# "To till or not to till?" Opportunities and constraints to the diffusion of conservation agriculture in Xieng Khouang Province, Lao PDR

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## Abstract

Over the past decade, efforts have been made to promote conservation agriculture as an ecologically-sound alternative to tillage-based agriculture in Lao PDR. This paper assesses some of the outcomes of a 5-year research-development project aimed at developing sustainable no-till cropping and pasture systems, and promoting their adoption by smallholders in Xieng Khouang Province. Based on extensive household surveys in 20 villages, the study highlights some of the key environmental and socio-economic factors influencing the adoption and diffusion of conservation agriculture. It provides a number of policy recommendations aimed at facilitating agricultural innovation and providing greater incentives for farmers to shift towards more sustainable farming practices.

**Keywords**: smallholders; agricultural innovation; conservation agriculture; adoption; Lao PDR

# Introduction

In response to growing concerns about the environmental impacts of the deep tilling of soils, the concept of conservation agriculture has gained increased public attention over the past three decades (Derpsch, 2005; Hobbs et al., 2008). Now, many key international development agencies are promoting conservation agriculture as a main alternative to 'conventional' tillage-based agriculture. The Food and Agricultural Organization (FAO) of the United Nations describes conservation agriculture as "a concept for resource-saving agricultural crop production that strives to achieve acceptable profits together with high and sustained production levels while concurrently conserving the environment" (FAO, 2007). Based on the three principles of minimum mechanical soil disturbance, maintenance of a permanent organic soil cover and establishment of crop rotations, conservation agriculture has been demonstrated to have very positive impacts on soil erosion control and agro-biodiversity enhancement (Montgomery, 2007; Triplett and Dick, 2008), maintenance and/or renewal of soil physical, biological and chemical properties (Rhoton, 2000; Chivenge et al., 2007) and conservation of soil moisture (Govaerts et al., 2009).

Between 2003 and 2009, the National Agro-Ecology Programme (PRONAE)[i] developed and promoted conservation agriculture systems adapted to the various natural and human environments of Xieng Khouang Province (Bouahom et al., 2005). The districts of Pek, Kham and Nonghet in this province were selected as target areas for the establishment of experimental and demonstration plots, the formation of farmer validation groups and the provision of on-farm training courses on conservation agriculture systems and livestock breeding (Lienhard et al., 2008). The systems tested all fall under the broad concept of direct seeding mulch-based cropping systems which involve no-tillage and permanent soil plant cover. By plant cover is meant dead mulch – crop residues or dead weeds – or live mulch associated with the main crop. Three main systems were addressed in the study area, namely:

1) <u>Direct seeding mulch-based maize monoculture</u>: This is a maize no-till cropping system with management of the residues of the previous season. As no association or rotation is involved, this cropping system does not completely match the FAO definition of conservation agriculture (FAO, 2007). However it does have significant advantages in terms of soil erosion control and reduced production costs, and has been promoted as an alternative to intensive tillage-based maize monoculture in Nonghet District and the basin area of Kham District.

2) <u>Two-year rotation of 'rice/forage legume'</u>: This is a rotational system where upland rice is directly seeded into a dead mulch of forage legume (e.g. *Stylosanthes g.*) on non-irrigated flat land. This no-till system has several positive aspects including soil regeneration, improvement of soil fertility and agro-biodiversity, and reduction of the weed pressure by biological control. This system has been promoted in the plain of Pek District as an option for increasing rice production and securing forage supply,

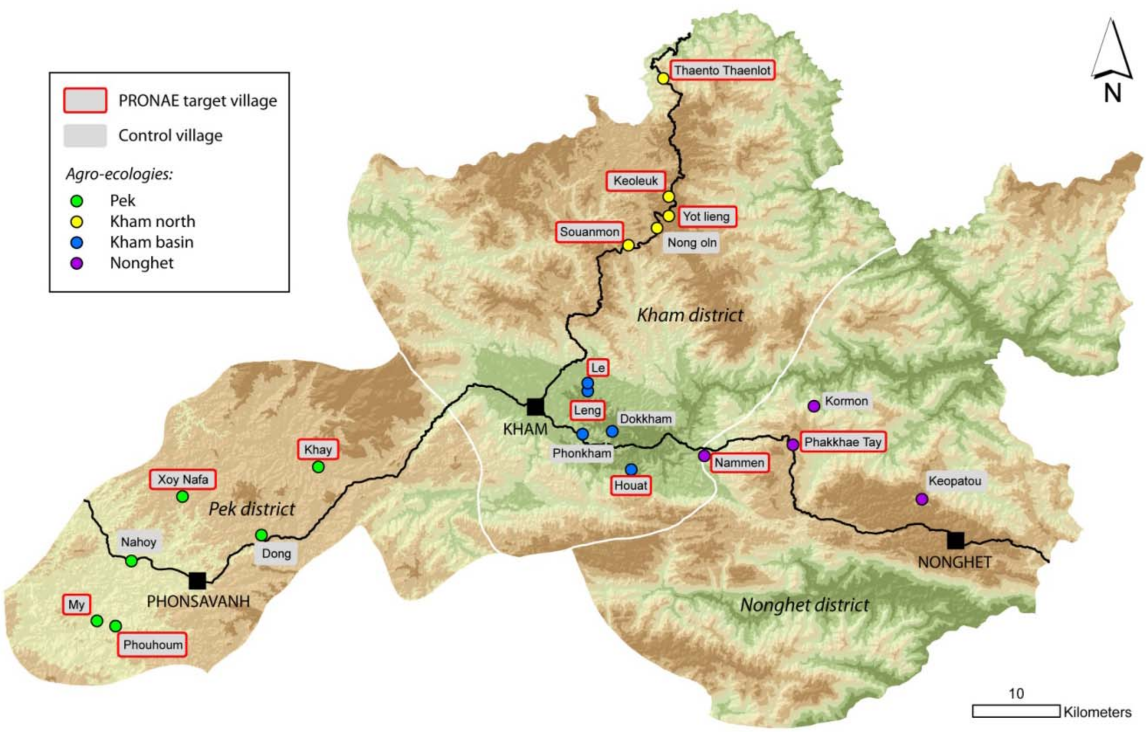
3) <u>Improved pasture</u>: This is the establishment and/or regeneration of pasturelands through initial mineral fertilization and introduction of *Bracharia ruziziensis* and/or *Stylosanthes g.* After three years of grazing, the costs of regenerating the pasture for a further three year cycle are financed by the growth of one cycle of a commercial crop (e.g. upland rice, soybean) under a no-till and residue management system. This system has been promoted in the plain of Pek District and in the northern mountains of Kham District as a way of improving soil fertility and increasing the quantity and quality of forage supply.

