Expansion of road networks in upland production areas: Impacts on landscapes and livelihoods in Huaphan Province, Lao PDR

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ABSTRACT

Land use and land cover change are very important that they affect the earth system function. The main driving forces for these changes are the interactions of human on land use in response to economic opportunities or markets development and policies. This lead to creation of opportunities and constraints for new land uses, and in turn has impact on livelihood. This research analyses the patterns of maize expansion in a northeastern province of Lao PDR (Huaphan province) in relation with the construction of feeder roads to reach maize production areas with hand tractors or small trucks. The study assesses the impact of the feeder roads constructed in the period from 2006 to 2008 on the subsequent period from 2009 to 2016 through the analysis of a chronological series of remote sensing data combined with repeated household surveys in 2009 and in 2016. The combined analysis of data related to social and economic contexts and spatial patterns aimed at: 1) evaluating the impact of feeder roads construction on spatial arrangement in land use and land cover at the village level, 2) quantifying the impact of feeder roads construction on livelihood in terms of agricultural production system, household assets, and income.

The study found that maize expansion supported by the feeder roads expansion led to changes in landscape structure that natural forest cover decreased in every year, while agriculture land in particular upland crop system increased in direction moving to forest areas. Land use intensity gradually emerged along the feeder roads and land sparing was introduced as the beginning state. The impact on livelihood appeared both positive and negative. Positive in term of accessing to market economy and increasing in material assets such as rice mill, motorcycles, and hand tractors, as well as opportunity for off-farm income sources. The negative impacts were brought indirectly to villages through environmental impacts because of forest degradation, soil erosion and fertility loss which affected agriculture practices that villagers had to put more labors and agricultural inputs.

Different livelihood alternatives are already explored by villagers and may be further supported by development projects in the future such as conservation agriculture or opportunities for income diversification through livestock or off-farm activities.

KEYWORDS

Feeder road; landscape; livelihood; land use and land cover change

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Abbreviations

DFID	the UK Department for International Development
FAO	Food and Agriculture Organization
GDEM2	Global Digital Elevation Model Version 2
GIS	Geographic Information System
GPS	Global Positioning System
IPCC	Intergovernmental Panel on Climate Change
MA	the Millennium Ecosystem Assessment
NTFPs	Non-timber Forest Products
PRF	the Poverty Reduction Fund project
RS	Remote Sensing
TEV	the Total Economic Value
USGS	The United States Geological Survey

Chapter 1 Introduction

This chapter introduces the context of the study, that is, the shift from subsistence agriculture to market-oriented agriculture in the northern uplands of Lao PDR, and the role of feeder roads for reaching to remote upland agricultural production areas. Then the chapter presents the objectives of the study, research questions, theoretical framework, literature review, and conceptual framework.

1.1 Background of the Study

Changes in landscapes structure in the form of land use and land cover are very important that they significantly affect the earth system function (Lambin, et al., 2001). They directly impact biotic diversity worldwide (Sala, et al., 2000; Lambin, et al., 2001); contribute to local and regional climate change (Chase, Pielke Sr., Kittel, Nemani, & Running, 2000); global warming (Houghton, Hackler, & Lawrence, 1999; Lambin, et al., 2001); are the primary source of soil degradation (Tolba, El-Kholy, El-Hinnawi, & Munn, 1992; Lambin, et al., 2001); altering ecosystem services – affect the ability of biological systems to support human needs (Vitousek, Mooney, Lubchenco, & Melillo, 1997; Lambin, et al., 2001). These changes also partially determine the vulnerability of places and people to climatic, economic or social-political perturbations (Kasperson, Kasperson, & Turner, 1995; Lambin, et al., 2001). The interactions of people on economic opportunities drive land-cover changes. Local as well as national markets and policies create opportunities and constraints for new land uses (Lambin, et al., 2001).

In northern upland Laos, the main factors altering landscape structures, in particular from forest cover to non-forest, are construction of roads and expansion of land use for agriculture. The government prioritized the improvement of the road transport system to facilitate movement of products (Asian Development Bank, 2014), improving accessibility to communities in order to provide public services such as health care, education, and market opportunity (Warr, 2006). The improvement of all-weather road in Lao PDR has significantly contributed to poverty reduction, provided opportunities to access to market, improved agriculture systems, and helped diversifying sources of income for villagers (Oraboune, 2008). In northern rural upland, many villages where the public investment is hard to reach, villagers decided to invest in opening roads to production areas in order to ease accessing to the land and market opportunity. This brought new income generation opportunities in the form of commercial crops such as rubber or maize, grown under contract-farming systems for export markets (Shi, 2008; Voungvisouk, 2014). This also lead to the shift from swidden-based subsistence agriculture to monocropping-based commercial agriculture is known as the agrarian transition.

However, the transformation of socio-ecological systems has tremendous impacts on landscapes and livelihoods. It has been extensively studied at multiple scales, i.e. regional, national and local, and from different perspectives. In Lao PDR, questions addressed by scholars are related to government policies on expansion of transportation network to rural areas as an instrument of sustainable development (Lestrelin, Castella, & Bourgoin, 2012). Therefore, while it is largely recognized that improved physical accessibility of upland areas to market outlets has a positive impact on livelihoods by providing income generation opportunities, many authors also point to the negative consequences in terms of concentration of residential areas and agricultural production along road networks, deforestation and land degradation (Castella, et al., 2013; Rivera, 2015). Also, as the Government of Laos (GoL) could not financially support the high cost of roads construction to reach all remote villages in the country, an active resettlement policy was implemented in the 1990s and 2000s aimed at moving the villages to the roads wherever the roads could not reach the villages. During more than two decades many villages have been relocated along the roads sometimes voluntarily, sometimes forced, but in all cases with important social consequences for both moving and hosting populations.

Consequently, the trade-offs between economic benefits and environmental losses, and social consequences related to the expansion of road networks in remote upland areas and relocation/merging of villages has been addressed by researchers in an attempt to raise awareness of policy makers about possible negative effects and to define possible compensation mechanisms through e.g. payment for ecosystem services. They balance short term economic opportunities provided by a new road construction versus long term risk of land degradation by applying ecological economics frameworks.

Another scientific question raised by road expansion is related to the induced changes in landscape structures. Agriculture and forestry and intimately linked in traditional shifting cultivation systems. These systems are sustainable as long as long fallow periods regenerate soil fertility between two cropping cycles. Forest environments provide precious ecosystem services to the traditional livelihoods based on swidden agriculture. But when production areas are concentrated along the roads after village resettlements the fallow periods are shortening because of the high population pressure on a limited agricultural space and the rotational cultivation system is not sustainable anymore. The upland fields are invaded by weeds that are not controlled anymore by long fallows and thus required constantly increasing labor investments for manual weeding. These increased weedings (from 2 weedings under 7 to 8 years long fallow to 4 weedings under 2 to 3 years long fallows) in turn exacerbate soil erosion that is already enhanced by the shorter fallow period. Faced with depleted natural resources under shortening fallow periods, the GoL has developed policies aimed at intensifying cropping systems in plots dedicated to agriculture combined while delineating forest areas to be preserved. A combination of land use planning and promotion of commercial crops was expected to overcome issues related to unsustainable swidden systems. These policy instruments tended to transform landscapes patterns from land sharing configurations, i.e. intricate mix of forest and agriculture under traditional swidden and agroforestry systems, to land sparing configurations, i.e. spatial divide between areas dedicated to intensive agriculture on one hand and protected forest on the other hand (Castella, et al., 2013).

But after a numbers of years of implementation, it turned out that land sparing strategies have also led in many places to unsustainable situations. Boom crops such as rubber, banana, maize or cassava, pushed by large market demands in neighboring countries were initially considered as alternatives to swidden systems that would allow intensifying land use. They have provided income opportunities to smallholders when developed through contract farming arrangements. But their uncontrolled expansion has contributed to rapid deforestation and serious land degradation and pollution due to intensive monocropping practices (Voungvisouk, 2014). In many cases, labor productivity gains from mechanization (i.e. tractor tillage, sowing machine, and herbicide sprayers) were reinvested in expanding the area of boom crops despite the constraints imposed on forest conservation by land use plans. The two policies instruments of land use planning and promotion of cash crops were somehow competing for space when implemented at the village level (Broegaard, Vongvisouk, & Mertz, 2016). A compromise has to be found at the local level between cash crop expansion and preservation of ecosystem services provided by forested environments. Sustainable management of natural resources therefore requires managing this trade-off between competing policies. One way to address this trade-off is to consider the conditions for the expansion of cash crops in the landscapes and how they are (or not) constrained by land use plans. However, the conditions of expansion differ largely from place to place depending on local interpretation and implementation of land policies. It is therefore important to better understand the condition of emergence of different landscape patterns and their relative impacts on local livelihoods and ecosystem services.

This research analyses the patterns of maize expansion in a northeastern province of Laos, Huaphan, especially its impacts on landscapes and livelihoods. Maize is a good example of the boom cash crops that contribute to the agrarian transition as government prioritized growing this crop for exporting to neighboring countries (Ministry of Planning and Investment, 2011) and maize already went through successive stages of adoption, expansion, intensification and diversification across the country, unlike for example, banana or cassava. The study will concentrate on one aspect of maize expansion related to the expansion of maize feeder roads. Indeed, in upland area, the construction of small feeder roads to reach maize production areas with hand tractors or small trucks is a key condition to expansion of production areas. In the upland rice based swidden system, farmers have to carry back to the village about from 1 to 2 tones harvest per hectare to the village. But with maize, they have to carry much higher weights (about 6t/ha) which is often considered as a major constraint to maize expansion far from the village residential area. Farmers constructed the roads to agricultural production areas by themselves or contract the maize company to open the road through a loan that they reimburse by selling their maize production at a lower price to reimburse their debt. In the recent years, road expansion to production areas has eased the transition from traditional subsistence production systems to market-oriented systems.

Huaphan is one of those maize production provinces. It is one of the provinces where the populations rely on agricultural production both for living and income generation. In recent years, the provincial authorities have actively encouraged its population to produce cash crop for income generation and rural poverty reduction. They also supported private companies, both domestic and foreign, to invest in agriculture (Willi, 2011; Voungvisouk, 2014). In Huaphan, Xiengkhor was classified as the maize district based on the scale of population involved in the maize contract (49 or about 80% of the villages from the total 62 villages in the district generated their main income from selling maize under contract farming) (Willi, 2011).

This study concentrates on some of the villages of Natong cluster[1]. A study by Viau et al, (2009) revealed that maize was first introduced in this region in 2005. There were only few households grew this crop in that season. However, the great benefit from maize production in that season attracted other villagers to adopt this cash crop and led to maize expansion in the region (Viau, Keophosay, & Castella, 2009).

1.2 Research Objectives

The objectives of this study are to quantify the impact of the feeder road construction on social and economic context and spatial pattern in the study site. The specific objectives are addressed bellow.

(1) To quantify the impacts of the feeder road construction on spatial arrangement in land use and land cover at the village level.
(2) To quantify the impacts of the feeder road construction on livelihood in terms of agricultural production system, household assets, and income.

1.3 Research Questions

This research specifically addresses the questions below:

(1) How feeder road expansion has impacted on land use and land cover at the village scale (land use intensification / land sharing or land sparing)?
(2) How has feeder road expansion impacted on livelihood in terms of agricultural production system, household assets, and income?

1.4 Theoretical framework

This study aimed at analyzing the impacts of maize expansion driven by feeder roads on landscapes and livelihoods. The study was designed base on the related theories of agricultural land use intensity, land sharing versus land sparing, sustainable livelihood framework, and landscape pattern as below.

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1 Village cluster is the group of village. It is an administrative level between district and village.

1.4.1 Land use changes and land use patterns analysis

1.4.1.1 Land use intensity

Lindenmayer et al. (2012) defined land use intensity as “the increased intensity of human use of the land in a given area or the increased number of areas dedicated to a given form of (productive) human land use across a landscape.” While Rudel, et al., (2009) stated that land use intensification generally refers to the intense use of land for modern agriculture dependent upon high yielding varieties with high inputs of fertilizers and pesticides. Land use is a broad topic which is covers many categories. In Laos, land is classified into 8 categories; there are agricultural land, forest land, water area land, industrial land, communication land, cultural land, land for national defense and security, and construction land (National Assembly of Laos, 2003). In this study, only agricultural land is emphasized for discussion.

Agricultural land use intensity is the degree of yield amplification caused by human activities (Dietrich J. , Schmitz, Muller, Fader, Lotze-Campen, & Popp, 2012). Intensive use of agricultural land is driven by increasing demand for agricultural products as the population grows and reduction of agricultural land (Hao & Li, 2011), changing dietary habit (Dietrich J. , Schmitz, Müller, Fader, Lotze-Campen, & Popp, 2012; Pingali, 2007; Von Braun, 2007), increasing in the use of land for non-agriculture, and environmental issues such as soil erosion also lead to intensifying in agriculture (Rudel, et al., 2009). Agricultural intensification sets in motion two countervailing forces – increases and reduces cultivated areas. Initially, intensified production provides farmers with higher yields per hectare and growth in their gross income. This prospect may induce them to expand the area for cultivation. If demand for the products is relatively inelastic, the increase in supply that results from the aggregation of individual farming decisions will result in a decline in crop prices. This will dissuade farmers from expanding the area for crops cultivation (Rudel, et al., 2009).

Many countries worldwide applied the approach of intensification which is believed that when the land is intensified, farmers will not expand area for cultivation and there will be spare land for other use (Rudel, et al., 2009). However, there are arguments that land use intensification could not spare land when there’s strong demand on products and inelastic price of products, and it does not ensure that an environmentally sustainable landscape will be maintained (Rudel, et al., 2009). Also there is debate that land use intensification causes the decline of plant species diversity and effects human well-being in form of impacting on delivering ecosystem services (Allan, et al., 2015).

1.4.1.2 Land sharing versus land sparing

Land sharing integrates the objectives of agriculture and benefits to wildlife on the same land, while land sparing separates intensive farming areas from protected natural habitats at larger scales (The Pariamentary Office of Science and Technology, 2012). The concept of "land sharing" and "land sparing" is the result of argument on how to combine the goals of biodiversity conservation, rural development, and global food security, and the concept of investments in high-tech industrial agriculture which would lead to more efficient land use and allowing for increased food production while sparing land for wild nature, as well as some argument that agriculture and nature need to share the same space, stressing the need to invest in smallholder, environment friendly farming (Kusters, 2014).

Land sharing attempts to meet both agricultural and conservation needs within the same area (Green, Cornell, Scharlemann, & Balmford, 2005), this approach aims to make existing farmland as hospitable to wildlife as possible by reducing pesticide and fertilizer inputs and retaining habitats such as trees, hedges and ponds. Land sharing aims to create a multifunctional landscape that attempts to integrate food production, nature conservation, biofuel production and other ecosystem services. However, it can limit yields, so more land area is required to produce a given amount of food (Fischer, et al., 2008).

One approach to meet the rapidly increasing global demand for agricultural products without causing biodiversity loss is to further intensify and mechanize agricultural production (Kusters, 2014). It is claimed that this will not only raise production but also protect biodiversity, as it ensures more efficient use of scarce lands. It implies setting aside and giving protected status to as many intact ecosystems as possible, while intensively growing crops in industrial agricultural systems on the remaining land. Crop diversity in these farming systems is usually low, individual fields are large, and there is heavy reliance on external inputs. But this form of agriculture has its own critics. It could bring opposite consequences, such as the heavy use of agrochemical can cause problems on land or soil degradation. Also, when intensification attracts a growing number of migrants and creates new business opportunities it may have opposite effect (Kusters, 2014).

1.4.2 Sustainable livelihoods framework

According to Robert Chamber and Gordon R. Conway (1991), “a livelihood comprises the capabilities, assets (stores, resources, claims and access) and activities required for a means of living; a livelihood is sustainable which can cope with and recover from stress and shocks, maintain or enhance its capabilities and assets, and provide sustainable livelihood opportunities for the next generation; and which contributes net benefits to other livelihoods at the local and global levels and in the short and long term”. In 1999, the UK Department for International Development (DFID) refined Chambers and Conway definition of livelihood. DFID defined that “a livelihood comprises the capabilities, assets (including both material and social resources) and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from shocks and stresses and maintain and enhance its capabilities and assets both now and in the future, whilst not undermining the natural resource base” (Satgé, 2002).

The livelihoods framework is a way of understanding how households derive their livelihoods by drawing on capabilities and assets to develop livelihood strategies composed of a range of activities (Satgé, 2002), it demonstrates the factors that constrain or enhance livelihood opportunities and shows how they relate to one another (Serrat, 2008). One of the most widely used frameworks is the one used by the UK Department for International Development (Satgé, 2002) as shown in the (Figure 1-1).

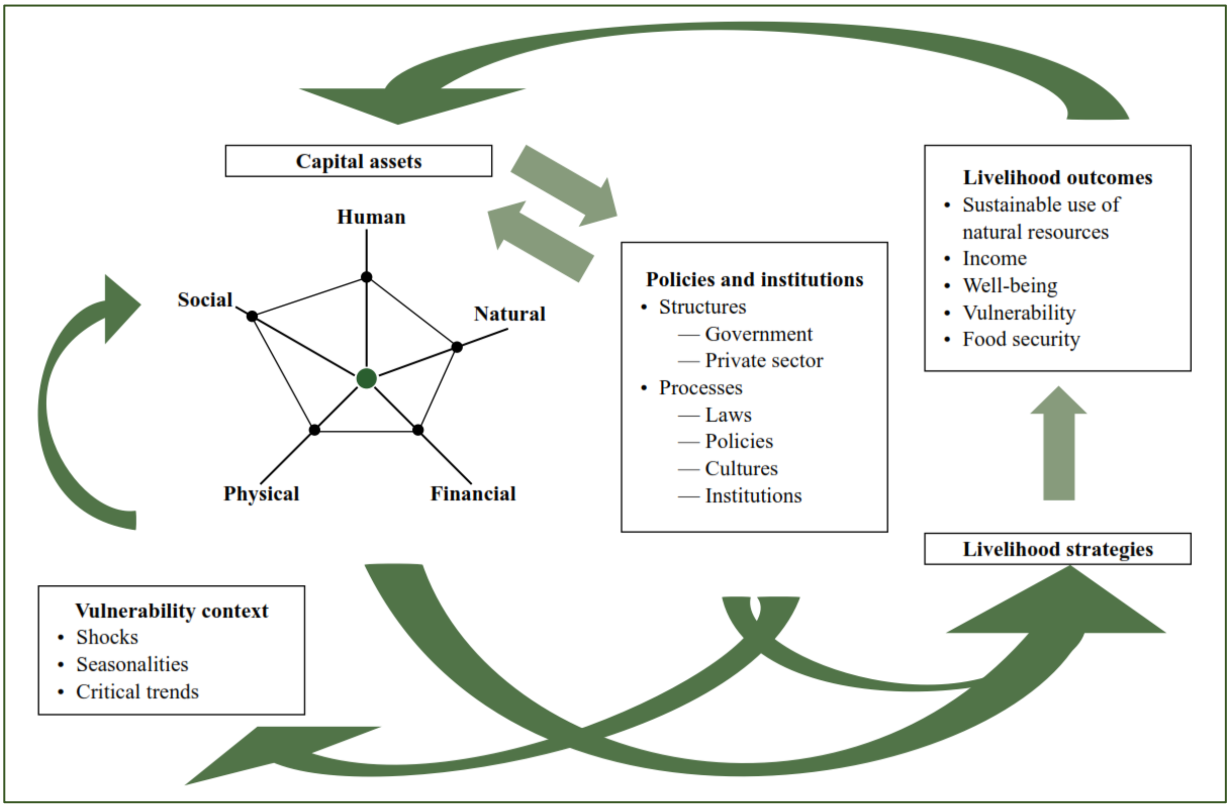

Figure 1-1 Sustainable livelihoods framework

Source: Olivier Serrat (ADB) adapted from Department for International Development of the United Kingdom

1.4.2.1 Livelihood assets

The livelihoods assets comprise of (Serrat, 2008):

(1) Human capital, e.g., health, nutrition, education, knowledge and skills, capacity to work, capacity to adapt.

(2) Social capital, e.g., networks and connections (patronage, neighborhoods, kinship), relation of trust and mutual understanding and support, formal and informal groups, share values and behaviors, common rules and sanctions, collective representation, mechanisms for participation in decision-making, leadership.

(3) Natural capital, e.g., land and produce, water and aquatic resources, trees and forest products, wildlife, wild foods and fibers, biodiversity, environmental services.

(4) Physical capital, e.g., infrastructure (transport, roads, vehicles, secure shelter and buildings, water supply and sanitation, energy, communication), tools and technology (tools and equipment for production, seed, fertilizer, pesticides, traditional technology).

(5) Financial capital, e.g., savings, credit and debt (formal, informal), remittances, pensions, wages.

1.4.2.2 Vulnerability context

Vulnerability is characterized as insecurity in the well-being of individuals, households, and communities in the face of changes in their external environment. Vulnerability has two facets: an external side of shocks, seasonality, and critical trends; and an internal side of defenselessness caused by lack of ability and means to cope with these. The vulnerability context includes:

(1) Shocks, e.g., conflict, illnesses, floods, storms, droughts, pests, diseases.
(2) Seasonality, e.g., prices, and employment opportunities.
(3) Critical trends, e.g., demographic, environmental, economic, governance, and technological trends.

1.4.2.3 Policies and Institutions

Livelihood strategies and outcomes are not just dependent on access to capital assets or constrained by the vulnerability context; they are also transformed by the environment of structures and processes. Structures are the public and private sector organizations that set and implement policy and legislation; deliver services; and purchase, trade, and perform all manner of other functions that affect livelihoods. Processes embrace the laws, regulations, policies, operational arrangements, agreements, societal norms, and practices that, in turn, determine the way in which structures operate. Policy determining structures cannot be effective in the absence of appropriate institutions and processes through which policies can be implemented. Processes are important to every aspect of livelihoods. They provide incentives that stimulate people to make better choices. They grant or deny access to assets. They enable people to transform one type of asset into another through markets. They have a strong influence on interpersonal relations. One of the main problems the poor and vulnerable face is that the processes which frame their livelihoods may systematically restrict them unless the government adopts pro-poor policies that, in turn, filter down to legislation and even less formal processes.

1.4.2.4 Livelihood strategies and outcomes

Livelihood strategies aim to achieve livelihood outcomes. Decisions on livelihood strategies may invoke natural-resource based activities, non-natural resource based and off-farm activities, migration and remittances, pensions and grants, intensification versus diversification, and short-term versus long-term outcomes, some of which may compete. Potential livelihood outcomes can include more income, increased well-being, reduced vulnerability, improved food security, more sustainable use of the natural resource base, and recovered human dignity, between which there may again also be conflict.

