Working Paper

Case study: Huong Khe district, Ha Tinh province, Viet Nam

Characterising agro-ecological zones with local knowledge

Uyen To Thi Doan, Elisabeth Simelton, An The Ngo,
Lien Thi Kim Tran, Bang Nguyen Tran

World Agroforestry Centre

Case study: Huong Khe district, Ha Tinh province, Viet Nam

Characterising agro-ecological zones with local knowledge

Uyen To Thi Doan, Elisabeth Simelton, An The Ngo,
Lien Thi Kim Tran, Bang Nguyen Tran

Working paper 201

LIMITED CIRCULATION

Correct citation:
Doan UTT, Simelton E, Ngo AT, Tran LTK, Tran BN. 2015. *Case study: Huong Khe district, Ha Tinh province, Viet Nam. Characterising agro-ecological zones with local knowledge*. Working Paper 201. Hanoi, Viet Nam. World Agroforestry Centre (ICRAF) - Vietnam. DOI: 10.5716/ WP15050.PDF

Titles in the Working Paper Series aim to disseminate interim results on agroforestry research and practices and stimulate feedback from the scientific community. Other publication series from the World Agroforestry Centre include: Agroforestry Perspectives, Technical Manuals and Occasional Papers.

Published by the World Agroforestry Centre (ICRAF)

Viet Nam Country Office
No. 17A, Nguyen Khang Street
Trung Hoa Ward, Cau Giay District
Hanoi, Viet Nam
Tel: +84 4 3783 4645
Fax: +84 4 3783 4644
Email: icraf-vietnam@cgiar.org
Website: http://www.worldagroforestry.org/regions/southeast_asia/vietnam

Southeast Asia Regional Program
PO Box 161, Bogor 16001
Jawa Barat
Indonesia
Tel: +62 251 8625415
Fax: +62 251 8625416
Email: icraf-indonesia@cgiar.org
Website: http://worldagroforestry.org/regions/southeast_asia

About the authors

Uyen TT Doan is a graduate student at Vietnam National University of Agriculture in Hanoi. Her research interests cover the GIS and Remote Sensing applications for land use/cover change analysis, biodiversity mapping and climate change impact assessment. She graduated with a BA in Environmental Science from Vietnam National University of Agriculture in Hanoi.

Elisabeth Simelton, is a climate change scientist at World Agroforestry Centre, based in Hanoi, Viet Nam, since 2010. She has over 15 years of experience in rural development and climate research in Asia and Africa. She is the Centre's focal point in Viet Nam for climate-adaptation research. Her research interests cover global environmental change, multifunctional land use and food security as well as participatory methodologies. She holds a PhD in Geography from Göteborg University, Sweden.

An T Ngo is a lecturer in Environment Science at Vietnam National University of Agriculture in Hanoi since 1996 and the head of the Department for Environmental Science since 2011. He has over 19 years of experience in Agroecology, Geographic Information System (GIS), remote sensing application for resources and environmental management and modeling in northern Vietnam. His research interests cover agroecology, GIS and Remote Sensing applications for land use/cover change analysis, climate change impact assessment, carbon stock monitoring, biodiversity mapping, and modeling application for environmental management in the upland and lowland of Vietnam. He holds a PhD in Modeling from University of Leeds, UK.

Lien TK Tran, was a field officer at the Centre based in Ha Tinh province in 2014, working for the project "Climate-smart, tree-based, co-investment in adaptation and mitigation in Asia". She has over 12 years of experience in forestry and rural development in north and central Vietnam. Her research interests include conservation, community forestry management and gender-based livelihood interventions. She holds an MSc in Forest Science and Management from Southern Cross University, Australia.

Bang N Tran, is a lecturer in Environmental Sciences at the Vietnam National University of Agriculture (VNUA) in Hanoi since 2012. He was a research fellow at the Centre for Agricultural Research and Ecological Studies (CARES) at VNUA between 2003 and 2011. He has over 10 years' experience in Geographic Information Systems (GIS) and remote sensing applications for natural resources and environmental management in northern Vietnam. He specialises in advanced GIS and Remote sensing applications for land use/land cover analyses, climate change impact assessments, carbon stock monitoring, biodiversity mapping and animal health control. He holds an MSc in Applied Sciences of Geographic Information Systems from the University of Melbourne, Australia.

Abstract

Local knowledge and active participation in research is increasingly encouraged, not the least for identifying sustainable adaptation options. However, despite that participatory mapping has advanced from sketches to informing digitalised maps since the 1990s this type of local knowledge is rarely included in agroecological zones (AEZ) mapping. For a new project on climate-smart agriculture and forestry local knowledge was incorporated to characterise agroecological zones in Huong Lien commune, Ha Tinh province, northcentral Viet Nam. The purpose was to determine adaptation options associated with particular agroecological zones. A GIS spatial database with land use, topography, NDVI was generated to derive an agroecological zones map and ground-truthed with the participation of local villagers through transect walks and SWOT analyses by land use type.

The study shows that local participation is vital for ground-truthing maps, to fill in gaps when time series data is available and for marking out natural hazard areas. In this particular case, local perceptions of strengths and potential adaptation options associated with particular agroecozones was useful for revealing adaptation gaps. The classification rules for the AEZ need careful consideration, especially when the mapped areas are small, to make the maps useful beyond the study area. This may require more careful transect walks to identify nuances in forest quality for determining forest management. Methodology for inclusive local knowledge needs to be further developed.

Keywords: Local knowledge, participatory mapping, agroecological zones

Acknowledgements

The research was partly funded by project Climate-Smart, Tree-Based, Co-Investment in Adaptation and Mitigation Asia (Smart Tree-Invest project) funded by IFAD and CGIAR Research Program on Forests, Trees and Agroforestry. The study builds on Doan Thi To Uyen's fieldwork for a Bachelor's degree in collaboration between Hanoi University of Agriculture and World Agroforestry Centre (ICRAF Viet Nam). The authors appreciate valuable inputs from Nguyen Mai Phuong and Dam Viet Bac. The authors are grateful for the support from Huong Lien commune, in particular Pham Thi Tham, Nguyen Van Ngoc, Duong Danh Xuan and farmers who participated in interviews and transect walks.

Contents

Acronyms

AEZ	Agroecological zones
DEM	Digital Elevation Model
GIS	Geographical Information Systems
GPS	Global Positioning System
FAO	United Nations Food and Agriculture Organization
IMHEN	Viet Nam Institute of Meteorology, Hydrology and Environment
MODIS	Moderate Resolution Imaging Spectroradiometer
MONRE	Viet Nam Ministry of Natural Resources and Environment
NDVI	Normalised Difference Vegetation Index
NIR	Near-infrared
TIN	Triangulated Irregular Network
SPOT HRV	Satellite Pour l'Observation de la Terre, High Resolution Visible
SWOT	Strength, Weakness, Opportunities, Threat
VIR	Visible Red
VND	Viet Nam Dong (1USD is worth ~VND21.000, October 2014)

Introduction

Globally, about one billion hectares of land have at least 10% tree cover (Nair and Garrity 2012), contributing to multiple co-benefits of food security, climate change adaptation and mitigation (FAO 2013). Such so-called climate-smart landscapes hosts a diverse range of species that maintain ecosystem services, e.g. providing habitats for biodiversity, maintaining connections between fragmented forest plots and supporting healthy watersheds by buffering for rainfall variations (Van Noordwijk et al. 2011). Monitoring such synergies are priorities for planning more resilient landscapes.

The value of participation and co-production of spatial information

Local ecological knowledge is co-production of knowledge between e.g. farmers, extension (Newsham and Thomas 2011). Co-learning approaches can prevent that different perceptions of a problem result in maladaptation (Simelton et al. 2013b). In addition, studies show that community carbon monitoring can be as reliable as expert monitoring (Larrazabal et al. 2012).

The value of local knowledge in participatory mapping activities has been recognised both as a way for developing local capacity, notably for generating a sense of co-ownership and compliance in community development and natural resource management (McCall and Minang 2005). For example, particpatory sketches range from stand-alone maps to potentially integrated with conventional GIS-maps for comparing perceptions (Vajjhala and Walker 2009). Participatory GIS developed as concept and tool to contrast the idea of one objective technical solution. It recognises the co-production of spatial information with multiple, sometimes blur boundaries (Dunn 2007, Tolo et al. 2012).

Agro-Ecological-Zoning (AEZ) mapping

Agro-ecological zoning (AEZ) was developed in the 1970s by FAO as an approach for rural land-use planning to design specific recommendations for land units (zones) depending on their potentials and constraints, to either increase production or limit land degradation. The zoning was based on soil, landform and climatic characteristics and combined with a land use inventory. (FAO 1996). Since then spatial and temporal resolutions of data, including satellite imagery, have developed and enabled diversified usages. Over large areas remote sensing imagery can easily be combined with socioeconomic map layers to identify benchmark sites for research projects (Thenkabail et al. 2000), assess and update environmental status for crop failure early warning or climatic vulnerability hotspots (Brown 2009, Sietz et al. 2011). At landscape or catchment scales this type of mapping easily lends itself to scenario modelling assessments with adaptation options (Pansak et al. 2010). Layered geographical information is seen as transparent and user-friendly for local planning and natural resource management purposes. Furthermore, the speed, ease and perceived certainly that remote sensing offers makes it popular for rapid assessments of land use changes and carbon storage and land use changes. However, a major limitation in AEZ is that biophysical information tend to dominate mapping while socioeconomic interactions and landscape dynamics are often lost in conventional datasets. One reason for this is that ground-truthing is often done by "external experts" without the participation of people who inhabit and use the areas, hence not taking full advantage of local knowledge. (Villamor et al. 2010). According to Esri ground-truthing is the "accuracy of remotely sensed or mathematically calculated data based on data actually measured in the field"[1]. Ground-truthing is typically research-led, excluding or not specifying local participation (e.g. Tolo et al. 2012). Engaging local knowledge for constructing or ground-truthing maps is associated with fuzzy and unstructured boundaries, therefore (wrongly) perceived as more time consuming and costly (Vajjhala and Walker 2009). Studies show that community participation can easily be integrated with conventional ground-truthing of satellite images for land use change analyses, adding contextual narratives between the sequences of maps (Lindström et al. 2012). Here, we refer to this as as "participatory ground-truthing".

The original purpose of this study was to derive adaptation options for each agroecological zone for a district in Viet Nam. However, to our surprise the scientific literature returned few methodologies or examples of where (i) local socioecological knowledge is incorporated in either agroecological zoning or ground-truthing, and (ii) where AEZ is linked to climate change impacts and adaptation (Table 1). Sutton et al. (2013) linked climate change impacts and national adaptation menues to AEZ in four countries. For benchmark site selection Thenkabail et al. (2000) used SPOT HRV and FAO soil maps with transects of biophysical samples for ground-truthing but did not link to climate change impacts. Tian et al. (2013) coupled a crop model and an AEZ-model to study climate change impacts. Here, using rice cultivar parameters to close the gap between simulated and (census) yield data confirms the validation, rather than participatory ground-truthing. For Binh Dinh province in Viet Nam, Nguyen et al. (2013a) used MODIS satellite image and land use maps to study climate impacts on rice production for different AEZ, providing no details of the ground-truthing method. Tran et al. (2013) used SPOT satellite imagery to identify management plans for planted forest in Phong Nha-Ke Bang National Park, using ground-truthing based on GPS points and Kappa index, but did not link to climate change adaptation. Nguyen et al. (2013b) used a random stratified method with two transect walks from north to south and west to east to validate the satellite imagery interpretations. Here, local knowledge was built-in through, semi-structured interviews with farmers on land use and cover types, temporal changes and meteorological impacts to identify adaptation strategies for different agroecological zones.

[1] Esri Online GIS Dictionary http://support.esri.com/en/knowledgebase/GISDictionary/term/ground%20truth Accessed on October 4, 2014.

Table 1. Agro-ecological zoning studies according to ground-truthing approach and links to climate change adaptation

Types of AEZ (area, location)	Data source	Ground-truthing method	AEZ links to CC-impacts/ adaptation	Reference
Central & West Africa, Benchmark site selection	SPOT FAO soil map	yes (Biophysical samples)	no	Thenkabail et al. (2000)
National	SPOT and Landsat	yes	no	Biodiversity Conservation Agency (BCA) et al. (2013)
Phong Nha – Ke Bang National Park, Vietnam Planted forest	SPOT	yes (transect)	no	Tran et al. (2013)
Binh Dinh, Vietnam Rice crop	MODIS Land use map	nd	yes	Nguyen et al. (2013a)
NE China	Rice production data DDSAT crop model	no (yield data)	yes	Tian et al. (2013)
Quang Ninh, Vietnam	Satellite imagery	yes (transect)	yes	Nguyen et al. (2013b)

Research questions

The Climate-smart, Tree-based, Co-investment in Adaptation and Mitigation in Asia programme, SmartTree Invest started in 2014[2]. The programme works with smallholder farmers, in selected vulnerable areas in Indonesia, the Philippines and Viet Nam to help create local solutions to cope with climate-change risks in collaboration with governments, development agencies and the private sector. As one objective the programme focuses on obtaining gender-sensitive, scientific assessments of vulnerability[3], adaptation and mitigation with the help of local people's ecological knowledge.

This working paper contains the first preliminary results to derive a suitable baseline methodology for (i) characterising agroecological zones with participatory ground-truthing, (ii) combining local knowledge and map information for identifying adaptation options. The report builds on the Bachelor thesis by Doan (2014).

[2] Background to the project is available at https://webapps.ifad.org/members/eb/109/docs/EB-2013-109-R-22.pdf and http://blog.worldagroforestry.org/index.php/2014/06/16/co-investing-in-landscapes-with-smart-tree-invest/

[3] Vulnerability is the extent of exposure to risks and the level of ability to survive their impact. It is scale-dependent, both across time and space: risks, shocks, changes and the ability to cope vary between physical spaces and within social groups.

Data & Methods

Study site

In Viet Nam the SmartTree Invest project is implemented in Ha Tinh and Quang Binh provinces. This study is carried out in Ha Tinh for piloting the method. Located on Viet Nam's northcentral coast, Ha Tinh province covers 600,000 hectares (out of which 20% agriculture land and 58% forestry land) and holds a population of 1.2 million (84% rural), according to statistics data for 2012 from Viet Nam General Statistics Office (2014). Agriculture, forestry and aquaculture expected to contribute to 18% of the province GDP in 2015. The economic growth of the primary sector is considerably slower than the secondary and tertiary sectors, and exposed to extreme weather events and impacts of climate change (People's Committee Ha Tinh province, 2014).