From October 2009 to April 2010, the Agriculture and Forestry Policy Research Centre (AFPRC) of the National Agriculture and Forestry Research Institute (NAFRI) in connection with the Catch-Up programme[ii] investigated the socio-economic impacts of conservation agriculture in the three PRONAE target districts. Two main objectives were identified for the study: (i) to assess local adoption rates and identify key constraints and opportunities for scaling up the process of agricultural innovation, and (ii) to inform and provide recommendations to policymakers, managers of research and extension agencies, and development practitioners.

# Materials and methods

The study involved field surveys conducted over a 6-month period in thirteen PRONAE target villages and seven control villages (Fig. 1). Surveys included: (i) an exhaustive village census identifying basic socio-economic variables of the 1,463 households in the 20 study villages, (ii) rapid questionnaire surveys on the livelihood systems of 600 households (random samples of 30 households per study village), (iii) detailed household surveys on farm economics, cropping systems and environmental knowledge of 180 households (stratified random samples of 10 households per study village), and (iv) several group discussions and interviews with key informants (on village land use history, access to and management of natural resources, etc.). Secondary data was provided by PRONAE (e.g. farming systems analyses and a series of detailed interviews with key informants in 2003) and by various provincial and district administrations (e.g. agricultural statistics). The research also benefited from the feedback from various stakeholders (e.g. agriculture and forestry officers, village authorities and development practitioners) gathered during a workshop held in the provincial capital of Phonsavanh on July 15, 2010.

Figure 1. Location of the study villages.




# Results

Contrasting agro-ecological contexts

The study villages were in four contrasting agro-ecological regions which are referred to as Pek, Kham north, Kham basin and Nonghet (Fig. 1). Pek region is characterised by a vast high plain with particularly acid and infertile soils. The natural vegetation is grasslands and pine forests. In general, the farming systems of this region are based on extensive cattle breeding and paddy rice cultivation (Lienhard et al. 2004). Access to productive uplands is fairly limited and crops like glutinous rice, maize (traditional varieties), chilli, garlic, onion and various vegetables are usually grown in small plots (0.2 hectares per household on average). With good access to Phonsavanh, the provincial capital and a relatively important urban centre, earnings from off-farm activities constitute a large part of annual household incomes (accounting for 10 million LAK out of an average income of 20 million).

In contrast, the region of Kham north is characterized by a rugged topography with steeply sloping agricultural land. Since the distance to the main provincial economic centres is important, agriculture here has long been dominated by subsistence (slash-and-burn) shifting cultivation which usually consists of a single annual crop of glutinous rice. Sometimes a crop of traditional maize varieties is grown in the year following the rice crop, and then the plot is left fallow for 3 to 15 years – depending on how far the plot is from the road/village and on the associated land pressure (PRONAE, 2003). Extensive cattle breeding and the collection of non-timber forest products are also important livelihood activities.

The fertile soils, the warm micro-climate and good accessibility characterizing the region of Kham basin, permit the production of a wide diversity of commercial agricultural produce. Over the past five years, the upland areas under cultivation have increased significantly. This increase has been largely driven by the rapid spread of a Vietnamese hybrid maize variety. From the mid-2000s, the existing upland rice fields, gardens, and chilli and fruit tree plantations have been replaced by hybrid maize plantations which by 2009 covered more than 85% of the upland cultivated areas (Kongay et al., 2010). Income from this maize production forms the main source of revenue for a large percentage of the population.

Lying to the east of Kham basin, the mountainous Nonghet District has the advantage of productive limestone soils. Accessibility is good and agricultural production is diversified (e.g. upland rice, traditional maize varieties, fruit trees and vegetables). At present agricultural production is mainly subsistence oriented however this is rapidly changing to the intensive commercial production of hybrid maize. Just as in Kham basin, the recent maize 'boom' has been associated with a significant expansion of the cultivated areas on the slopes. However, tillage is expanding less rapidly than in Kham basin because of the steeper slopes that limit access by tractors.