1.4.3 Landscape patterns

Landscape is "an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors." (Council of Europe, 2011). Landscape reflects the relationship between people and place, and the part it plays in forming the setting to human everyday lives (Tudor, 2014). Landscape patterns are spatially structured at a number of scales. A landscape contains complex spatial patterns in distribution of resources and varies over time (McGarigal, 2015). Landscape patterns can be quantified in a variety of ways depending on the type of data collected, the manner in which data is collected, and the objective of the investigation. Landscape patterns relatively link to terrestrial ecosystem thus could provide different services to organism in the landscape in all four dimensions of supporting, provisioning, regulating, cultural services. For landscape patterns analysis (McGarigal, 2015), spatial data is categorized into four basic types in order to represent the spatial heterogeneity or models of landscape structure. The four landscape basic types are spatial point patterns, linear network patterns, surface pattern, and categorical map patterns.

1) Spatial point patterns represent collections of entities where the geographic locations of the entities are of primary interest, rather than any quantitative or qualitative attribute of the entity itself.
2) Linear network patterns represent collections of linear landscape elements that intersect to form a network.
3) Surface patterns represent quantitative measurements that vary continuously across the landscape (i.e., there are no explicit boundaries between patches). In this pattern, the data can be conceptualized as representing a three-dimensional surface, where the measured value at each geographic location is represented by the height of the surface.
4) Categorical map patterns represent data in which the system property of interest is represented as a mosaic of discrete patches. Hence, this type of spatial pattern is also referred to as a "patch mosaic". From an ecological perspective, patches represent

relatively discrete areas of relatively homogeneous environmental conditions at a particular scale. The patch boundaries are distinguished by abrupt discontinuities in environmental character states from their surroundings of magnitudes that are relevant to the ecological phenomenon under consideration. A familiar example is a map of land cover types, where the data consists of polygons or grid cells classified into discrete land cover classes.

In case of considering relationship between landscape pattern and ecosystem services, the categorical map pattern of landscape could be more weighted to take into account, which would lead to a clear conclusion. In Laos, measurable ecosystem services are carbon storage and non-timber forest products (NTFPs). These forms of services could be measured through categorical map landscape pattern in the form of land cover.

1.5 Literature reviews

In globally, the study on the impacts of the roads mainly focused on the expansion of in town road infrastructure on resettlement or urban landscape. There are some papers publish the study on the impact of the road construction on ecological such as in 1998, Forman and Alexander studied the major ecological effects by roads. The study led to conclusion that the major ecological impacts of a road network at the landscape scale are the disruption of landscape processes and loss of biodiversity, the same as Harris, et al., (1996) said that roads interrupt horizontal natural processes, such as groundwater flow, stream flow, fire spread, foraging, and dispersal, fundamentally alters the way the landscape works. The same as Mo, et al., (2017) studied the impacts of road network expansion on ecological risk in the urban landscape in a megacity of China, a case study of Beijing by employing spatial analysis toolset of Geographic Information System technology. The study showed that there was dynamic change in landscape pattern, and the changes in landscape were relate to land use type. The changes in a time series, the expansion of the road kernel area was consistent with the extension of the sub-low-risk area in the urban center, but there were somedifferences during different stages of development. For the spatial position, the expanding changes in the road kernel area were consistent with the grade changes of the urban central ecological risk. The influence of road network expansion on the ecological risk in the study area had obvious spatial differences, which may be closely associated with the distribution of ecosystem types.

There are few researchers interested in studying the impact of the road expansion on the overall natural landscape structure. In 2008, Liu, et al., brought this view into the discussion through the study of the influence of roads on landscape within Lancang River Valley of Southwest China. The results showed that forest and shrub land decreased while farmland and constructed land increased in the past 20 years in the study area. Also, the ecosystem's change rate near roads increased while the diversity evenness, patch density and human disturbance indices all decreased. Different aspects of road development had different negative consequences for the environment.

In Laos, there are few studies on the impact of the road expansion and most of papers published are focus raising the positive effects of the road project on livelihood in terms of transportation or accessibility, such as Warr, (2006) studied the impact of road development on poverty in the Lao PDR based on evident suggesting that road improvement in rural areas can contribute significantly to lowering the incidence of poverty, improving educational participation of primary school aged children, and reducing rates of illness. He pointed that the most important form of road improvement to effect poverty reduction is conversion of dry season access roads to all season access. The same as Syviengxay Oraboune (2008) also said that the improvement of all-weather road in Lao PDR has significantly contributed to poverty reduction as the consumption expenditure increased. The rural roads provide opportunities to access to market by peasants. Accessing to market could help peasants diversifying their income sources. In terms of farming system could also be improved when accessing to market is available. He believes that this ensures a stable income; improve living standard, and reducing poverty. Pearse, (2006) studied the social and economic impact of the construction of the Nam Ham and Nam Ven roads, Huaphan province, Lao PDR to investigate the benefits provided by good accessibility to the village. The study found that the livelihood had great improved since the roads were built. The main reasons were ease of travelling, reducing travel time, availability of bus services, personal transport, etc. The research also found that good accessibility by the roads brought villages out of isolation, supported off-farm employment opportunities.

Our case study aimed at analyzing the impacts of the roads construction on natural landscape structure by focusing on the changes in land use and land cover composition and the impact of those change in landscape on local livelihood in remote area where villagers rely on agricultural-based economy. Therefore, the core context was on the relation of agricultural land use and agricultural production practices on livelihood.

There are several study that were used to shape our conceptual framework such as the study by Lambin, et al., (2001) studied the causes of land use and land cover change by examining each classes, namely, tropical deforestation, rangeland modification, agricultural intensification, and urbanization. His study revealed that neither population nor poverty alone constitute the sole and major underlying causes of land-cover change worldwide, but peoples' responses to economic opportunities drive land-cover changes. The opportunities and constraints for new land uses are created by local as well as national markets and policies. Global forces become the main determinants of land-use change, as they amplify or attenuate local factors. A research studied by Thongmanivong and Fujita (2006) on land use and livelihood transition (1993 to 2000 in 4 Northern provinces of Lao PDR: Luang Prabang, Oudomxay, Bokeo, and Luang Namtha) found that agro-ecological landscape of the upland areas was undergoing rapid transformation from subsistence and Swidden-based landscapes to commercial and multifunctional use of the uplands. The government policy of restricting the expansion of shifting cultivation has induced farmers to seek alternatives, which has been further driven by integration into the market economy and the development of road networks. As the road links are improved and regional trade is institutionalized, it could be foresee the increased commercialization of agricultural production and natural resource use in northern Laos. As well as Keophoxay, et al., (2011) studied on the impact of maize expansion on household economy and production system in Xiengkhor district (Huaphan Province) and in Kham and Nonghet districts (Xiangkhuang Province), northern Lao PDR. His study revealed that maize had rapidly spread in the areas because of government policies and investment in infrastructures and pulled by the growing Vietnamese market. Maize become the main source of income and had tremendous impact on local communities, widening farmer's differentiation and changing in social networks in favor of powerful middlemen and traders. Besides, it leaded to the spread of credit system and emerging of local institutions. And Castella, et al., (2016) investigated the impact of maize expansion on the household economy by analyzing the contribution of maize to local incomes using 2 household data series surveyed in 2003 and 2009. The research revealed that with tillage system, the use of herbicides, pesticides and hybrid seeds, farmers could significantly reduce the time spend in the fields. Maize expansion presented gradual homogenization of landscapes and agriculture production, by this path, farmer become more vulnerable to land degradation, agrobiodiversity loss and price fluctuation.

1.6 Conceptual framework

Agrarian transition is the transition from traditional subsistence production systems to market - oriented systems encouraged by the government's policies and market availability. Market-oriented agriculture system requires intensive production both quality and quantity thus need expansion of area and the use of agricultural inputs. Agriculture expansion not only impact on livelihood, but also landscape system and ecosystem services.

This study aims at evaluation and quantifying the impact of investment in agriculture, road network expansion, on landscape and livelihood. For the impact on livelihood we consider the change in agricultural production system, household assets, income, and debt. The impact on the landscape, we consider land use and land cover change and transition, and land use intensity (**Error! Reference source not found.**).

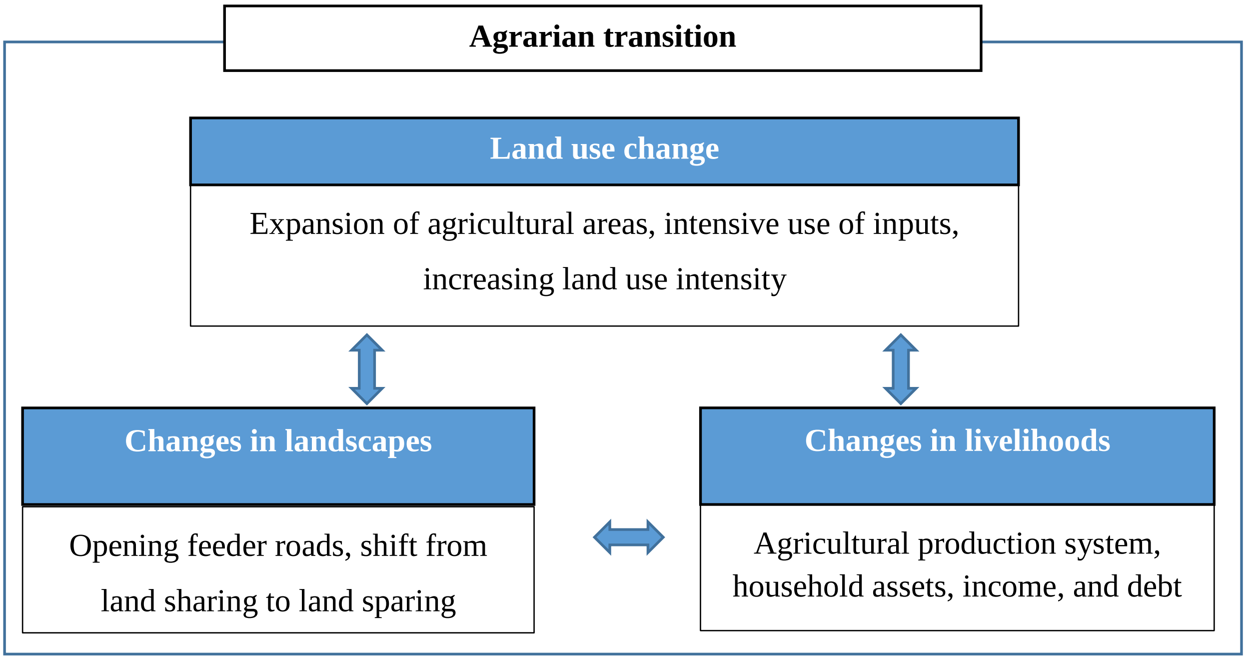

Figure 1-2 Conceptual framework

Chapter 2 General Information of the Study Site

This chapter presents general information about the study area and the specificities of its 5 villages. The context of the study in this chapter are location of those study site, demography and some significant changes, infrastructure, institutions, financial resources, village awards, and maize and feeder roads story in brief.

2.1 Location

The study site is in Natong village cluster (Kumban or group of village), Xiengkhor district, in northern of Huaphan province, which is one of the northern province of Laos, located between 19°48'N and 103°00'E. It is an old community of the country which has been existed since Lanxang Kingdom era. Huaphan is bordered by 3 provinces of Vietnam, namely, Son La to the North, Thanh Hoa to the East, and Nghe An to the Southeast; and 2 domestic provinces of Laos, namely, Louangprabang to the West, Xiangkhuang to the Southwest. The terrain is mountainous ranging from 200 to 2,300 m ASL and covers an area of 16,500 km^2, consists of 10 districts, namely, Xamneua, Xiengkhor, Xon, Viengxay, Houameuang, Xamtay, Sopbao, Add, Kuan, and Hiam district. There are 90 village clusters, 716 villages. The province is the home to 9 ethnic groups or about 289,400 populations in 2015 (Lao Statistics Bureau; Huaphan Province).

Natong village cluster composes of 9 villages, namely, Natong, Nanong, Xiengdaen, Deua, Phouk, Thaensan, Sobpin, and Sobdoung. In this study, 5 villages (Natong, Nanong, Xiengdaen, Deua, Phouk) were selected based on their location and the similarity of cultural, as well as maize trading. These 5 villages occupy total area of 5,190 ha[2] (Natong 1,600 ha; Phouk 1,426 ha; Nanong 460 ha; Xiengdaen 920 ha; Nadeua 785 ha). The terrain of these five villages are characterized by mountain which covers about 98%, while flat area is paddy rice field covers 2% of total area. The highest elevation within these villages is about 1,179 meters and the lowest elevation is about 262 meters[3].

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[2] The area was calculated using GIS software. The boundaries of the villages are based on the previous study and they were participatory checked and updated with village authorities during field work in the study site based on their agreement on village land administration.

[3] Elevation is based on ASTER GDEM2 (ASTER-Advanced Spaceborne Thermal Emission and Reflection Radiometer; GDEM2-Global Digital Elevation Model Version 2). ASTER GDEM2 is available from **www.glovis.usgs.gov** (the U.S. Geology Survey).

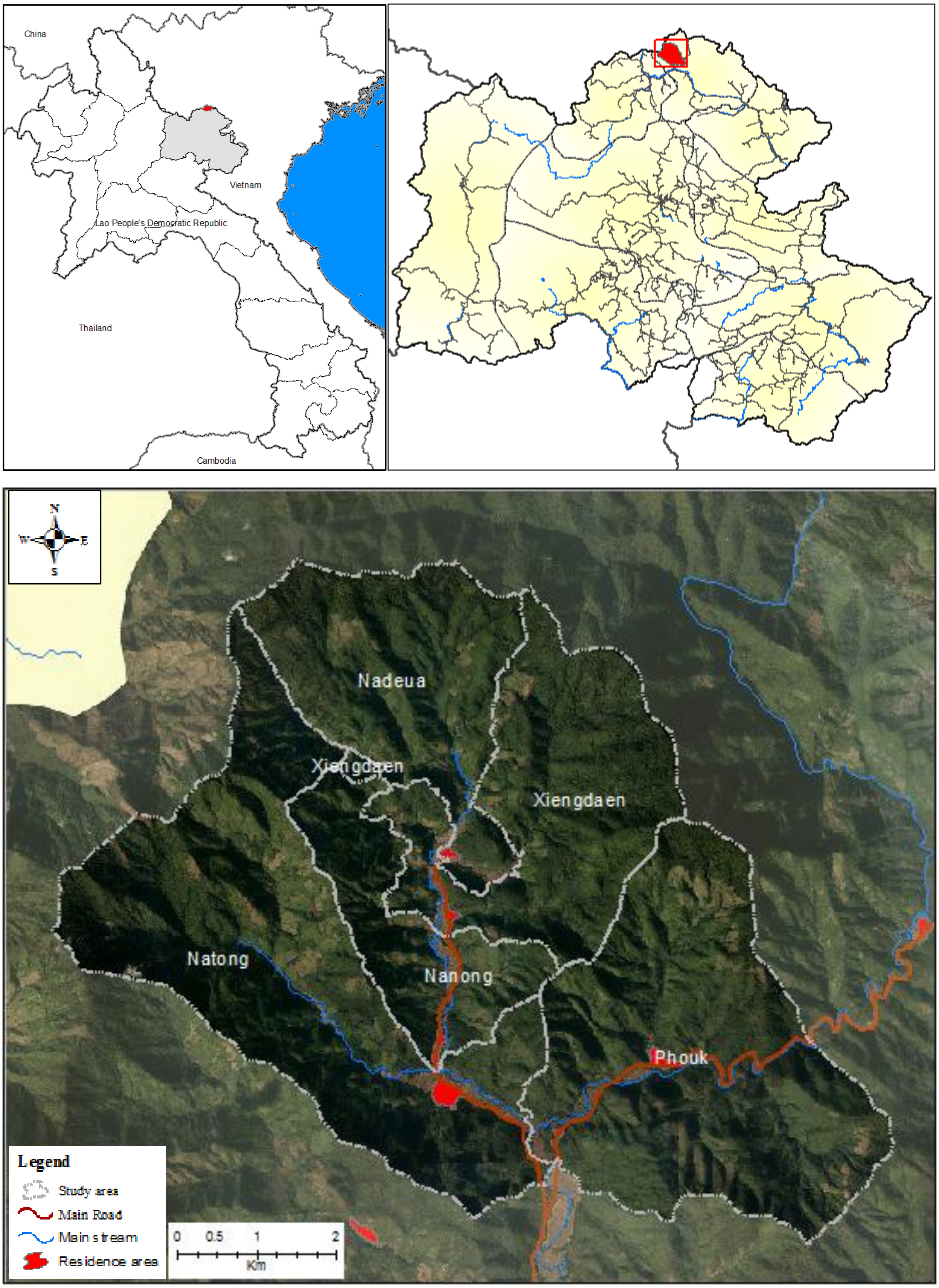

Figure 2-1 Location of the study site

2.2 Population

Before inception of Lao’s People Democratic Republic in 1975, there were 11 hamlets within this study area (Figure 2-2) which were the homes of four tribes: Tai Dam, Ksing Mool, Khmu, and Yao (Viau, Keophosay, & Castella, 2009).

Tai Dam is a minor group of Lao-loum[4], Tai Dam lived in four villages (Natong, Nanong, Nakiu, and Phouk). Ksing Mool and Khmu are minor groups of Lao-therng[5]; Ksing Mool lived in three villages (Natia, Bui, and Ho), Khmu lived in three villages along the Dea, Hit, and Niup stream and the villages were named according to the streams. Yao, a minor group of Lao-soung[6], lived in Phoukang village in the North.

After establishing Lao People’s Democratic Republic in 1975, the government integrated mountainous hamlets by relocating them to accessible lowland and form a larger community in order to ease development and providing services. In 1975, according to Viau et al. (2009), three Khmu hamlets (Dea, Niup, and Hit) were moved and merged together in new settlement named Nadeua village. Phouk village was also created that year by merging the old Phouk village which was the Tai Dam hamlet, two Ksing Mool hamlets (Bui and Ho) together. The succession of resettlement policy in inception of Laos led to new movements of population. In the mid-1990s, the Yao community was moved from high land to merge to Phouk village, and Ksing Mool community in Natia merged with Natong village. As most villagers from the area are from Tai Dam ethnic group they can easily communicate in their local language with people from the same ethnic group who live in Vietnam at the other side of the border. They have many commercial and cultural interactions with neighboring villages in the Vietnam side.

Current population according to data from field survey in April 2016, there are total 349 households in five villages (Natong 109 HH, Nanong: 48 HH, Xiengdaen: 35 HH, Nadeua: 50 HH, and Phouk: 107 HH); Total population is 2,170, female 1,087 (Figure 2-4).

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4 Lao-loum (low-land Lao) refers to Lao people who live in lowland. This group mainly does agriculture in lowland, in particular paddy rice production, but they also grow upland rice when the rice from paddy is not sufficient for living.

5 Lao-therng (mid-land Lao) refers to Lao people who live in between lowland and mountains. These people live lower than Lao-soung.

6 Lao-soung (high-land Lao) refers to Lao people who live in the mountains.

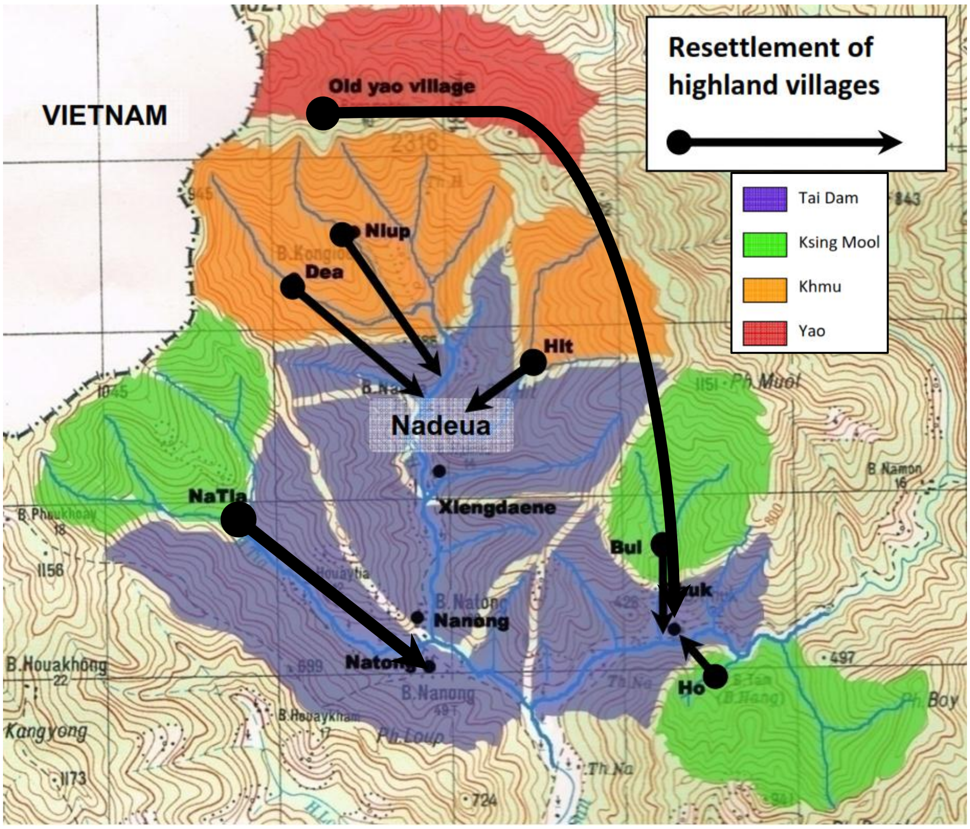


Figure 2-2 Population movements in the study area after the inception of Lao PDR in 1975

Source: (Viau, Keophosay, & Castella, 2009)