The average annual temperature is 24.5°C while minimum temperature can dip to 3-7°C leading to cold snaps and maximum temperatures reaching over 40°C (Figure 1). The annual total rainfall varies between 1500 and 2000 mm with the majority falling between August and November and spring droughts are common in association with the dry Lao (foehn) winds. The province is on average hit by one severe storm per year. The peak storm period August and September is associated with heavy rainfall, flooding and flash floods. (Simelton et al. submitted-a). In 2006, the province's agriculture and forestry production was valued at 6.4 billion VND, equivalent to an annual 16% increase of GDP between 2001 and 2006. Further preparedness and planning are needed for mitigating risks related to sea level rise, salt water intrusion, increasing storm frequency and magnitude, as well as dry spells (ISPONRE 2009).

Table 2. General socioeconomic information for the study sites in Huong Khe district, Ha Tinh province (May 2014)

	Huong Lien commune	Village 1	Village 4
Total area (ha)	5010	620	432
In which, forest area (ha)	4600	560	350
In which, agricultural area (ha)	380	16	20
Population	2448	449	480
Ethnic group	Kinh, Chut	Kinh	Kinh

Source: PC (2014)

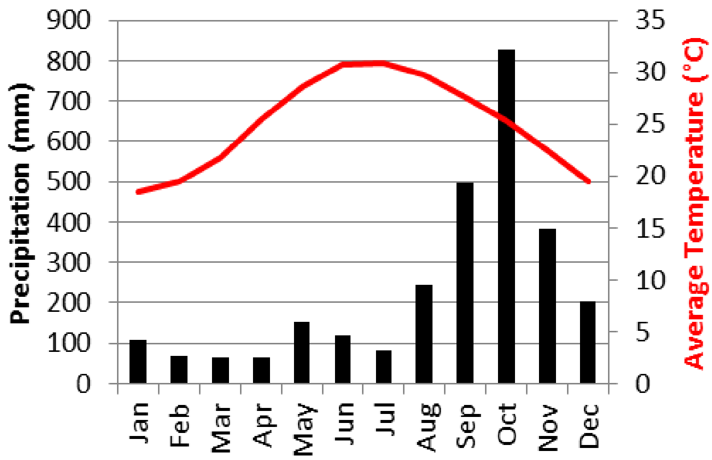

Figure 1. Climate for Ky Anh, average monthly temperature and rainfall 1982-2011

Data and methods

The methodology follows the conventional agro-ecological characterisation of FAO (1996) which derives agro-ecosystems from biophysical data such as climate, topography, soil, hydrology, land use and land cover. Land cover is based on vegetation while land use implicitly includes socio-economic information such as labour, capital inputs and management.

Meteorological data

The meteorological data includes daily minimum and maximum temperatures and precipitation for 1982-2011 for four stations in Ha Tinh province: Ha Tinh, Huong Khe, Huong Son and Ky Anh and originates from IMHEN. The dataset underwent conventional quality control and statistical analyses of trends (e.g. Song et al. 2004). Less than 1% of data is missing for each station (the highest was 0.5% of temperature observations for Huong Khe station).

The meteorological data is not mapped due to lacking information on the exact location and elevation of the stations to sufficiently represent agroclimatic zones (Bouma 2006). Instead analyses incorporate local perceptions of change and variability (Simelton et al. 2013b) based on interviews and focus group discussions in the same district between 2012-14 (Simelton et al. submitted-a).

Mapping

All data used for producing maps is described in Table 3. The flowchart Figure 2 illustrates each step of the procedure with details described below and the type of GIS-file is indicated in [*.xxx]-brackets. The resolution of all maps is 1:50,000. All GIS maps are produced and analysed in ArcMap 10.

Table 3. Data used for deriving agroecological characterisation, Huong Lien commune. Arrows indicate the steps involved to derive the final map.

Type of data	Source of data	Time period	Final output
Satellite image →Land cover map [*.shp]	Landsat 8, UTM-WGS84-48N (USGS, 2014[a])	8 Oct 2013	Land Cover map 6 classes [vector]
Satellite image →Biomass [*.hdr]			NDVI map [raster]
Contour map [vector; *.shp] → DEM [raster; *.tif] → Slope [raster; *.tif]	MONRE[b]	2008	Slope map 3 classes [raster]
Administrative map [*.shp]	MONRE[b]	2010	[vector]
Land Use map [*.shp] + Local information + Agricultural census data Huong Lien commune, Huong Khe district	MONRE[b]	2010	Land Use map 2013
	Fieldwork Report current status of agricultural production	First quarter of 2014	
Land cover map + Biomass (NDVI) + Slope map (fuzzy overlay)	N/A	2013	Ecological zones map 3 classes [raster]
Ecological zones + Land use map (fuzzy overlay)	N/A	2013	Agroecosystem zones map 10 classes [raster]

[a] Downloaded from USGS http://earthexplorer.usgs.gov/; [b]MONRE=Ministry of Natural Resources and Environment Viet Nam

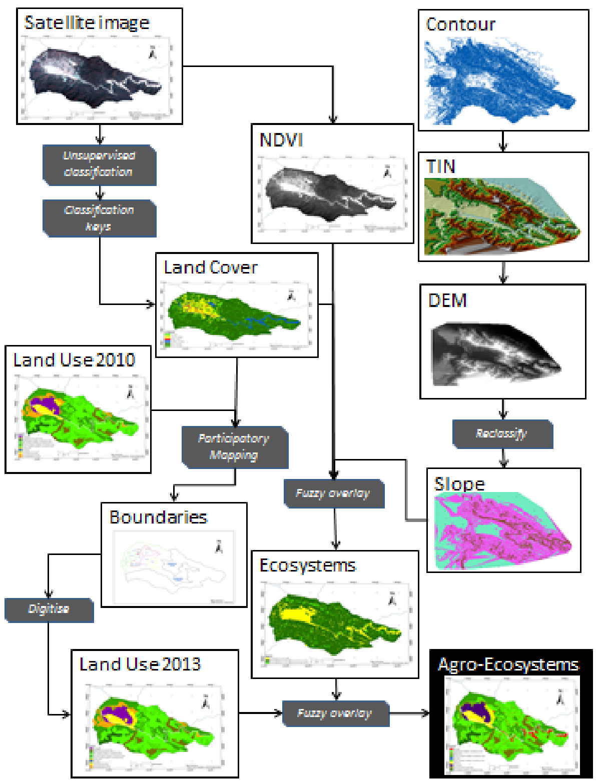

Figure 2. Flow chart for the agro-ecological characterization and analysis

The agroecological mapping is done in the following major steps (See Figure 2):

- **Land cover.** A Landsat 8 satellite image [raster] is interpreted first using unsupervised classification, which resulted in 10 land cover classes (automatic classification). After ground-truthing (transect) and participatory "evaluation" the classification keys were reduced to six land cover classes [shape]: rich forest, poor forest, shrub, short grass, water surface and bare land. The area is estimated per land cover type.

- **NDVI.** Vegetation density is interpreted from the remote sensing image. By focusing on the bands that are most sensitive to vegetation information, the near-infrared (NIR) and visible red (VIR), the Normalised Difference Vegetation Index (NDVI) is calculated following Tucker (1979) as:

$$NDVI = \frac{(NIR - VIS)}{(NIR + VIS)} \qquad \textbf{Eq. 1}$$

  The NDVI index ranges between 0 and 1, with 0 representing bare land and 1 thick vegetation. The produced NDVI map is in raster format.

- **Slopes.** Contour data [layer]is first converted into Triangulated Irregular Network (TIN) then a Digital Elevation Model (DEM) [raster]. Using the 'Slope' function the DEM a slope layer is created and reclassified into 3 slope classes: <5°, 5-25° and >25°.

- **Land Use.** The land use map from 2010 was updated through participatory mapping, transect walk and statistical data. The 2013-map [vector data, shape file] is redrawn (digitalised) from 2010-map using Toolbars>Editor (see Boundaries in Figure 2). The two maps are compared in land use change.

- **Ecosystems map.** The ecosystems map includes the following three maps: land cover, NDVI and slopes. First the land cover data layer is converted from vector to raster. Next the three maps are combined by the 'fuzzy overlay' subtended by 'AND'. The overlay resulted in three ecosystems.

- **Agro-ecosystems map.** The agro-ecosystems map includes two maps: the ecosystems map and the land use map from 2013. First the land use map is converted from vector to raster. Next the two maps are combined by 'fuzzy overlay' subtended by 'OR', to identify the characteristics of both maps. Ten agroecosystems classes (zones) are derived. Here we use the term "zone" for larger areas while "system" is more specific, i.e. an agroecological zone can contain different agoecosystems. In the case of forestry we classify only four types.

Local socioecological knowledge

- **Participatory ground-truthing.** Two transect walks with local farmers are done to ground-truth land cover and vegetation maps as well as informing the characterisation of agroecozones. The farmer groups consist of four key informants, one woman and one man from each village. In total seven observation points were made in March 2014, one in east-west direction and one in south-north direction. For each point the following information is documented: GPS reference point (longitude and latitude, elevation), slope, soil and land use description, information about agricultural production, pest and diseases, incomes, tenure and natural hazards.

- **Agroecosystem characteristics.** Local knowledge incorporated in the characterisation include farming calendar, exposure to climatic risk and adaptation solutions (Simelton et al. 2013a), and a SWOT analysis is done for each zone, e.g. strengths, weaknesses, opportunities and threats are identified.

Validation

- **Ground-truthing.** Technical ground-truthing of maps is based on random stratified method (Brogaard and Olafsdottir 1997). The initial analysis is done by visual interpretation of the satellite image to identify different land cover types. For each land cover type, a number of samples will then be visited in field recording e.g. coordinates (GPS), vegetation type and land cover density. In addition to conventional approaches, local observations and knowledge are included in the ground-truthing. (Nguyen et al. 2006, Leisz and Rasmussen 2012).

- **Interpretation of accuracy.** The accuracy of the image classification process is evaluated by an error matrix and Kappa statistics following Congalton (1991). The Kappa(κ) indicators are calculated following Jensen (1996, p. 318):

$$\kappa = \frac{N\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r}(x_{i+}.x_{+i})}{N^2 - \sum_{i=1}^{r}(x_{i+}.x_{+i})}$$

Eq. 2

where r is the number of rows in the error matrix; x_{ii} is the number of observations in row $_i$ and column $_I$; x_{i+} denotes the marginal totals of row $_I$; x_{+i} is the marginal totals of column $_I$ and N stands for the total number of observations (Bishop et al. 1975).

Results

Climate – meteorological observations and farmers' perceptions

Table 4 gives the average meteorological data for four stations in Ha Tinh province and Table 5 gives a brief summary of five observed temperature and rainfall extremes for the two locations closest to Huong Lien commune. Few record dates overlap for both locations (one cold spell and two heavy rainfalls), suggesting that extreme events are local. Furthermore, except for cold spells the record dates are fairly spread over the 30-year period.

Discussions with local farmers, suggest that the combination high humidity and low temperatures may better indicate the type of cold spells that cause fungus or crop failures and animal diseases. Local farmers say that the frequency of storms has increased and is no longer associated with a particular month as it used to be. Four particularly damaging floods occurred in 2006, 2007, 2010 and 2013 and are partly explained by discharge from the Ho Ho hydropower station located upstream of the two villages in this study and which opened in 2007. This is partly confirmed by the rainfall observations for Ky Anh which do not indicate abnormal rainfall in recent decade, while the average levels for Huong Khe are slightly higher from 2007 and onwards compared to the 20 previous years (Figure 3 and Supplementary Figure A2). In addition, two of Huong Khe's five rainiest days in 30 years occurred in 2007 and 2010 (Table 5).

Table 4. Daily meteorological data for Ha Tinh province, 1982-2011

Variable	Information	Meteorological station			
		Ha Tinh	Huong Son	Ky Anh	Huong Khe
Temperature (minimum, maximum)	Annual mean (°C)	24.8	24.7	24.9	25.0
	Min observation (°C)	4.4 *7 Feb 1995*	2.3 *24 Dec 1999*	7.4 *2 Mar 1986*	3.7 *24 Dec 1999*
	Max observation (°C)	40.2 *3 May 1994*	40.5 *9 May 1992*	40.4 *16 Jun 2006*	42.6 *9 May 1992*
Precipitation	Annual total (mm)	2680	2085	2816	2444
	Max observation (mm)	657 *10 Aug 1992*	519 *11 Oct 1983*	573 *7 Aug 2007*	493 *3 Oct 1983*

Table 5. Extreme weather events in Huong Khe and Ky Anh meteorological stations 1982-2011

Top 5	Huong Khe	Ky Anh
Coldest days	3.7-5.4°C *Jan 1983[a], Dec 1999*	7.4-8.4°C *Dec 1982, Jan 1983[a], Feb 1986, Feb 1996*
Hottest days	41-42°C *May 1992, Jul 1998, May 2003, Apr 2007*	39.5-40.4°C *Jul 1984, May 1987, May-Jul 2006*
Rainiest days	347-480 mm in one day *Oct 1983[a], Aug 1990, Sep 1996, Aug 2007[a], Oct 2010*	455-573 mm in one day *Oct 1983[a], Oct 1984, Oct 1993, Oct 1999, Aug 2007[a]*
Longest dry spell days with<1 mm rainfall*	30-77 days *Feb-Apr 1992, Jul-Aug 1992, Dec 1999-Jan 2000, Jan-Feb 2009*	32-37 days *Mar-Apr 1984, May 1992, Jul-Aug 1993, Jun-Jul 1996, Jul-Aug 1998, Jul-Aug 2000, May-Jul 2006, Jun-Jul 2007*

**) Assuming meteorological observations indicate that rain gauge is fully functioning; [a]) records coincide in both places*

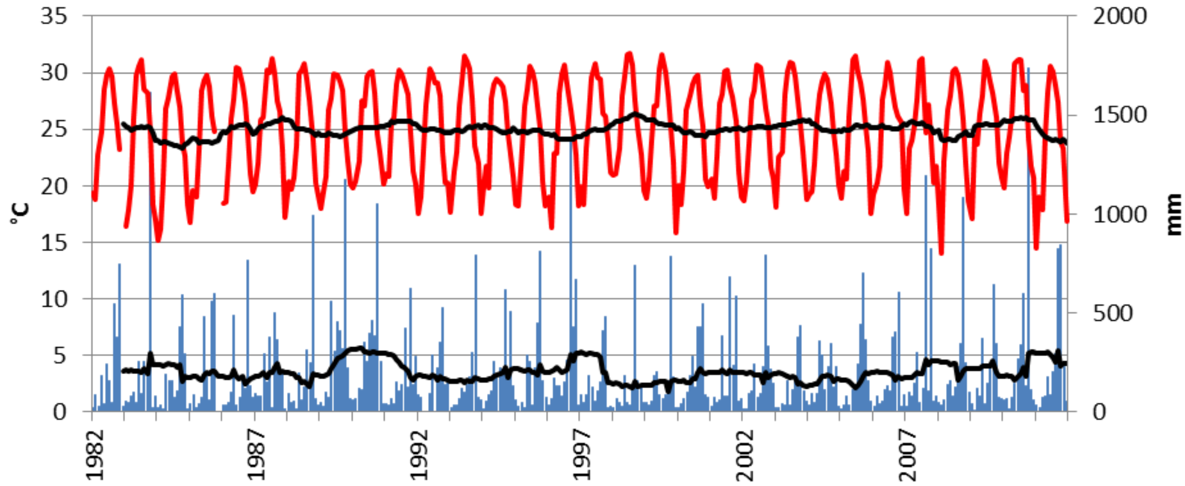

Figure 3. Time series for monthly average temperature (red) and total rainfall (blue) for Huong Khe with 12 months moving average (black line) 1982-2011. Corresponding time series for Ky Anh see Supplementary Figure A2.

