend to have fragmented land, which prevents them from taking advantage of economies of scale (Pham Van Hung *et al.* 2007). High transaction costs in the land market and strong administrative intervention constrain land market transactions, which may hinder the efficiency of the whole agricultural sector (Wells-Dang 2013).

There has not been much empirical research on the costs (both implementing and opportunity costs) of adopting agroforestry in NMR of Vietnam, although capital constraints have been identified as a potential barrier (Nguyen Quang Tin *et al.*, 2014). Trees used in agroforestry systems often have a long growing cycle, which may be a challenge for the low-budget households to switch to because they rely on agricultural production for continuous income (Nguyen *et al.* 2007). Other potential constraints include lack of market information, underdeveloped extension network and its lack of expertise in agroforestry, and poor infrastructure (Doanh and Tiem 2001; Hoang Thi Lua *et al.* 2013).

## ii. Sustainable Land Management

Sustainable Land Management (SLM) refers to an integrated and sustainable approach to managing land resources—soil, water, and biological resources—to meet changing human needs while maintaining their long term productive potential (UN, 1992). Examples of SLM include use of cover crops, vegetative barriers, extensive crop rotations, minimum tillage, and straw mulch.

Practices such as vegetative barriers and cover crops with food or fodder species, and minimum tillage, are especially relevant in uplands of Northern Vietnam as they can potentially combine short- term economic interests with the long-term environmental benefits by reducing soil erosion and degradation (Wezel *et al.* 2002b). For example, farmers in the mountainous area of Son La Province normally grow cassava, sometimes intercropped with maize, in a two-year period. During the first year, maize provides some soil cover when the canopy cover of cassava is still low. Starting from the second year, cassava can serve as a vegetative barrier with nearly closed canopy while maize can grow in a more benign environment as a food crop. This practice is favoured compared to wild indigo (Tephrosia) hedgerows because it provides direct benefit of food while wild indigo can only be used as mulch (Wezel *et al.* 2002b).

A combination of SLM practices developed for the sloping lands of NMR include soil cover, minimum tillage, direct sowing, mini terraces, live fences, biological weed control and fodder crops is called conservation agriculture (not to be confused with the common definition of conservation agriculture that consists of the first two practices as well as crop rotation; FAO 2012b) or direct-seeding mulch-based cropping system (DMC) during early 2000s (Le Quoc Doanh and Ha Dinh Toan, 2008). DMC was shown to decrease soil erosion and increase incomes of project participants providing suggestive evidence only.

Assessing the CSA potential of SLM practices requires site-specific evidence on food security, adaptation and mitigation benefits, as well as the local institutional structures affecting adoption. Although most of these practices have the potential to contribute to one or more of these objectives as mentioned above, site specific literature assessing all three is very scarce/non-existent. We review studies published in English that assess various benefits of relevant SLM practices for the NMR of Vietnam.

### (a) Economic returns and climate resilience impacts of SLM

One of the major efforts to improve the climate resilience of agriculture in NMR is soil protection, given that climate change is likely to give rise to increased rainfall intensity and further degrade the sloping lands in the region (FAO 2011). A number of soil protection technologies are tested such as residue retention, mini-terraces, grass barriers, cover crops and mulching.

Kirchhof *et al.* (2012) found in NMR that erosion of the maize fields occurred mainly during the early phase of the growing season when the soil is unprotected. Their field experiment revealed that residue retention significantly decreased soil erosion compared to slash and burn. Interestingly, no significant difference in soil-erosion was observed in Na Ot Commune among 3 different treatment groups: minimum tillage with retained residues, retained residues with mini-terraces, and conventional with retained residues. The study implies that the residue retention is the deciding factor of soil protection, and the effects of mini-terraces and intensity of cultivation are rather negligible in the presence of residue retention.

Tuan Vu Dinh *et al.* (2012) found similar soil protection effects of grass barriers, cover crops, and relay cropping in two catchments in Son La Province. After comparing the control group —maize grown in the conventional way—and three treatment groups—maize with guinea grass (*Panicum maximum*) grass barriers, maize under minimum tillage with pinto peanut (*Arachis pintoi*) as a cover crop, and maize relay-cropped with the common bean (*Phaseolus calcaratus*)), they found that all three conservation measures in the treatment groups can significantly reduce soil loss from the second year onwards, but both established grass barriers— guinea grass —and cover crops— pinto peanut—decreased maize yield. Relay-cropping of the common bean did not show similar negative effects on maize yield and thus seemed like a promising option. However, it is unclear from this study how the net economic returns (taking into account costs) rank among the practices studied in the experiment.