Adoption of the agricultural innovations

The household adoption rates in the 20 study villages show significant spatial and temporal variations. Overall over the past 5 years, there has been a slight increase in the percentage of households engaging in direct seeding mulch-based maize monoculture and 'rice/forage crop' rotation from 6 to 13% – with a peak at 14% in 2008 (Table 1). In 2009, the highest adoption rate was observed in Phakkhae Tay village with 43% of households engaged in direct seeding mulch-based maize monoculture. However, in several villages the adoption rate has decreased. In some villages (e.g. in Le, Leng and Nammen) this has been a gradual decrease since 2005 while in others it has been rather sudden, with for example, the percentage of households engaging in conservation agriculture decreasing from 76 to 28% between 2008 and 2009. Spontaneous diffusion[iii] in the control villages appears relatively limited. A notable exception is Nong Oln village, where some farmers adopted direct seeding mulch-based rotations in 2008. However no such adoption was recorded in the other control villages.

Just as the popularity of these cropping systems has increased, improved pasture has also become increasingly popular over the past 5 years. Over the entire study area, the percentage of households establishing improved pastures increased from 5% in 2005 to 16% in 2009 (Table 2). Although recently there has been a slight decrease in several villages, the 2009 adoption figures remain particularly high in Kham north. For instance, half of the population in the villages of Keoleuk and Yot Lieng adopted improved pastures. Significant adoption rates were also observed in some of the villages in Pek (with rates of 30% and 23% in Khay and Xoy Nafa villages respectively) and in Kham basin (with a rate of 37% in Houat village).

In general, spontaneous diffusion has proved difficult to assess since several Non-governmental Organisations (NGOs) and development agencies active in the study area have been promoting systems quite similar to the PRONAE innovation. Furthermore, in Keopatou, village, traditional pasture systems based on 'elephant grass' dedicated to the fattening of fighting bulls were also recorded as 'improved pasture' during the surveys, thus explaining the high adoption rate (57% in 2009) observed in this village. Nonetheless, a comparison of the average 2009 adoption figures in the PRONAE target villages (with a rate of 19% ) and the control villages excluding Keopatou village (with a rate of 3%) suggests that spontaneous diffusion of PRONAE improved pasture systems has generally remained very low.

Table 1. Adoption rates for direct seeding mulch-based maize monoculture and rotation 'rice/forage crop' (percent of households, 2005-2009)

| Area | Village | 2005 | 2006 | 2007 | 2008 | 2009 | Long-term adopters (≥ 3 years in 2009) |
|---|---|---|---|---|---|---|---|
| Kham basin | Dokkham | 0 | 0 | 0 | 0 | 0 | 0 |
| | Houat* | 16 | 16 | 21 | 24 | 27 | 13 |
| | Le* | 21 | 13 | 4 | 3 | 7 | 3 |
| | Leng* | 23 | 21 | 20 | 20 | 20 | 17 |
| | Phonkham | 0 | 0 | 0 | 0 | 0 | 0 |
| Kham basin sub-total | | 15 | 12 | 9 | 10 | 11 | 7 |
| Kham north | Keoleuk* | 0 | 4 | 7 | 14 | 23 | 0 |
| | Nong oln | 0 | 0 | 0 | 3 | 10 | 0 |
| | Souanmon* | 5 | 4 | 15 | 21 | 28 | 10 |
| | Thaento Thaenlot* | 0 | 0 | 0 | 0 | 0 | 0 |
| | Yot Lieng* | 0 | 0 | 0 | 0 | 0 | 0 |
| Kham north sub-total | | 1 | 2 | 5 | 8 | 13 | 2 |
| Nonghet | Keopatou | 0 | 0 | 0 | 0 | 0 | 0 |
| | Kormon | 0 | 0 | 0 | 0 | 0 | 0 |
| | Nammen* | 4 | 12 | 31 | 30 | 23 | 17 |
| | Phakkhae Tay* | 16 | 19 | 30 | 37 | 43 | 20 |
| Nonghet sub-total | | 4 | 7 | 15 | 16 | 16 | 9 |
| Pek | Dong | 0 | 0 | 0 | 0 | 0 | 0 |
| | Khay* | 0 | 0 | 0 | 0 | 8 | 0 |
| | My* | 13 | 25 | 42 | 76 | 28 | 13 |
| | Nahoy | 0 | 0 | 0 | 0 | 0 | 0 |
| | Phouhoum* | 0 | 18 | 18 | 18 | 25 | 10 |
| | Xoy Nafa* | 6 | 6 | 12 | 12 | 6 | 3 |
| Pek sub-total | | 4 | 9 | 14 | 24 | 12 | 4 |
| Grand total | | 6 | 7 | 10 | 14 | 13 | 5 |