Climate change scenarios for Huong Khe district were based on the high emission (A2) scenario for the north central region in Viet Nam in 2012. Trends for the season rainfall and temperature up to 2030s are shown in Supplementary Figure A3. Overall, temperatures are projected to increase throughout the year but winter and spring temperatures increase slightly faster. The projected annual total precipitation changes are very small; instead the distribution throughout the year may change to drier winter and spring seasons and wetter summer and autumn seasons (Appendix A Figure A3).

Table 6. Participatory identification of major risk periods for extreme events associated with four land uses.

<table>
<tr><th>Weather</th><th>J</th><th>F</th><th>M</th><th>A</th><th>M</th><th>J</th><th>J</th><th>A</th><th>S</th><th>O</th><th>N</th><th>D</th></tr>
<tr><td>Cold spell</td><td colspan="2">A</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="2">A</td></tr>
<tr><td>Hot spell</td><td></td><td></td><td></td><td colspan="3">A</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Drought</td><td></td><td></td><td></td><td colspan="3">HG, A, PF, NF</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Floods</td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="4">HG, A</td><td></td><td></td></tr>
<tr><td>Landslide</td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="4">HG, A, PF, NF</td><td></td><td></td></tr>
<tr><td>Storm, tornado</td><td colspan="6">HG, A, PF, NF</td><td colspan="4">NF (especially)</td><td colspan="2">HG, A, PF, NF</td></tr>
</table>

Land uses: A= Agricultural Land, HG = Home Garden, PF = Plantation Forest, NF = Natural Forest

Source: Transect walk 2014

Agro-ecological zones

The mapping flowchart is given in the methodology section Figure 2. Here we highlight a few of the maps. The ecosystems map is combined of NDVI, land cover and slope (Figure 4a), where the resulting categories (shown in Figure 4c) is an interim map before finally combined with the 2013 land use map (Figure 4b) resulting into the agroecological map (Figure 4c). The maps are provided in full scale in Appendix B.

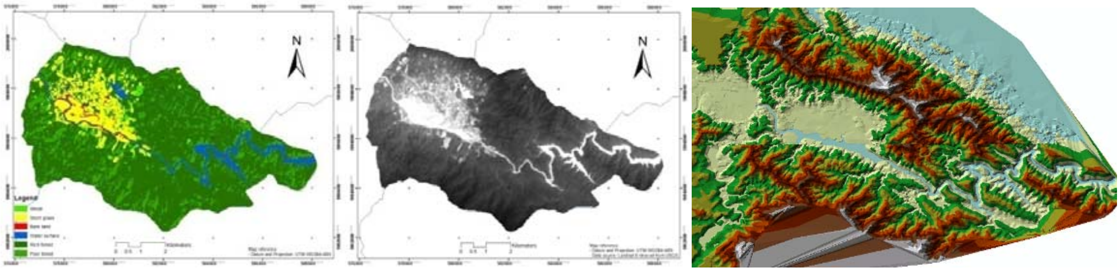

Figure 4a. Three maps forming the ecosystem map: land cover, NDVI and topograhy (TIN image is shown for more detail)

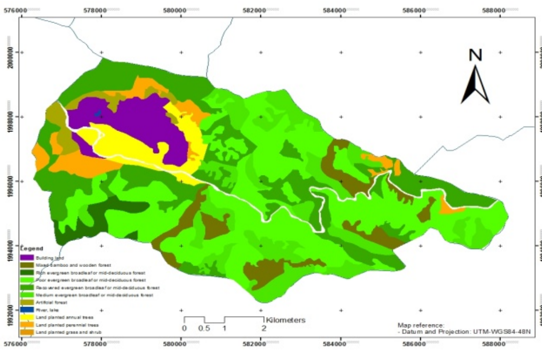

Figure 4b. Land Use map 2013

Table 7. Land cover types in Huong Lien commune

Land cover 2013	Area (ha)
Bare land	54.9
Short vegetation, incl annual crops	477.8
Shrub	162.1
Rich forest	3344.0
Poor forest	836.8
Water surface, incl Ngan Sau river*	227.0
Total area	5102.6

**) Ngan Sau river area is interpreted from the satellite image not from the land use map (compare Table 11)*

The maps indicate that vegetation (density) is closely associated with topography. Cultivated areas and homesteads (home gardens) with high human impact on low elevations and plains near rivers. Forested areas with low human impact and high biomass value on higher elevation with moderate slopes and with less human impact but low biomass value on higher elevations with steep slopes.

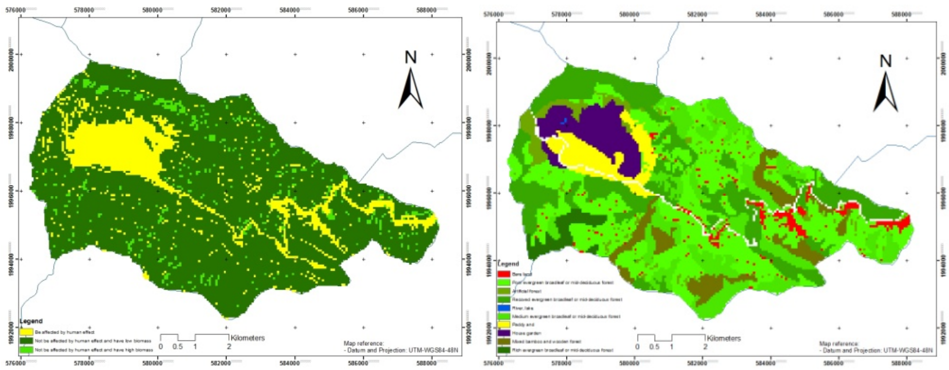

Figure 4c. Maps of ecosystems (left) and agroecological zones (right), Huong Lien commune

The resulting seven agroecological zones were reclassified into four (Table 8): (i) paddy and agricultural crops, (ii) home garden, (iii) plantation forests (mixed bamboo and timber forest) and (iv) natural forests (merged rich, average and poor forests and regeneration forests). The natural forest zones were merged due to practical difficulties separating the categories in field. In this case the management is regulated by forest protection policies and thus the same regardless of the forest classes.

Table 8. Summary of agroecological zones in Figure 4c. GPS point refers to transect walk in Supplementary Figure A1 (Appendix A)

Agroecological zone	Approx. range NDVI	Characteristics	GPS reference point UTM- WGS84 – 48N
Annual crops (*paddy rice, field crops especially maize and peanut*)	0.01-0.03	Flat terrain, alluvial soil near/on river banks, average fertility, coarse gravel mixes Land tenure for most households	Point 1 (48N X578099 Y1997798) Point 6 (48N X579330 Y1996996)
Home-garden (*vegetables, fruit trees, maize intercropping*)	0.03-0.04	Slopes <5° Ferralsol, average fertility, compaction, risk of drying	Point 2 (48N X577770 Y1997941) Point 4 (48N X579306 Y1997471)
Plantation forest (*Acacia spp*)	0.04-0.06	Hilltops and foothills Slopes 10-30° Ferralsol, good drainage Tenure since 2009	Point 3 (48N X577410 Y1997862) Point 7 (48N X579374 Y1996454)
Natural forest	0.07-0.09	Steep slopes >25° Ferralsol, good drainage	Point 5 (48N X580311 Y1997697)

Table 9. Land use and farming calendar depending on soil type in Village 1 and 4, Huong Lien commune

<table>
<tr><th>Village</th><th>Soil types</th><th>J</th><th>F</th><th>M</th><th>A</th><th>M</th><th>J</th><th>J</th><th>A</th><th>S</th><th>O</th><th>N</th><th>D</th></tr>
<tr><td rowspan="3">1</td><td>Lowland</td><td colspan="5">Rice I</td><td colspan="4">Rice II</td><td colspan="3"></td></tr>
<tr><td>Upland poor soil</td><td colspan="5">Maize or peanut</td><td colspan="7"></td></tr>
<tr><td>Avg fertile soil</td><td colspan="5">Maize I</td><td colspan="4">Peanut</td><td colspan="3">Maize II</td></tr>
<tr><td rowspan="4">4</td><td rowspan="2">Lowland</td><td colspan="5">Rice I</td><td colspan="4">Rice II</td><td colspan="3"></td></tr>
<tr><td colspan="5">Peanut</td><td colspan="4"></td><td colspan="3">Green bean</td></tr>
<tr><td rowspan="2">Upland avg fertile soil</td><td colspan="5">Maize I</td><td colspan="3"></td><td colspan="4">Maize II</td></tr>
<tr><td colspan="5">Peanut I</td><td colspan="4">Peanut II</td><td colspan="3"></td></tr>
</table>

Source: Transect walk 2014

Paddy and agriculture fields

Paddy rice is traditionally grown along Ngan Sau river banks. The soils vary from moderate drainage and fertility to poor soil with coarse mixed gravel and suffer from fluvial erosion processes. Annual crops are grown on ferralsols near the foot of the hills which have been converted from forestry. The distance from the river means they have less water access (see Table 8 and “lowland” and “upland” in Table 9).

The production in Village 1 is unstable due to its vicinity to the river due to landslides and compaction and in Village 4 flood risks are high between July and October. Monoculture is more common in the drier parts while on more fertile soils it is possible to rotate at least two crops of peanut, maize and green beans or intercrop maize and peanuts.

Land tenure status varies in the two villages: the Red Book procedures started in 2013, while at the time of the survey some households had received “licenses” to use land but not the actual legal documents. In Village 1 this depended on that land use designations were changed after a flood disaster in 2013.

Home gardens

Home gardens are usually located in low-lying areas near paddy and crops fields. The soils are moderately deep Ferralsols with average soil fertility. Home gardens contain fruit trees (bananas, pomelo), ornamental trees, maize intercropped with peanut, mixed vegetables and *Aquilaria*. Yield declines of traditional fruit trees have resulted in policies promoting *Aquilaria* since 2007. Farmers expected higher incomes, however at the time of the survey few *Aquilarias* had been harvested. Home gardens are affected by two main natural hazards: hot spells with drought risks from April to June and flood risk during the typhoon season from July to October (Table 6). Village 4 is situated in lower elevation and severely affected by floods. Home gardens on Ngan Sau river banks in Village 1 are exposed to landslides. Slopes with compacted soils near the rivers are easily dried up in April-May before the rains, aggravating the risks for overland flow during heavy rains.

Production forests

Huong Lien commune has two main forest production areas, predominantly with monoculture Acacia hybrid or *A. auriculiformis*. Some 42 ha were planted in 2009 on hill tops at relatively higher elevation adjacent to the central valley in northwest and another 50 ha planted in 2009-10, is located at relatively lower elevations near Ngan Sau river in the eastern part of the commune. By March 2014 no trees had yet been harvested. All forest plantation owners have Red Book. The plantations and are generally located on 10 and 30° steep slopes on rocky brown and yellow Ferralsols. The soils are fertile with good drainage. The spacing is approximately 1.5-2 m x 1.5-2 m with 2,500 to 4,400 trees per hectare which reduces soil erosion, especially on very steep thin soils.

Plantation forests are typically converted to annual crops when households are in need of cash or when land use types are provisionally changed without full Government authorisation.