Thai Phien and Tran Thi Tam (2007) also confirmed the grass barriers' effect on reducing soil erosion. They looked into the effectiveness of vetiver grass (*Vetiveria zizanioides*), a species that has been widely used in contour planting in Thailand and much researched in Vietnam since the 90s by the National Institute for Soils and Fertilizers. Their research results show that vetiver grass significantly decreased soil erosion by 50-90% in three different agricultural systems —cassava intercropped with peanuts, monoculture of cassava, and monoculture of peanut— at different sites[10]. While most field experiments also generate positive evidence of vetiver grass improving yields and net economic returns of cassava-peanut intercropping system, especially if fertilizers are used, it is worth noting that at the Dong Rang Site, Luong Son, Hoa Binh Province, the use of hedgerow coupled with fertilizers actually decreased yields and economic returns of this system, compared with the same crops under fertilizer application only. The authors also found that vetiver grass is more effective as a hedgerow in decreasing soil erosion than other species including wild indigo, pineapple (*Ananas comosus*), and a leguminous dye plant with the common name of *Cải đuôi chồn* or *Đậu công* in Vietnamese (*Flemingia congesta*). The intercropping of cassava and peanut with fertilizers and vetiver grass hedgerows generated the most favorable net income at about 10 million VND/ha at Phuong Linh, Thanh Ba, Phu Tho Province. Despite the promising implications of the study, it can only provide suggestive evidence as the authors simply used the farmer participants' average yield, economic returns, and soil loss to figure out which practice was the most recommendable without a multivariate analysis.

Field trials conducted by Affholder *et al.* (2010) gathered empirical evidence for the returns and barriers to adoption for DMC systems on mountainous slopes of Vietnam. According to their research, DMC in Ngoc Phai, located in the Northeastern Vietnam, did not significantly increase maize yields or economic returns to land, but instead, decreased labour productivity by about 30% due to large labour costs in collecting biomass and applying it to the field to build a straw mulch layer. On the other hand, DMC in Na Son, located in the Northwestern Vietnam, increased grain yields by 45% for maize and 18-31% for rainfed rice (depending on the duration of application). The practice also increased economic returns to land and labour productivity in Na Son, underlying the importance of site-specific research.

[10] For cassava-peanut intercropping system, long-term farmer-participation trials were conducted in ferralsols on clay shales at Phuong Linh, Thanh Ba, Phu Tho Province (average data of 43 farmer participants from 1995-1998); on sandy soil at Pho Yen, Thai Nguyen Province (average data of 35 participants in 1996); at Dong Rang, Luong Son, Hoa Binh Province (average data of 45 participants form 1995-1998). For monoculture of peanut, trials were conducted in ferralsols on clay shales at the Thai Ninh, Thanh Ba, Phu Tho Province (average data for year 1996 and 1997 respectively, number of participants unclear). For monoculture of cassava, trials were conducted on clay shale at Dong Rang, Luong Son, Hoa Binh Province (number of participants and years unclear)

### (b) Mitigation effects of SLM in NMR of Vietnam

As is the case for agroforestry, evidence on the mitigation effects of SLM practices in NMR is extremely scarce. The abundant literature on the sequestration effects of SLM in other parts of the world, however, can provide some insights on the likelihood and magnitude of such mitigation effects (Scopel *et al.* 2013; Smith and Cai 2007; West and Post 2002; Lal and Bruce, 1999; Niles *et al.*, 2002). These studies sometimes show contradictory results, depending on the specific agro-ecological conditions of the location and how a specific CA practice is implemented. A meta-analysis of global literature on the topic shows the small scale of sequestration impacts of SLM practices ranging from 0.6 – 1.4 tC/ha/year (Branca *et al.*, 2011).

The only paper that indirectly addresses the specific mitigation impacts in northern Vietnam is by Ramakrishna *et al.* (2006), who studied the effect of various mulching materials (polythene, rice straw and chemical) on weed infestation, soil temperature, soil moisture and groundnut yields. They show that mulch effectively suppresses weed infestation, increases soil temperature and prevent soil water evaporation retaining soil moisture. Using rice mulch also decreases $CO_2$ emissions from rice burning (the common practice in the region), providing suggestive evidence of mitigation benefits, however, the authors did not measure the mitigation potential directly.

### (c) Determinants of adoption of SLM in NMR of Vietnam

While many sustainable land management practices have been available for a long time in Vietnam, their take-up rate remains low, due to the incompatibility of these techniques with the socio-economic characteristics of smallholder farmers in NMR (Pham Thi Sen *et al.* 2012). In the NMR, the poverty rate is still high and farmers are not interested in growing a cover crop without an immediate economic value. Mulch is usually in short supply, as free grazing in the autumn and winter clears much of the naturally accumulated biomass. The combination of free grazing and farmers' reluctance to grow cover crops constrain the adoption of mulching in the region. Zero tillage and mini-terraces, on the other hand, are constrained by a lack of labor and direct sowing tools in the NMR, which explains why farmers prefer minimum tillage either by cultivating with buffalo or manually by hand hoes (Nguyen Quang Tin *et al.*, 2014; Pham Thi Sen *et al.* 2012). Anecdotal evidence also suggests that intercropping with legumes (both of maize and cassava) on sloping lands is constrained by lack of knowledge and necessary seeds and markets for legumes (Nguyen Quang Tin *et al.*, 2014).