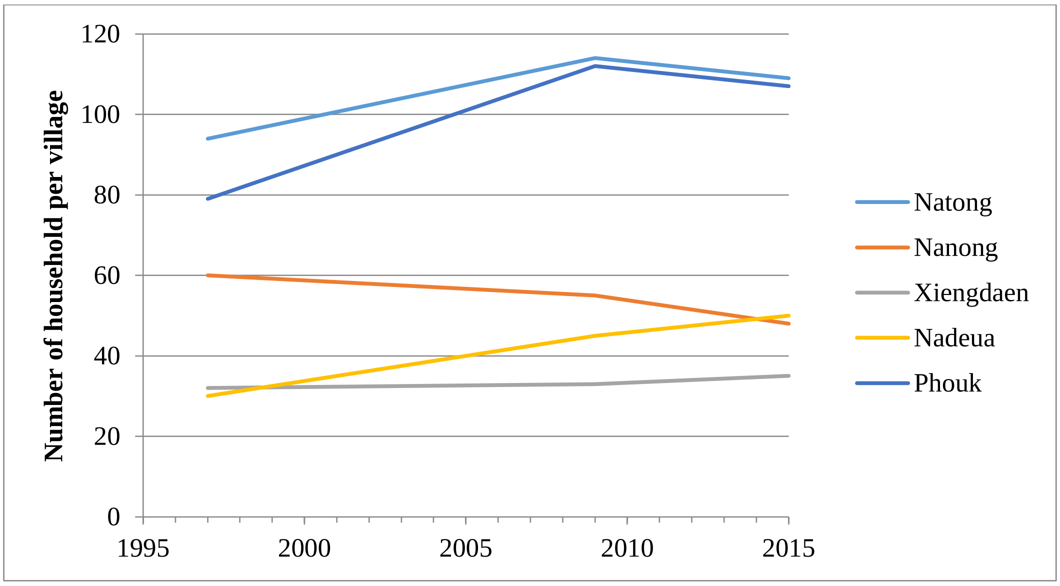


Figure 2-3 Population changes in the study area 1997-2009-2015

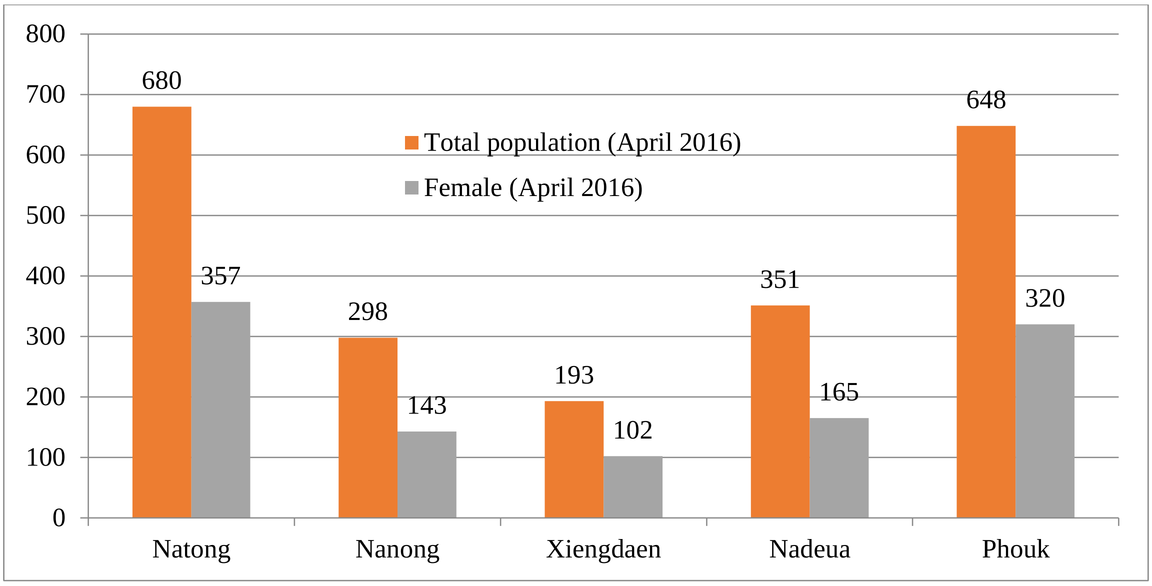


Figure 2-4 Population in the study area in April 2016

2.3 Infrastructure

Roads. There is a main road from Xiengkhor through part of Natong and Phouk villages to Vietnam and a road to Natong valley: access to Natong, Nanong, Xiengdaen, and Nadeua villages (Figure 2-5). The road to Natong valley is connected to the main road. All roads including roads accessing Natong valley and the main road through Phouk to Vietnam are currently unpaved. However, access to these villages is possible in all seasons, which is good in term of development opportunity. Being located at the border with Vietnam, the study area is highly influenced by market demand from the neighboring country. This was especially the case for maize expansion as the large demand from Vietnam for transformation in animal feedstock as largely influenced agricultural changes in the past decade.

In 2003, Xiengkhor district entered the list of the 47 poorest districts in Laos. This list was made so funds could be concentrated in the poorest areas, especially in the uplands. Between 2003 and 2008, the PRF (Poverty Reduction Fund), a national agency that is partly financed by the World Bank, improved road access, making the roads accessible for trucks, built water supplies, built schools, financed nurses' formation, financed concrete irrigation and built a bridge across the river (which can be crossed on motorcycle only). This infrastructure dramatically changed local livelihoods. Children could go to school in the village up to the third year of secondary school). Services (market, health dispensary, secondary school, gas station) in the district capital Xiengkhor could be reached in 30 minutes by motorcycle; previously, it took half a day. Infrastructure investment was not the only external factor. The district government decided to improve market access by reducing taxes on exports to Vietnam and by exempting Vietnamese traders from paying a specific tax on foreign investment. However, more than that administrative move, regional trends in commodities and the cheapness of Lao commodities are responsible for the introduction of cash crops in the study area. Previously, cash crops such as maize, vegetables or even cotton were grown in very small quantities. The possibility of finding traders who could buy directly in the village allowed farmers to focus more on cash crop production. The first attempts were made with soya bean production between 2003 and 2004, followed by maize in 2005; at this point, every household started to shift their production system from subsistence to commercialization.

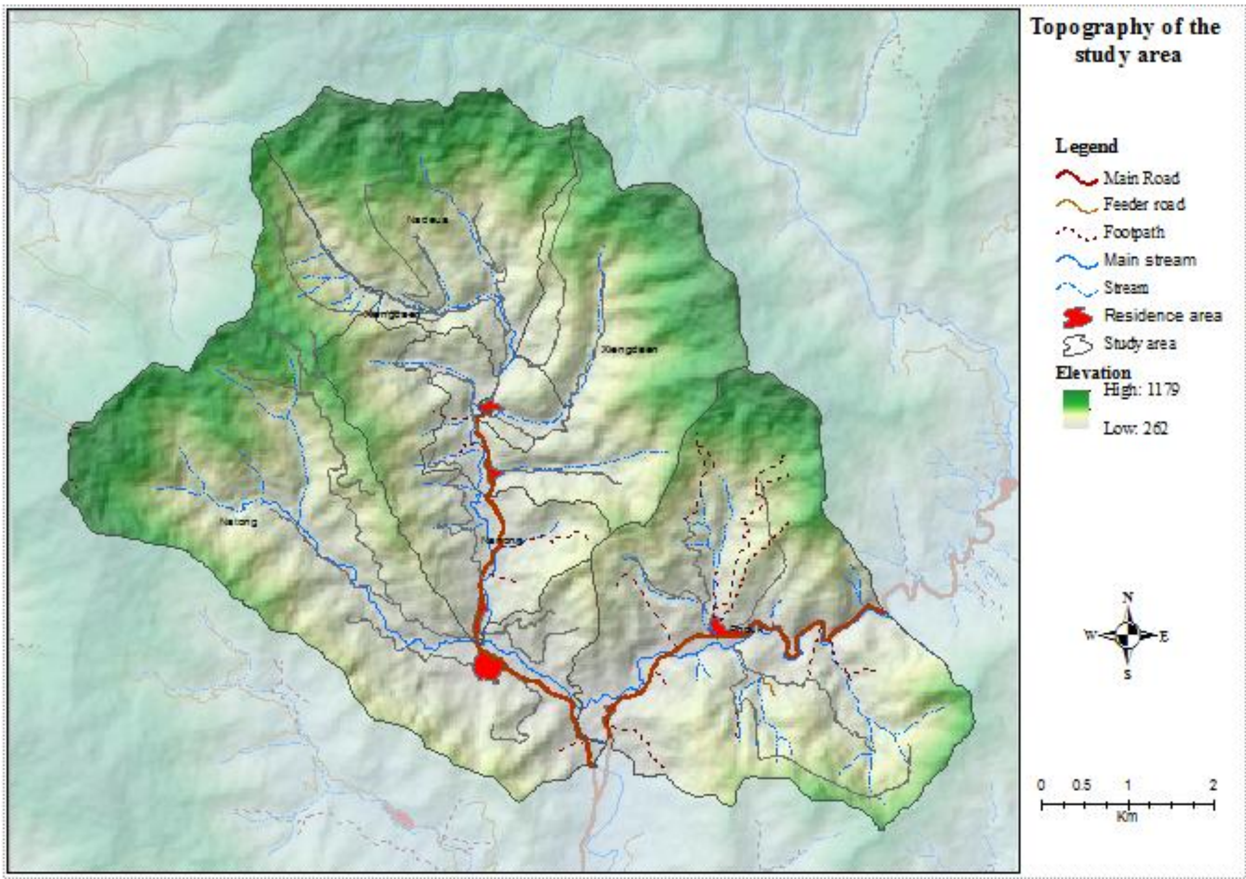


Figure 2-5 Topographic of the study area

Electricity: The four villages in Natong valley (Natong, Nanong, Xiengdaen, and Nadeua) were connected to the national power grid since 2013, while Phouk was connected in 2014.

Water supply system is now sufficient for domestic use in 4 villages, except Natong. There is occasional water shortage in Natong village, but that is not the problem. The number of the water points are different in each village depending on the number and density of households, i.e., there are 5 points in Nadeua and Xiengdaen, 6 in Nanong, and 11 in Natong and Phouk which are the larger villages in terms of population size (**Table 2-1**).

Table 2-1: Water points in the study area

Village name	Population	Number of water points	Number of house with pipes
Nadeua	351	5	10
Xiengdaen	193	5	0
Nanong	298	6	25
Natong	680	11	50
Phouk	648	11	40

Because there are closed-water sources that they can use instead of water points (Figure 2-5). There is only Phouk village that suffers the lack of water for irrigation.

2.4 Local institutions

Village authority organizations in these five villages have the same structure. The organization is composed of 21 village-committee members and divided into 7 units as follows:

1) Village front: composed of 3 members; a head of the village front and 2 deputies.
2) Village committee: composed of 3 members; 1 head of the village and 2 deputies.
3) Village youth union: composed of 3 members; 1 head and 2 deputies.
4) Village woman union: composed of 3 members; 1 head and 2 deputies.
5) Village security unit: composed of 3 members; 1 head and 2 deputies.
6) Village defense unit: composed of 3 members; 1 head and 2 deputies.

Each village also divides the households into smaller "village unit", in order to manage easily. In each group there are 1 head and 2 deputies of village units.

Collective works in these five villages are similar. The common works consist in fixing & cleaning the village road, cleaning the village and school, and fixing & cleaning the water supply system. The data in **Table 2-2** shows that cleaning the village and school is the major task of collective work. They spend more time with this activity than others.

Table 2-2: Collective works in the study area

Village name	Fixing & cleaning the village road (man-days/year)	Cleaning the village and school (man-days/year)	Fixing/cleaning the water supply system (man-days/year)
Nadeua	100	200	150
Xiengdaen	70	490	420
Nanong	144	336	48
Natong	436	2725	1308
Phouk	428	1605	1284

Financial resources refer to the funding mechanism for social help in the villages. Only Natong, Phouk, and Xiengdaen have this kind of units. There is a rice bank in Xiengdaen village that was created in order to use rice for payment of any collective activities in the village and also to help the household who suffers the lack of rice for consumption. Phouk and Natong have the same funding system named "Korng Theun Suay Leua Seng Kan Lae Kan (the Fund for helping each other)" which was supported by the Poverty Reduction Fund project of the Lao government.

Village awards are the certificates delivered by district line agencies indicating the achievement of the village on implementing the district's development goals. The award, through its appraisal mechanism encourages villager to comply with the government policies implemented by the local administrations. There are many programs running in this area such as cleaned-village, no crime - no case, healthy, cultural, all household-heads finished primary school, all household-heads finished secondary school, strength-youth, developed-village, good women union, stopped shifting cultivation, etc. Some programs are annually awarded, but some awards are one time award, i.e., stopped shifting cultivation. The **Table 2-3** shows the date deliverance of different awards to the study villages.

Table 2-3: Awards indicating the achievement development programs

Awards	Awarded-Year				
	Phouk	Natong	Nanong	X-dane	Nadeua
Clean village	2005	2013	2013	2005	2013
No crime - no case village		2008	2010	2013	
Healthy village	2016	2013	2013	2013	2013
Cultural village		2015	2013	2015	
All household heads completed primary school	2013	2013	2010	2002	2013
All household heads completed secondary school	2015	2011	2013		
Youth strength		2012	2013		2013
Developed village		2013	2013	2015	
Good women union	2015	2012	2013		
Stopped shifting cultivation		2015	2013		

2.5 Agriculture

Before 1975, upland rice production was the main agricultural activity in the area. The Ksing Mool, Yao and Khmu ethnic groups traditionally grew upland rice. The Tai Dam are lowland farmers and started terracing paddies more than one century ago, but the paddy area was not sufficient to feed everyone and they continued to grow upland rice. During the last two decades, the Tai Dam gradually extended their individual paddy field (Nati) even by buying in Nadeua village. Rice and livestock are the only mean to get cash. The economy was based on subsistence crops until a road was built in 2003 that allowed commercial exchanges. In 2005, the maize production started and in 2007 all of the households produced maize. In parallel with this shift to a commercial economy a minority of household stopped the upland rice production and the majority reduced their field's area as they had limited labor force available to attend to their upland rice fields.

2.5.1 The 3 main crops

Maize is the most important cash crop in the study area, as every household grows maize in 1, 2 or 3 fields without rotations. Sometimes pumpkin or chili is associated in the maize fields but mainly for self-consumption (100-200 Kg).

In 2005, a relative of Natong village's head who lived in Xiengkhor gave him 40 kg of maize seeds who then gave 20 kg to someone in Nadeua. In Xiengdane, only one farmer tried to grow maize in 2005. All of them got a good production and then sold to traders who came in the villages to buy. In 2006, a lot of people in Natong, Xiengdane, Nadeua but few in Phouk produced maize. At this time Vietnam traders started to provide seeds to farmers by contracting local middlemen. All households gradually engaged in maize production on their upland rice fallows, pushing upland rice away from the feeder roads that rapidly spread all across the landscape. Farmers build storage huts in their field near the maize feeder roads. The traders come 10-20 days after the harvest to thresh the maize cobs and load the bags of maize grain in their trucks for transportation out of the village. Rats and wild pigs are seen as the most important threat to maize production. Then some weather problems such as droughts, storms or coldness are also mentioned. Then soil fertility and germination problems. Since 2007/2008, the majority of the maize's fields are situated along the maize feeder roads.

Upland rice is produced through shifting cultivation. Upland rice fields are usually located up the hills, above the maize fields or in remote areas. A 2 to 3 years fallow rotation system is used since more than 10 years. In 1975, fallows were 6 to 7 years long. Diverse crops are associated with upland rice in the same shifting cultivation field, such as cucumber, watermelon, sugarcane, chili, pumpkin, eggplant and traditional maize. The quantities range from 5 to 200 Kg for each. Weed control is considered as an important constraint to upland rice production especially as the fallow length is gradually decreasing.

Paddy rice is produced during two successive cycles (spring and rainy season) since 1975. Not all the area can be used two seasons, mostly because of water shortage for irrigation. Weather conditions (coldness) and water quantity are seen as the most important limitation of the spring rice production. The harvest takes place during the raining season, which leads to losses in production. In case villagers do not grow spring rice, they usually grow winter vegetable in their paddies after the harvest of the rainy season cycles (mostly in Phuk and Natong). Buffaloes were traditionally used for land preparation but they have been gradually replaced by hand tractors when farmers got enough cash to buy this equipment. In Natong, Phouk and Xiengdane, paddy land is owned collectively like in many other parts of Houaphan province. This collective tenure system is called Na Muang. The Na Muang area is reallocated every 5 years (or 3 years in some villages) to individual households according to the size of the household based on the follows rules: 1 People > 10 Years old = 1 unit / 1 People < 10 Years old = 0.5 unit. Each family gets an area according to its number of units. This area is a new one every 5 years and the newly formed couples/household doesn't get a part of the Na Muang of their parents but a new one. The overall collective land is then divided by the number of unit to compute how many square meters will be allocated to each household according to its size (i.e. number of units): Natong households get 300 m^2/unit, Xiengdane households get 500 m^2/unit and Phouk households get 262 m^2/unit.

Only in Natong there is a different rule for spring rice (200 m^2/unit) so that everybody can grow rice during the spring season. In Xiengdaene and Phuk there is a rotation of the land, the farmer who can do just 1 season will get a field with 2 seasons at the next allocation. In Nadeua, when they created the village in 1975, they created a Na Muang, but the area is too small (81 m^2) and, so, there has been no change of the use (no rotation) since this time, but farmers are not allow to sell. As consequences, it is very difficult for a young couple in Nadeua to get access to a Na Muang.

Apart from those communal lands that somehow buffer the disparities between households, there are also individual paddy fields (Nati). Those fields have been built by farmers themselves or bought from someone else. The majority of the Nati have been built during the period from 1980 to 2000. Generally, farmers build a small area with irrigation and then extend every year. Nati are the only lands which can be sold between villagers. Those fields are away from the villages, along small rivers, and sometimes farmers choose to build a 2nd house close to it.

2.5.2 Livestock

Villagers raise cows, buffaloes, goats, pigs, chicken and duck in all villages. Large livestock are considered as living capital that can be sold in case of problem. A few buffaloes are still used for paddy land preparation but they have been rapidly replaced by cattle in the recent years after some animals had been stolen when roaming in the remote forests around the village. Cows and buffaloes are sold in the villages to other villagers or traders. Cows and buffaloes are kept in 1 or 2 livestock areas in each village, with fences around between April to November, then they are left roaming after the crop harvests are completed. As there is no fence around the paddy fields nor upland crop fields, livestock owners are responsible for damages their animals may cause to the crops and would have to pay for losses incurred. The pigs are kept in pigsty near the houses all year long. Farmers feed them with cassava, banana trunk, banana, traditional maize, leaf and vegetables. For each litter they sell half of the piglets at 10 Kg and keep half to feed them and sell them at more than 100 Kg (3 years old). Traders come to the villages to buy. They do no vaccinate their animals but they reported only few losses from diseases. Every households breed chicken. They have between 5 to 10 mothers in each household. They don't eat eggs. Chickens eat rice bran, cassava and kitchen waste. Few households breed ducks. They always complain about the difficulty to breed ducks compare to chicken. So they prefer to eat or sell the eggs.

2.5.3 Non-timber forest products

The 3 main products collected are Phak No, Phak Waen and bamboo shoots, mostly for the family consumption. Phak No and Phak Waen are found in paddy field, bamboo shoots in fallows or open forests. The other products collected are mostly found in upland fallows and along the rivers. Some households in Natong or Phouk sell those products, but no one in Xiengdane and Nadeua, where it is exclusively collected for household consumption.

In every village there is a production forest, where the villagers find timber for their houses and firewood in addition to their fallow fields. Hunting is limited to small animals, birds and rats in maize fields. Some households have a fishpond (60 to 150 Kg/Year). In Natong and Phouk they fish in the river (10 to 20 Kg/Year). In all the 4 villages they collect frogs during the rainy season. No hunting of big wild animals has been reported.

Chapter 3 Research Methodology

This chapter presents the research methodology applied for this research. The study began with analyzing the impact of the feeder roads on the landscape. In this context, we analyzed the change in the landscape by considering change and transition in land use and land cover between time periods of the study. Then we analyzed the impact of the feeder roads construction on livelihood by considering the household economy, the changes of agricultural performance.

Two main sources of information feed the analysis. Firstly, a time series of remote sensing data at the key periods of the maize boom, introduction (2003), expansion (2008-2013), revival 2015, were used to generate land use and land cover maps. The land uses were checked through ground surveys and the roads measured both on the imageries and on the ground with GPS units. Secondly, village and household data were collected during two successive field studies in 2009 and 2016. Both quantitative and qualitative data were collected through individual interviews and focus group discussion. Figure 3-1 presents the steps of data analysis.

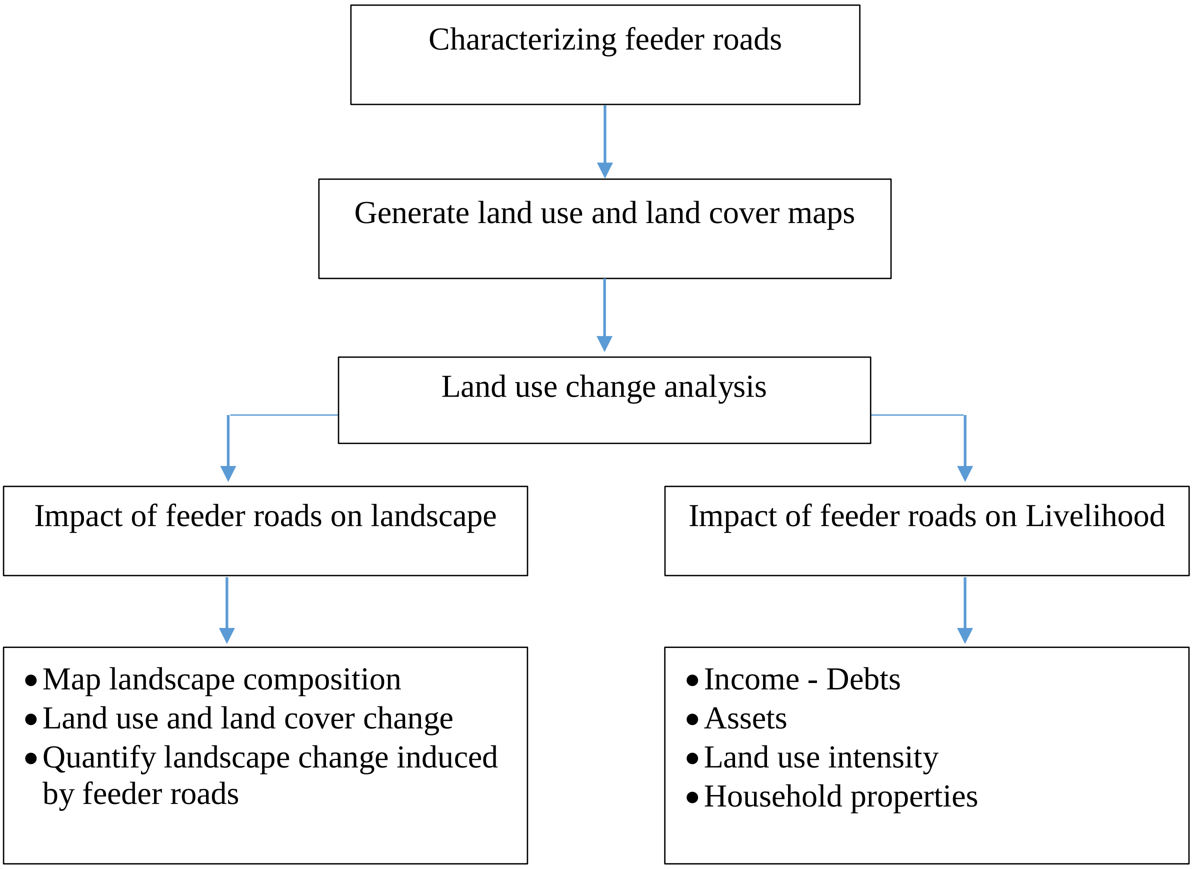


Figure 3-1 Data analysis frame works

3.1 Data collection

3.1.1 Geographic data collection

Geographic spatial data was used to quantify the impacts of the feeder road construction on landscape, especially in land use and land cover between the years 2003 to 2015. Landsat satellite images derived from USGS (The United States Geological Survey) were used to generate land use and land cover maps. Since this study aimed at investigating the changes in landscape between 2003 and 2015, Landsat imagery from different sensors such as TM (Landsat 5), ETM and ETM+ (Landsat 7), and OLI (Landsat 8) were used. The clear images from Global Visualization (Glovis) satellite platform of the USGS, for the study period, are rarely available. Only images between February and April of each year are free of cloud. Therefore, most of images used in this study are of the date between February and April. The spatial resolution of the image is 30 meters (**Table 3-1**).