Natural forests

Natural forests cover approximately 260 ha on slopes steeper than 25°. These ecosystems are protected and managed through the Ngan Sau forest management board and Chuc A Forestry company. The soils are fertile yellow brownish Ferralsols, with good drainage and soil moisture. Soil erosion, mainly landslides are limited to the steep slopes. The forest cover reaches up to 98% with natural regrowth of short trees and undervegetation of shrubs. Local species include e.g. *Vatica tonkinensis, Michelia mediocris, Fagus sylvatica, Engelhardtia roxburghiana, Endospermum chinense, Rhodomyrtus tomentosa* and *Melastoma affine.*

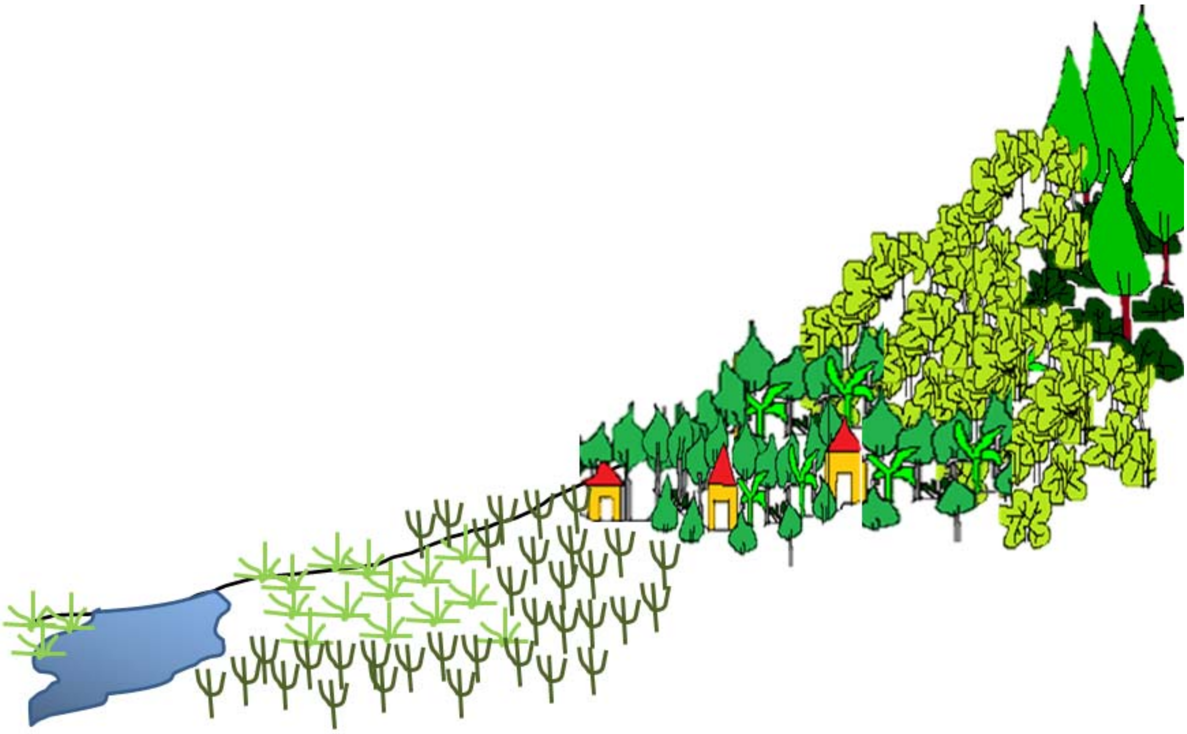

Table 10. Transect for four major land use types in Huong Lien commune

Land Use Type	Annual crops	Home garden	Production forests		Natural forest
Elevation (m)	77-86	75-83	90	64	99
Slope	0-5°	5-10°	10°	30°	35
Soil	Ferralsol or alluvial (plains) Moist, average fertile soils A: light erosion B: heavy soil, severe erosion	Ferralsol Heavy, average fertile soil; severe erosion average soil moisture dry soils	Ferralsol severe erosion A: heavy, dry, average fertile soil	B: moist, fertile soils	Ferralsol moist fertile soils; light erosion
Hazards	Floods, drought		landslide		
Land Use and Land cover	Annual crop A: 1-2 harvests per year B: 2 harvests per year (upland); 1 harvest (lowland) "Short grasses": paddy, peanut, maize, green soybean, 95% A: Rotation if fertile soil B: Intercrop (peanut, corn); rotation (peanut, green soy)	Homestead, home gardens 7-10 year rotations A: Trees: *Aquilaria* with (i) grapefruit, 50% (ii) banana, maize, 70%	Production forest 5-7 year rotations B: Shrub and trees, 98%	Acacia trees (same-age monoculture), 75 - 98%	Protected natural forest Shrub and tree (mixed age), 98%
Productivity (t/ha/ season)	Paddy: 5 – 5.6; Peanut: 5 – 6; Maize: >4	*Aquilaria*: No harvest Grapefruit: 0.1t/ season	No harvest	No harvest yet	No harvest
Annual income	VND6 – 7 million VND 1.7 million (1 crop)	VND1 million (unstable)	none	_	none
Pests	stem-borer, brown plant hopper (rice)	Leaf-eating insects	none		none
Tenure (Red Book)	Land use rights; Red Book in process	Land Use Rights; Red Book completed	Land use rights; Red Book in process	Land Use Rights; Red Book completed	Land use rights (forest protection)

Source: Transect walk March, 2014

Analyses

Land use change

There major change in land use in the commune between 2010 and 2013 was conversion of forestland to agriculture crops (Table 11). The losses of forest and fruit trees (pomelo, lemon and orange) can be compared with 26% increase in agricultural area (especially peanut and bean). Part of the conversion relates to an attempt by the local government to limit the frequent impacts of rain disasters (landslides and rock fall), to allocate less sensitive land in exchange for land on the unstable riverbanks starting in 2009.

Table 11. Land use types in Huong Lien commune 2010 and 2013

Land use type (MONRE)	Area (ha) 2010	Change (ha) 2013
Annual crops	208.5	+55.0
Perennial crops/ trees	251.0	0
Short grass and shrub	219.9	
Mixed bamboo and timber forest	348.7	0
Rich forest[a]	123.5	0
Medium forest[a]	748.4	0
Poor forest[a]	1697.2	0
Regeneration forest[a]	1152.8	-44.6
Plantation forest	131.4	-10.4
Lake (excl Ngan Sau river)	1.8	0
Built-up land	337.1	0
Total area	**5220.3**	**0**

[a] *Evergreen broadleaf or semi-deciduous forest*

The three tables with statistical data (Table 2), land cover types (Table 7) and land use types (Table 11) are not directly comparable however several differences need further explanation. One such example is that the land cover analysis identified 227 ha water surface including the Ngan Sau river, while the land use classification only recognised the lake (1.8ha) and the river is excluded in the analysis. The total areas vary with 210 ha (5010, 5103 and 5220 ha respectively). This depends on that Ngan Sau river (appr. 225 ha) is not built-up land and therefore excluded in the land use map but included in the automatic satellite image interpretation (compare Tables 6 and 10).

Moreover, the area with trees and grassland totals approximately 4600 ha in both the statistical data and land use types, but reaches a maximum of 4343-4400 ha when adding relevant land cover types. This depends on the land cover analysis categorises the actual vegetation structure not the actual plant. In addition, area classified as forest land does not necessarily have a tree cover.

Lastly there is a considerable difference in the estimates for land associated with agriculture or annual crops (380, 478 and 264 ha). The 478 ha for short vegetation as a land cover includes both grass or crops. Assuming that 220 ha is grass as stated in Table 11 would leave 258 ha for crops, similar to the land cover data. This makes the 120 ha difference between the statistical and land use type definitions curious. The difference likely depends on incompatible boundaries of Huong Lien commune land use map and land cover map, so that some accuracy was lost in the image interpretations.

Participatory assessments during ground-truthing transect walks

The participatory assessments were done during the transect walk in three steps. First, the SWOT analysis (Table 12) builds on a participatory assessment made during the transect walks (Table 10) with strengths, weaknesses, opportunities and threats discussed in field. The exercise is finished with concrete recommendations for reducing climate vulnerability. The SWOT adds to the more factual transect table, farmers' perceptions, thoughts, worries and hopes associated with the land uses, or agro-ecosystems. In particular, we note their concerns over high pesticide consumption; meanwhile pests are expected to increase as a consequence of climate change impacts. In addition, with the lack of drought-tolerant varieties and frequent mentioning of losses related to natural disasters, many crops seem unsuitable for the current climatic conditions.

Second, a range of weather events have notable impacts on all agro-ecosystems (Tables 5 and 12) and are expected to increase in frequency and intensity. The risks include direct meteorological indicators droughts, floods (both ends of rainfall extremes), hot dry winds and wet storms as well as the impacts thereof. Such indirect risks include soil degradation, pests and mechanical damage causing crop failures or reduced values of timber in addition to human and animal health risks. Strategies to adapt to and for mitigating these risks may involve planting technologies, selecting stress-tolerant species, sloping land technologies and landscape-scale planning and assessments.

Table 12. SWOT analysis for four agro-ecosystem zones in Huong Lien commune

Agro-ecosystems	Strengths	Weaknesses	Opportunities	Threats
Paddy and agriculture fields (Point 1, village 1 & point 6, village 4)	Good soils, flat land Suitable for intercropping and crop rotation Irrigated channel systems Grazing banned (to protect from roaming animals) Techniques for seed selection and fertiliser use applied Red Book	Permanent use of pesticides No drought tolerant crops Surface water easily contaminated during heavy rainfall	Change to new more economic crops Switch from monoculture to rotation (Point 6, Village 4)	More or new pests Unstable production associated with natural disasters (e.g. fragile riverbanks, floods, droughts, landslides) Risk for water pollution (pesticides)
Home garden	Good drainage, soil suitable for *Aquilaria* Safe water supply (ground-water) Nearby residential areas eases transportation	Heavy gravelly and rocky soils, dry soil, leaching during rains Common pests and high pesticide usage Unstable productivity (pomelo, vegetables) Surface water easily contaminated during heavy rainfall	Economic and species diversification, e.g. plant *Aquilaria*	Natural disasters (drought, hot dry winds, storms, floods) affect flowering, fruiting, wood breakage, cause soil erosion Uncertain market trends for *Aquilaria* (slow-growing), risks being harvested prematurely when farmers are financially pressed
Plantation forest	Soils suitable for acacia Water resources No pesticide and fertiliser use Trees require little maintenance Red Book Near residential areas on higher land that is not flooded (Point 7, Village 4)	Soil erosion Monoculture, no trees for intercropping Low investment capacity Steep roads separated by the river makes transport difficult (Point 7, Village 4)	Switch to higher value species (e.g. *Aquilaria*, rubber) if the required investment can be afforded	Stormfell and damage Land degradation, nutrient leaching with short forest cycles
Natural forest	Fertile soils Natural water resources High biodiversity Generally ecosystem in balance	Forest degradation due to overharvesting, construction and mining activities Some scars after natural disasters (e.g. landslides, broken trees, forest fires)	Protecting ecosystem balance for local resilience	Natural disasters

Third, the SWOT analysis was completed with a list of proposed recommendations per agroecosystem that would lead to better adapted agroecosystems with the horizon of 2030s (Table 13). One particular challenge concerns water resources. Currently surface water (reservoirs, lakes and streams) and groundwater (drilled wells or holes) is used for irrigation. Only groundwater is considered safe for human consumption, as surface water is easily contaminated during the rainy season. Moreover, both heavy and long duration light rains lead to landslides and leaching of already nutrient poor soils, with soil particles accumulating in reservoirs and in the long run risking to aggravate flood risk from reservoirs.

Table 13. Local suggestions for adapting to climatic impacts per agroeco system

Agroeco system	Proposed adaptation measures
Paddy and agriculture fields	Adapt cropping systems, including converting agriculture land uses Identify drought tolerant varieties Adjust farming calendar to avoid natural hazards Promote economically and environmentally efficient crop rotations and intercropping Limit pesticide use to prevent pesticide resistance in crops
Home gardens	Improve tree maintenance to avoid storm damage Find an appropriate combination of *Aquilaria* and other species, that is both economically viable for the household and environmentally viable, e.g. conserving soil moisture Implement agroforestry Replace unprofitable crops with more cost-effective ones Cover the soils during the dry season to improve soil moisture storage (plastic och green mulching)
Forest plantations	Contour planting to reduce soil erosion Shelterbelts and better tree maintenance to reduce storm damage Identify appropriate tree species to combine with acacia Expand agroforestry Complete land tenure processes (Red Book)
Natural forests	Maintain forest cover to enhance soil water holding capacity and control soil erosion into Ngan Sau river Strengthen forest protection, including biodiversity Build a reservoir in Khe Co area to better regulate water flow (avoid flooding) and provide water reserves Improve water regulation from Ho Ho hydropower dam for irrigation and to avoid future flooding disasters

Discussion

Limitations of the study

This characterisation study of agroecological zones used satellite imagery, maps and local knowledge. There are four main limitations of the study. (1) The naming of the agroecological zones is very close to the land use categories although the two maps are different. The land use types indicate the designated land uses, while the AEZ focus on actual natural conditions and vegetation quality, which thus gives less coherent zones. As land use (especially for paddy land) is rather regulated and the number of species quite limited, the land use and land cover maps are quite concurring.

(2) Climate zones were not included due to too few meteorological stations for useful interpolation. For such small area as a commune, elevation is likely to the biggest difference. To overcome this a participatory microclimate/hazard mapping can complement the discussions during transect walks. (3) The AEZ study contains one snapshot satellite image. The lack of NDVI time series data is troublesome in that neither major vegetation changes were quantified nor soil quality changes identified. The single map and census data time series therefore can give misleading differences in forest cover (see Table 11). In this case the 2010-land use map was updated to represent 2013 with the help of local informants, as well as land cover for the season that is not covered by the satellite image. Similar to Lindström et al. (2012), we find that ground-truthing and transect walks are important guides to compensate some data limitations and for adding land use history. (4) The final AEZ map was reduced to two distinct forest zones. A potential problem with this particular study is that the unsupervised classification of NDVI satellite imagery resulted in ten land cover classes, where particularly for forest quality classes not all could be verified on ground. This may have been alleviated by time series data, but in its absence vegetation quality distinctions are entirely dependent on participatory ground-truthing. Thus more transect walks would be required. Here, further sub-zoning according to forest quality and species, should be particularly useful for conservation priorities of natural forests and identifying sustainable management options for plantation forests. Standardised methodologies for mixing conventional quantitative maps with qualitative community mapping (McCall and Minang 2005) could be matched with e.g. participatory carbon monitoring (Larrazabal et al. 2012) for assessing forest quality. This may serve co-learning objectives and environmental awareness raising purposes.

Local knowledge and participatory ground-truthing

As result of this study the question arises, what is the smallest unit area for useful AEZ-characterisation? For small areas such as a commune, agroecological zoning may benefit from boundary conditions that are external to the target area or forced, pre-determined classification limits (e.g. slope and elevation classes). The participatory ground-truthing highlights two key limitations of AEZ. First, unless the AEZ boundaries are based on a larger context, the AEZ classes may be very local and incompatible when merged into e.g. province or national maps. Second, unless socioeconomic indicators are included from start, the AEZ-categories exaggerate the biophysical conditions. While this may be benefit top-down land use management recommendations, at smaller scales such as a catchment, the trees and crops that are actually planted are based on economic decisions or designated land use plans. The AEZ mapping requires two separate steps for characterising current land use and recommending economically and environmentally sustainable options.

The SWOT analyses highlight the case of high value tree recommended by policies and local leaders. In this area *Aquilaria* and rubber are commonly seen as universal solutions to rural poverty. However, not until the discussion with farmers about threats, it turns out that there is great uncertainty about markets for *Aquilaria*. Similar to other provinces policies supporting one or two high value species is promulgated based on the current economic demand and seemingly without any market-value-chain assessment under near-future economic conditions (Simelton et al. submitted-b). In addition to economic assessments, we recommend the the direct and indirect climatic suitability of existing *Aquilaria* stands and the great supply of wild tree species is assessed to help select a greater diversity of reforestation and higher value species.