Based on a farm model designed to simulate the agricultural behavior of households, Affholder *et al.* (2010) argued that the low adoption rate of DMC could be attributed to high labor and capital costs. Affholder *et al.* (2010) calibrated their farm model with data from agronomic on-farm trials and surveys[11] in the mountainous regions of Vietnam, and found that, for most farm types, even those well-connected to an output market, labor costs needed to be reduced by at least 30% before DMC could be considered profitable by farmers. Accomplishing this would decrease mulch establishment by more than 30%, compromising the weed-control function of mulch. Consequently, substantial subsidies, estimated by the authors to be between 50 to more than 200 USD $ha^{-1}$, would be needed for farmers to purchase herbicides for weed-control purposes. Such input subsidies, however, are often problematic due to overutilization of agricultural inputs like fertilizers and pesticides and thus causing soil and water degradation problems (Mishra 2010; Grossman and Carlson 2011), inequality as the less wealthy and less well-connected are usually left out (Shively and Gilbert 2013), and market distortions for the private input sector (Shively and Gilbert 2013; Grossman and Carlson 2011). Nonetheless, if farmers were to purchase herbicides with subsidies, as the authors suggest, the question still remains whether the net benefit for the environment would be positive when increased herbicide use is taken into account in addition to decreased soil erosion.

Other barriers to adoption are also identified by Affholder *et al.* (2010), such as the lack of markets for by-products of SLM practices, cultural reluctance of forsaking full tillage, which may be especially relevant in the NMR where the ethnic minorities have entrenched traditions of tillage (Tran Duc Vien 2003), and risk of decreasing yield when switching to new agricultural practices, especially during the learning period. Most of these statements, however, are based on anecdotal evidence, which underlines the importance of site-specific studies of farmers' choices of agricultural practices to support evidence-based and targeted policy-making in the region.

[11] Their study were conducted at two sites with contrasting biophysical and economic environment, one in Northeastern Vietnam, and another in Northwestern Vietnam, including 142 farm households. The farm model was applied to 3 farms in Ngoc Phai and Na Son each.

## 4. Discussion and Conclusion

Smallholder farmers in Vietnam's NMR, as is common all around the world, prioritize short-term economic and food security interests over long term gains (Doanh and Tiem 2001; Dao Kim Nguyen Thuy Binh *et al.* 2008). Agricultural practices that require large quantities of inputs, large upfront costs, or place the main subsistence or commercial crop in an unfavorable competition, are unlikely to be adopted, regardless of any potential mitigation or other environmental benefits (Hilger *et al.* 2013, Section 7.7). Therefore, detailed site-specific studies on the benefits, costs, and adoption barriers of agricultural practices that can be considered climate smart are needed to develop a feasible CSA strategy.

Despite their potential long-term environmental and economic benefits and their intensive promotion, neither agroforestry nor SLM is widely adopted in the NMR, suggesting that famers do not perceive them as attractive alternatives to conventional farming in the immediate short-run. The high opportunity costs in the short run, and constraints on markets, labor, capital, and land seem to contribute to the low adoption rates of these practices. The scarcity of empirical literature discussed at length in this paper, however, makes this argument a tentative one subject to verification with more site-specific data.

None of the papers reviewed here encompass representative large-scale data collection[12] or robust econometric analysis to assess the food security, adaptation, and mitigation benefits of potential climate-smart agricultural practices. Nor does the literature explicitly incorporate risk factors into calculating the costs and benefits of different practices. It also largely omits farmers' perceptions of climate variability and its relation to their decisions on agricultural practices as a factor in explaining barriers to adoption. Most farmers, although they are conscious of climate change, cannot prioritize adaptation investments as information on full benefits of CSA is rare and there are binding constraints on credit, labor and input markets, among others. Local extension officers thus need to emphasize the importance of climate adaptation and provide accessible information of suitable technologies (Hoa Le Dang *et al.* 2013). To address these issues above, site-specific studies are needed that carry out careful sampling and data collection to conduct econometric analyses that can identify the costs, benefits and barriers to the adoption of potential CSA practices under different climatic, agro-ecological and institutional conditions. Another important component required for robust assessments of the CSA potential is the incorporation of risk and uncertainty of different livelihood strategies to provide a comprehensive understanding of food security under climate change.