Table 3-1: List of satellite images used in this study

Year	Satellite/Sensor	Acquisition date	SLC	Sources of images
2003	Landsat 7/ETM+	2003/04/10	on	glovis.usgs.gov
2008	Landsat 7/ETM+	2008/01/02	off	glovis.usgs.gov
2013	Landsat 7/ETM+	2013/03/20	off	glovis.usgs.gov
2015	Landsat 8/OLI	2015/03/18	on	glovis.usgs.gov

Note: Landsat imageries in 2008 and 2013 are SLC-off (Scan Line Correction off) scenes. The gaps in these images were filled using other scenes acquired very close to the date of acquisition of these two images. For Landsat 2008, only one scene acquired on the 1st of December 2007 was found appropriate to use filling gaps, and Landsat on the 5th of April 2013 was used to fill gaps in Landsat image of 2013.

SPOT image and aerial photograph were also used in order to support the classification processes and field works. Google Physical and Google Satellite image also covers large part of the study site. Therefore it was also used through OpenLayers, a function of QGIS (**Table 3-2**).

Table 3-2: List of supporting images used in this study

Type of image	Acquisition date	Sources
SPOT7	2015/03/31	EFICAS project in Lao PDR
Aerial Photo	2014	National Geographic Department in Lao PDR
GoogleEarth	2014/05/15 & 2013	GoogleEarth and OpenLayers in QGIS

3.1.2 Socio-economic data collection

Socio-economic data was collected by variety methods in order to capture and analyze the impacts of the feeder road on livelihoods, as well as to support spatial analysis. The primary data was collected during field survey from the 27th of March to the 4th of April, 2016. Data was mainly collected through focus group discussion, observation in the fields, and interviewing the key persons, e.g., the village heads and members of the village committee.

All households, totally 368 households, were included in rapid survey to collect data about household composition, agricultural practices, assets, and income. Data derived from rapid survey provided general situation. We then collected more details about household composition, agricultural practices, assets, and income from sample population totally 118 or about 30% of the study population (Table 3-3).

Table **3-3 Participants involved in data collection**

Villages	Total HH in the village (registered)	Number of the village organization committee	Focus Group	Rapid Survey	Details Survey
Nadeau	50	18	8	59	30
Nanong	48	18	0	47	24
Natong	109	18	7	113	24
Phouk	107	18	7	112	21
Xiengdaen	35	18	8	37	19
Total	349	90	30	368	118

Then we conducted focus group in each village in order to collect data about development trajectory, general information of the village, cropping system, livestock system, contract farming, feeder road development, and perspective on the value of natural resources in the village (**Table 3-4**).

Table 3-4: data collected and methodology

Data collected	Purpose	Methods
History of the village	Understand dynamic or development trajectory.	Focus group
General information of the village	Understand current situation of the village	Focus group
Cropping system	Understand cropping practice	Focus group + Playing game
Livestock system	Understand livestock husbandry system	Focus group + Playing game
Contract farming	Understand contract farming situation and processes	Focus group
Opening road to production areas	Understand situation and processes in opening roads	Focus group
Land use/land cover valuation	Understand the values given to land use land cover by villagers in terms of ecosystem services.	Focus group + Playing game
Household survey: Rapid & Details survey	Understand the change in agricultural activities and well-being.	Focus group

3.2 Data analysis

3.2.1 Feeder roads construction

The expansion of the feeder roads is described base on statistic data obtained from group discussion and interviewing key informants of each village. We analyzed contents from interviewing key informants and in charge district authorities, from focus groups, and from official documents related to feeder road construction.

3.2.2 Impact of the feeder roads on landscapes

3.2.2.1 Generating land use and land cover maps

To analyze the impact of feeder roads on landscape, we first generated land use and land cover maps from Landsat satellite images using combination of supervised and unsupervised classification technique. The images used in this study are level 1G product of Landsat 5, 7, and 8. Land use and land cover categories are adjusted from the top-level categories suggested by Intergovernmental Panel on Climate Change (IPCC, 2003) with some additional sub-divisions of forest land (FAO, 2004) (**Table 3-5**).

Table 3-5: Land use and land cover categories

Code	Categories	Description
1	Dense forest	This refers to forest land of native species, where there are no clearly visible indications of human activities and the ecological processes are not significantly disturbed.
2	Open forest	This refers to area of forest regenerated largely through natural processes after significant human or natural disturbance of the original forest vegetation. This category includes the areas of mix woody with bamboo and old fallow.
3	Fallow	This refers to vegetation types where the dominant woody elements are shrubs i.e. woody perennial plants, generally more than 0.5 meters and less than 5 meters in height at maturity and without a definite crown. This category includes clear bamboo which the spectral reflectance is close to the features classified as fallow.
4	Upland crop	This category refers to land area in higher slope which is mainly used for dry cropping such as upland rice, maize, etc.
5	Paddy field	This category refers to paddy fields both dry-season and wet-season paddy fields.
6	Water	This category includes land that is covered or saturated by water for all or part of the year and that does not fall into the forest land, cropland, grassland, or settlements categories. It includes reservoirs, natural rivers, and ponds.
7	Residence area	This category includes all developed land, including transportation infrastructure and human settlements of any visible size.

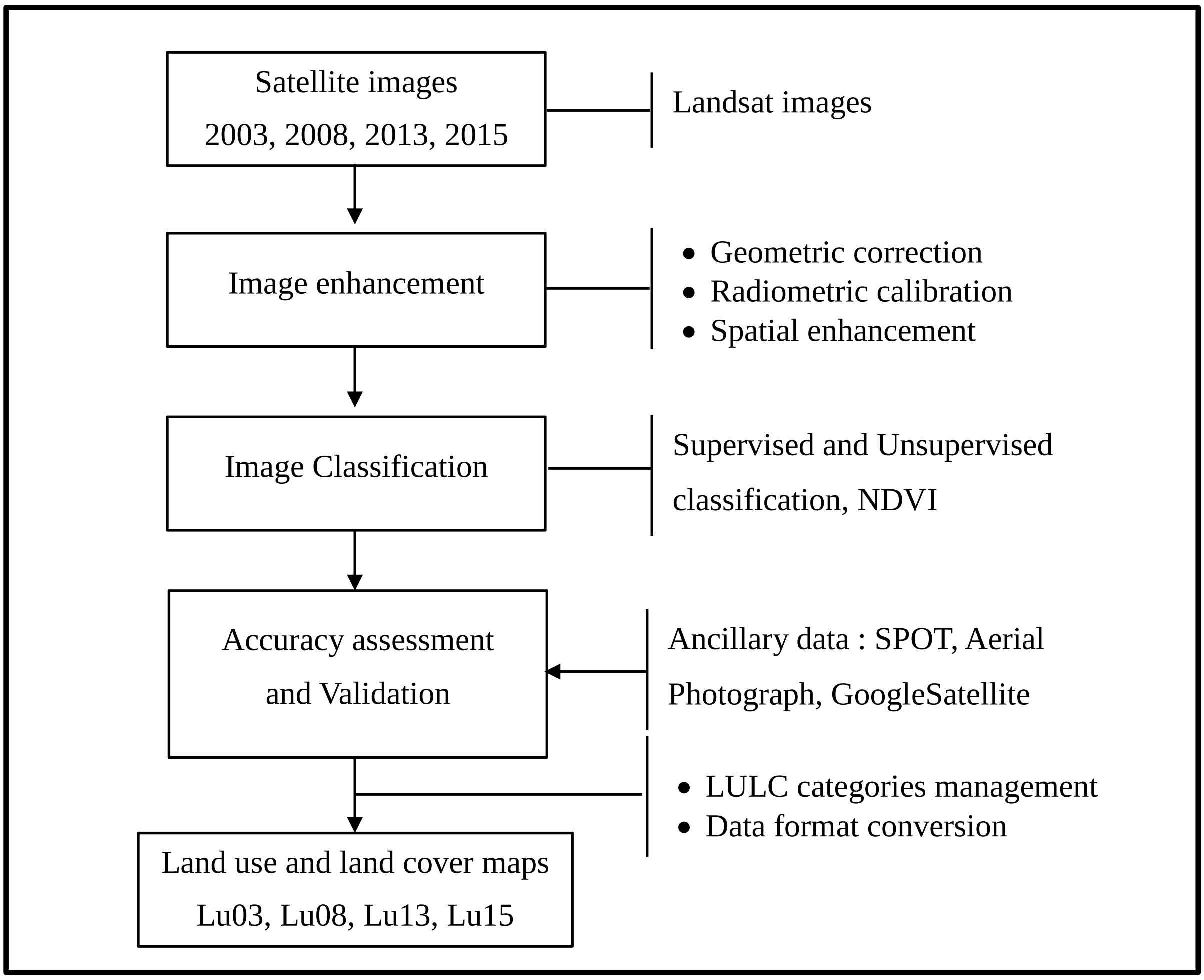


Figure 3-2 Image processing processes

Accuracy assessment for image classification is available only 2015 based on reference data from aerial photograph, SPOT image, and reference data from the field. Aerial photograph is of the year 2014, the SPOT image is of March 2015, data from field work during March – April 2016. The number of reference data is defined by multiply the number of land use and land cover categories by 40 - base on FAO (2016), the minimum sample size should be at least 20 to 100 samples per class. The reference point is randomly generated. As a result, each category has different reference points (**Table 3-6**).

Table 3-6: Result of accuracy assessment for land use and land cover map of 2015

Classified Data	DF	OF	YF	UC	PA	WA	RI	C-Total	Num. Correct	PA (%)	UA (%)	(K^) stat.
	Reference Data											
DF*	30	3	1	0	0	0	0	34	30	96.77	88.24	0.86
OF	1	93	9	2	0	0	0	105	93	86.92	88.57	0.81
YF	0	9	62	0	0	0	0	71	62	74.70	87.32	0.81
UC	0	2	11	34	0	0	0	47	34	94.44	72.34	0.68
PA	0	0	0	0	15	0	1	16	15	100	93.75	0.93
WA	0	0	0	0	0	2	0	2	2	100	100	1
RI	0	0	0	0	0	0	5	5	5	83.33	100	1
R-Total	31	107	83	36	15	2	6	280	241	90.88	90.03	0.81
Overall Classification Accuracy = 86.07%												

* DF=Dense forest; OF=Open forest; YF= Young fallow; UC=Upland crop; PA= Paddy field; RI= Residence area; WA=Water; R-Total= Reference Total, C-Total= Classified Total, PA= Producer Accuracy, UA= User Accuracy.

3.2.2.2 Land use and land cover change

Land use land cover changes between dates were analyzed directly through statistic data obtained from maps of each date.

3.2.2.3 Quantifying impacts of the feeder roads on landscape

In order to quantify the impact of the feeder roads on landscape composition, we generated buffer along the roads with the extent of 200 meters. The extent of buffer is set based on the spatial analysis of upland crop distribution along the roads. The analysis showed that 200 meters (by average) from roads are possibly to be used for cropping.

In an attempt to relate feeder roads to other components of the landscape a spatial analysis was conducted within and outside of buffer zone to relate the intensity of changes to the presence of the roads in the form of forest regeneration and deforestation since 2003 to 2015.

1) Forest regeneration: Others land use and land cover types in previous date become dense forest and open forest in the later date.
2) Unchange: One land use and land cover type in previous date overlap the same type in the later date.
3) Deforestation**:** Dense forest and open forest in previous date become others land use and land cover types in the later date**.**

Table 3-7: Forest regeneration and deforestation

		Forest change						
	LULC	DF	OF	YF	UC	PA	RI	WA
Previous date	DF							
	OF							
	YF							
	UC							
	PA							
	RI							
	WA							

** XX= impossible for this change. This must not happen in reality.*

Land use and land cover

DF Dense forest
OF Open forest
YF Young fallow
UC Upland crop
PA Paddy field
RI Residence area
WA Water

Forest transition

Forest regeneration
Unchange
Deforestation

3.2.3 Feeder roads and farmers' livelihood

Exploring changes in agriculture practice is considered as a way of exploring changes on livelihood. In this context, agriculture production practices are evaluated through analysis of socio-economic data gained from detail survey. This included the evaluation of production field area, labour force, and cultivation versus raising livestock. Household economy is analyzed based on the changes of house and assets of the family between 2009 and 2015, e.g. vehicles, modern tools or equipment for production, technology, etc.

3.2.4 Farmers' perspective on environmental changes

Farmers' perception on the environment is analyzed using frequency analysis based on their perception provided to all aspects of questions about environment. The perception on environmental change is evaluated based on 5-scale, namely, (-2) sharp decrease, (-1) decrease, (0) stable, (+1) increase, (+2) large increase. Pivot-table and pivot-chart was used to summarize the perception of the villagers on the values of land use and land cover for local livelihood and natural environment.

Chapter 4 Results and Analysis

This chapter presents the result of the study around the three main components presented in the conceptual framework of the previous chapter. The agrarian transition, namely the transition from traditional subsistence production systems to market-oriented agricultural systems sets the scene of the overall study. In this study, the transition is analyzed through the lens of maize expansion (the main commercial crop in the area) over more than a decade, between 2003 and 2015.

The chapter first introduces the interactions between land use changes and landscape transformations then between land use changes and livelihoods before investigating the interactions between the three components of the socio-ecological system under scrutiny (Figure 1-2).

4.1 Impacts of feeder roads expansion in upland landscapes

4.1.1 Expansion patterns of feeder roads

After maize harvesting in 2006, the Vietnamese maize trader offered opening the feeder roads to production areas in order to promote maize production. The first two feeder roads were opened in Nanong village. These first two roads costed 28 million Lao kip (MLAK). In 2007, Nadeua village invested about 25 MLAK to open a road to one of their production areas. Then, in 2008, there was a big investment in opening feeder roads, four roads were opened in Natong village for a total cost of 102 MLAK and three roads for 40 MLAK in Xiengdaen village. At the same time, Phouk village invested 68 MLAK to open four roads, for 10.5 MLAK per km. But three of the roads built in Phouk village which costed 55 MLAK were not reimbursed by villagers because the contract was canceled as the trader did not come to buy maize from villagers.

In 2009, Natong village opened two more roads. A road cost 24 MLAK, while another met contract breaking condition as it was not maintained by the company as per contract agreement. In 2012, Natong invested in two more roads which cost 31 MLAK. In 2013, Nadeua invested in opening one more road after long period use of land along their first feeder road built in 2007, this new-road cost 15 MLAK. There was a break between 2013 and 2015 as no new-road was constructed. In the early of 2016, 5 new-roads are being constructed: 2 roads in Xiengdaen, 3 roads in Nadeua, see Figure 4-1.

In the short future, Natong village plans to open 2 more roads to access to the rest of their production areas, Phouk village plan to open 2 roads, and Nadeua plan to open one more road so that every production areas are accessible. Nanong has already expanded feeder roads to its maximum length with only two roads because their production areas are limited.

Since constructing the first feeder road until 2015, villagers invested more than 300 MLAK in building feeder roads along the hillsides to reach their production areas. As shown in Figure 4-3, there were two main periods of road construction: at the initial time of the maize boom, between 2007 and 2008 and more recently, 2015, which may mark as a second wave of maize expansion.

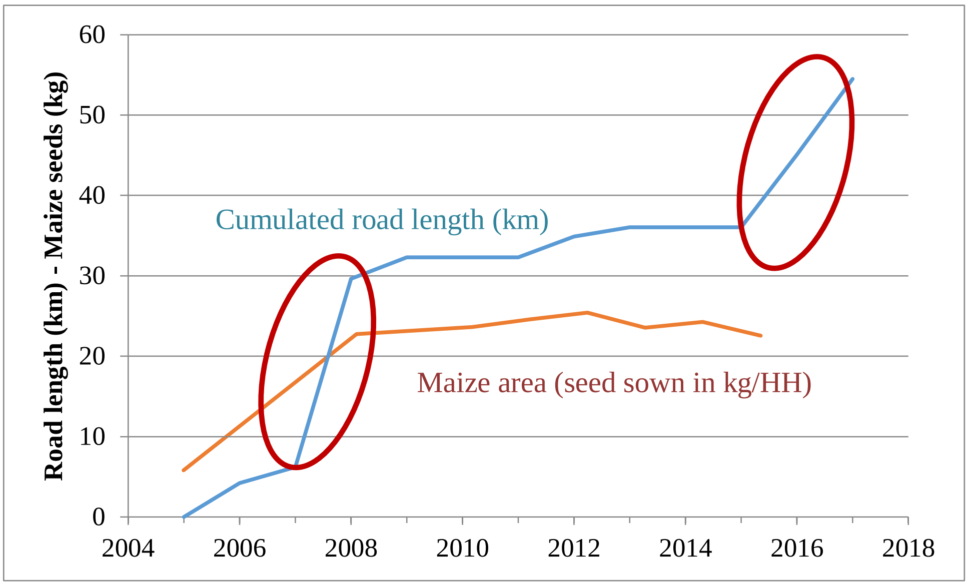


Figure 4-1 Cumulative length of feeder roads and expansion of maize areas

In summary, most of feeder roads were constructed before 2009 accounting for about 29 Km (villagers reported 19 Km). Between 2009 and 2015, there were some additional road construction with total length about 6 Km (villagers reported 4 Km), and then more roads were constructed after 2015 estimated to account for about 18 Km (**Table 4-1**).

Table 4-1: Summarized feeder roads statistics in the study site

Time periods	No of roads	Calculated length* (km)	Reported length** (km)
Before 2009	**16**	**29.65**	**19.81**
2006	3	4.22	2.30
2007	1	1.97	2.18
2008	12	23.45	15.33
2009 - 2015	**5**	**6.41**	**4.27**
2009	2	2.66	0.00
2012	2	2.59	3.10
2013	1	1.16	1.17
After 2015	**10**	**18.42**	**7.00**
2016	5	9.02	7.00
Plan	5	9.42	0.00
Total	**31**	**54.50**	**31.08**

*Calculated length using GIS software: is the length calculated based on participatory mapping during field work.