Adaptation strategies by agro-ecological zones

The adaptation strategies (Table 13) suggested by farmers are muddled with expectations of higher incomes. The SWOT provides a useful tool to scan farmers' worries and expectations associated with various land uses. We will highlight two examples where current strategies seem to be guided by opportunism rather than careful impact assessments. Firstly, in addition to the uncertain markets, very little is known about the climatic suitability range of *Aquilaria,* while for acacia markets are known but payments relatively low. This is reflected in reluctance towards planting and that some suggested assessing an appropriate ratio, or combination of *Aquilaria* and acacia. In contrast, we note that the adaptation strategies for the home gardens are less conventional and more innovative compared to the other three zones. Home gardens, which are unregulated by production quota, protection regulations or availability of reforestation seedlings, are currently underutilised as experimentation grounds for intercropping, tree domestication and nursery development, which all could contribute to greater diversity. Studies from Africa confirm the potentials of farmer-led domestication for rural economic development (Tchoundjeu et al. 2010).

Secondly, in terms of water regulation to control droughts and floods, suggestions included constructing a reservoir in the protected natural forest area. This suggestion endures despite that a severe flooding at Ho Ho hydropower dam already had caused major damages. One important role of the Smart-Tree Invest project seem to be to show evidence for economic and ecosystem synergies of upgrading the status of standing trees and biodiversity values, that integrate local needs and wishes. The problems with soil erosion and landslides are clearly allochtonous, e.g. compaction on slopes causing slides onto lower lying fields. The study shows that planned and unplanned landscape and catchment solutions exist already, however impacts are seldom tested or simulated beforehand. Participatory mapping of risk zones and adaptation strategies could provide useful insights for scenario modelling studies and include participatory monitoring of interventions (Vajjhala and Walker 2009, Lindström et al. 2012, Nguyen et al. 2013b). We propose that participatory AEZ-mapping can make a good baseline for interventions (Sutton et al. 2013).

In summary, participatory ground-truthing and mapping is a low-cost complement to quantitative spatial assessments, such as census and satellite data, useful for

1. Adding quantitative information to snapshot images and/or narratives between snapshot images of land use change - “the string that connects the pearls of metrics”
2. Deriving locally workable boundaries for agroecological zones
3. Identifying gaps between land use policy interventions and implementation
4. Monitoring and evaluations environmental assessments and risk maps
5. Disseminating and discussing adaptation scenarios
6. Educational and awareness-raising on natural resources/ecosystem services

Conclusion

Local knowledge adds qualitative information that is important for ground-truthing of maps especially when time series data is unavailable, for confirming past natural hazards and land use history. Active local participation in ground-truthing can be contributing to raised awareness about natural resource management and environmental impacts and adaptation strategies.

Agroecological characterisation can show the actual land use practices in contrast to the land use planning maps. To maximise its usefulness and compatibility, clear reasoning for determining the classes and a methodology for incorporating participatory information are needed.

Appendix A

Supplementary maps and graphs

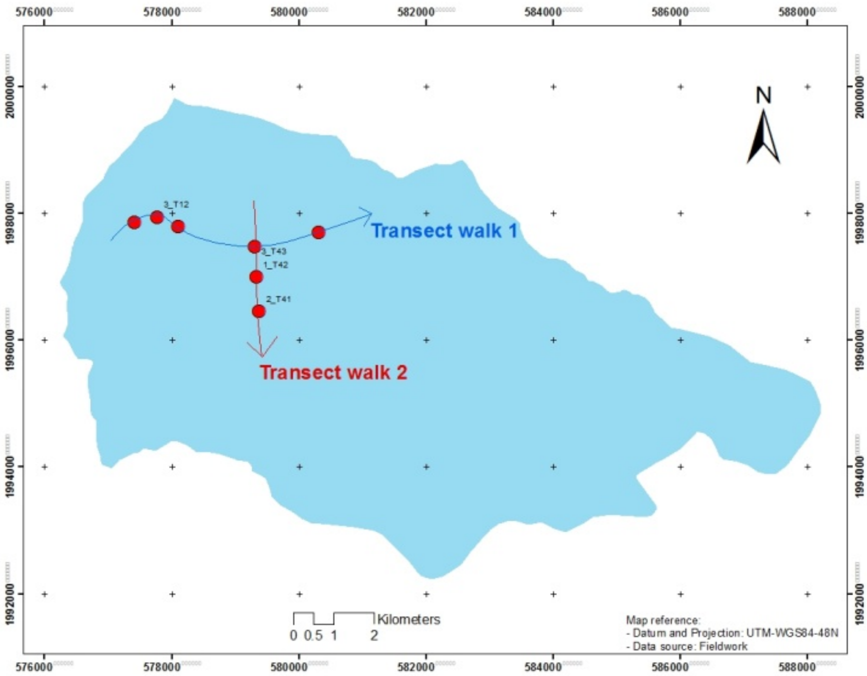

Figure A1. Transect walk in Village 1 and 4, Huong Lien commune

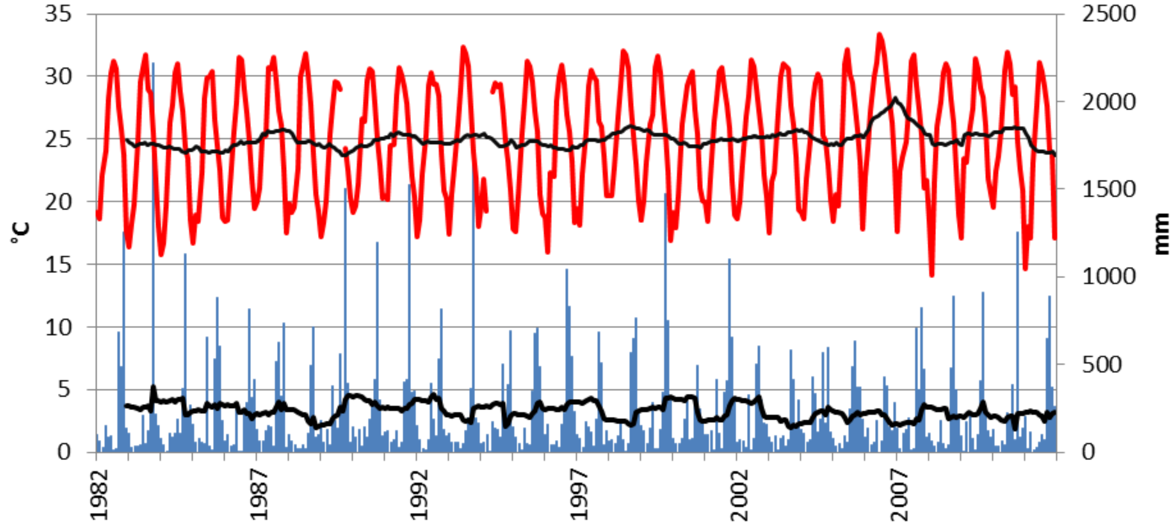

Figure A2. Time series for monthly average temperature (red) and total rainfall (blue) for Ky Anh with 12 months moving average (black line) 1982-2011

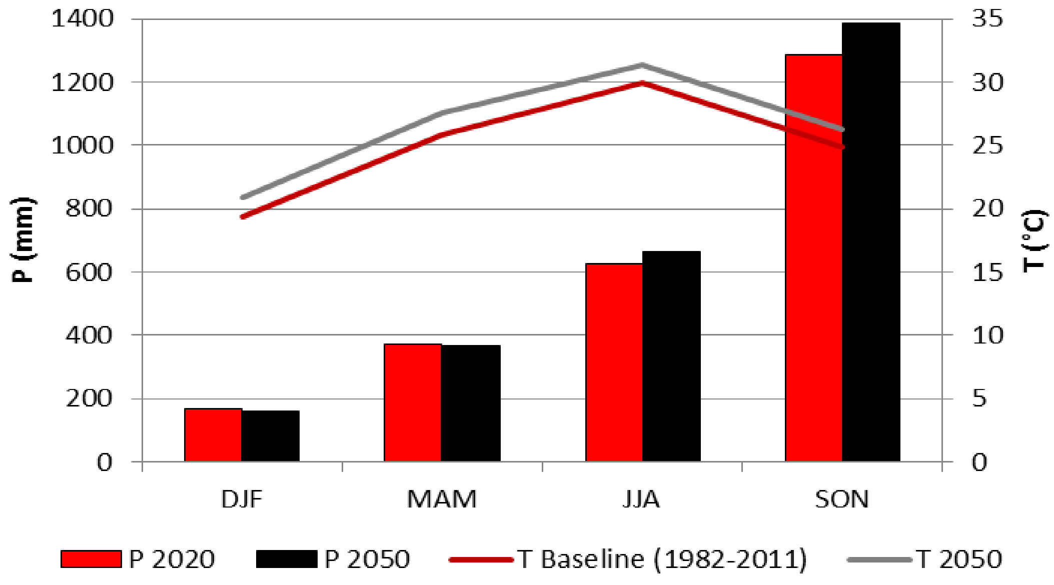

Figure A3. Seasonal climate change scenario for Huong Khe district. Baseline from IMHEN, Scenario from ISPONRE (2009, Table 3.5 and 3.6). DJF = December, January, February, etc.