* PRONAE target villages

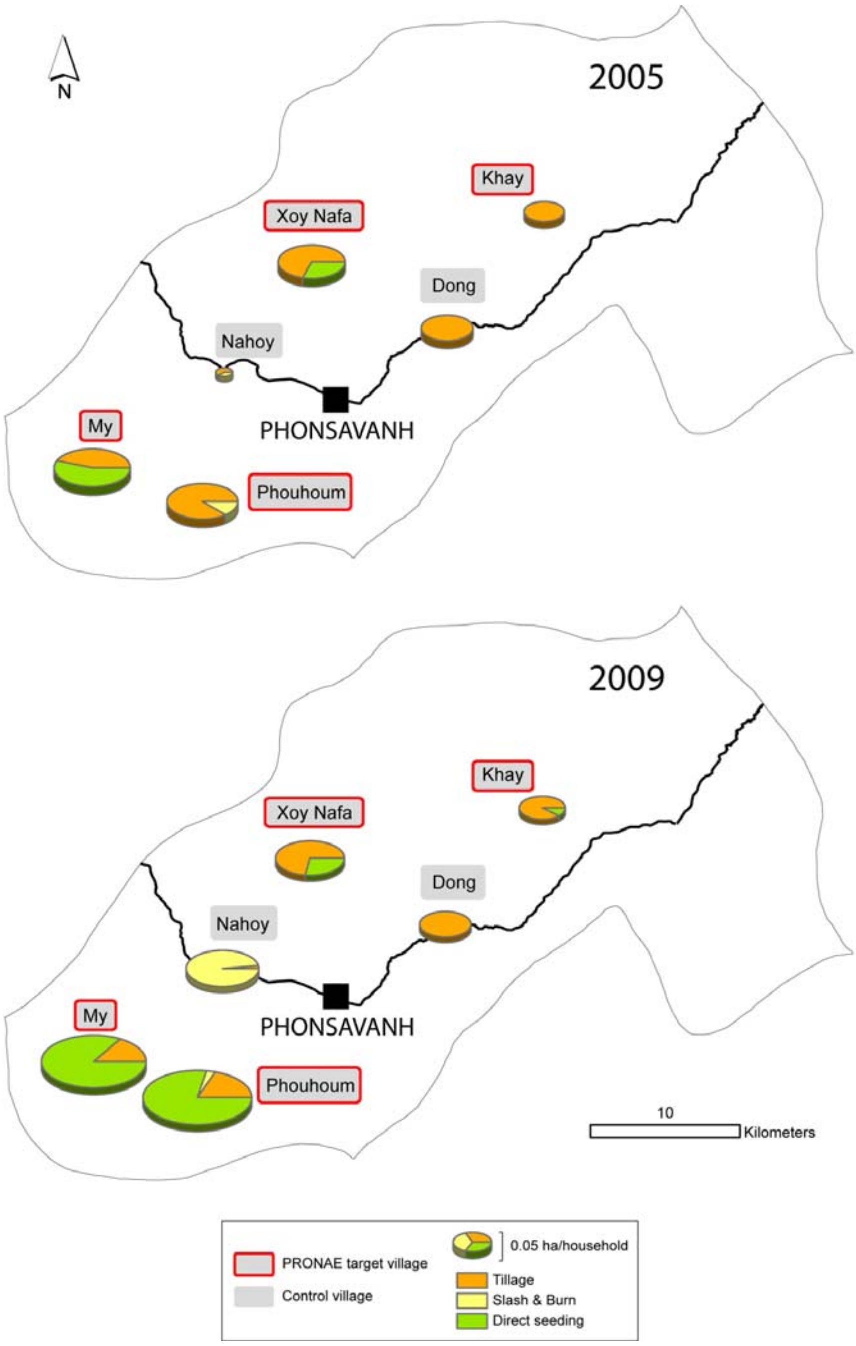
Table 2. Adoption rates for improved pasture (percent of households, 2005-2009)

| Area | Village | 2005 | 2006 | 2007 | 2008 | 2009 | Long-term adopters (≥ 3 years in 2009) |
|---|---|---|---|---|---|---|---|
| Kham basin | Dokkham | 0 | 0 | 0 | 0 | 0 | 0 |
| | Houat* | 10 | 30 | 30 | 33 | 37 | 27 |
| | Le* | 3 | 3 | 3 | 3 | 3 | 3 |
| | Leng* | 0 | 0 | 0 | 0 | 0 | 0 |
| | Phonkham | 0 | 3 | 3 | 3 | 3 | 3 |
| Kham basin sub-total | | 15 | 3 | 7 | 7 | 8 | 7 |
| Kham north | Keoleuk* | 3 | 37 | 53 | 53 | 50 | 23 |
| | Nong oln | 3 | 3 | 20 | 7 | 3 | 0 |
| | Souanmon* | 10 | 23 | 27 | 27 | 23 | 20 |
| | Thaento Thaenlot* | 10 | 7 | 0 | 3 | 3 | 0 |
| | Yot Lieng* | 13 | 33 | 57 | 57 | 53 | 30 |
| Kham north sub-total | | 1 | 8 | 21 | 31 | 29 | 15 |
| Nonghet | Keopatou | 30 | 37 | 50 | 50 | 57 | 37 |
| | Kormon | 0 | 0 | 7 | 3 | 0 | 0 |
| | Nammen* | 3 | 3 | 7 | 7 | 7 | 3 |
| | Phakkhae Tay* | 0 | 0 | 0 | 10 | 3 | 0 |
| Nonghet sub-total | | 4 | 8 | 10 | 16 | 18 | 10 |
| Pek | Dong | 7 | 13 | 13 | 13 | 13 | 10 |
| | Khay* | 7 | 27 | 30 | 30 | 30 | 27 |
| | My* | 0 | 13 | 13 | 13 | 10 | 10 |
| | Nahoy | 0 | 0 | 0 | 0 | 0 | 0 |
| | Phouhoum* | 3 | 13 | 13 | 10 | 7 | 3 |
| | Xoy Nafa* | 3 | 20 | 30 | 27 | 23 | 17 |
| Pek sub-total | | 4 | 3 | 14 | 17 | 16 | 11 |
| Grand total | | 6 | 5 | 13 | 18 | 18 | 11 |