** Reported length: is the length reported by key informant during group discussion in field work

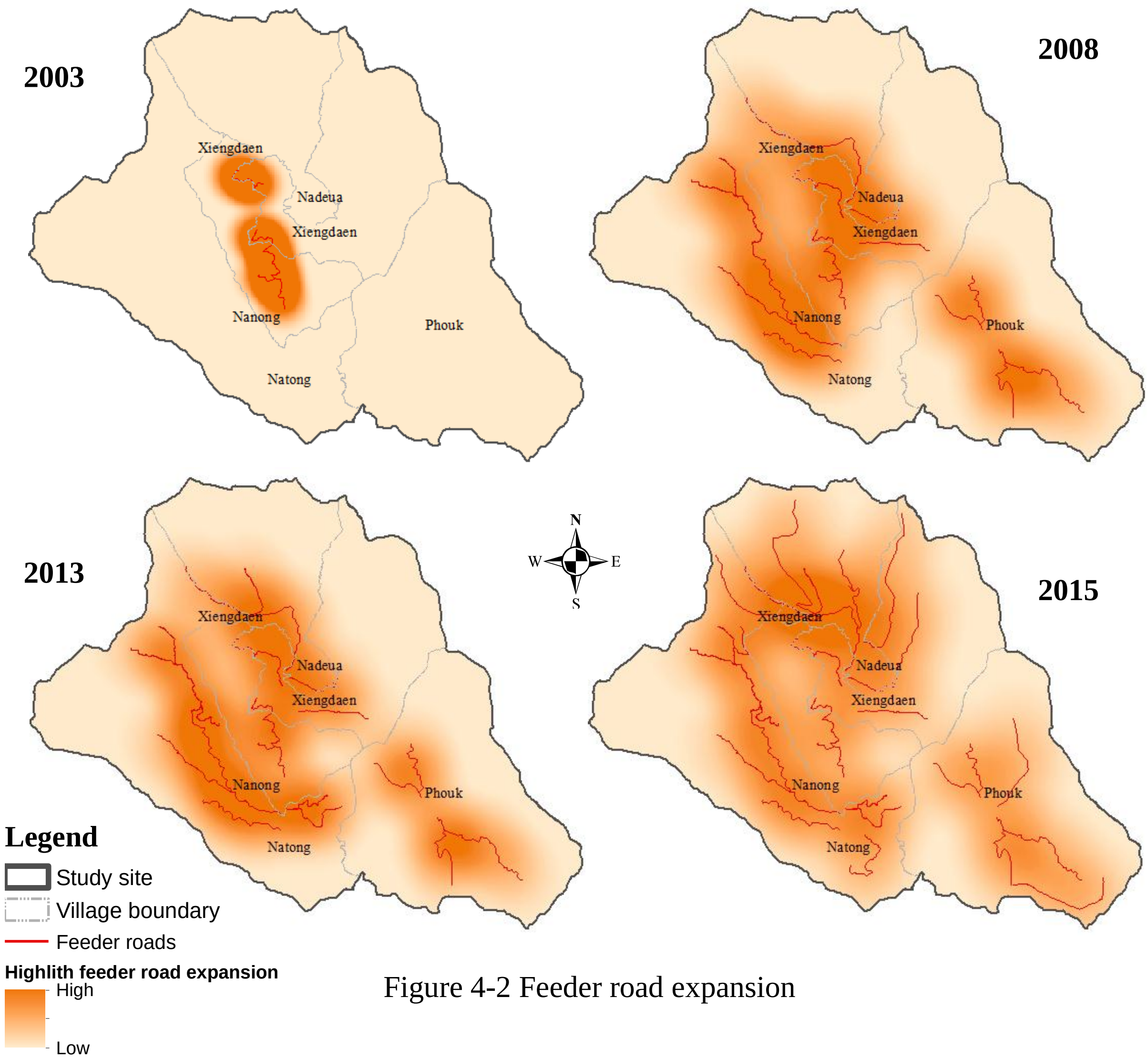


Figure 4-2 Feeder road expansion

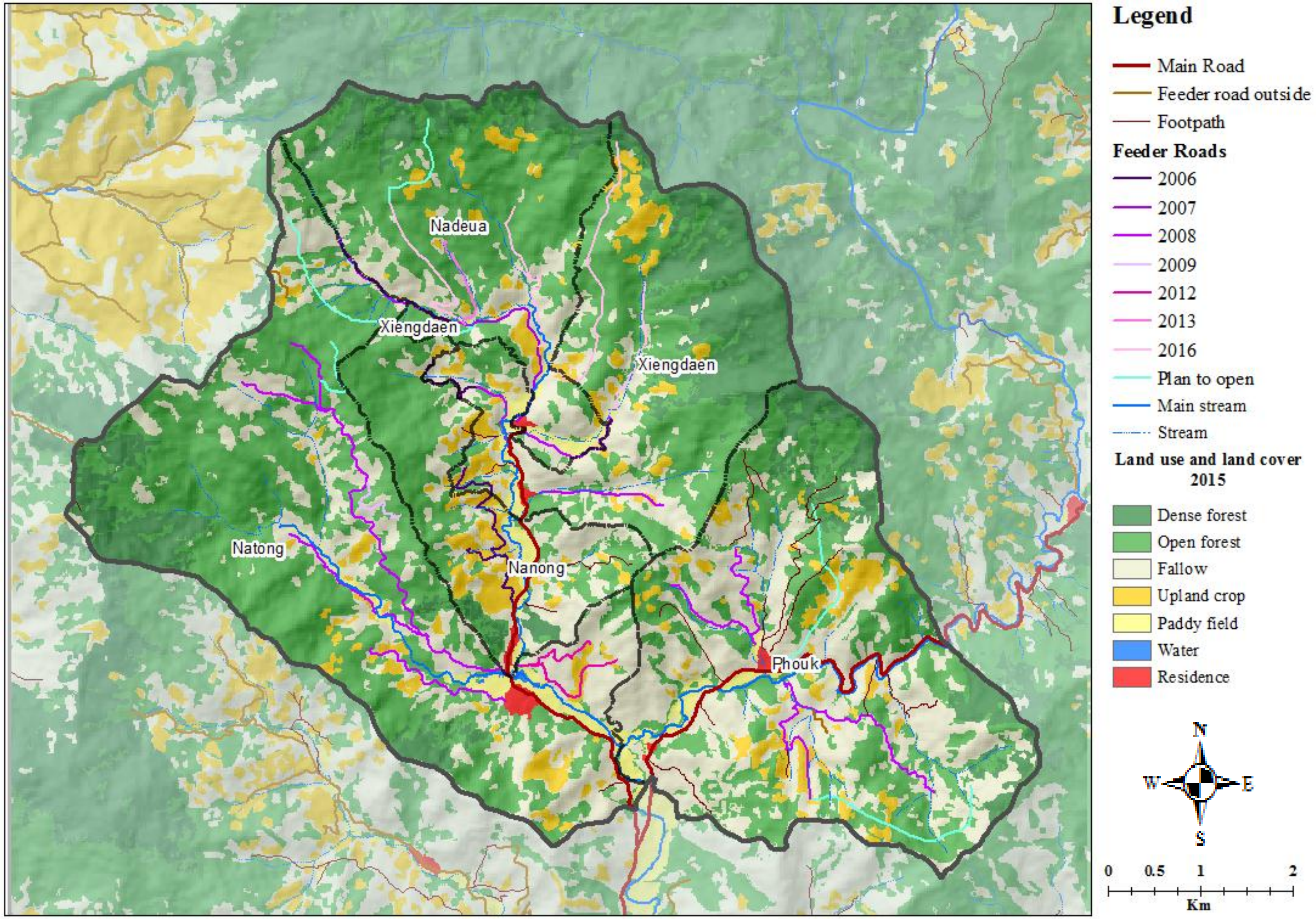


Figure 4-3 Spatial distribution of feeder roads in the study landscape

4.1.2 Feeder road construction processes

Villagers usually agree on which plot they would like to grow maize and then decide where they would like to open a feeder road and the design. Next, villagers who have land around this production area contact the trader to present their plan and negotiate a price. Then, the road project is further presented to the village head and committee who may survey the area planned for road construction together with the trader to agree on a price. After that, the village head introduces the project to 3 district services: Department of civil construction and transportation, Department of Natural Resources and Environment, Department of Agriculture and Forestry. The district authorities may ask for a field survey of the area where the villagers propose to construct the road to insure that the road will not run through protected areas (Figure 4-4). After receiving an official agreement from the three departments, the village head is allowed to sign a contract with the maize trader on behalf of the villagers' group.

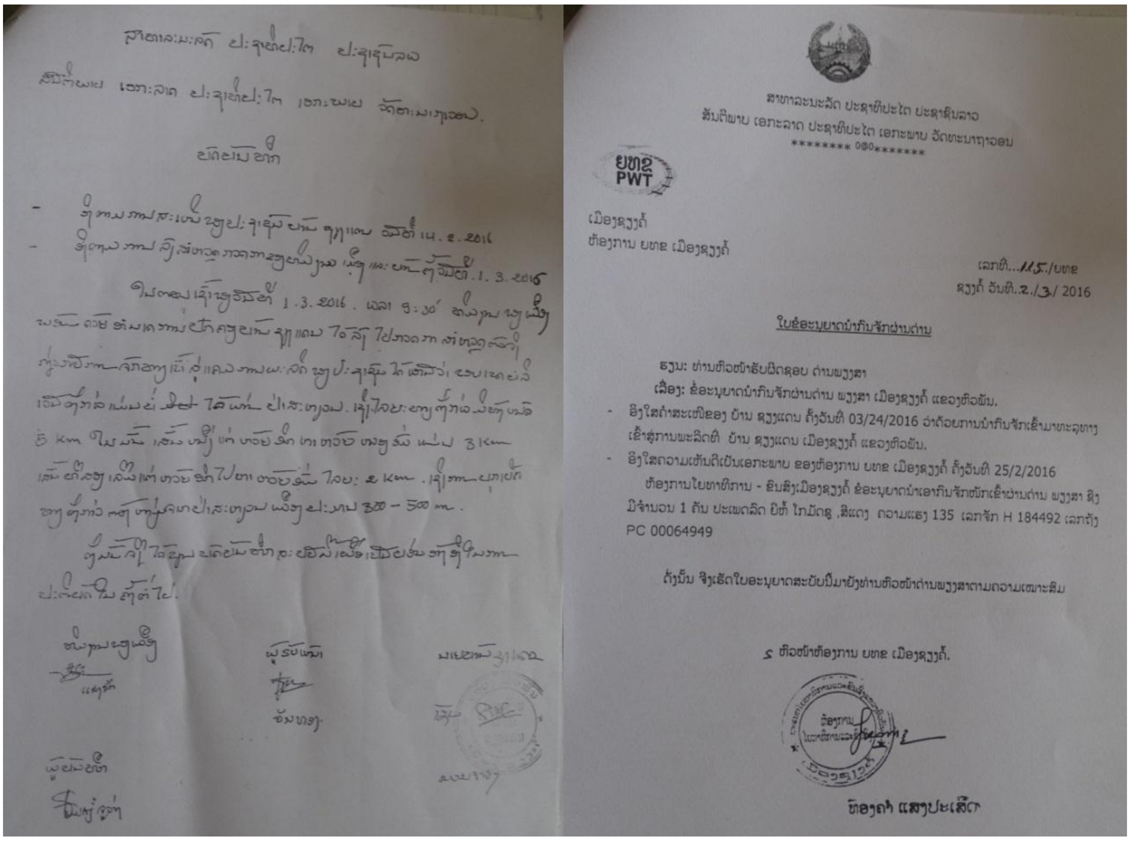


Figure 4-4 Feeder road authorization documents for Xiengdaene village, March 2016

Left: Report about checking feeder road project proposed by Xiengdane village in order to ensure that the road will not pass through protected forest (dated 1/3/2016)

Right: Letter from the District Public Works and Transportation to the border check point for importing excavator from Vietnam in order to repare existing feeder roads and openning new feeder road in Xiengdaen (dated 2/3/2016)

The conditions are presented in the contract: the trader constructs the road with his own equipment or rent equipment from private owners or construction companies. The road should be finished before the beginning of the rainy season. The trader commits to repair the road every year at the end of the rainy season to facilitate the harvest. The villagers will sell all their production to this trader for 3 or 5 years depending on how difficult the road open is and will sell their maize at a reduced price (100 LAK/kg) from the market price.

These official rules are provided by the department in charge at the district level, but in reality the roads are often opened before receiving the official agreement and in many cases an official request is not sent to the offices in charge. This leads to a large discrepancy in available data depending on the sources of information: 45km through participatory mapping and measurements with GPS and Remote sensing tools, 31km through focus group discussions at village level and 7 km at the district office for officially registered roads (only since 2014).

Furthermore, the conditions negotiated between the different parties vary very much from village to village and period to period depending on the information level of the different parties, their previous experience and bargaining power and whether the conditions of the agreement are written down in a contract or remain oral (Box **1**).

Box **1: History of road negotiations in Xiengdaen village**

In 2008, villagers paid their first roads in cash according to the cost agreed upon per km. The total amount was divided among all households according to the number of household members. They paid once a year after harvest time during 3 years.

In 2016, Xiengdaen villagers decided to open two more maize roads. One about 5 km and another one only opened on 2km at the time of the survey but has surely been extended since then. The village committee discussed about the roads and their location then invited all villagers (35 households) to survey the area. Villagers were all offered to select a field close to the future road. For each section of the road, the village head would ask who is interested to get his/her field at the right and left side of the road. Those who then raised their hand would get allocated a field to grow maize.

Once the road construction was decided, the village committee discussed with the trader about the conditions. This year, the negotiated contract stipulates that the villagers will have to sell exclusively to this trader; that they will get paid 100LAK/kg less for the maize collected along the new roads than the one collected along the old feeder roads. The reference price for the old roads will be the market price. The problem is that villagers do not know the cost of the new roads. As per the contract, they will have to pay 100LAK/kg maize harvest along these roads for the next 5 years. In case they would like to reimburse in cash (like for the first set of roads in 2008) and not with maize, it is not clear how much they would have to reimburse as the road cost is not known. The contract is then sent to the district officers who check it and modify if necessary. It should go through the District Agriculture and Forestry Office (DAFO), District Office of the Natural Resources and Environment (DoNRE), Industrial and Trade, and the District Public Work & Transportation Offices. DAFO and DoNRE staffs have already surveyed the area before the road was built to avoid problems with a road that would go through conservation forest or other land use types that are not allowed to convert into maize.

The previous roads built in 2008 caused a number of problems to both the trader and villagers. The new regulations with stronger involvement of the district authorities and formally written contract are based on the past experiences. One year after building the road, the villagers in Xiengdane decided not to grow maize and therefore no reimbursing the road by selling their maize. It took a long negotiation for the trader to get reimbursed in cash by villagers who were not growing maize. On the other hand, the traders wrote in one contract that the maize price would be fixed to 700LAK/kg for villagers who benefited from the newly built road. But the price was fixed, whatever the market price of maize would be. As a result villagers were receiving 700 LAK/kg even when the market price was 1000 or 1200 LAK/kg; a deal that was highly benefiting the trader. As a consequence, a price decreased of 100LAK/kg from the market price was decided in the next contracts. The quality of the contracts and the quality of the negotiators therefore improved gradually through the successive experiences they went through. A compromise was found between the three main actors of the negotiation: the villagers, the traders, and the officers of the district line agencies.

4.1.3 Land use and land cover between 2003 and 2015

Figure 4-5 and Figure 4-6 presents the movement of land use and land cover in each year. Open forest covered large proportion in each year, follow by fallow land and dense forest.

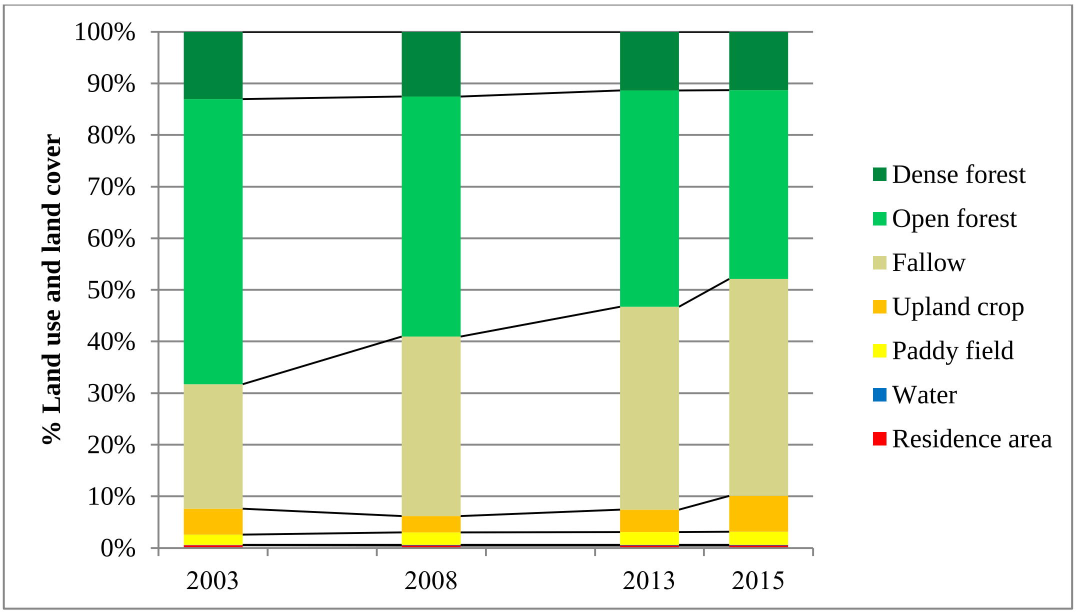


Figure 4-5 Land use and land cover between period of the study

Forest covered large proportion in the study area in the early 2000s, but it decreased continuously both in dense forest and open forest areas over the past decade. Open forest, the largest land cover category, decreased dramatically from 74% in 2003 to 54% in 2015. Fallow areas increased inversely to open forest. Upland crop areas, essentially upland rice prior to the maize boom in 2006 and then a mix of upland rice and maize, increased continuously in the recent years.

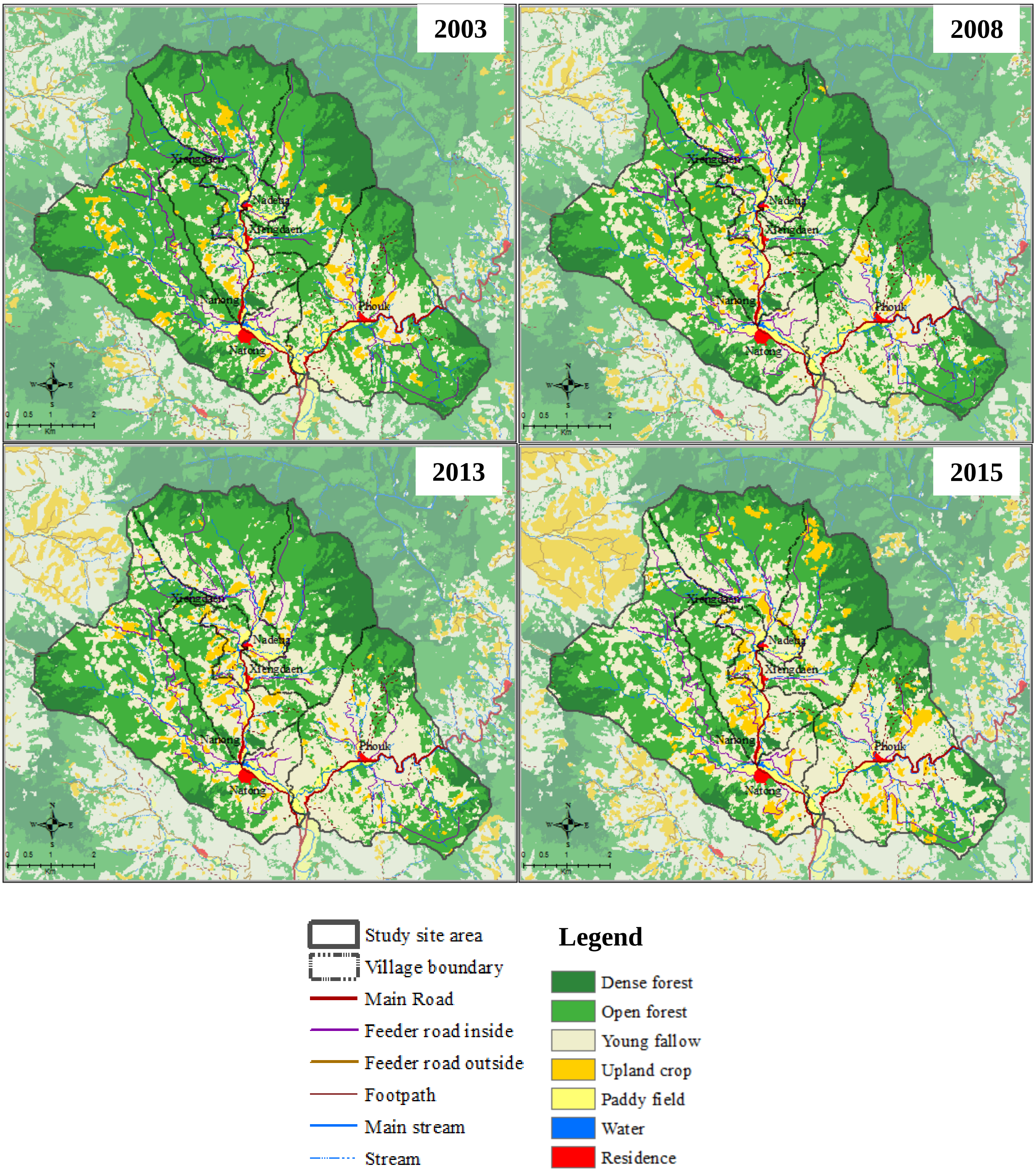


Figure 4-6 Land use maps 2003, 2008, 2013, 2015

4.1.4 Land use changes from 2003 to 2015

Between 2008 and 2013, all households in the study area engaged in the production of hybrid maize and many feeder roads were opened. The roads were necessary for maize expansion as farmers could not carry back the heavy harvest from scattered fields on their back as they use to do with upland rice. When they harvest one tone per hectare of upland rice in average, the maize yield is about 5 times higher, which would require to carry down the hills 5 tons per hectare cultivated with maize. The feeder roads allowed the hand tractors to get closer to the fields and facilitated the transportation of the harvest and circulation within the village territory. It is considered by villagers as a considerable improvement of their workload and their lifestyle.

Expansion of maize crop transformed dramatically the agricultural landscape as the rotational system was shortened as compared to upland rice-based shifting cultivation systems. While upland rice cultivation was usually followed by 5 to 7 years of fallow and forest regeneration before returning to the same plot for cultivation, maize rotational systems involved only 2 years of fallow and in most accessible areas close to the feeder roads farmers were cropping their plots almost continuously. There is therefore a gradient of land use intensity from remote areas towards more accessible areas in the landscape, with decreasing proportion of fallow in the rotational agricultural system as it is located closer to the feeder road network.

As a result of maize expansion, large areas of forest land, both dense and open forest, were converted to upland rotational agriculture (or shifting cultivation): represented by the upland crop and fallow land use categories in Figure 4-6. The natural forest regeneration involved in the traditional shifting cultivation system could not compensate anymore for the forest degradation induced by upland crop expansion and shortening fallow periods leading to an overall degradation of the forest cover. This forest change had further consequences on water cycles and availability in the streams and river, on land degradation, erosion and fertility decrease and on the availability of non-timber forest products that used to be a major component of farmers' livelihood systems in the area.

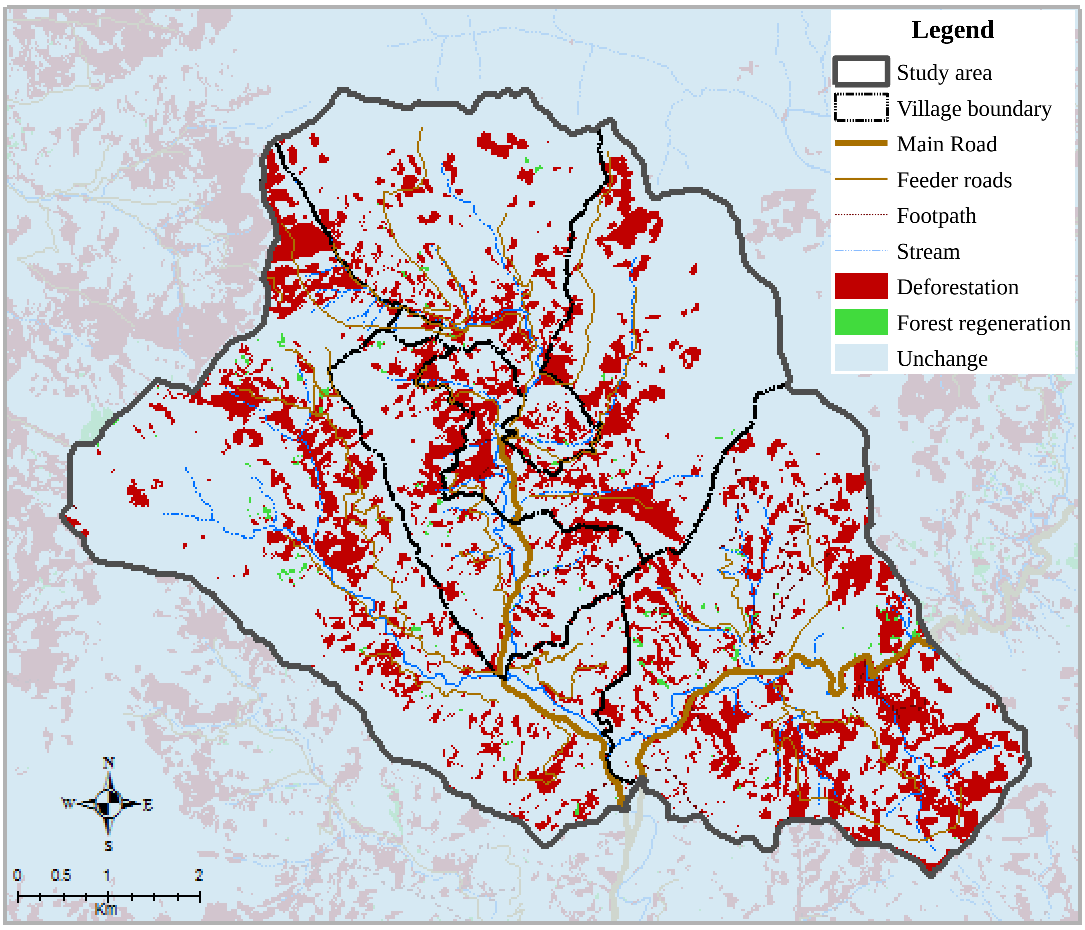


Figure 4-7 Land use change 2003 – 2015

4.1.5 Feeder roads and land use changes

As presented above, there is a direct relation between the expansion of feeder roads and farmers' capacity to expand maize cultivation to remote areas of the village territory that used to be reachable only by foot tracks. The roads are necessary for the maize expansion and on the other hand maize production pays for the roads. Both processes are therefore intimately related and feeder roads can be considered as an instrument of maize expansion. We have shown in the previous section that maize expansion comes with many other land use changes that have major impacts on local landscapes and livelihoods. In an attempt to relate feeder roads to other components of the landscape, a spatial analysis was conducted within and outside of a 200 meters buffer area around the feeder roads to relate the intensity of changes to the presence of the roads (Figure 4-8).