Appendix B

Figure 4

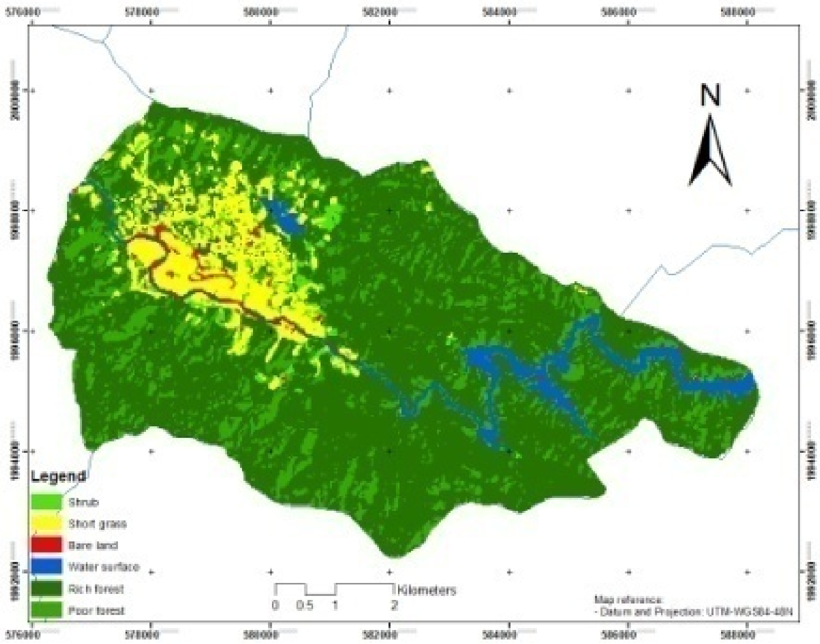

Figure 4a(1). Land cover

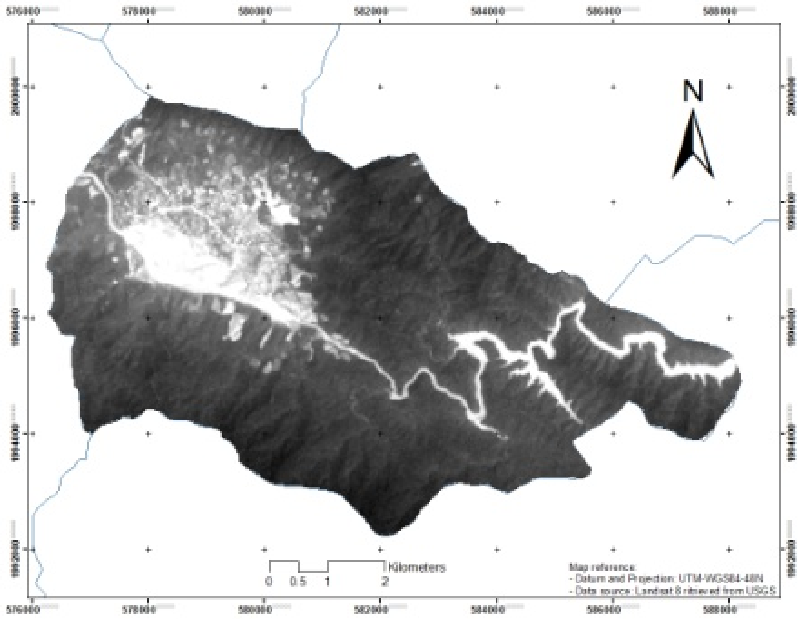

Figure 4a(2). NDVI

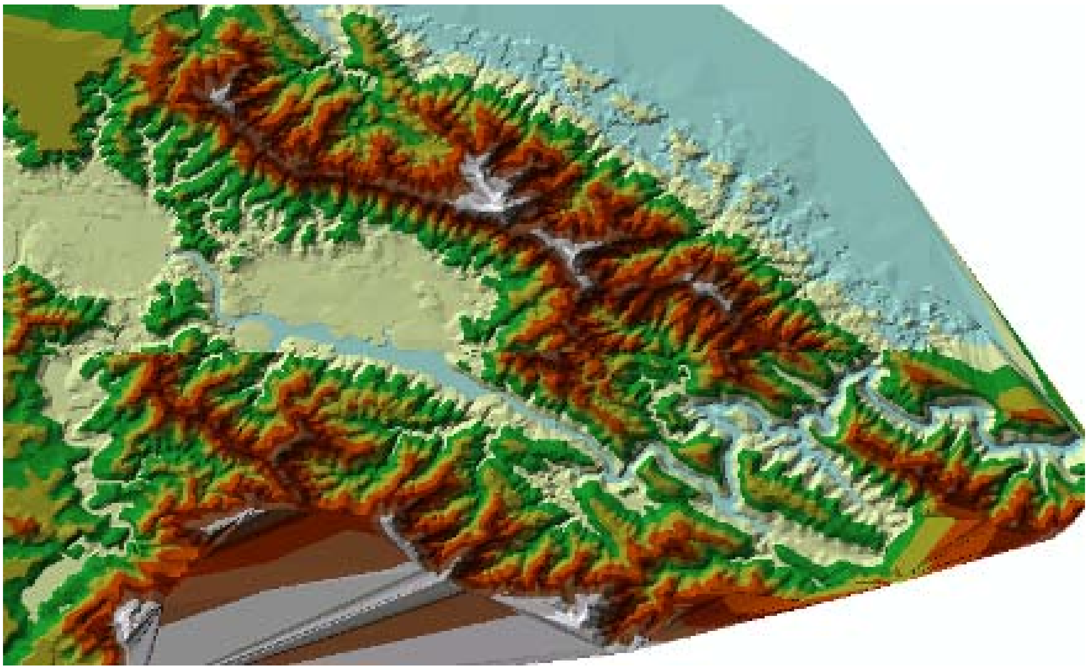

Figure 4a(3). Topograhy

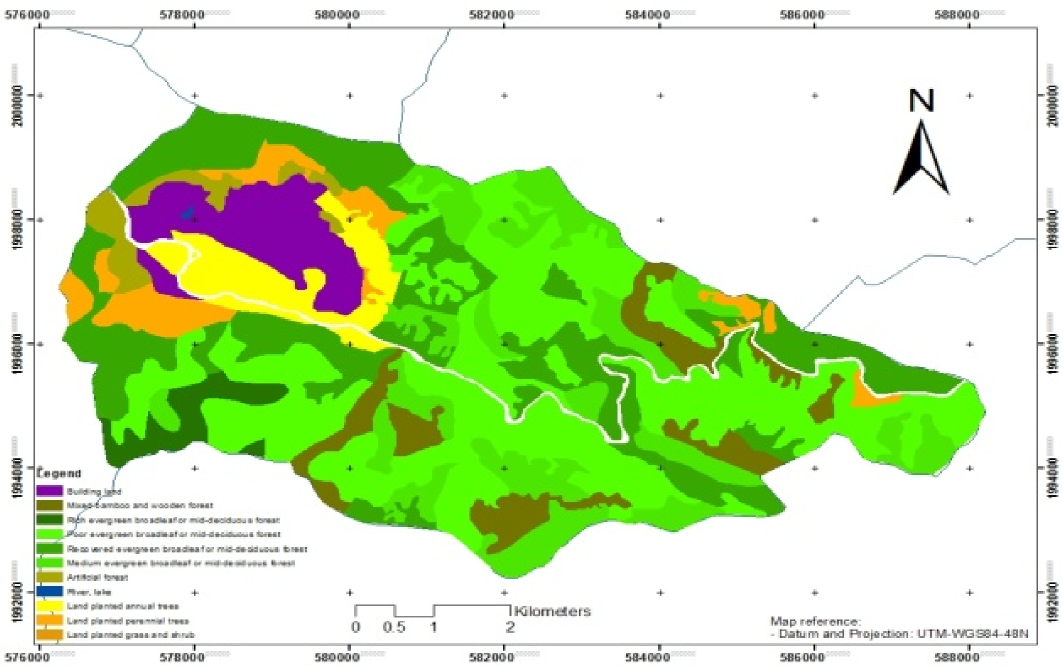

Figure 4b. Land Use map 2013

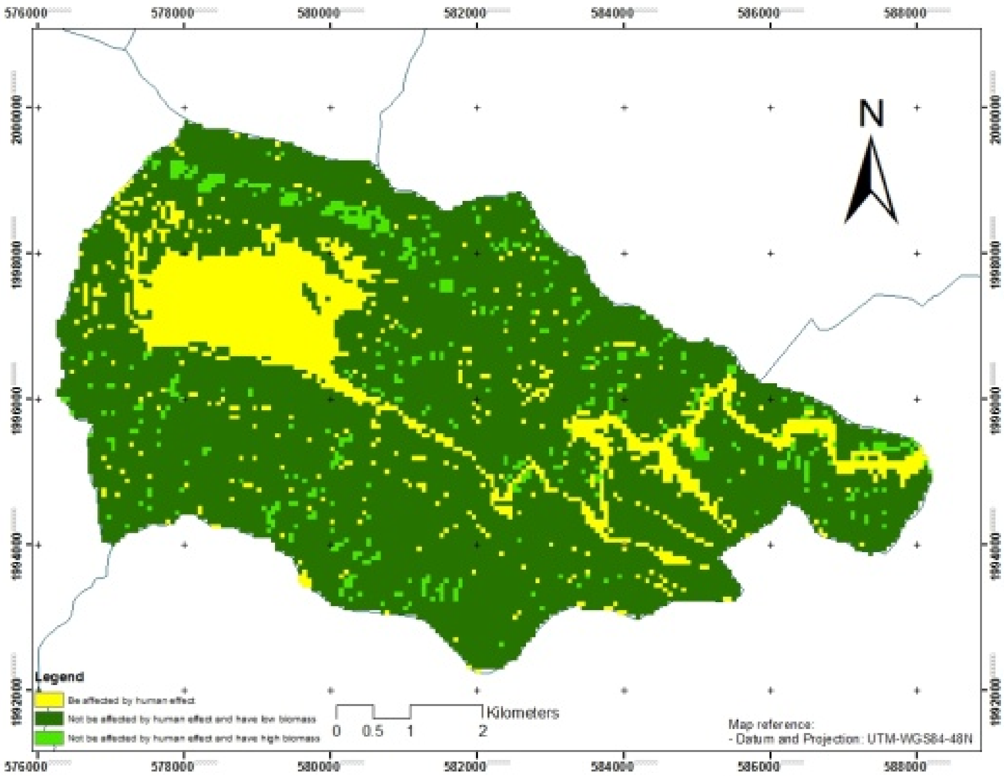

Figure 4c(1). Ecosystems, Huong Lien commune

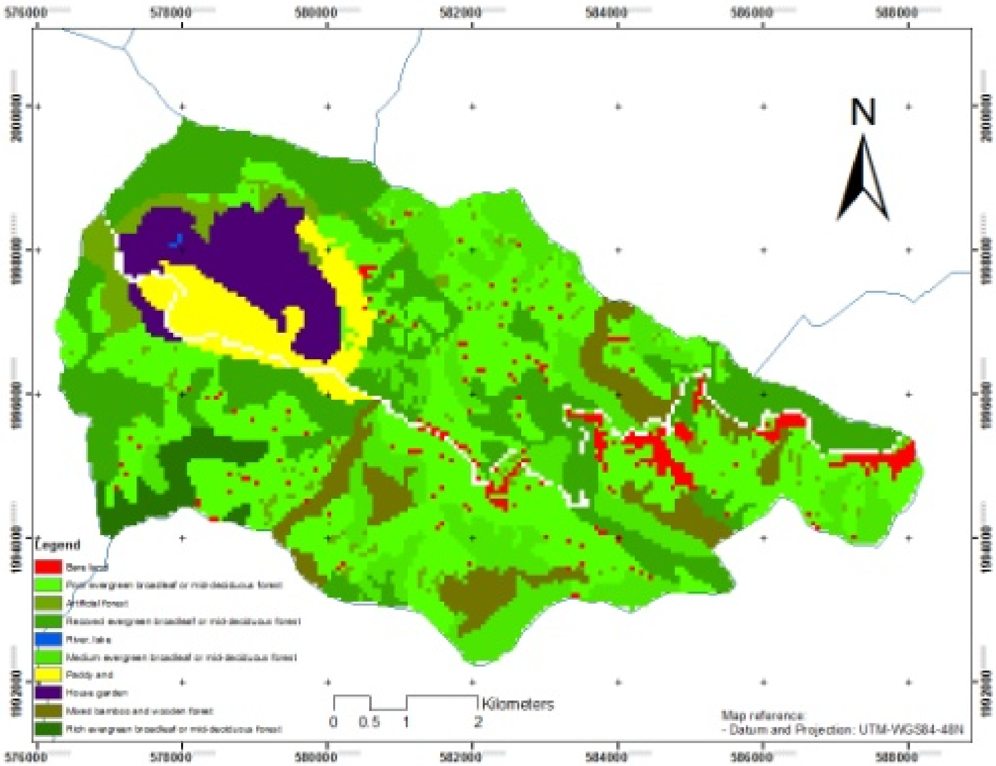

Figure 4c(2). Agroecological zones, Huong Lien commune

References

Websites

People's Committee Ha Tinh province, 2014.

http://www.hatinh.gov.vn/thanhtuukinhte/chitieukinhte/Pages/default.aspx/ Accessed on June 30, 2014

Viet Nam General Statistics Office, 2014. http://www.gso.gov.vn/ Accessed on June 30, 2014

Literature

Biodiversity Conservation Agency (BCA), WWF, and Stockholm University. 2013. Ecosystems classification mapping in Vietnam. Hanoi, Vietnam.

Bishop, Y. M. M., S. E. Fienberg, and P. W. Holland. 1975. Discrete Multivariate Analysis: Theory and Practice. MIT Press, Cambridge, Massachusetts.

Bouma, E. 2006. Development of comparable agro-climatic zones for the international exchange of data on the efficacy and crop safety of plant protection products. OEPP/EPPO Bulletin **35**:233-238.

Brogaard, S. and R. Olafsdottir. 1997. Ground-truths or Ground-lies? Environmental sampling for remote sensing application exemplified by vegetation cover data. Lund Electronic Reports in Physical Geography **1**.

Brown, M. E. 2009. Biophysical remote sensing and climate data in famine early warning systems. Geography Compass **3**:1381-1407.

Congalton, R. 1991. A review of Assessing the Accuracy of Classification of Remotely Sensed Data. Remote Sensing of Environment **37**:35-46.

Doan, T. T. U. 2014. The summarize report of thesis. Assessing status and proposing solutions to develop agricultural ecosystem to climate change adaptation in Huong Lien commune, Huong Khe district, Ha Tinh province. Hanoi Agricultural University. Hanoi.

Dunn, C. 2007. Participatory GIS - a people's GIS? Progress in Human Geography **31**:616.

FAO. 1996. Agro-ecological zoning. Soil resources, managment and conservation service. FAO Land and Water Development Division. Food and Agriculture Organization of the United Nations, Rome.

FAO. 2013. Climate-smart agriculture - Sourcebook. Page 570. Food and Agriculture Organization of the United Nations, Rome.

ISPONRE. 2009. Ha Tinh assessment report on climate change. Institute of Strategy and Policy on Natural Resources and Environment (ISPONRE), Ha Noi, Viet Nam.

Jensen, J. R. 1996. Introductory Digital Image Processing - A remote sensing perspective. Second Edition edition. Prentice Hall, Upper Saddle River, New Jersey.

Larrazabal, A., M. McCall, T. Mwampamba, and M. Skutsch. 2012. The role of community carbon monitoring for REDD+: A review of experiences. Current Opinion in Environmental Sustainability **4**:707-716.

Leisz, S. J. and M. S. Rasmussen. 2012. Mapping fallow lands in Vietnam's north central mountains using yearly Landsat imagery and a land-cover succession model. International Journal of Remote Sensing **33**:6281-6303.

Lindström, S., E. Mattsson, and S. P. Nissanka. 2012. Forest cover change in Sri Lanka: The role of small scale farmers. Applied Geography **34**:680-692.

McCall, M. and P. A. Minang. 2005. Assessing participatory GIS for community-based natural resource management: claiming community forests in Cameroon. The Geographical Journal **171**:340-356.

Nair, P. K. R. and D. Garrity. 2012. Agroforestry-The future of global land use. Advances in Agroforestry **9**:531.

Newsham, A. J. and D. S. Thomas. 2011. Knowing, farming and climate change adaptation in North-Central Namibia. Global Environmental Change **22**.

Nguyen, D. T., D. N. Dinh, N. T. Do, and N. H. T. Mai. 2013a. Using remote sensing data with high temporal resolution for rice monitoring and yield prediction in winter-spring rice season in Phu My District, Binh Dinh Province. Pages 73-79 *in* Seminar proceedings Nationwide GIS applications Hanoi.

Nguyen, H., T. Nguyen, and L. Nguyen. 2013b. Using object-based classification method for building land use and land cover – a case study in Tien Yen district, Quang Ninh province. Pages 195-201 *in* Proceedings seminars nationwide GIS applications, Hanoi.

Nguyen, T. T. H., T. L. Nguyen, T. D. Vien, and S. J. Leisz. 2006. Composite swiddening agroecosystem: Recent status and its future in the Northern Mountain Region of Vietnam. International symposium towards sustainable livelihoods and ecosystems in mountainous regions. . Chiang Mai, Thailand.

Pansak, W., T. Hilger, B. Lusiana, T. Kongkaew, C. Marohn, and G. Cadisch. 2010. Assessing soil conservation strategies for upland cropping in Northeast Thailand with the WaNuLCAS model. Agroforestry Systems **79**:123-144.

PC. 2014. Report on the implementation of socio-economic development, defense - security in 2013; direction, objectives and tasks in 2014, Huong Lien commune, Ha Tinh province. People's Committee Huong Lien commune, Ha Tinh.

Sietz, D., M. Ludeke, and C. Walther. 2011. Categorisation of typical vulnerability patterns in global drylands. Global Environmental Change **21**:431-440.

Simelton, E., B. V. Dam, and D. Catacutan. submitted-a. Trees and agroforestry for coping with extreme weather events - experiences from northern and central Viet Nam Agroforestry Systems.

Simelton, E., B. V. Dam, A. T. Ngo, K. Q. Doan, and H. Nguyen. submitted-b. Household Food Security and Land Use Diversification in northern Viet Nam. Land Use Policy.

Simelton, E., V. B. Dam, R. Finlayson, and R. Lasco. 2013a. The talking toolkit: how smallholding farmers and local governments can together adapt to climate change. World Agroforestry Centre (ICRAF), Ha Noi, Viet Nam.

Simelton, E., C. Quinn, N. Batisani, A. Dougill, J. Dyer, E. Fraser, D. Mkwambisi, S. Sallu, and L. Stringer. 2013b. Is rainfall really changing? Farmers' perceptions, meteorological data, and policy implications. Climate and Development **5**:123-138.

Song, F., H. Qi, and Q. Weihong. 2004. Quality control of daily meteorological data in China, 1951-2000: A new dataset. International Journal of Climatology **24**:853-870.

Sutton, W., J. Srivastava, and J. Neumann. 2013. Risks, Impacts, and Adaptation Menus for Study Countries. Pages 65-110 Looking Beyond the Horizon: How Climate Change Impacts and Adaptation Responses Will Reshape Agriculture in Eastern Europe and Central Asia. World Bank, Washington.

