Direct Seeding Mulch-Based Cropping Systems – A Holistic Research Approach implemented in Northern Laos

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Abstract

Farming systems throughout the Lao PDR have changed drastically over the last 15 years due to a range of factors. In some areas where market forces are prevalent, shifting cultivation systems have given way to more conventional high-input agricultural systems. In other more remote areas, the traditional swidden system with long rotations has been put under pressure primarily due to modification of land access and increasing population pressure. In southern Xayabury in the Mekong corridor, where there is access to the Thai market, land preparation has become based on burning residues and ploughing on steep slopes. Because of the environmental and financial costs of land preparation, farmers are shifting to herbicides, which lead to chemical pollution, while crop residues and weed mulch are usually burned, thereby increasing mineral losses and erosion on bare soil. In mountainous areas such as Xieng Khouang Province, the rationale of shifting cultivation is collapsing as farmers use land for longer periods of cropping and return more frequently to each field. A holistic research approach has been implemented in Xayabury and Xieng Khouang to find direct seeding mulch-based cropping (DMC) systems that are compatible with farmers' strategies and which can be reproduced inexpensively on a large scale. The methodological framework, based on five main components, emphasises the process of adaptation and validation by farmer groups, meaning that priorities are defined by smallholders in light of the constraints of their farming systems and the overall environmental conditions.

Media summary

This paper gives an overview of the holistic research approach implemented by NAFRI and CIRAD in the Lao PDR in adapting soil conservation technologies with farmer groups.

Keywords

Laos, holistic research approach, direct seeding mulch-based cropping systems, farmer groups, process of adoption.

Introduction

Laos is a landlocked country (Map 1) with a total area of 236,800 km^2 and an average of 25 inhabitants per km^2. The agriculture and forestry sector accounts for more than 50% of the GDP and provides the economic, social and cultural base for more than 80% of the population (GoL 2004). Rice is the most important crop, accounting for about 70% of total calorie intake across the nation (Maclean et al. 2002). In 2003, rice area harvested was approximately 756,000ha, or 73% of the total cropped land area (MAF 2003). It is estimated than 620,000 households depend on agriculture and that 79% of these rely on subsistence farming. Farming systems throughout Laos have changed drastically over the last 15 years due to a range of factors. In some areas where market forces are prevalent (e.g. southern Xayabury in the Mekong corridor), shifting cultivation systems have given way to more conventional high-input agricultural systems. In other, more remote areas (e.g. Xieng

Map 1: National Programme of Agroecology site locations

Khouang province), the traditional swidden system with long rotations has been put under pressure primarily due to modification of land access and increasing population pressure. Intensification of shifting cultivation, with longer periods of cropping and more frequent returns to a given field, has rendered this system unable to face the main challenges of food safety, soil and water conservation and environmental protection (Hansen and Sodarak 1996; Roder et al. 1997). Maintaining productive capacity of the soil is a crucial element for long-term improvement of smallholders' conditions and poverty alleviation (GoL 2004). During the past few decades, many approaches and alternatives based on bench terracing, reforestation and alley-cropping have been tested and scaled-up for the uplands without achieving the expected results (Fujisaka 1991; Roder 1997). The objective of this paper is to give an overview of the holistic research approach implemented by NAFRI and CIRAD and of the iterative process of generating direct seeding mulch-based cropping (DMC) systems with smallholders. This approach has been implemented by the Lao National Programme of Agroecology since 2002 in southern Xayabury and was extended to Xieng Khouang in early 2003.

Characteristics of Southern Xayabury and Xieng Khouang Provinces

Southern Xayabury – Mekong Corridor

The main characteristics of this region are its integration with the Thai market and the transfer of technologies from Thailand. The climate is characterised by a wet season (approximately 1,250 mm rainfall) from mid-April to the end of October and a dry season from November to mid-April. Sandstone, basaltic 'green' stones and clayey schist are the dominant geological formations. Traditional rotational cultivation has changed drastically here since the 1990s, through extensive agricultural development based on cash crops such as maize, rice-beans, peanuts, Job's tears and sesame production). Cropping is largely opportunistic, related to the demands of the Thai market. Land preparation, based on burning residues and ploughing on steep slopes, has allowed for cultivation of large upland areas every year. Within a few years, this conventional land preparation generates heavy soil degradation and depletion of natural resources, and seasonal migration frequently occurs due to collapsing livelihoods.