* PRONAE target villages

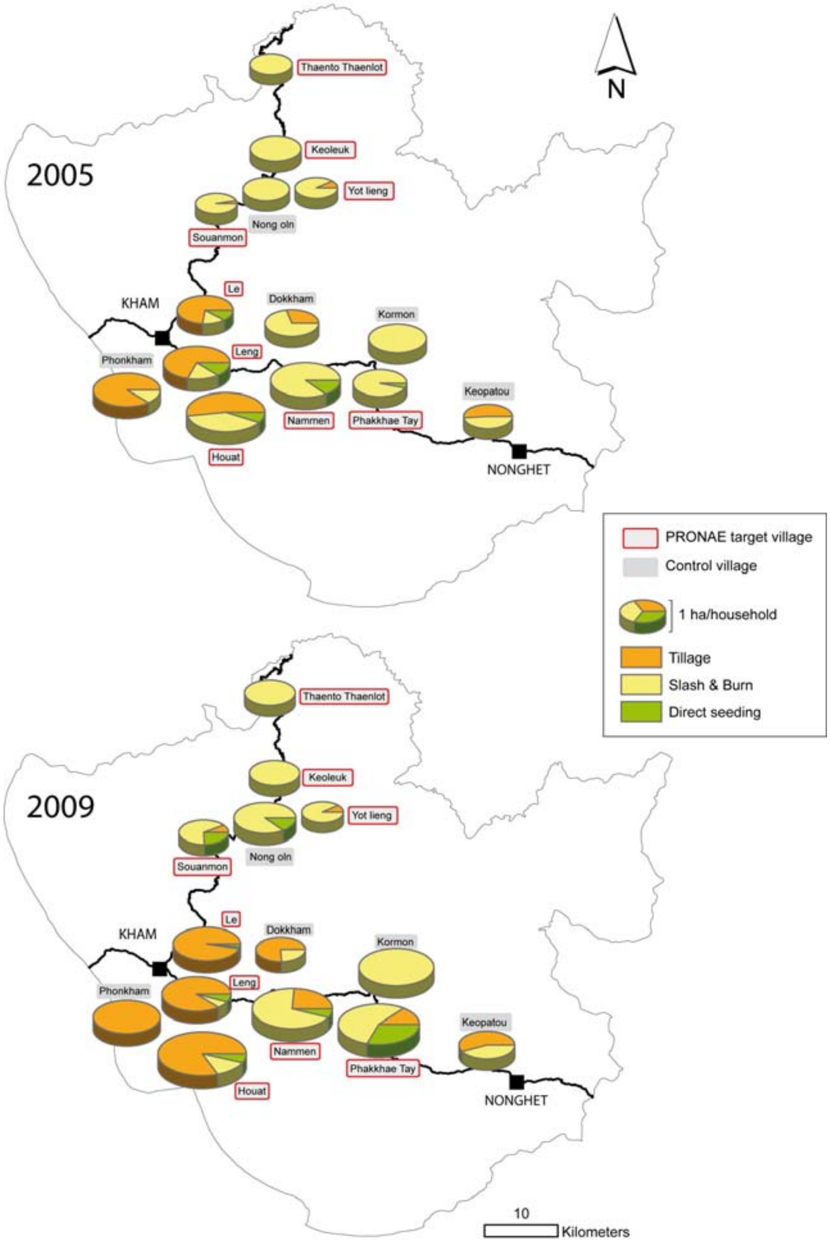
Other observations can be made when looking at the spatial extent of the main cropping techniques present in the PRONAE target villages (Fig. 2 and Fig. 3). In Pek, for instance, the emergence of conservation agriculture in villages like Khay, Xoy Nafa, My and Phouhoum coincided with, and partly contributed, to a slight expansion of the upland cultivated areas – from 0.1 to 0.2 hectares per household on average for the four study villages[iv]. In the villages of My and Phouhoum, conservation agriculture has not only been adopted for the cultivation of idle land; it has also largely replaced tillage as the main cropping technique on the slopes. In 2009, 'rice/forage legume' rotations covered 80 to 85% of all the cultivated uplands in these villages.

Figure 2. Relative distribution of the different cropping practices in Pek district (2005-2009).




With the exception of Yot Lieng village where the upland areas under cultivation have remained stable, the other villages of Kham north have witnessed an agricultural expansion over the past 5 years – from 0.8 to 1.2 hectares per household on average for the 5 study villages (Fig. 3). Although the emergence of direct seeding mulch-based maize monoculture has played a role in villages like Suanmon and Nong Oln, the process essentially reflects an expansion of the area under shifting cultivation. In 2009, conservation agriculture remained, as did tillage, a fairly marginal cropping technique – accounting for 25% and 13% of the cultivated uplands in the villages of Suanmon and Nong Oln respectively. Only one out of four of the PRONAE target villages – the village of Suanmon – saw a development of conservation agriculture after 2007. But one year later, in 2008, this practice had spread to the neighbouring control village of Nong Oln.