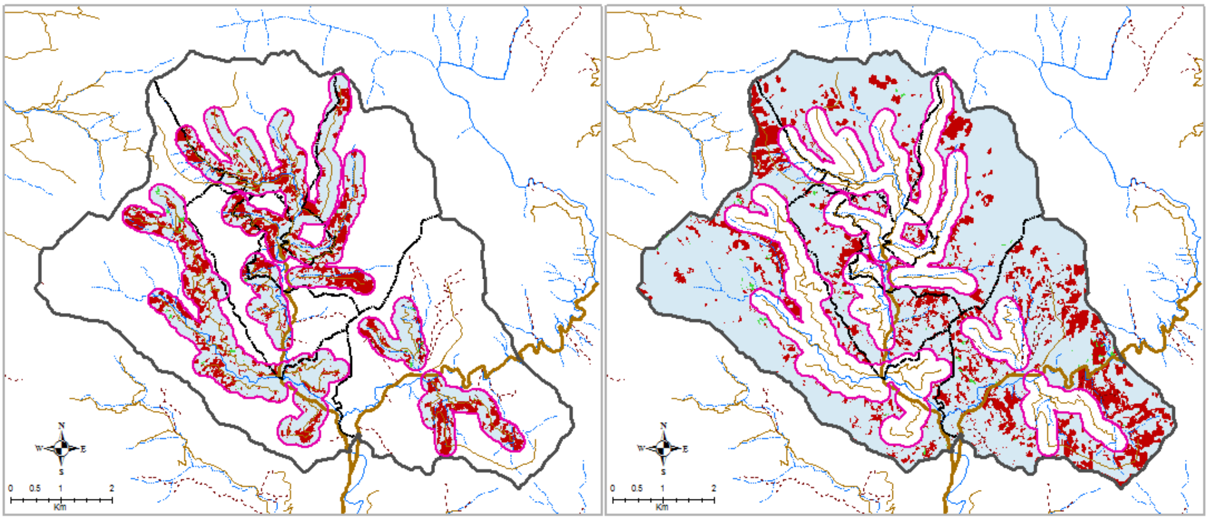


Figure 4-8 Land use changes 2003-2015 induced by feeder roads within a 200m buffer area

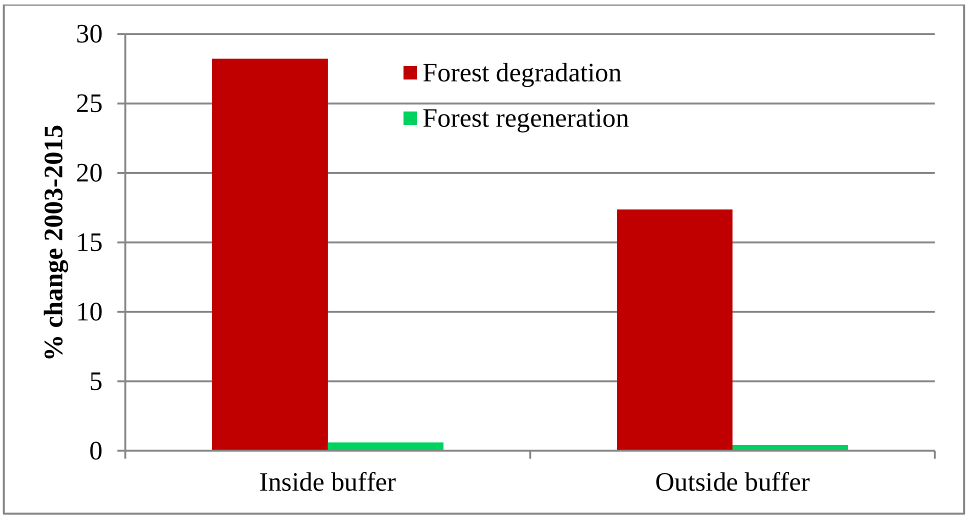


Figure 4-9 Percentage of forest degradation and regeneration inside/outside a 200m buffer zone around the feeder roads

4.2 Feeder roads and farmers' livelihood

As discussed in the previous section, the 54km feeder road network built over the years came with a direct cost for the local population, estimated at about 300 MLAK and indirect costs in terms of forest loss and land degradation. It also came, of course, with direct benefits for the local population in terms of income generated through maize cultivation and indirect benefits depending on how the maize money was reinvested by villagers into other income generating activities. In this section, we analyze the impacts of maize expansion on livelihood changes. The results are based on the analysis of exhaustive household surveys, i.e. all 350 households in the 5 target villages responded to a rapid quantitative survey in 2009 and then again in 2016, and a more detailed survey involving 73 households in the 4 villages of Natong, Phouk, Xiendane and Nadeua who responded to a detailed questionnaire in 2009 and then again in 2016. Besides, thematic focus group discussions were conducted in the four latter villages and provided more qualitative perspectives on the topics addressed by the two other questionnaires.

Data analysis was conducted either by individual household across the whole study area or individual results were averaged per village whenever relevant to the questions at hand.

5.1.1 Changes in agriculture

4.2.1.1 The maize boom

Indeed, most livelihood changes happened in relation with the maize boom that started in 2006 in the study area. This rapid increase in maize cultivation marked a shift from **subsistence based agriculture** with villagers depending (i) on paddy land and upland fields to cultivate their staple food: rice, and (ii) livestock (mainly buffaloes) and forest products to provide limited amount of cash, to **market-oriented agriculture** involving the use of more inputs for production, indebtedness, land use intensification and diversification of income generation sources. We detail these multiple aspects of agricultural changes in the successive graphs based on analysis of household surveys.

Figure 4-10 below shows the gradual expansion of the three main crops produced in the study area, namely paddy rice, upland rice and maize, expressed as average quantity of seeds sown per household. In relation to the sharp increase in maize cultivation that replaced many fallow plots of the upland rice sifting cultivation system one observe an overall decrease in upland rice cultivation since 2007. This reduction of shifting cultivation has been compensated by an increase in paddy rice production, not so much as an expansion of paddy areas as shown in the previous section by as an intensification of the production through generalization of the 2 cycle rice production while spring rice was cropped only on some plots before maize expansion.

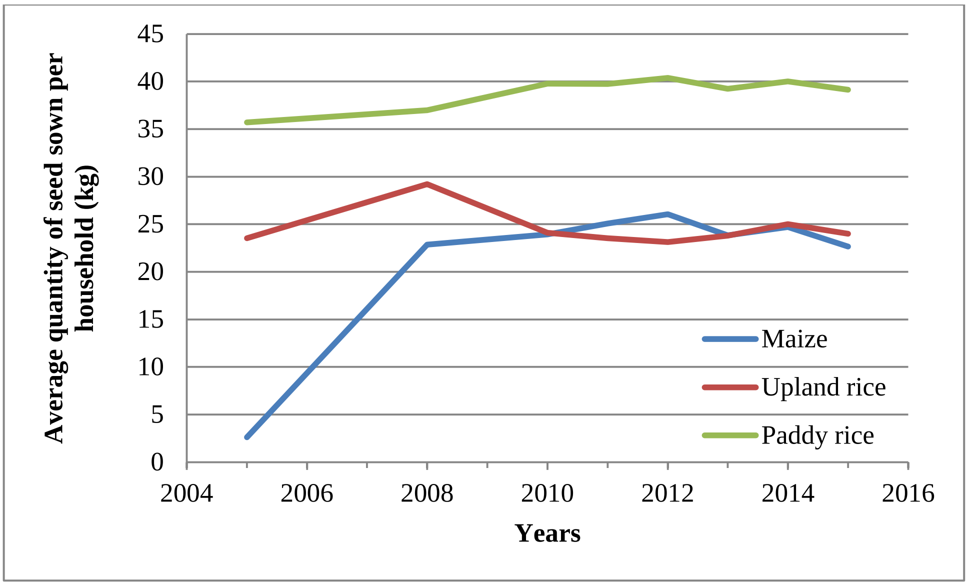


Figure 4-10 Change in the three main crops from 2005 to 2015

The Figure 4-11 confirms the trends presented above about the limited expansion of agriculture after the initial increase in maize areas in 2006-2008. The change in the average level of production per household has not evolved significantly between 2009 and 2016.

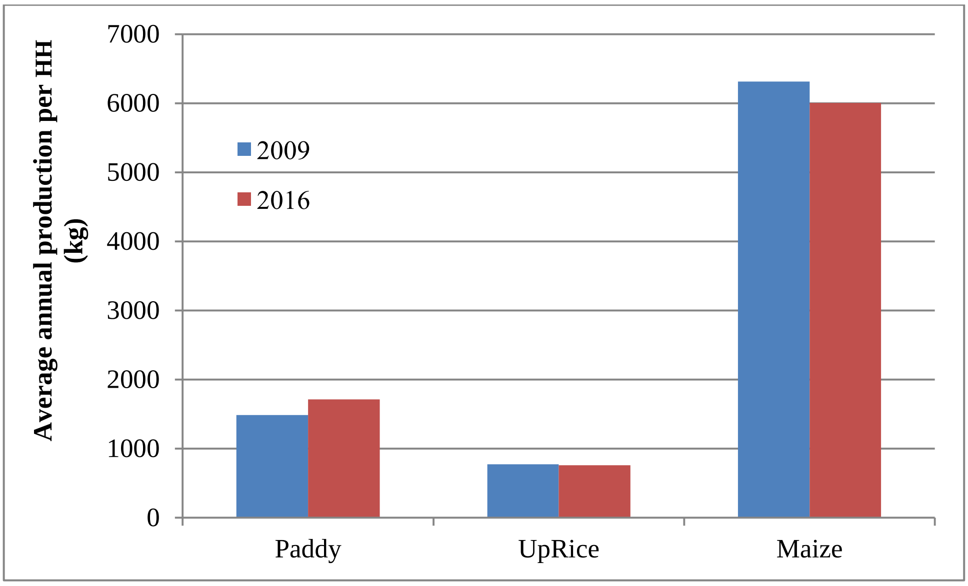


Figure 4-11 Change in production of the three main crops between 2009 and 2016

4.2.1.2 Livestock changes

Over the same period, major changes have been observed in relation to livestock. Buffaloes were gradually replaced by hand tractors for plowing the paddy land as villagers could afford to buy machinery with the money they earned from maize in 2007-2008. Also, some buffaloes that used to roam freely in remote forests when the maize largely spread in the uplands got stolen or disappeared because were roaming too far away, leading villagers to sell the remaining ones to avoid further losses. They then decided to buy more cattle as they had a faster reproduction rate than buffaloes but decided to delineate livestock areas closer to the villages to avoid further losses, and damages to upland crops, especially during the rainy season. As there are no fences in the village territory, the livestock need to by tended or parked in fenced livestock areas to avoid damages on crops by domestic animals.

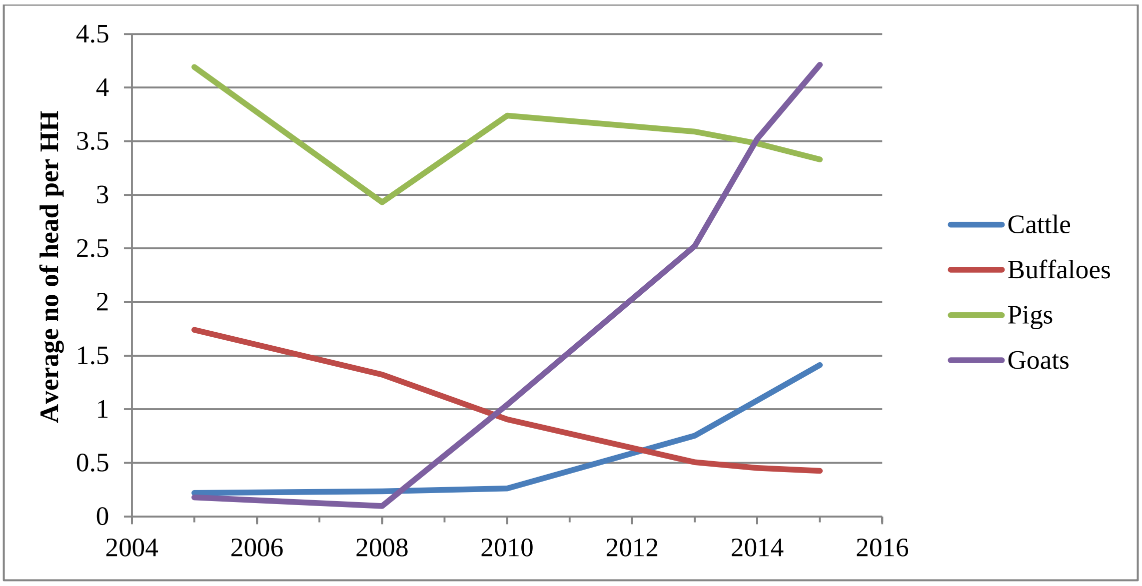


Figure 4-12 Livestock changes

The villagers started raising goats in 2010 and the number of heads increased sharply over the recent years. Goats spend the night in sheds. Owners alternate to take care of the animals that tended at all time and are usually brought to the fallow areas for grazing.

Livestock owners are responsible for damages their animals may cause to the crops as there is no fence in the village except around the livestock areas. Whenever animals get out of the livestock area the livestock owner is responsible for any damage cause by its animals. This local institution emerged in 2006 when a large proportion of villagers started growing maize in the village. Maize expansion therefore triggered a major change in livestock management style with a shift from free roaming to collectively managed livestock areas.

4.2.1.3 Drivers of agricultural change

The *population* (359 HH in 2009 and 368 HH in 2016) did not change much over the recent years and was therefore not a major driver of changes. No *land use plan* implemented so far by the district authorities in the study area. An initial plan was designed by the villagers themselves in 1997 (see report Viau et al., 2009) and the Poverty Reduction Fund did a plan about forest use in 2010. They delineated village protection forest, located above the village to protect against landslides and at the border with Vietnam, village production forests and sacred forests. In 2015 DAFO delineated livestock areas with villagers. These areas already existed since 2009, set up by villagers themselves but were formalized in 2015 only (Figure 4-13).

Many fruit trees (mango, tamarind, etc.) were planted from 2003 to 2005 with the support of development projects but traders did not come to buy the harvests. From 2003 to 2006 almost all villagers also grew soybean, but they stopped when they started growing maize because of labor shortage and limited market opportunities for alternative crops such as fruit trees, vegetable or soybean.

The main drivers of change were the expansion of feeder roads that allowed the expansion of maize fields in 2006-2008, the improvement of the main access road to the village in 2009 that brought the traders to the village and offered market opportunities, and then the connection to the electricity grid in 2013.

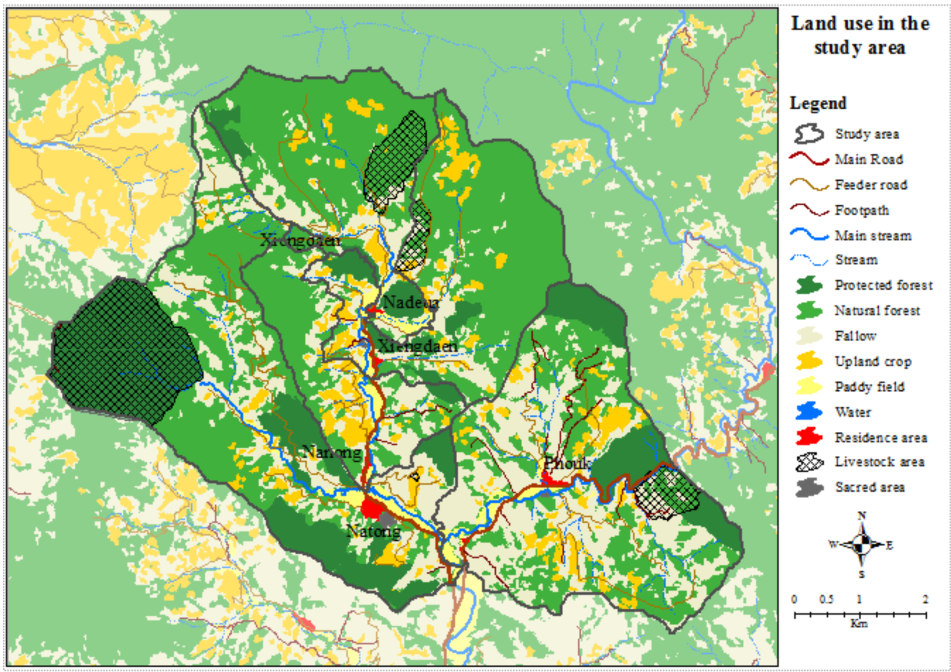


Figure 4-13 Land use in the study area in 2015

5.1.2 Change in agricultural practices

Changes in agricultural practices were induced by both the *opportunities* provided by maize benefits that allowed farmers to invest in new equipment and the *constraints* imposed by maize expansion on the family labor force available on the farms that required some level of mechanization or input use to expand maize area and maintain yields beyond the initial boom period, i.e. 2006-2008.

The Figure 4-14 below shows that the first wave of equipment bought by villagers in relation with the maize boom was first rice mills, then motorcycles and finally hand-tractors. The steep slope on the motorcycle and hand-tractor curves in Figure 4-14 during the period 2006-2008 confirms the statements of the surveys' and focus groups' respondents that the maize money was rapidly invested in livelihood improvements such as renovating houses and paying for the study of the children but also time saving equipment such as motorcycles and hand-tractors. Both needed feeder roads to easier transportation to production areas in the village landscape, so the purchase of transportation equipment further accelerated the construction of new feeder roads.

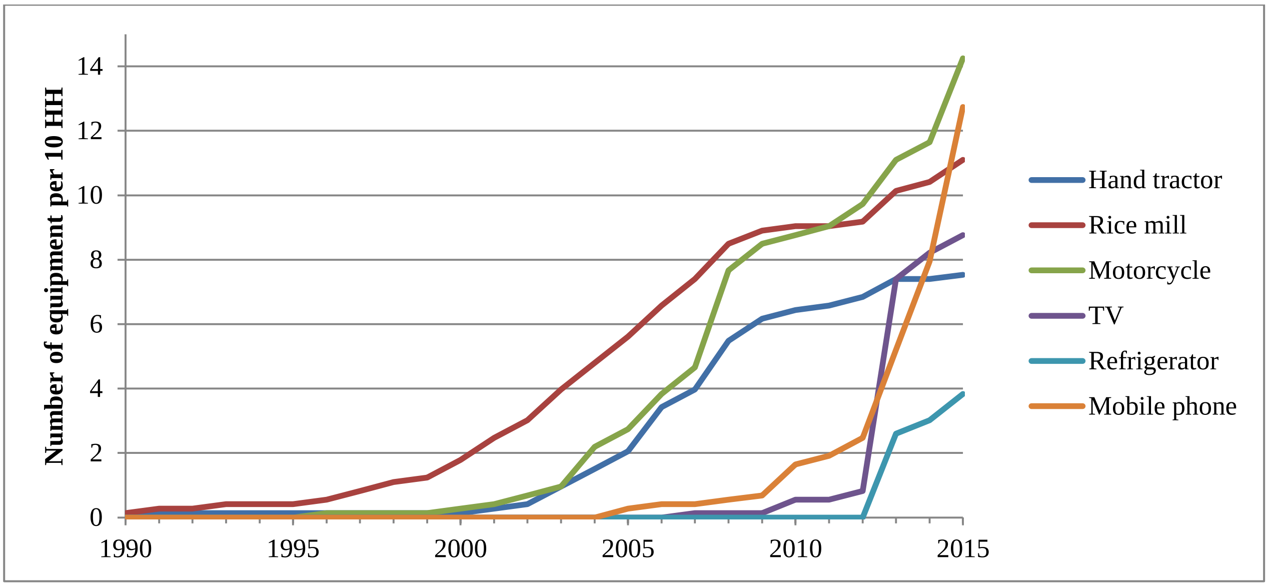


Figure 4-14 Time of equipment purchase by households in the study area (cumulative values)

The second wave of investments took place in 2012 and 2013 at the time the village got connected to the electricity grid. Contrary to the first batch of investment, this one was less oriented towards agricultural production and transportation and more in communication as it mainly consisted in buying TV and mobile phones, and more recently, refrigerators.

The number and value of assets each household own increased significantly between 2009 and 2016 as displayed in Figure 4-15 below. One can thus conclude that livelihoods improved thank to maize money.