[12] With perhaps the exception of Hoang Thi Lua *et al.* (2013) who collected data from 45 "farmer co-operators" from three agro-ecozones (elevation ranges) and 4 ethnic groups in 17 villages in Yen Bai, Son La, and Dien Bien provinces. They state that "there was no previous systematic study at this scale" to their knowledge.

A robust CSA strategy cannot consist of an individual practice to address the food security and climate change challenges in both the short and long run, therefore, a portfolio of mutually supportive approaches including safety nets and other improvements in enabling institutions should be explored. Some scholars argue that the agricultural activities need to be diversified and evaluated in a comprehensive system, one that incorporates climate smart practices on the farm level, diversity of land use across landscapes, and proper management of the interactions among different landscapes (Scherr *et al.* 2012). The logic is that each individual practice can only be best utilized in a system to capture the synergies. Integration of livestock with crops is encouraged by some scholars (Section 7.7, Hilger *et al.* 2013; Keil *et al.* 2011), as it allows the smallholder farmers not only to benefit from the increasing urban demand for high-quality animal products but also to exploit the complementarities in the context of climate change.

Considering the often delayed start of the positive income stream from agroforestry and SLM practices, and the potential positive externalities they bring to soil protection and carbon sequestration, financing options such as payments for environmental services (PES) have the potential to support adoption (Wilkes *et al.* 2013). Given the complex nature of PES and the lack of local capacity to manage them, clear implementation guidelines and capacity building programs are essential (Simelton *et al.* 2013).

The key to a successful CSA strategy is combining short-term economic incentives to support transformation of agricultural systems with long-term sustainable agricultural development needs. The poor in the NMR mostly depend on maize or rice production and often face disadvantageous positions in market transactions (Keil *et al.* 2011). Diversification of agricultural activities as well as income sources are an integral part of CSA, and thus improving value chains is an important issue (e.g. for tea and coffee in the NMR). It is also critical to undertake institutional reforms to address the constraints on land, capital, insurance and information in order to ensure a complete CSA approach to agricultural development that can achieve national food security goals under climate change.

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## Appendix

**Table 1**
**Fixed effects regression coefficients of various climate variables on time trend in the NMR**

| | Year | Cons. | Observations |
|---|---|---|---|
| **AvgTemp_Maize Growing Season** | 0.03*** | -36.83*** | 53,658 |
| **AvgTemp_Annual** | 0.03*** | -31.77*** | 53,658 |
| **Rainfall_Annual** | -8.36*** | 18,586.80*** | 53,658 |
| **CoV_Rainfall** | 0.004*** | -7.55*** | 53,658 |
| **Seasonality Index_Rainfall** | 0.005*** | -10.11*** | 53,658 |
| **Index of Ideal Temperature** | 0.091*** | -78.82*** | 53,658 |

* $p<0.05$, ** $p<0.01$, *** $p<0.001$

**Table 2**
**Ideal rainfall and temperature for maize growing season**

| | **Very optimal** | **Optimal** | **Average Optimal** | **Less Optimal** | **Not Optimal** |
|---|---|---|---|---|---|
| Temperature at growing stage ($^0$C) | 25-22 | 22-18<br>25-30 | 18-16<br>30-35 | 16-14<br>35-40 | <14<br>>40 |
| Rainfall in the 1st month (mm) | 75-200 | 200-275<br>75-50 | 275-400 | 400-475 | >475 |
| Rainfall in the 2nd month (mm) | 125-200 | 200-275<br>125-100 | 275-400<br>100-70 | 400-475<br>70-50 | >475<br><50 |
| Rainfall in 3rd month (mm) | 125-200 | 200-275<br>125-100 | 275-400<br>100-70 | 400-475<br>70-50 | >475<br><50 |
| Rainfall in 4th month (mm) | 75-200 | 200-275<br>75-50 | 275-400<br>50-30 | 400-475<br><30 | >475 |

Source: Thanh *et al.* (2013)

**Economics and Policy Innovations for Climate-Smart Agriculture (EPIC)**
EPIC is a programme hosted by the Agricultural Development Economics Division (ESA) of the Food and Agriculture Organization of the United Nations (FAO). It supports countries in their transition to Climate-Smart Agriculture through sound socio-economic research and policy analysis on the interactions between agriculture, climate change and food security.

This paper has not been peer reviewed and has been produced to stimulate exchange of ideas and critical debate. It synthetizes EPIC's ongoing research on the synergies and tradeoffs among adaptation, mitigation and food security and the initial findings on the impacts, effects, costs and benefits as well as incentives and barriers to the adoption of climate-smart agricultural practices.

For further information or feedback, please visit:
**www.fao.org/climatechange/epic**

I3983E/1/10.14

Food and Agriculture Organization of the United Nations
Agricultural Development Economics Division
Viale delle Terme di Caracalla
00153 Rome, Italy
www.fao.org/climatechange/epic
epic@fao.org

*This publication has been produced with the assistance of the European Union*