Figure 3. Relative distribution of the different cropping practices in Kham basin and Nonghet district (2005-2009).




The agricultural expansion observed in Kham north is even more marked in Kham basin and Nonghet (Fig. 3). On average, in the study villages of Kham basin, upland cultivated areas increased from 1.3 to 2.3 hectares per household between 2005 and 2009, with a sudden peak between 2006 and 2007. Essentially, this process is linked to the boom in (hybrid) maize production and the rapid development of mechanized tillage. The emergence of mechanized tillage has certainly permitted a massive conversion of the upland fallows to intensive annual cultivation areas. As observed in the three PRONAE target villages in 2009, direct seeding mulch-based maize monoculture represented a marginal land use – covering 1.5%, 4% and 5.5% respectively of the total uplands cultivated in Le, Houat and Leng villages.

In Nonghet, the history of maize production, agricultural expansion and the development of DMC practices appear to differ greatly and are contingent on the accessibility of the study villages. The situation in Nammen village, located just upstream of Kham basin, is typical of the villages within the basin. The maize boom occurred between 2006 and 2007 and, although slash-and-burn still represents the main technique for soil preparation (70% of the upland cultivated areas in 2009), mechanized tillage has spread rapidly since 2007. This spread has been accompanied by a decline in the extent of direct seeding mulch-based maize monoculture after 2007, which by 2009 accounted for only 6% of the cultivated uplands. In the more remote villages of Phakkhae Tay and Kormon, the maize boom and the associated agricultural expansion occurred one year later in 2008. In these two villages, the cultivated areas per household increased on average from 1.5 to 2.5 hectares between 2007 and 2008. While this process took place entirely through the expansion of the area under shifting cultivation in the village of Kormon, the PRONAE target village of Phakkhae Tay witnessed a significant expansion of direct seeding mulch-based maize monoculture. In 2009, in spite of a slight contraction in relation to the recent emergence of mechanized tillage, conservation agriculture accounted for one third of the cultivated uplands. In Keopatou village, there has been a much less significant change in land use over the past 5 years. The slight increase in the areas under cultivation was associated with the growth of hybrid maize production in 2007 and 2008. Upland agriculture later reduced in 2009 when the maize crop was discontinued. Cropping techniques underwent no major changes with half of the land remaining under hand tillage and the other half under slash and burn.

# Discussion

Risk assessment and decision-making at the farm level

During the 5-year project, activities were largely focused on experimentation with only a limited investment in agricultural extension. The key proximate factor explaining the observed spatial and temporal variability was the presence or absence of PRONAE interventions (e.g. through test and demonstration plots and farmer groups) in the study villages. Adoption was observed however in one out of the seven control villages surveyed. Although there was no direct PRONAE intervention in this village, the adoption of direct seeding mulch-based maize monoculture by some farmers occurred after village leaders had participated in study tours organized by the Programme to the neighbouring village of Suanmon and to the southern province of Sayaboury (where the Programme has been active since the early 2000s). This single instance of spontaneous diffusion therefore highlights an obvious, yet essential condition to the adoption of conservation agriculture by farmers, that is, access to information and technical knowledge in relation to agricultural innovations.

Apart from access to knowledge and information, a second key element contributing to the shaping of local decision-making relates to access to farmland. As shown in Table 3, conservation agriculture adoption does not appear to be correlated with farm-level variables such as capital assets, annual incomes, dependency ratio[v] or availability of labour. However there is a significant and positive statistical correlation between farmland area and the percentage of land under direct seeding mulch-based cropping systems. This was shown by a comparison of the average farmland area of those farmers who adopted conservation agriculture (during the first year of experimentation) and those farmers who never practiced conservation agriculture (Table 4). This suggests that farmers with only limited access to land are probably less willing than others to take the risk of investing in 'experimental' systems such as direct seeding mulch-based cropping systems. This conclusion is also supported by the fact that 'insufficient land' was given by the farmers interviewed as the most important reason for not experimenting with improved pasture and the second most important reason – after 'lack of technical knowledge' (see above) – for not experimenting with direct seeding mulch-based maize monoculture or 'rice/forage legume' rotations (Table 5).

Table 3. Correlation matrix: household capital assets (LAK), total annual incomes (LAK per year), dependency ratio, farm labour (workers), farmland area (hectares) and proportion of land in direct seeding mulch-based cropping systems (percent of farmland area) (2009 data; n=600)

| Variables | Capital assets | Incomes | Dependency ratio | Farm labour | Farmland area | % DMC |
|---|---|---|---|---|---|---|
| Capital assets | **1** | **0,638** | -0,037 | **0,115** | 0,096 | 0,073 |
| Incomes | **0,638** | **1** | **-0,112** | **0,252** | **0,470** | 0,054 |
| Dependency ratio | -0,037 | **-0,112** | **1** | **-0,388** | -0,067 | 0,030 |
| Farm labour | **0,115** | **0,252** | **-0,388** | **1** | **0,343** | 0,050 |
| Farmland area | 0,096 | **0,470** | -0,067 | **0,343** | **1** | **0,168** |
| % DMC | 0,073 | 0,054 | 0,030 | 0,050 | **0,168** | **1** |

Note: Underlined values represent statistically significant correlations (at the 0.01 level).