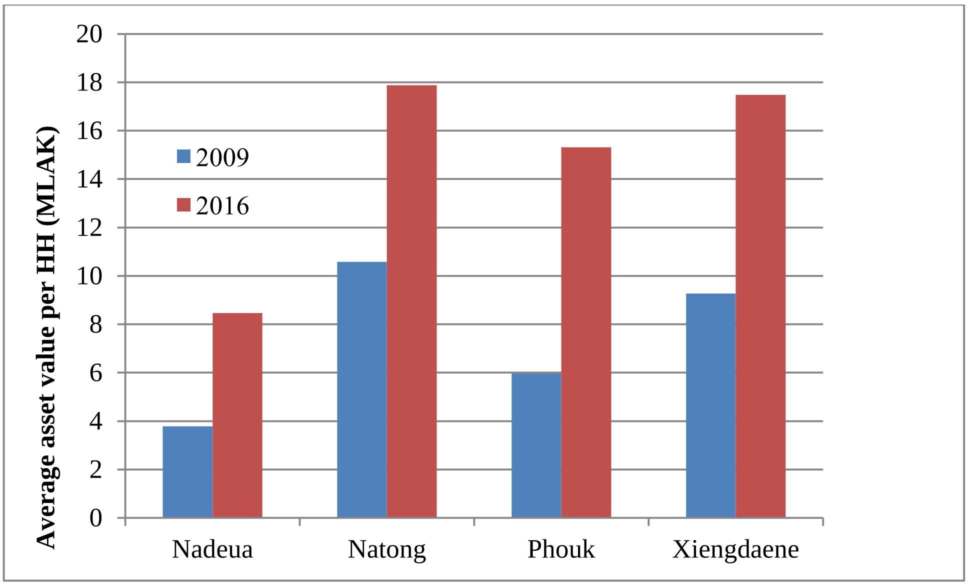


Figure 4-15 Average household asset value per HH in each village in 2009 and 2016

But maize expansion also brought other changes that may not be considered as positive in terms of livelihood impacts. Due to shortening maize-based rotational system farmers faced more and more problems with weed control that used most of their labor force and therefore reduced their capacity to expand the crop or to intensify cultivation in the lowland due to labor shortage.

Farmers first used herbicides in 2014. The first year they hired Vietnamese people to spray as they did not know how to do. Then villagers sprayed themselves. Many households also started using chemical fertilizers at the same time as herbicides, on maize and upland rice. They also started using urea in paddy since 2014. Since then, the few households who were using animal manure as fertilizer in the paddies stopped doing so as applying chemical fertilizer was considered more convenient despite the cost: urea is sold 190.000 LAK/bag.

But these new practices, developed as a response to decreasing yields, had negative effects on the household economy. They increased indebtedness of the households with the maize traders and middlemen forcing them to continue growing maize despite decreasing economic margins due to (i) increasing production costs due to: price of hybrid seeds (from 42.000 to 55.000 LAK/kg), chemical fertilizers and herbicides, used to compensable (ii) decreasing yields due to weed infestation, soil erosion and land degradation on hill slopes cropped continuously with maize.

As a consequence, farmers are searching alternative to what is now considered as unsustainable production systems. Indeed, intensive rotational systems on the hillsides are not sustainable as they are associated to soil fertility depletion. Depending on the villages, the soil quality and the household four main rotational systems are used in the study area, either with separate maize and upland rice fields (options 1 and 2) or mixed systems (options 3 and 4):

1. Maize – maize – maize – fallow – fallow – fallow (maize can be cropped up to 7 years on the same plot)
2. Rice – fallow – fallow – fallow (usually only one year cropped)
3. Rice – rice – maize – maize – maize – fallow – fallow – fallow (most common succession)
4. Rice – maize – maize – maize – fallow – fallow – fallow.

In 2016, many villagers have decided to cut maize production by half and to raise more animals on natural grass left on former maize fields. This gradually increasing disinterest for maize also comes from strict conditions imposed by the companies on maize quality as the production conditions are degrading. If the quality is not good the company informed that it will not buy the harvest. When maize prices were high on the international market, the company committed to provide the seeds, buy the whole production from the village and to maintain the feeder roads. But some problems occurred with the company in 2014, in a context of low maize price, as they did not fix the road properly and the truck could not reach some areas. As a result they did not collect some maize areas, therefore increasing the tensions with maize producers.

Finally, respondent all agreed that 2008 was the best maize year in the village. They could sell a good harvest (high yields on relatively good soils at the initial stage of the maize boom) at a good price 1400 LAK/kg as compared to 900 to 1000 LAK/kg in 2016. The maximum cropped area in the village was reached in 2013 in an attempt to compensate gradual land degradation and therefore decreasing yields by expanding maize to new, more fertile fields. Indeed, 2013/2014 is a turning point in the history of the study area with the decrease in maize production and the massive investment in goats and cattle as an attempt to diversify income generation sources. In 2016 villagers decided to expand the maize roads so that they can open new fields further away from the village and fallow the old fields that have been cropped for many years.

5.1.3 Changes in income generation patterns

Faced with decreasing maize yields due to land use intensification in the uplands (i.e. shortening of the rotational systems), villagers are currently faced with three strategic options:

1. Transforming their cropping systems towards more sustainable ones. So far they have introduced herbicides and fertilizers to compensate for weed infestation and fertility losses but these changes reduce their economic margin and make the maize production not economically sustainable. Other practices such as conservation agriculture have been tested in the area, but not adopted by villagers because they were not under pressure to change their practices at the time they were invited to experiment some sustainable cropping practices,
2. Expanding the feeder road network to expand maize to more remote and more fertile fields within the village territory. This option consists in temporarily moving the problem to another place so that farmers can continue growing maize. But this will be the last time such a ‘geographic shift’ will be possible because this second batch of road expansion that has occurred between 2015 and 2017 as reached the limits of the village territory,
3. Diversifying on-farm and off-farm income generation activities has been mentioned many times by respondents during focus group discussions. Diversification of agricultural activities concentrates on livestock at the moment as the market for fruit trees is still limited. Many villagers plan to turn their maize fields into improved pastures to raise cattle. This change as already started during the period from 2009 to 2016 as shown in Figure 4-16. While crops still generate the bulk of income there is a clear trend of diversification towards livestock and off-farm activities (see arrows in Figure 4-17).

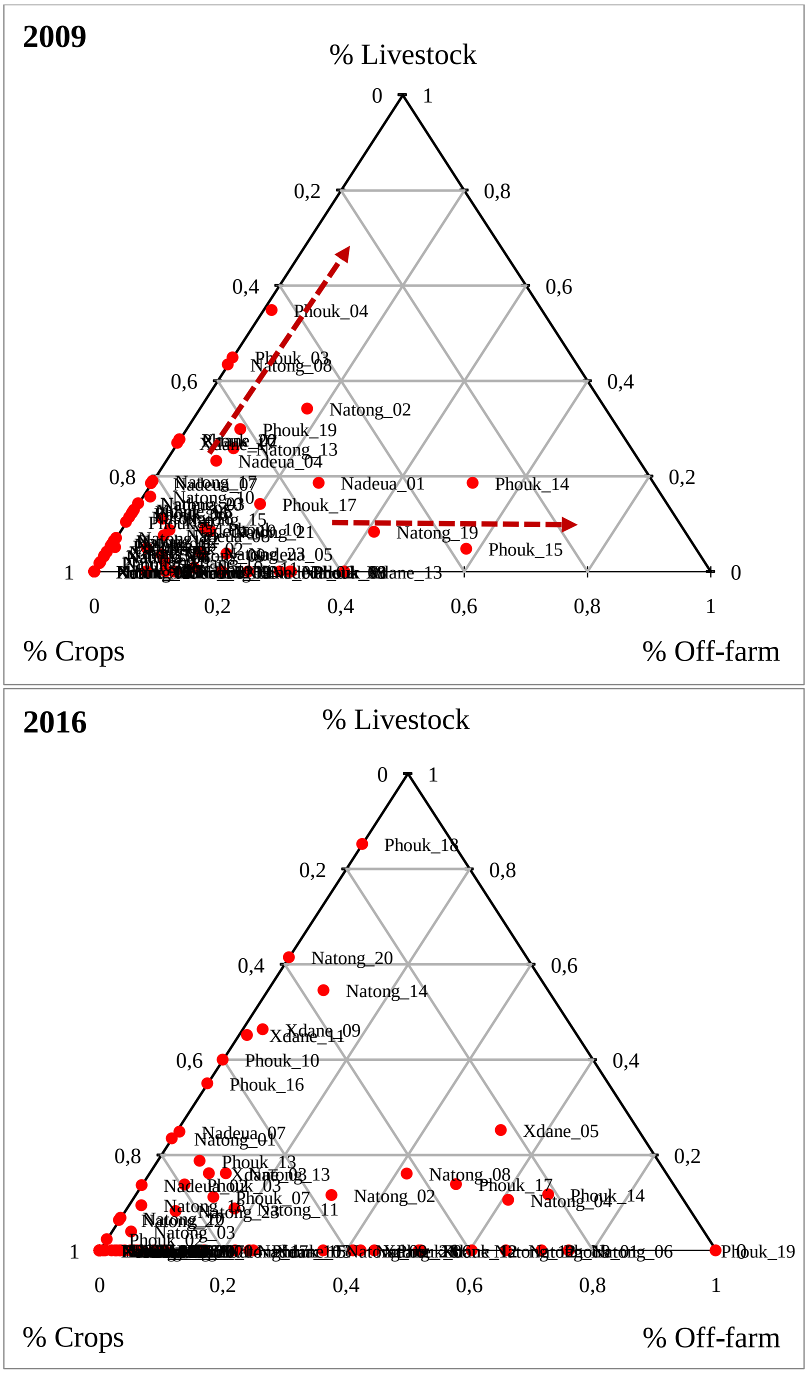


Figure 4-16 Relative contribution of crops, livestock and off-farm activities in household incomes in 2009 and 2016

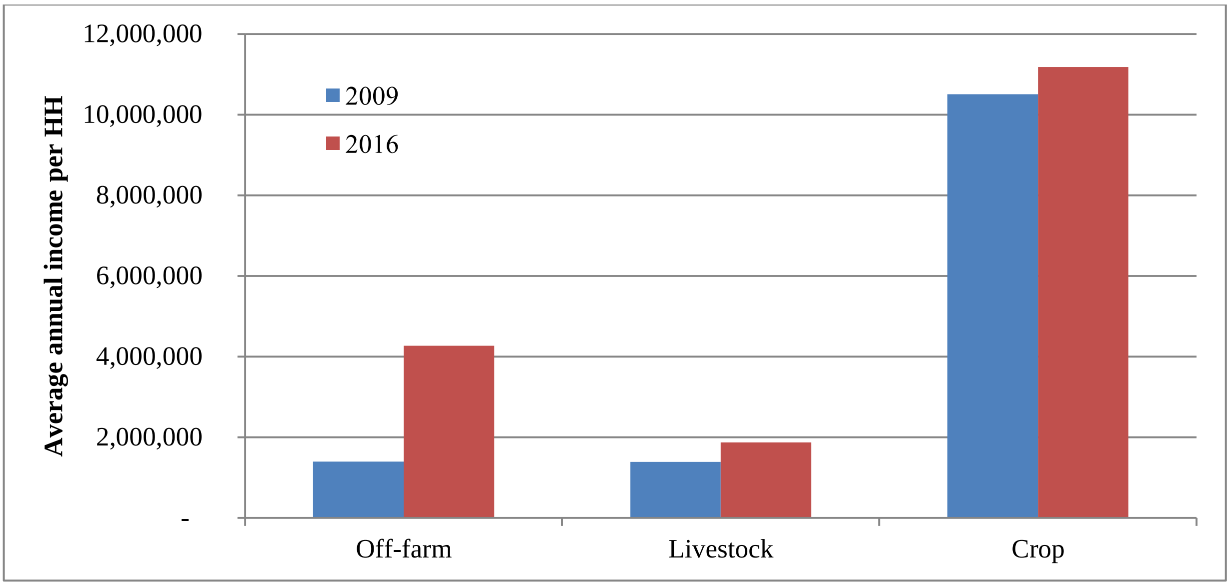


Figure 4-17 Main income sources between 2009 and 2016

Looking in more detail at the pattern of activities that generate incomes in the study area we ranked in Figure 4-18, below, the same 73 households surveyed in 2009 and 2016 according to their total annual income. From there, we found that while 50% of the households owned less than 20MLAK in 2009, the lowest 50% of the households earned less than 15 MLAK in 2016. The median income has been reduced by 5MLAK within a few years, which may explain why villagers are so much in search of alternative income sources. From the comparison of income distribution in 2009 and 2016, one can also observe that income from NTFP and gardens has almost completely disappeared with the rapid spread of maize areas. There are less NTFP in the remaining degraded forest and villagers have less time than before to collect and sell them because they are busy maintaining their declining maize-based system by using more inputs that reduce their economic margin or expanding to new forested area which is detrimental to forest resources as an economic safety net for the poorest household as it used to be.

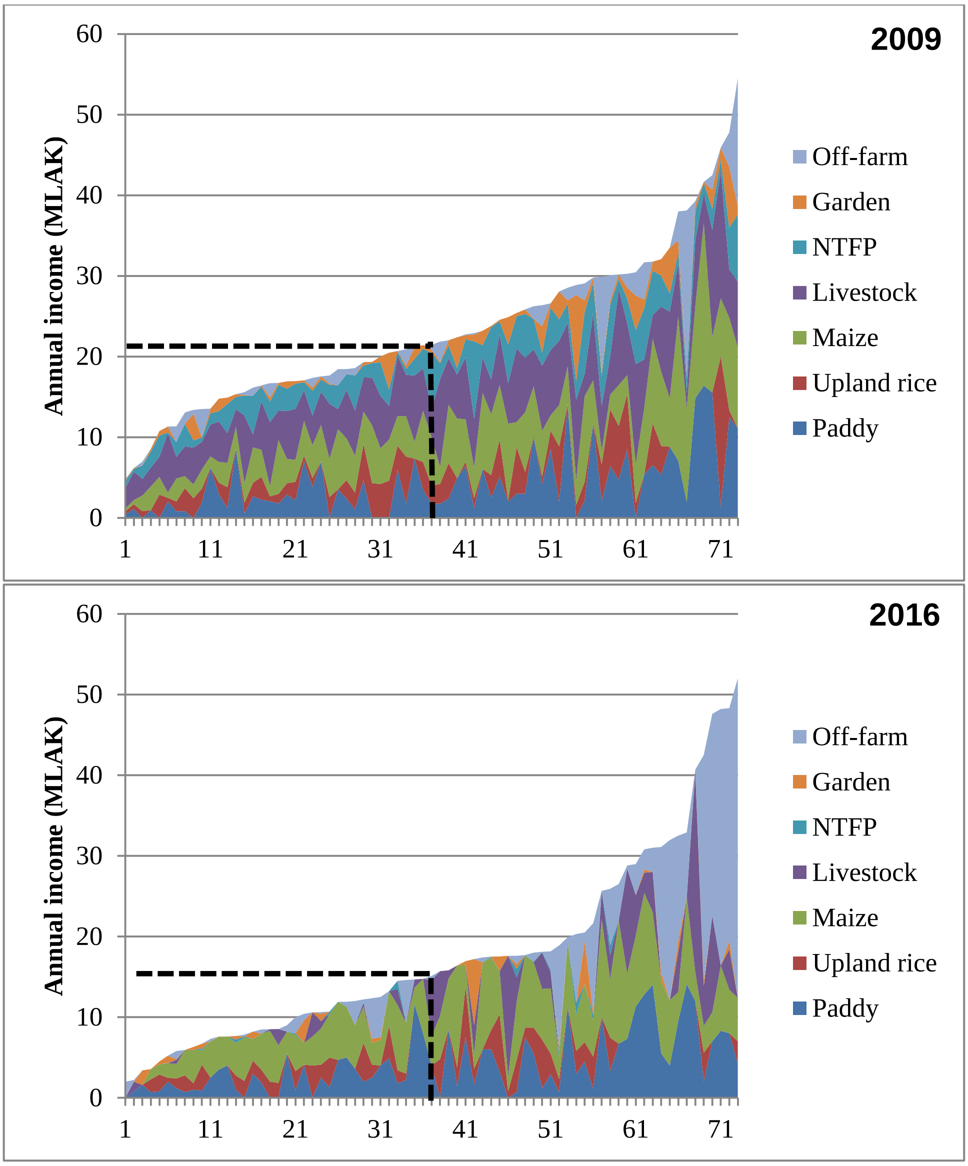
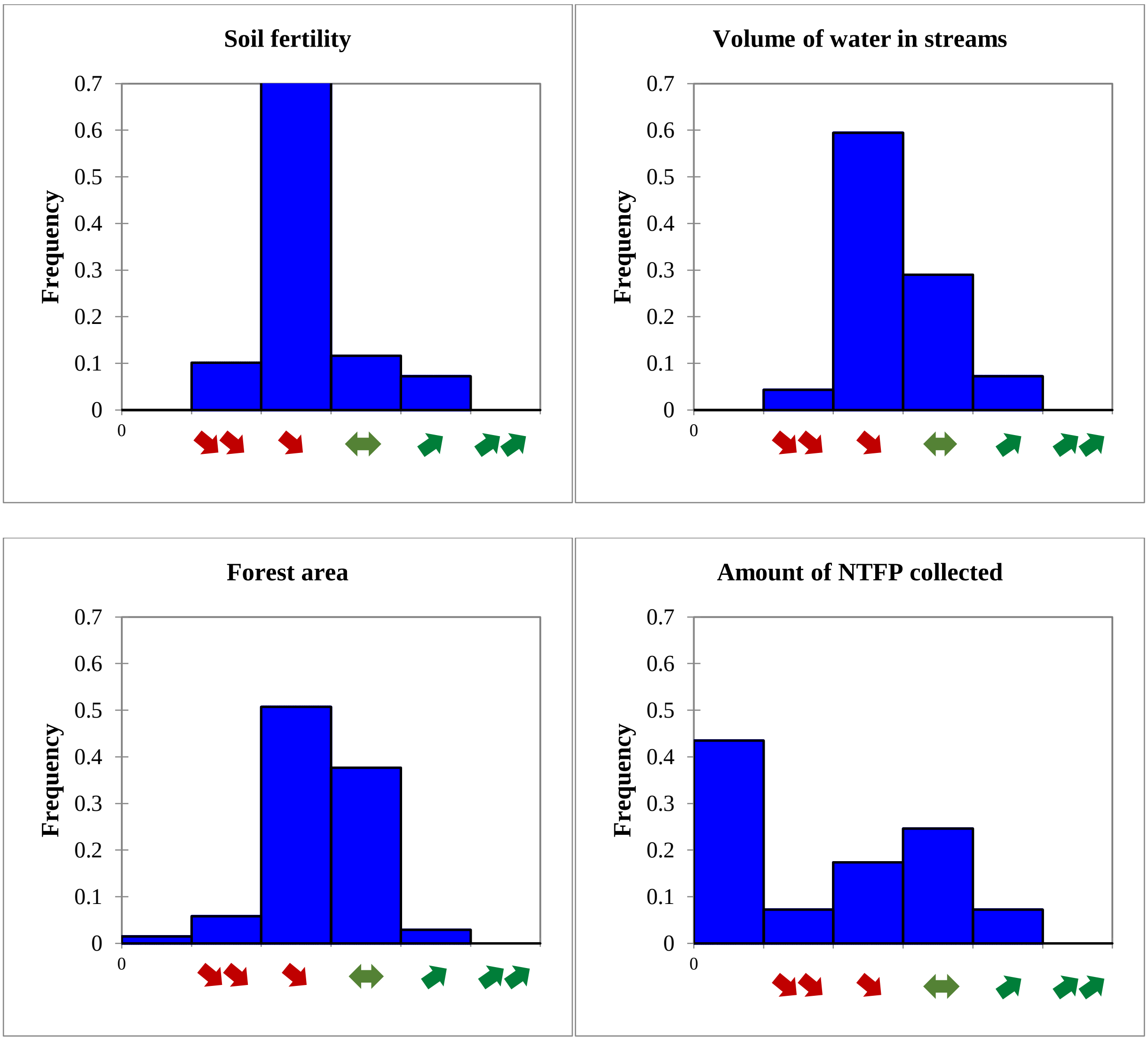


Figure 4-18 Income composition of the same 73 households surveyed in 2009 and 2016

As a consequence, the share of off-farm activities in the income of the 50% richer households has increased tremendously. Farmers who could accumulate sufficient capital from maize cultivations are now turning to other activities such as livestock and off-farm. The poorest ones are poorer than before because they do not have access to NTFP products anymore and are stuck with maize production in a context of decreasing yields. They have somehow compensated these losses through the second expansion of feeder roads 2013-2016 but this further exploitation of the natural resource based will provide only temporary benefits. Indeed, the maize yields are expected to drop again in the coming years through the same mechanisms as the one that took place between 2006 and 2009 for the first batch of feeder roads.

5.1.4 Farmers' perception of environmental changes

Farmers' decisions on land use also depend on their perception of the negative impacts of their practices on the environment. The results of the household survey conducted on 118 households of the study area in 2016 clearly show that farmers perceive a decrease in soil fertility over the past decade. They are also concerned about the reduction of forest areas and related changes in volume of water in the streams as well as availability of NTFP in the forest.



NB: bars from left to right correspond to: no answer, sharp decrease, decrease, stable, increase, large increase.

Figure 4-19 Distribution of responses to questions on the perception of environmental changes over the past decade from 118 households surveyed in 2016

They often use arguments related to the environment to justify their choice to move away from maize cultivation towards livestock related activities. While they recognize the negative impacts of intensive shifting cultivation systems on their environment (Figure 4-20), it is clear that maize is still the main source of cash income and alternatives will have to provide similar monetary value. Intensification of paddy fields also appear as a promising options as paddy is central to the local livelihood system and is considered by villagers as the most sustainable production system.