Tchoundjeu, Z., A. Degrande, R. Leakey, G. Nimino, E. Kemajou, E. Asaah, C. Facheux, P. Mbile, C. Mbosso, T. Sado, and A. Tsobeng. 2010. Impacts of participatory tree domestication on farmer livelihoods in West and Central Africa. Forests, Trees and Livelihoods **19**:217-234.

Thenkabail, P., C. Nolte, and J. G. Lyon. 2000. Remote sensing and GIS modeling for selection of a benchmark research area in the inland valley agroecosystems of West and Central Africa. Photogrammetric Engineering & Remote Sensing **66**:755-768.

Tian, Z., H. Zhong, L. Sun, G. Fischer, H. van Velthuizen, and Z. Liang. 2013. Improving performance of Agro-Ecological Zone (AEZ) modeling by cross-scale model coupling: An application to japonica rice production in Northeast China. Ecological Modelling.

Tolo, C. U., E. Majule, and J. Perfect. 2012. Changing Trends of Natural Resources Degradation in Kagera Basin: Case Study of Kagera Sub-Basin, Uganda. Natural Resources **3**:95-106.

Tran, H. T., Q. T. Phan, T. T. T. Cao, D. V. Luong, and D. T. Nguyen. 2013. Application remote sensing technology in the building sustainable forest for management and sustainable use in Phong Nha - Ke Bang national park Pages 95-104 in Seminar proceedings Nationwide GIS applications Hanoi.

Tucker, C. 1979. Red and photographic infrared linear combinations for monitoring vegetation. Remote Sensing of Environment **8**:127-150.

Vajjhala, S. P. and W. M. Walker. 2009. Roads to Participatory Planning. Integrating Cognitive Mapping and GIS for Transport Prioritization in Rural Lesotho. Resources for the future, Washington.

Van Noordwijk, M., M. H. Hoang, H. Neufeldt, I. Oborn, and T. Yatich. 2011. How trees and people can co-adapt to climate change. Reducing vulnerability in multifunctional landscapes. Page 136. World Agroforestry Centre (ICRAF), Nairobi.

Villamor, G., M. van Noordwijk, Q. Le, B. Lusiana, R. Matthews, and P. Vlek. 2010. Diversity deficits in modelled landscape mosaics. Ecological Informatics.

WORKING PAPERS WITH DOIs

2005

1. Agroforestry in the drylands of eastern Africa: a call to action
2. Biodiversity conservation through agroforestry: managing tree species diversity within a network of community-based, nongovernmental, governmental and research organizations in western Kenya.
3. Invasion of *prosopis juliflora* and local livelihoods: Case study from the Lake Baringo area of Kenya
4. Leadership for change in farmers organizations: Training report: Ridar Hotel, Kampala, 29th March to 2nd April 2005.
5. Domestication des espèces agroforestières au Sahel : situation actuelle et perspectives
6. Relevé des données de biodiversité ligneuse: Manuel du projet biodiversité des parcs agroforestiers au Sahel
7. Improved land management in the Lake Victoria Basin: TransVic Project's draft report.
8. Livelihood capital, strategies and outcomes in the Taita hills of Kenya
9. Les espèces ligneuses et leurs usages: Les préférences des paysans dans le Cercle de Ségou, au Mali
10. La biodiversité des espèces ligneuses: Diversité arborée et unités de gestion du terroir dans le Cercle de Ségou, au Mali

2006

11. Bird diversity and land use on the slopes of Mt. Kilimanjaro and the adjacent plains, Tanzania
12. Water, women and local social organization in the Western Kenya Highlands
13. Highlights of ongoing research of the World Agroforestry Centre in Indonesia
14. Prospects of adoption of tree-based systems in a rural landscape and its likely impacts on carbon stocks and farmers' welfare: The FALLOW Model Application in Muara Sungkai, Lampung, Sumatra, in a 'Clean Development Mechanism' context
15. Equipping integrated natural resource managers for healthy Agroforestry landscapes.
17. Agro-biodiversity and CGIAR tree and forest science: approaches and examples from Sumatra.
18. Improving land management in eastern and southern Africa: A review of policies.
19. Farm and household economic study of Kecamatan Nanggung, Kabupaten Bogor, Indonesia: A socio-economic base line study of Agroforestry innovations and livelihood enhancement.
20. Lessons from eastern Africa's unsustainable charcoal business.
21. Evolution of RELMA's approaches to land management: Lessons from two decades of research and development in eastern and southern Africa
22. Participatory watershed management: Lessons from RELMA's work with farmers in eastern Africa.
23. Strengthening farmers' organizations: The experience of RELMA and ULAMP.
24. Promoting rainwater harvesting in eastern and southern Africa.
25. The role of livestock in integrated land management.
26. Status of carbon sequestration projects in Africa: Potential benefits and challenges to scaling up.
27. Social and Environmental Trade-Offs in Tree Species Selection: A Methodology for Identifying Niche Incompatibilities in Agroforestry *[Appears as AHI Working Paper no. 9]*
28. Managing tradeoffs in agroforestry: From conflict to collaboration in natural resource management. *[Appears as AHI Working Paper no. 10]*
29. Essai d'analyse de la prise en compte des systemes agroforestiers pa les legislations forestieres au Sahel: Cas du Burkina Faso, du Mali, du Niger et du Senegal.
30. Etat de la recherche agroforestière au Rwanda etude bibliographique, période 1987-2003

2007

31. Science and technological innovations for improving soil fertility and management in Africa: A report for NEPAD's Science and Technology Forum.
32. Compensation and rewards for environmental services.
33. Latin American regional workshop report compensation.
34. Asia regional workshop on compensation ecosystem services.
35. Report of African regional workshop on compensation ecosystem services.

36. Exploring the inter-linkages among and between compensation and rewards for ecosystem services CRES and human well-being
37. Criteria and indicators for environmental service compensation and reward mechanisms: realistic, voluntary, conditional and pro-poor
38. The conditions for effective mechanisms of compensation and rewards for environmental services.
39. Organization and governance for fostering Pro-Poor Compensation for Environmental Services.
40. How important are different types of compensation and reward mechanisms shaping poverty and ecosystem services across Africa, Asia & Latin America over the Next two decades?
41. Risk mitigation in contract farming: The case of poultry, cotton, woodfuel and cereals in East Africa.
42. The RELMA savings and credit experiences: Sowing the seed of sustainability
43. Yatich J., Policy and institutional context for NRM in Kenya: Challenges and opportunities for Landcare.
44. Nina-Nina Adoung Nasional di So! Field test of rapid land tenure assessment (RATA) in the Batang Toru Watershed, North Sumatera.
45. Is Hutan Tanaman Rakyat a new paradigm in community based tree planting in Indonesia?
46. Socio-Economic aspects of brackish water aquaculture (*Tambak*) production in Nanggroe Aceh Darrusalam.
47. Farmer livelihoods in the humid forest and moist savannah zones of Cameroon.
48. Domestication, genre et vulnérabilité : Participation des femmes, des Jeunes et des catégories les plus pauvres à la domestication des arbres agroforestiers au Cameroun.
49. Land tenure and management in the districts around Mt Elgon: An assessment presented to the Mt Elgon ecosystem conservation programme.
50. The production and marketing of leaf meal from fodder shrubs in Tanga, Tanzania: A pro-poor enterprise for improving livestock productivity.
51. Buyers Perspective on Environmental Services (ES) and Commoditization as an approach to liberate ES markets in the Philippines.
52. Towards Towards community-driven conservation in southwest China: Reconciling state and local perceptions.
53. Biofuels in China: An Analysis of the Opportunities and Challenges of Jatropha curcas in Southwest China.
54. Jatropha curcas biodiesel production in Kenya: Economics and potential value chain development for smallholder farmers
55. Livelihoods and Forest Resources in Aceh and Nias for a Sustainable Forest Resource Management and Economic Progress
56. Agroforestry on the interface of Orangutan Conservation and Sustainable Livelihoods in Batang Toru, North Sumatra.
57. Assessing Hydrological Situation of Kapuas Hulu Basin, Kapuas Hulu Regency, West Kalimantan.
58. Assessing the Hydrological Situation of Talau Watershed, Belu Regency, East Nusa Tenggara.
59. Kajian Kondisi Hidrologis DAS Talau, Kabupaten Belu, Nusa Tenggara Timur.
60. Kajian Kondisi Hidrologis DAS Kapuas Hulu, Kabupaten Kapuas Hulu, Kalimantan Barat.
61. Lessons learned from community capacity building activities to support agroforest as sustainable economic alternatives in Batang Toru orang utan habitat conservation program (Martini, Endri et al.)
62. Mainstreaming Climate Change in the Philippines.
63. A Conjoint Analysis of Farmer Preferences for Community Forestry Contracts in the Sumber Jaya Watershed, Indonesia.
64. The highlands: a shared water tower in a changing climate and changing Asia
65. Eco-Certification: Can It Deliver Conservation and Development in the Tropics.
66. Designing ecological and biodiversity sampling strategies. Towards mainstreaming climate change in grassland management.
67. Towards mainstreaming climate change in grassland management policies and practices on the Tibetan Plateau
68. An Assessment of the Potential for Carbon Finance in Rangelands

69 ECA Trade-offs Among Ecosystem Services in the Lake Victoria Basin.

69. The last remnants of mega biodiversity in West Java and Banten: an in-depth exploration of RaTA (Rapid Land Tenure Assessment) in Mount Halimun-Salak National Park Indonesia
70. Le business plan d’une petite entreprise rurale de production et de commercialisation des plants des arbres locaux. Cas de quatre pépinières rurales au Cameroun.

71. Les unités de transformation des produits forestiers non ligneux alimentaires au Cameroun. Diagnostic technique et stratégie de développement Honoré Tabuna et Ingratia Kayitavu.
72. Les exportateurs camerounais de safou (Dacryodes edulis) sur le marché sous régional et international. Profil, fonctionnement et stratégies de développement.
73. Impact of the Southeast Asian Network for Agroforestry Education (SEANAFE) on agroforestry education capacity.
74. Setting landscape conservation targets and promoting them through compatible land use in the Philippines.
75. Review of methods for researching multistrata systems.
76. Study on economical viability of *Jatropha curcas* L. plantations in Northern Tanzania assessing farmers' prospects via cost-benefit analysis
77. Cooperation in Agroforestry between Ministry of Forestry of Indonesia and International Center for Research in Agroforestry
78. "China's bioenergy future. an analysis through the Lens if Yunnan Province
79. Land tenure and agricultural productivity in Africa: A comparative analysis of the economics literature and recent policy strategies and reforms
80. Boundary organizations, objects and agents: linking knowledge with action in Agroforestry watersheds
81. Reducing emissions from deforestation and forest degradation (REDD) in Indonesia: options and challenges for fair and efficient payment distribution mechanisms

2009

82. Mainstreaming climate change into agricultural education: challenges and perspectives
83. Challenging conventional mindsets and disconnects in conservation: the emerging role of eco-agriculture in Kenya's landscape mosaics
84. Lesson learned RATA garut dan bengkunat: suatu upaya membedah kebijakan pelepasan kawasan hutan dan redistribusi tanah bekas kawasan hutan
85. The emergence of forest land redistribution in Indonesia
86. Commercial opportunities for fruit in Malawi
87. Status of fruit production processing and marketing in Malawi
88. Fraud in tree science
89. Trees on farm: analysis of global extent and geographical patterns of agroforestry
90. The springs of Nyando: water, social organization and livelihoods in Western Kenya
91. Building capacity toward region-wide curriculum and teaching materials development in agroforestry education in Southeast Asia
92. Overview of biomass energy technology in rural Yunnan (Chinese – English abstract)
93. A pro-growth pathway for reducing net GHG emissions in China
94. Analysis of local livelihoods from past to present in the central Kalimantan Ex-Mega Rice Project area
95. Constraints and options to enhancing production of high quality feeds in dairy production in Kenya, Uganda and Rwanda

2010

96. Agroforestry education in the Philippines: status report from the Southeast Asian Network for Agroforestry Education (SEANAFE)
97. Economic viability of Jatropha curcas L. plantations in Northern Tanzania- assessing farmers' prospects via cost-benefit analysis.
98. Hot spot of emission and confusion: land tenure insecurity, contested policies and competing claims in the central Kalimantan Ex-Mega Rice Project area
99. Agroforestry competences and human resources needs in the Philippines
100. CES/COS/CIS paradigms for compensation and rewards to enhance environmental Services
101. Case study approach to region-wide curriculum and teaching materials development in agroforestry education in Southeast Asia
102. Stewardship agreement to reduce emissions from deforestation and degradation (REDD): Lubuk Beringin's Hutan Desa as the first village forest in Indonesia
103. Landscape dynamics over time and space from ecological perspective
104. Komoditisasi atau koinvestasi jasa lingkungan: skema imbal jasa lingkungan program peduli sungai di DAS Way Besai, Lampung, Indonesia

105. Improving smallholders' rubber quality in Lubuk Beringin, Bungo district, Jambi province, Indonesia: an initial analysis of the financial and social benefits
106. Rapid Carbon Stock Appraisal (RACSA) in Kalahan, Nueva Vizcaya, Philippines
107. Tree domestication by ICRAF and partners in the Peruvian Amazon: lessons learned and future prospects in the domain of the Amazon Initiative eco-regional program
108. Memorias del Taller Nacional: "Iniciativas para Reducir la Deforestación en la region Andino - Amazónica", 09 de Abril del 2010. Proyecto REALU Peru
109. Percepciones sobre la Equidad y Eficiencia en la cadena de valor de REDD en Perú –Reporte de Talleres en Ucayali, San Martín y Loreto, 2009. Proyecto REALU-Perú.
110. Reducción de emisiones de todos los Usos del Suelo. Reporte del Proyecto REALU Perú Fase 1
111. Programa Alternativas a la Tumba-y-Quema (ASB) en el Perú. Informe Resumen y Síntesis de la Fase II. 2da. versión revisada
112. Estudio de las cadenas de abastecimiento de germoplasma forestal en la amazonía Boliviana
113. Biodiesel in the Amazon
114. Estudio de mercado de semillas forestales en la amazonía Colombiana
115. Estudio de las cadenas de abastecimiento de germoplasma forestal en Ecuador http://dx.doi.org10.5716/WP10340.PDF
116. How can systems thinking, social capital and social network analysis help programs achieve impact at scale?
117. Energy policies, forests and local communities in the Ucayali Region, Peruvian Amazon
118. NTFPs as a Source of Livelihood Diversification for Local Communities in the Batang Toru Orangutan Conservation Program
119. Studi Biodiversitas: Apakah agroforestry mampu mengkonservasi keanekaragaman hayati di DAS Konto?
120. Estimasi Karbon Tersimpan di Lahan-lahan Pertanian di DAS Konto, Jawa Timur
121. Implementasi Kaji Cepat Hidrologi (RHA) di Hulu DAS Brantas, Jawa Timur. http://dx.doi.org/10.5716/WP10338.PDF
122. Kaji Cepat Hidrologi di Daerah Aliran Sungai Krueng Peusangan, NAD,Sumatra http://dx.doi.org/10.5716/WP10337.PDF
123. A Study of Rapid Hydrological Appraisal in the Krueng Peusangan Watershed, NAD, Sumatra. http://dx.doi.org/10.5716/WP10339.PDF