Table 4. Average farmland area among adopters (during their first year of experimentation with direct seeding mulch-based cropping systems) and farming households that have never experimented with direct seeding mulch-based cropping systems

| | 2005 | | 2006 | | 2007 | | 2008 | | 2009 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Experi mented n=19 | Never n=339 | Experi mented n=8 | Never n=359 | Experi mented n=17 | Never n=400 | Experi mented n=21 | Never n=414 | Experi mented n=12 | Never n=436 |
| Farm land area (ha) | 2,2 | 1,1 | 1,6 | 1,2 | 2,2 | 1,4 | 2,0 | 1,6 | 2,2 | 1,6 |

Note: Only the households with access to rainfed farmlands are considered in the comparison. Mann-Whitney test highlights that the difference between the two samples is significant (at the 0.01 level).

Table 5. Farmers' reasons for not experimenting with conservation agriculture (frequency of answers, 2009)

| **Cropping systems** (555 respondents) | |
|---|---|
| *Reasons* | *Freq.* |
| No knowledge of techniques | 48.7% |
| Insufficient land | 12.4% |
| Insufficient labour | 9.0% |
| Preference for traditional techniques | 9.0% |
| Insufficient capital | 6.4% |
| Risk of low production | 4.8% |
| Toxicity of the herbicides | 2.5% |
| Systems not adapted to dense fallows | 2.2% |
| Weed invasion risks | 1.4% |
| Systems not adapted to livestock area | 0.9% |
| Systems not adapted to sloping land | 0.6% |
| Pest-related risks | 0.6% |
| No productivity issues | 0.5% |
| Other | 0.5% |
| No access to inputs | 0.2% |
| Plots too far from road | 0.1% |

| **Improved pasture** (501 respondents) | |
|---|---|
| *Reasons* | *Freq.* |
| Insufficient land | 25.7% |
| Insufficient cattle | 16.9% |
| Insufficient capital | 16.5% |
| Insufficient labour | 13.3% |
| No interest in cattle | 9.2% |
| No knowledge of techniques | 8.3% |
| No access to inputs | 5.4% |
| Sufficient natural pasture | 3.7% |
| Other | 0.9% |
| Risk of low production | 0.5% |

A third factor in decision-making particularly important for the farmers of Kham north is local access to financial capital and investment capacity. Where agricultural production is largely subsistence-oriented and where most of the monetary revenues derive from non-timber forest products, potential livestock breeders lack the means to cover the initial financial investment required to establish improved pastures (e.g. the purchase of cattle, herbicides and fertilizers, fencing and grass seeds). 'Insufficient capital' was cited as the first reason (given by 18% of respondents) for not experimenting with improved pasture in Kham north. Thus adopters are usually among the better-off farmers who had either enough cattle and could afford to sell part of their herd and/or had other assets (e.g. small shops, regular salaries or remittances) to finance pasture improvement. To a lesser extent, as only herbicides and seeds are required, this constraint is also valid for the establishment of direct seeding mulch-based maize monoculture in Kham north. The poor accessibility of the Kham north area provides limited market opportunities for the sale of intensively produced hybrid maize. Hence, there is little incentive for subsistence farmers to shift away from traditional shifting cultivation systems.

Finally, it must be mentioned that local experience of environmental degradation may become an increasingly important decision-making factor in the maize production areas of Kham basin and Nonghet. Although none of those farmers interviewed reported land degradation issues, reports on other regions of Lao PDR suggests that tillage-based maize monoculture, as practised in our study area, can lead to important soil fertility depletion, soil erosion and weed resistance in the medium term (e.g. Tran Quoc et al., 2005). Land degradation and its impacts on farm productivity (e.g. reduced crop yields, increasing labour and production costs for herbicides and fertilizers) may in turn constitute key impetuses for farmers to shift towards conservation agriculture (Slaats and Lestrelin, 2009). As a matter of fact, most of the interviewees who participated in PRONAE activities in our study area reported that although they understood the logic and functioning of the conservation techniques proposed, they felt that there was no pressing need to apply them as the soil quality was still fairly good and they could still apply them in the future. Some farmers interviewed in Phakkhae Tay village made this very clear in stating that, in the event of soil fertility depletion occurring, they would alternate mechanical tillage with direct seeding mulch-based cropping techniques as a way of managing soil fertility.

Constraints and opportunities for scaling up conservation agriculture

At the level of rural development planning and policy-making, several possible avenues for enhancing the diffusion of conservation agriculture in Xieng Khouang Province and other similar regions of Lao PDR are apparent. Most importantly, access to information and technical knowledge on conservation agriculture as well as awareness of the potential social and environmental impacts of 'conventional' agricultural intensification appear as fundamental prerequisites for facilitating the diffusion of more sustainable farming practices. In this regard, agricultural extension agencies have a key role in raising environmental awareness among rural populations, providing adequate technical support locally and promoting or maintaining conservation agriculture systems as possible options for farmers. In some instances (e.g. where the environmental drawbacks of 'conventional' agriculture are not perceptible to local farmers), extension efforts could also benefit from strengthened environmental regulation (e.g. a ban on mechanical tillage on steeply sloping lands).