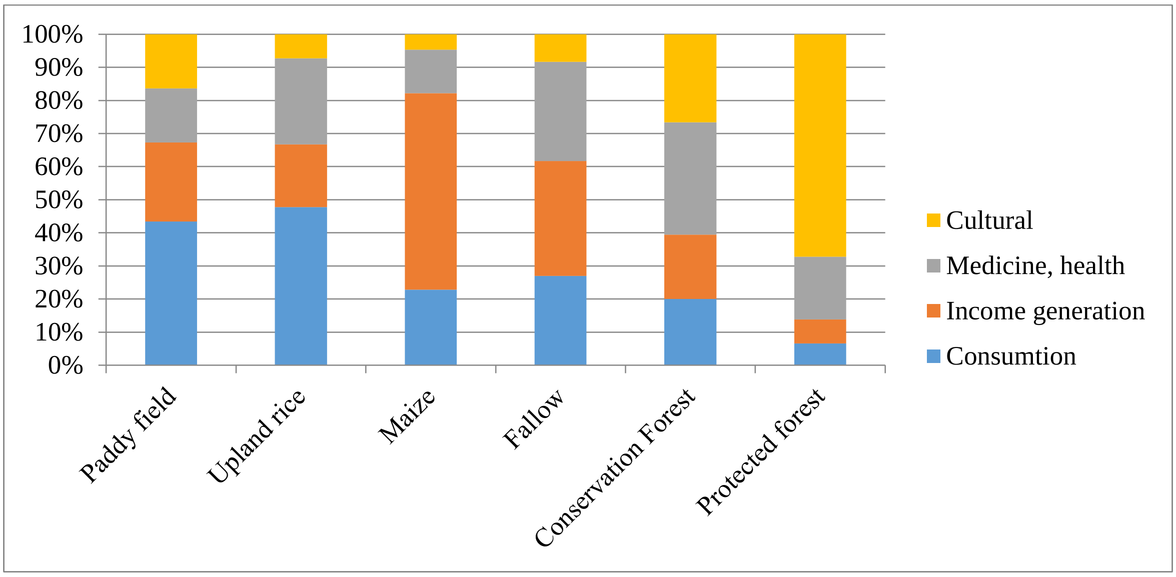


Figure 4-20 Perceived value for local livelihoods of the different land use types present in the study area

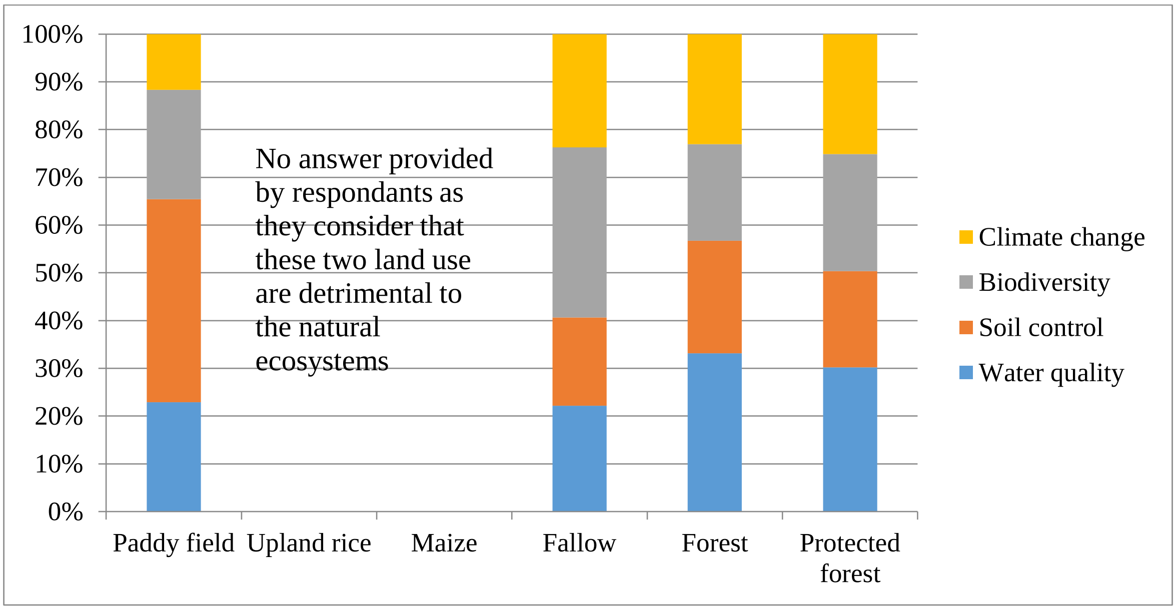


Figure 4-21 Perceived value for the natural environment of the different land use types present in the study area

Villagers are thus willing to change towards more sustainable practices and they are already exploring alternatives such as livestock and off-farm activities. They are clearly in search of agricultural activities that would have a high level of market demand while preserving the environment.

Chapter 5 Conclusion, Discussion, Implication and Forward

This chapter concludes the study, and presents the discussion and forward session for further study. The conclusion summarizes overall study, the discussion is to respond to the initial question of the study about the impacts of feeder roads on the landscapes and livelihoods in the northern uplands of Lao PDR and to explore scenarios to buffer the negative impacts identified.

5.1 Conclusion

This research analyses the patterns of maize expansion in a northeastern province of Lao PDR (Huaphan province) in relation with the construction of feeder roads to reach maize production areas with hand tractors or small trucks. The study assesses the impact of the feeder roads constructed in the period from 2006 to 2008 on the subsequent period from 2009 to 2016 through the analysis of a chronological series of remote sensing data combined with repeated household surveys in 2009 and in 2016. The combined analysis of data related to social and economic contexts and spatial patterns aimed at: 1) evaluating the impact of feeder roads construction on spatial arrangement in land use and land cover at the village level, 2) quantifying the impact of feeder roads construction on livelihood in terms of agricultural production system, household assets, and income.

This research analyzed the patterns of maize expansion in Huaphan, a northeastern province of Lao P.D.R., in relation with the construction of feeder roads to reach maize production areas with hand tractors or small trucks. The study concentrated on some of the villages of Natong cluster including Nadeua, Xiengdaen, Nanong, Natong, and Phouk villages which started growing maize as a cash crop for income generation since 2005. The study assesses the impact of the feeder roads constructed in the period from 2006 to 2008 on the subsequent period from 2009 to 2016 through the analysis of a chronological series of remote sensing data combined with repeated household surveys in 2009 and in 2016. The objective of this study was to quantify the impact of the feeder road construction on socio-economic context and spatial pattern in the study area using combination analysis of data related to social and economic contexts and spatial patterns. The study of the impact of the feeder roads on landscape was implemented based on spatial analysis employing Geographic Information System (GIS) and Remote Sensing Techniques. The data used include Landsat imageries, SPOT image, aerial photo, data from ground survey, and other related GIS data. The impact of the feeder roads on livelihood was evaluated through statistical analysis. The data used include primary data from field work in the beginning of 2016 and secondary data from CHATCH-UP project in 2009. The study revealed that:

1) Feeder road expansion in order to support maize production led to changes in landscape structure. It caused decreasing of natural forest cover in every year. Agricultural land, in particular upland crop system, increased inversely to open forest. The expansion of agricultural land seemed to move forward to forest areas. Land use intensity gradually emerged along the feeder roads and land sparing appeared as at the beginning state.

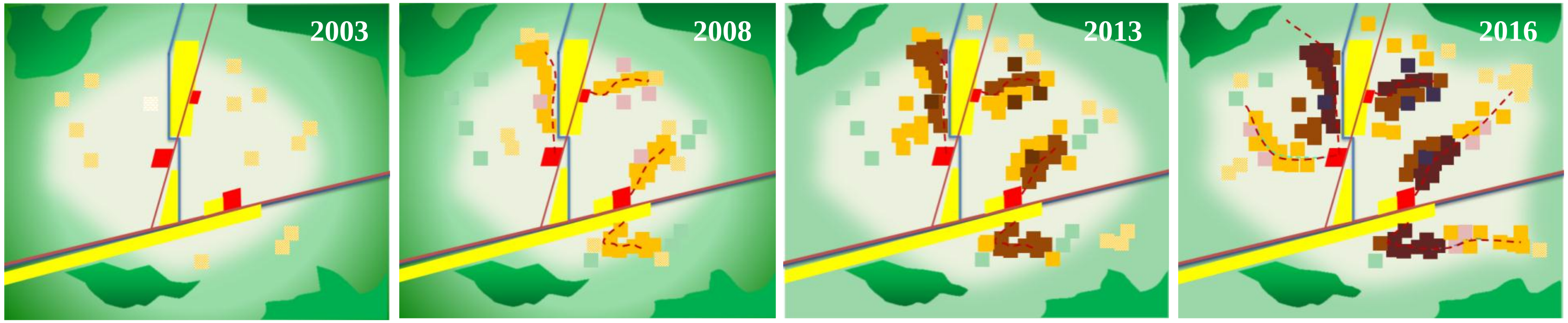
2) The impact of the feeder roads expansion on livelihood had both positive and negative. The positive impact was that it eased accessing to production areas, reduced the constrains in production in terms of times spent in the fields and products transportation, allowed engaging remote communities into the market economy through intensive cropping of maize. They could invest in basic livelihood assets such as better house, motorcycles for transportation, cash to send children to schools, etc. and also invest in off-farm activities that provide a significant part of their income at present. However, these maize-driven land use changes also came with negative impacts such as reduction of income from NTFP, soil erosion and land degradation that reduce the yields in the upland fields and force villagers to use more inputs, to contract more debts and engage in more economically risky activities as compared with the previous decade.

As we have seen, the consequences on local livelihoods of such changes in landscapes are dramatic as the forest does not provide NTFP anymore which used to be an important component of the household economy, as the soil is eroding rapidly and losing the fertility that used to be maintained by the fallow system and that is now substituted by intensive use of herbicide and chemical fertilizer to artificially maintain reasonable level of fertility. But intensive use of agricultural inputs come with debts and reduced economic margins up to a level that makes maize production not sustainable anymore.

5.2 Discussion

There was only subsistence agriculture before an adoption to growing maize as a cash crop in 2005. In subsistence agriculture, rice was the main crop grown in the study area both in low land and upland area. Lowland was limited by mountainous topography. Therefore, the main source of rice was from upland fields. Upland rice was produced through shifting cultivation. As a result, upland fields distributed scatter over the areas within village boundary as shown in 2003 land use and cover map. In 2008, upland crop areas were subtracted to the feeder roads which started constructing in 2006 and expanded to every villages in 2008, and it appeared that villagers cultivated upland crop in the same region, rather than separated the fields as shown in 2003. At the beginning state of changing from growing rice as a main crop to growing maize as a cash crop, there were obvious changes in landscape that upland crop area decreased because of an unsure about new crop and new cropping practice from individual to group cultivation. When villagers were confident about the benefit from maize, they expanded their production area as well as quantity of seed based on labor forces of their households. The combination of convenient accessing to production areas and labor forces drove upland crop expansion between 2008 and 2015. Agriculture practice also change from annual rotation cropping system to reiteration cropping for 3 to 5 years system. Because of such cropping practice, there was no expansion in feeder road after first batch between 2006 and 2009. Within a period of 7 years, from 2009 to 2016, the landscape and the local livelihoods have been completely transformed through an overall process of land use intensification as described in Figure 5-1. The resulting landscape is characterized by more degraded land along the feeder roads due to intensive farming without erosion control and fertility management. The whole agricultural activity has concentrated on these areas during the 5 years that followed the opening of the feeder roads and as a result the forest somehow regenerated in remote areas at the periphery of the village territory. But as the land along the feeder road was degrading some farmers started growing upland rice in more remote and more forested areas, then they managed to convince the village community to expand the feeder roads to these new areas, moving the land degradation problem to these new places until the forest limit is reached. Two successive periods can be described in relation with opening of the feeder roads:

- a first one of *contraction of the agricultural space* along theses feeder roads that provide easy access to formally remote fields combined with and *intensification of land use* in these new agricultural areas until land degradation reach a level that makes the cultivation system not profitable anymore, and then
- a second one of expansion of the feeder roads to more remote, forested environments that were relatively preserved during the previous period and where a similar process of contraction and intensification of land use starts as for the first batch of feeder roads.



• Subsistence agriculture based on a combination of paddy fields cropped 2 cycles per year and upland rice under shifting cultivation, • Collective paddy fields are redistributed among households every 3 to 5 years and upland fields are rotating with a 5 years fallow.	• Maize expansion as a cash crop following the opening of feeder roads, • Upland rice fields far from villages were abandoned and the one close to feeder roads cultivated in priority. • Some farmers still combine upland rice and maize in the same fields.	• Maize is cropped several successive years in the same fields along the feeder roads especially, • Traditional shifting cultivation systems are moved at the periphery of the village as land use is intensified along the feeder roads.	• Land around the feeder roads is saturated and fertility is degrading rapidly, • Villagers extend the feeder roads to reach more fertile lands, • They combine maize and upland rice wherever possible or more upland rice fields to remote areas, closer to the remaining forest.

Legend

Dense forest	Maize (mixed with upland rice)	Residential area
Open forest	Maize (1st year)	River
Fallow	Maize (2nd year)	Main road
Upland rice	Maize (3rd year)	Feeder road
Paddy field	Maize (permanent)	

Figure 5-1 Graphic representation of the process of land use intensification induced by maize expansion in the study area

A similar process was observed across the border to Vietnam in an area located at the north-west of our study area (Figure 5-2). Within a decade, the forest completely disappeared from the uplands in this area, the feeder roads gradually progresses up the hills until the whole area was cultivated permanently with maize.

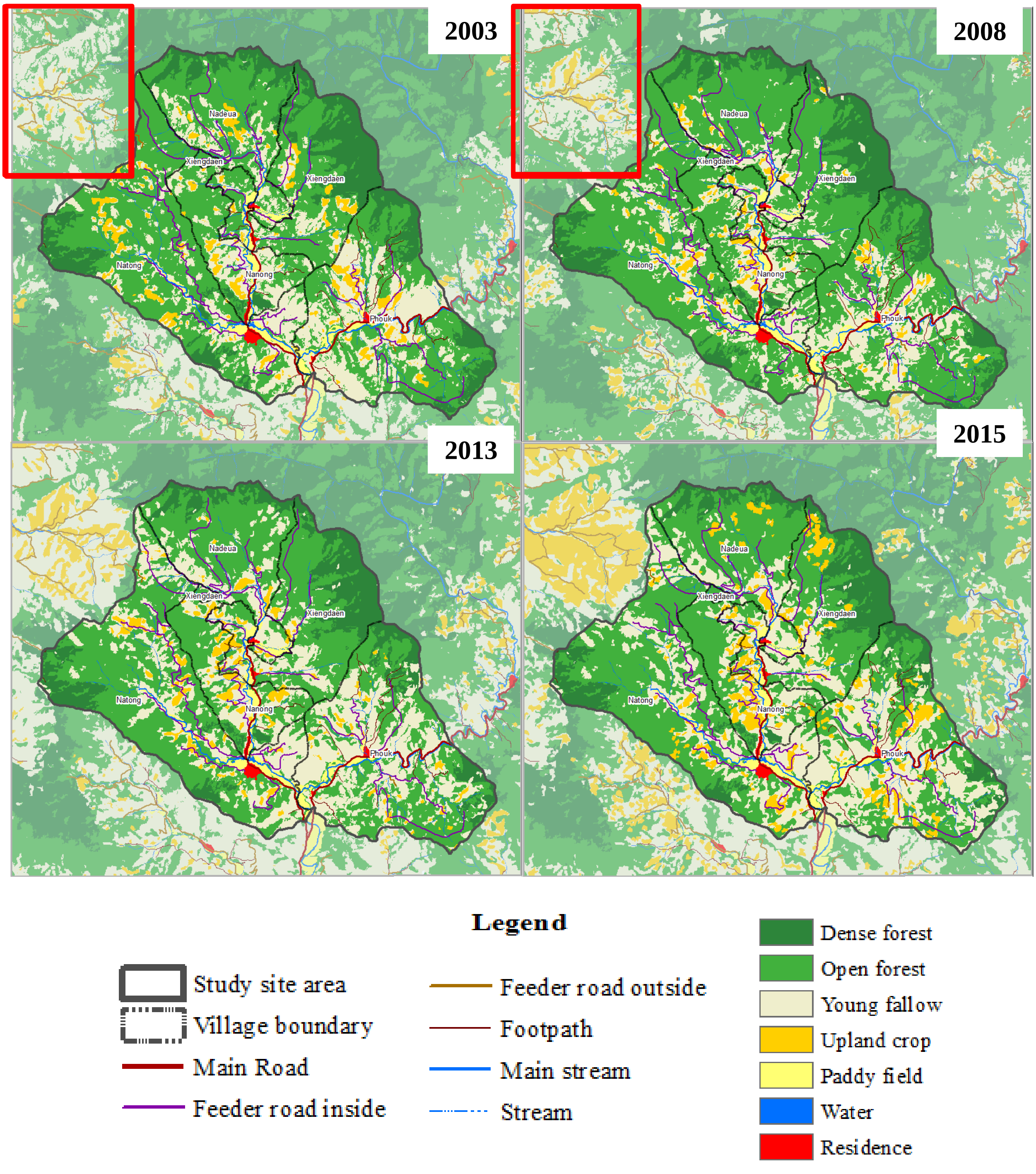


Figure 5-2 Highlights land use change across the border to Vietnam 2003 - 2015

5.3 Implication

In a context of high environmental and economic pressure what are the possible options for local communities to maintain their livelihood status? A number of options have already been explored by villagers that we classify into 2 sub-groups: one within the maize production realm and the other one based on diversification processes away from maize.

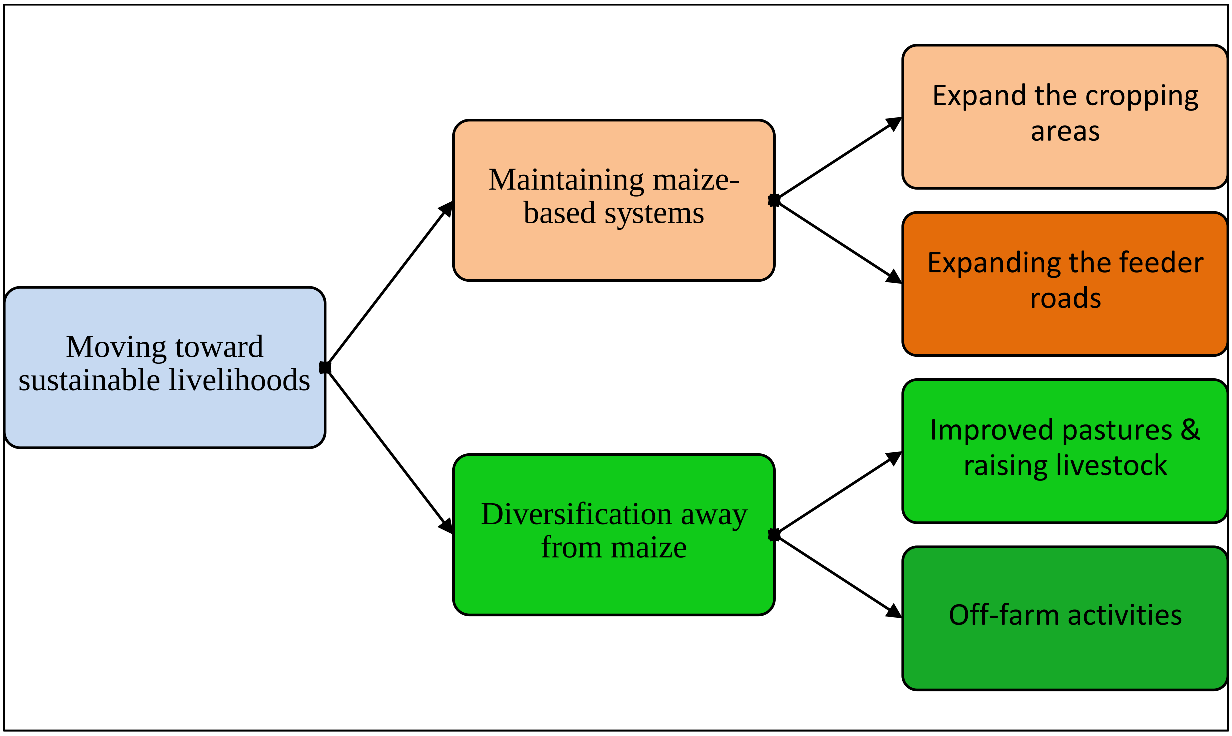


Figure 5-3 Scenarios exploration towards more sustainable livelihoods

5.3.1 Maintaining maize-based systems

1. The first option explored by maize farmers when they faced decreasing yields due to land degradation was to expand the cropping areas so that they could maintain the same level of production despite lower soil fertility. But to expand the area with the same labor force, they needed to overcome the main production bottleneck which is the labor force needed for manual weeding operations. In 2014, they started using herbicide to expand their maize areas and fertilizers to maintain some level of production in the permanently cropped fields.
2. The second option consists in expanding the feeder roads in an attempt to move their production areas to more fertile lands. But they just recreate the same conditions as for the 1st batch of feeder roads further away in the landscape. They somehow delay the time they

will have to stop their unsustainable practices by moving them temporarily to new areas at the periphery of the village territory.

5.3.2 Diversification away from maize

1. Another option explored by farmers who could accumulate capital during the maize boom consists in gradually turning the maize fields into pasture land and to buy livestock that will graze on these improved pastures. Many villagers in the study area are preparing to this major change and are only limited by the capital available to invest in livestock. Some of them therefore invest in goats that require less capital to start with before they turn to cattle ranching.
2. Off-farm activities are providing an increasing share of the household incomes as villagers who could accumulate capital invest in new activities such as small trade or purchase a truck for transportation of agricultural products, etc. Those who could not accumulate capital are employed by the richest villagers to work in their fields as daily wage workers once the latter have moved to off-farm activities.

All villagers would be ready to produce other cash crops as soon a market opportunities raise. They are prompt to engage in producing new crops as shown by the recently introduced Sacha inchi (2015) or the rapid development of fruit tree orchards in 2003-2004 that are still handicapped today by a highly uncertain market demand that dissuade many household from engaging into these income generating options.

We should also mention past attempts by development projects to introduce alternative production techniques as a basis for sustainable maize cropping systems. Combination of legume crops with maize was tested in 2009 as a way to control weeds with a permanent soil cover and increase soil fertility with legume residues. However, it was difficult to convince farmers at that time of the benefits of conservation agriculture as they were at the peak of the maize boom and had not experience yet the yield decreases that they are facing nowadays. It would therefore be interesting to test this option again as farmers would now be more receptive as they were before.

5.4 Forward

A number of alternative livelihood options have been explored, such as development of improved livestock systems. These could be further supported by development projects that would reorganize the complex interactions between different land use types that make up the village landscapes, namely: the paddy fields in the lowlands, the cultivated hillsides that may be turned into livestock areas and perennial tree plantations in the future if villagers cannot adopt some sustainable land management practices on the slopes to continue cropping annual crops such as upland rice and maize, and the forests that would provide a safety net thanks to the many NTFP and would regulate water cycles for the benefit of the whole community and ecosystem.

Despite the constraints imposed by revisiting the same site and same villagers 7 years after a similar study was conducted in the same group of villages, the proposed longitudinal study brought precious knowledge about the drivers of the land use changes that occurred during the period between 2009 and 2016 and their impacts on local landscapes and livelihoods. Many collected data could not be analyzed in the limited time allocated to this M.Sc. research but will be published in subsequent document relying on the large database developed by the EFICAS project over the years in the study area. This longitudinal study may be further continued so as to check in the future if the foresights we propose in this report, such as the same land use intensification trends happening in the future around the 2nd batch of feeder roads (2015-2017), will actually take place or if the village communities will be able, with the support of research-development projects such as the EFICAS project, to engage the village communities in designing more desirable landscapes and livelihoods towards a sustainable development.

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