2011

124. An Assessment of farm timber value chains in Mt Kenya area, Kenya
125. A Comparative financial analysis of current land use systems and implications for the adoption of improved agroforestry in the East Usambaras, Tanzania
126. Agricultural monitoring and evaluation systems
127. Challenges and opportunities for collaborative landscape governance in the East Usambara Mountains, Tanzania
128. Transforming Knowledge to Enhance Integrated Natural Resource Management Research, Development and Advocacy in the Highlands of Eastern Africa http://dx.doi.org/10.5716/WP11084.PDF
129. Carbon-forestry projects in the Philippines: potential and challenges The Mt Kitanglad Range forest-carbon development http://dx.doi.org10.5716/WP11054.PDF
130. Carbon forestry projects in the Philippines: potential and challenges. The Arakan Forest Corridor forest-carbon project http://dx.doi.org10.5716/WP11055.PDF
131. Carbon-forestry projects in the Philippines: potential and challenges. The Laguna Lake Development Authority's forest-carbon development project http://dx.doi.org/10.5716/WP11056.PDF
132. Carbon-forestry projects in the Philippines: potential and challenges. The Quirino forest-carbon development project in Sierra Madre Biodiversity Corridor http://dx.doi.org10.5716/WP11057.PDF
133. Carbon-forestry projects in the Philippines: potential and challenges. The Ikalahan Ancestral Domain forest-carbon development http://dx.doi.org10.5716/WP11058.PDF
134. The Importance of Local Traditional Institutions in the Management of Natural Resources in the Highlands of Eastern Africa http://dx.doi.org/10.5716/WP11085.PDF
135. Socio-economic assessment of irrigation pilot projects in Rwanda http://dx.doi.org/10.5716/WP11086.PDF
136. Performance of three rambutan varieties*(Nephelium lappaceum* L.*)* on various nursery media http://dx.doi.org/10.5716/WP11232.PDF

137. Climate change adaptation and social protection in agroforestry systems: enhancing adaptive capacity and minimizing risk of drought in Zambia and Honduras http://dx.doi.org/10.5716/WP11269.PDF
138. Does value chain development contribute to rural poverty reduction? Evidence of asset building by smallholder coffee producers in Nicaragua http://dx.doi.org/10.5716/WP11271.PDF
139. Potential for biofuel feedstock in Kenya. http://dx.doi.org/10.5716/WP11272.PDF
140. Impact of fertilizer trees on maize production and food security in six districts of Malawi. http://dx.doi.org/10.5716/WP11281.PDF

2012

141. Fortalecimiento de capacidades para la gestión del Santuario Nacional Pampa Hermosa: Construyendo las bases para un manejo adaptativo para el desarrollo local. Memorias del Proyecto. http://dx.doi.org/10.5716/WP12005.PDF
142. Understanding rural institutional strengthening: A cross-level policy and institutional framework for sustainable development in Kenya http://dx.doi.org/10.5716/WP12012.PDF
143. Climate change vulnerability of agroforestry http://dx.doi.org/10.5716/WP16722.PDF
144. Rapid assesment of the inner Niger delta of Mali http://dx.doi.org/10.5716/WP12021.PDF
145. Designing an incentive program to reduce on-farm deforestationin the East Usambara Mountains, Tanzania http://dx.doi.org/10.5716/WP12048.PDF
146. Extent of adoption of conservation agriculture and agroforestry in Africa: the case of Tanzania, Kenya, Ghana, and Zambia http://dx.doi.org/10.5716/WP12049.PDF
147. Policy incentives for scaling up conservation agriculture with trees in Africa: the case of Tanzania, Kenya, Ghana and Zambia http://dx.doi.org/10.5716/WP12050.PDF
148. Commoditized or co-invested environmental services? Rewards for environmental services scheme: River Care program Way Besai watershed, Lampung, Indonesia. http://dx.doi.org/10.5716/WP12051.PDF
149. Assessment of the headwaters of the Blue Nile in Ethiopia. http://dx.doi.org/10.5716/WP12160.PDF
150. Assessment of the uThukela Watershed, Kwazaulu. http://dx.doi.org/10.5716/WP12161.PDF
151. Assessment of the Oum Zessar Watershed of Tunisia. http://dx.doi.org/10.5716/WP12162.PDF
152. Assessment of the Ruwenzori Mountains in Uganda. http://dx.doi.org/10.5716/WP12163.PDF
153. History of agroforestry research and development in Viet Nam. Analysis of research opportunities and gaps. http://dx.doi.org/10.5716/WP12052.PDF
154. REDD+ in Indonesia: a Historical Perspective. http://dx.doi.org/10.5716/WP12053.PDF
155. Agroforestry and Forestry in Sulawesi series: Livelihood strategies and land use system dynamics in South Sulawesi http://dx.doi.org/10.5716/WP12054.PDF
156. Agroforestry and Forestry in Sulawesi series: Livelihood strategies and land use system dynamics in Southeast Sulawesi. http://dx.doi.org/10.5716/WP12055.PDF
157. Agroforestry and Forestry in Sulawesi series: Profitability and land-use systems in South and Southeast Sulawesi. http://dx.doi.org/10.5716/WP12056.PDF
158. Agroforestry and Forestry in Sulawesi series: Gender, livelihoods and land in South and Southeast Sulawesi http://dx.doi.org/10.5716/WP12057.PDF
159. Agroforestry and Forestry in Sulawesi series: Agroforestry extension needs at the community level in AgFor project sites in South and Southeast Sulawesi, Indonesia. http://dx.doi.org/10.5716/WP12058.PDF
160. Agroforestry and Forestry in Sulawesi series: Rapid market appraisal of agricultural, plantation and forestry commodities in South and Southeast Sulawesi. http://dx.doi.org/10.5716/WP12059.PDF

2013

161. Diagnosis of farming systems in the Agroforestry for Livelihoods of Smallholder farmers in Northwestern Viet Nam project http://dx.doi.org/10.5716/WP13033.PDF
162. Ecosystem vulnerability to climate change: a literature review. http://dx.doi.org/10.5716/WP13034.PDF
163. Local capacity for implementing payments for environmental services schemes: lessons from the RUPES project in northeastern Viet Nam http://dx.doi.org/10.5716/WP13046.PDF
164. Seri Agroforestri dan Kehutanan di Sulawesi: Agroforestry dan Kehutanan di Sulawesi: Strategi mata pencaharian dan dinamika sistem penggunaan lahan di Sulawesi Selatan http://dx.doi.org/10.5716/WP13040.PDF
165. Seri Agroforestri dan Kehutanan di Sulawesi: Mata pencaharian dan dinamika sistem penggunaan lahan di Sulawesi Tenggara http://dx.doi.org/10.5716/WP13041.PDF
166. Seri Agroforestri dan Kehutanan di Sulawesi: Profitabilitas sistem penggunaan lahan di Sulawesi Selatan dan Sulawesi Tenggara http://dx.doi.org/10.5716/WP13042.PDF

167. Seri Agroforestri dan Kehutanan di Sulawesi: Gender, mata pencarian dan lahan di Sulawesi Selatan dan Sulawesi Tenggara http://dx.doi.org/10.5716/WP13043.PDF
168. Seri Agroforestri dan Kehutanan di Sulawesi: Kebutuhan penyuluhan agroforestri pada tingkat masyarakat di lokasi proyek AgFor di Sulawesi Selatan dan Tenggara, Indonesia http://dx.doi.org/10.5716/WP13044.PDF
169. Seri Agroforestri dan Kehutanan di Sulawesi: Laporan hasil penilaian cepat untuk komoditas pertanian, perkebunan dan kehutanan di Sulawesi Selatan dan Tenggara http://dx.doi.org/10.5716/WP13045.PDF
170. Agroforestry, food and nutritional security http://dx.doi.org/10.5716/WP13054.PDF
171. Stakeholder Preferences over Rewards for Ecosystem Services: Implications for a REDD+ Benefit Distribution System in Viet Nam http://dx.doi.org/10.5716/WP13057.PDF
172. Payments for ecosystem services schemes: project-level insights on benefits for ecosystems and the rural poor http://dx.doi.org/10.5716/WP13001.PDF
173. Good practices for smallholder teak plantations: keys to success http://dx.doi.org/10.5716/WP13246.PDF
174. Market analysis of selected agroforestry products in the Vision for Change Project intervention Zone, Côte d'Ivoire http://dx.doi.org/10.5716/WP13249.PDF
175. Rattan futures in Katingan: why do smallholders abandon or keep their gardens in Indonesia's 'rattan district'? http://dx.doi.org/10.5716/WP13251.PDF
176. Management along a gradient: the case of Southeast Sulawesi's cacao production landscapes http://dx.doi.org/10.5716/WP13265.PDF

2014

177. Are trees buffering ecosystems and livelihoods in agricultural landscapes of the Lower Mekong Basin? Consequences for climate-change adaptation. http://dx.doi.org/10.5716/WP14047.PDF
178. Agroforestry, livestock, fodder production and climate change adaptation and mitigation in East Africa: issues and options. http://dx.doi.org/10.5716/WP14050.PDF
179. Trees on farms: an update and reanalysis of agroforestry's global extent and socio-ecological characteristics. http://dx.doi.org/10.5716/WP14064.PDF
180. Beyond reforestation: an assessment of Vietnam's REDD+ readiness. http://dx.doi.org/10.5716/WP14097.PDF
181. Farmer-to-farmer extension in Kenya: the perspectives of organizations using the approach. http://dx.doi.org/10.5716/WP14380.PDF
182. Farmer-to-farmer extension in Cameroon: a survey of extension organizations. http://dx.doi.org/10.5716/WP14383.PDF
183. Farmer-to-farmer extension approach in Malawi: a survey of organizations: a survey of organizations http://dx.doi.org/10.5716/WP14391.PDF
184. Seri Agroforestri dan Kehutanan di Sulawesi: Kuantifikasi jasa lingkungan air dan karbon pola agroforestri pada hutan rakyat di wilayah sungai Jeneberang
185. Options for Climate-Smart Agriculture at Kaptumo Site in Kenyahttp://dx.doi.org/10.5716/WP14394.PDF

2015

186. Agroforestry for Landscape Restoration and Livelihood Development in Central Asia http://dx.doi.org/10.5716/WP14143.PDF
187. "Projected Climate Change and Impact on Bioclimatic Conditions in the Central and South-Central Asia Region" http://dx.doi.org/10.5716/WP14144.PDF
188. Land Cover Changes, Forest Loss and Degradation in Kutai Barat, Indonesia http://dx.doi.org/10.5716/WP14145.PDF
189. The Farmer-to-Farmer Extension Approach in Malawi: A Survey of Lead Farmers. http://dx.doi.org/10.5716/WP14152.PDF
190. Evaluating indicators of land degradation and targeting agroforestry interventions in smallholder farming systems in Ethiopia. http://dx.doi.org/10.5716/WP14252.PDF
191. Land health surveillance for identifying land constraints and targeting land management options in smallholder farming systems in Western Cameroon
192. Land health surveillance in four agroecologies in Malawi
193. Cocoa Land Health Surveillance: an evidence-based approach to sustainable management of cocoa landscapes in the Nawa region, South-West Côte d'Ivoire http://dx.doi.org/10.5716/WP14255.PDF
194. Situational analysis report: Xishuangbanna autonomous Dai Prefecture, Yunnan Province, China. http://dx.doi.org/10.5716/WP14255.PDF

195. Farmer-to-farmer extension: a survey of lead farmers in Cameroon. http://dx.doi.org/10.5716/WP15009.PDF
196. From transition fuel to viable energy source Improving sustainability in the sub-Saharan charcoal sector http://dx.doi.org/10.5716/WP15011.PDF
197. Mobilizing Hybrid Knowledge for More Effective Water Governance in the Asian Highlands http://dx.doi.org/10.5716/WP15012.PDF
198. Water Governance in the Asian Highlands http://dx.doi.org/10.5716/WP15013.PDF
199. Assessing the Effectiveness of the Volunteer Farmer Trainer Approach in Dissemination of Livestock Feed Technologies in Kenya vis-à-vis other Information Sources http://dx.doi.org/10.5716/WP15022.PDF
200. The rooted pedon in a dynamic multifunctional landscape: Soil science at the World Agroforestry Centre http://dx.doi.org/10.5716/WP15023.PDF
201. Characterising agro-ecological zones with local knowledge. Case study: Huong Khe district, Ha Tinh, Viet Nam http://dx.doi.org/10.5716/WP15050.PDF

The World Agroforestry Centre is an autonomous, non-profit research organization whose vision is a rural transformation in the developing world as smallholder households increase their use of trees in agricultural landscapes to improve food security, nutrition, income, health, shelter, social cohesion, energy resources and environmental sustainability. The Centre generates science-based knowledge about the diverse roles that trees play in agricultural landscapes, and uses its research to advance policies and practices, and their implementation that benefit the poor and the environment. It aims to ensure that all this is achieved by enhancing the quality of its science work, increasing operational efficiency, building and maintaining strong partnerships, accelerating the use and impact of its research, and promoting greater cohesion, interdependence and alignment within the organization.

United Nations Avenue, Gigiri • PO Box 30677 • Nairobi, 00100 • Kenya
Telephone: +254 20 7224000 or via USA +1 650 833 6645
Fax: +254 20 7224001 or via USA +1 650 833 6646
Email: worldagroforestry@cgiar.org • www.worldagroforestry.org

Southeast Asia Regional Program • Sindang Barang • Bogor 16680
PO Box 161 • Bogor 16001 • Indonesia
Telephone: +62 251 8625415 • Fax: +62 251 8625416
Email: icraf-indonesia@cgiar.org • www.worldagroforestry.org/regions/southeast_asia