Even so, adopting more sustainable farming practices would not necessarily be without costs for smallholders. In mountainous areas like Kham north, poor accessibility, weak market integration and the very limited investment capacity of subsistence farmers represent important constraints to the diffusion of agricultural innovations like direct seeding mulch-based rotations and improved pasture. Therefore, the dissemination of capital-intensive agricultural innovations must go hand in hand with improvements in communication and road infrastructure, a development of market channels for farm inputs and production, and a design of adapted credit systems. The provision of adequate credit can also be considered crucial in more accessible areas like Pek where high interest rates and too short refund periods impose considerable pressure on farmers willing to establish improved pasture and cattle fattening activities (Lienhard et al. 2008).

Beyond the above structural constraints faced by smallholders, there may also be more conjunctural and external factors to contend with. In relatively accessible areas like Pek, the development of small-scale agriculture and livestock breeding is now competing with a growing demand for large land concessions by private investors. Thus, maintaining a competitive smallholder farming sector requires an increase in the bargaining power of rural populations, an enhanced local production capacity and an offset of the opportunity cost of land sales. Land-use planning, land allocation and registration may assist in demarcating smallholdings and clarifying land tenure while identifying potential areas for private concessions.

Finally, the establishment of producer groups could contribute to both empower local smallholders and facilitate agricultural production and innovation. As illustrated by the history of conservation agriculture in Brazil (Bolliger et al., 2006) and in line with recent policy decisions of the Government of the Lao PDR (GoL, 2010), agricultural cooperatives could provide a strong basis for the establishment of innovations like direct seeding mulch-based cropping systems – allowing for e.g. enhanced access to information, farm inputs and market channels and empowerment of smallholders vis-à-vis large agribusinesses and land speculators. Compatible with this option, Public-Private Partnerships – e.g. possibly combining state land lease, environmental certification and '2+3' contract farming agreements[vi] – may also provide strong foundations for the diffusion of conservation agriculture. Not least, they could provide a valuable follow-up to initiatives like PRONAE which, as do most research-development projects, remain limited in both time and spatial extent.

# Conclusion

As argued by numerous scientists (e.g. Bolliger et al., 2006; Triplett and Dick, 2008; Govaerts et al., 2009) and demonstrated by a growing body of research-development initiatives worldwide, conservation agriculture represents an increasingly popular and potentially valuable option for enhancing agricultural productivity and regenerating degraded lands while mitigating the social and ecological impacts of agricultural intensification. However, smallholders often face diverse and substantial challenges when attempting to engage in conservation agriculture (Erenstein, 2003; Knowler and Bradshaw, 2007; Giller et al., 2009; Serpentié, 2009; Affholder et al., 2010). This study has shown that, under the impetus of a 5-year research-development programme, conservation agriculture has become a fairly important component of the agricultural landscapes in several villages of Xieng Khouang Province. It can therefore be considered a realistic alternative to both traditional shifting cultivation systems and intensive tillage-based monoculture.

Nevertheless, substantial constraints and issues would need to be addressed for the prospect of facilitating further diffusion of conservation agriculture in the province and in other similar regions of Lao PDR. The explanation for most of the spatial and temporal variations in adoption rates was that PRONAE did not intervene everywhere and did not invest a great deal in farm extension activities. Furthermore, the fact that spontaneous adoption was the outcome of the participation of village leaders in study tours reveals that access to information and technical knowledge is a key to the diffusion of agricultural innovations. Finally, the key challenges to the diffusion of conservation agriculture lie in providing sufficient information and technical support locally, raising environmental awareness among rural populations, and improving credit systems, exchange infrastructure and market channels. As a corollary, enhancing the competitiveness of smallholder production could also contribute to prevent large scale land grabbing by powerful private investors.

**Acknowledgments**

This research was conducted within the framework of the Multi-country Support Programme for Agro-ecology (PAMPA) and funded by the French Agency for Development (AFD), the French Ministry of Foreign and European Affairs (MAEE) and the French Fund for World Environment (FFEM). The authors thank the Agriculture and Forestry Offices of Xieng Khouang Province, and the districts of Pek, Kham and Nonghet districts for their support during the fieldwork, the CIRAD and PRONAE teams in Lao PDR for their willingness to share knowledge and information, and all the villagers interviewed for their kind cooperation.

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[i] PRONAE was established by the National Agriculture and Forestry Research Institute (NAFRI, Lao PDR) in collaboration with the Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD, France).

[ii] A joint research programme of the Institut de Recherche pour le Développement (IRD) and the Center for International Forestry Research (CIFOR)

[iii] Spontaneous diffusion refers here to a process whereby farmers start employing conservation agriculture techniques without having received direct technical support from the project.

[iv] Although not a PRONAE target village and apparently not influenced by spontaneous diffusion, the case of Nahoy is worth mentioning. It shows a significant expansion of shifting cultivation on the slopes over the past 5 years.

[v] Ratio between dependent household members (e.g. children, elders) and workers.

[vi] Under such agreements, smallholders provide land and labour while the company provides farm inputs, technical support and market channels.