Xieng Khouang Province

Farming systems in this province show considerable diversity, related to the presence of several ethnic groups, differences in access to market, and varying geological and morpho-pedological formations (granite, sandstone, limestone). Three main situations can be presented. In the vicinity of the provincial capital, it is estimated that 60,000ha of acid, infertile savannah grasslands are under-utilised by smallholders. On the higher plains (altitude 800-1100 msl), farming systems are mainly based on lowland rice and extensive livestock production. In other more remote areas, particularly at the highest altitudes (900-1200 msl), upland rice production is the cornerstone of farming systems. As mentioned above however, the stability of swidden cultivation is being affected by population growth, which leads to competition for the limited arable land and results in shorter fallow periods and lower yields. In some locations, household production strategies are being greatly modified by the emergence of new economic opportunities. These include (i) increasing local and regional urban demand following the development of cities, and (ii) better access to markets due to road construction or renovation. Across the province, hunting, gathering and off-farm activities are common and play a key role in livelihoods.

Comparative indicators (MAF 1999) reported that the socio-economic paths of the uplands and of the Mekong corridor diverged from 1994 to 1998 following modification of the agricultural sector and rural economic growth. During the 1994-1998 period, the mean value of household assets stood at US$471 for the Mekong corridor and $247 for the uplands, while this value had been equal ($240) in both locations from 1986 to 1993. Some places, like southern Xayabury, experienced significant rural growth related to Thai market demand. However, even very good soils with high potential for agricultural development can be rapidly degraded. Such damage to natural resources and cultivated area has immediate negative social and economic impacts (Photo 1).

Photo 1: Land erosion generated by ploughing and destruction of paddy fields, southern Xayabury, 2004

A Holistic Research Approach to Generate, Adapt and Validate Technologies with Smallholders

This approach, based on knowledge of local farming systems and environmental conditions such as morpho-pedological formations, access to market, credit, and inputs, is composed of five components (Séguy *et al.* 1998):

- Initial assessment: agro-economic and social diagnosis of farming systems, human and physical environments provides a basis for generating technologies adapted to smallholders' strategies and environmental conditions.
- Setting up medium-term experimental units where conventional systems are continuously compared with DMC systems based on available technologies, and innovative DMC systems based on new technologies and inputs.
- Adaptation and validation by smallholders of DMC systems and simple technologies:
    - On-farm implementation with farmer groups: agro-economic evaluation for labour requirement, production costs, yields, net income and labour productivity;
    - Community-based approach which focuses on the adoption of technologies at village level, taking into account collective land management.
- Permanent training for smallholders, extension agents and information provision to policy makers.
- Follow-up and analysis of the conditions of extension and adoption by farmers.

The third and fifth components have so far been implemented only in southern Xayabury, due to the more advanced situation in this location.

Initial Assessment

Initial assessment has been carried out at different levels in order to integrate all aspects of smallholder strategies and environmental conditions. The first step is based on data collection (province, district, extension services and village) and environmental diversity observations. Headmen and village councils are interviewed in each village to assess community practices and recent changes related to land tenure and agriculture. Information on market channels is obtained through interviews with agriculture officers, traders and village headmen. The second step records knowledge of farming systems in order to identify the advantages and constraints of present systems and to evaluate new technologies at farm level. Quantitative and qualitative household surveys are carried out on targeted farmer groups in order to acquire information on household conditions and farming systems. A total of thirty-one (eight villages) and seventy-four households (twenty-two villages) were surveyed in southern Xayabury and Xieng Khouang respectively.

Setting up Medium-Term Experimental Units and Diversification of Technologies

In both locations, and related to initial assessment, medium-term (at least four years) experimental units representative of the bio-physical (integrating soil, slope and climate) and farming systems diversities were set up in order to test a large range of cropping systems (actually eight, see Table 1) and technologies. Soil and crop management, cultivars, others inputs (fertiliser and/or pesticide) and natural conditions are cross-linked to obtain a set of highly varied conditions (Séguy et al. 1998). Four experimental sites have been implemented in each province with a total area of 15ha and 20ha in southern Xayabury and Xieng Khouang respectively. Throughout the trial, permanent comparisons are made among traditional cropping systems, which remain the reference, and different levels of DMC systems optimisation (Photo 2). Conventional systems are modified iteratively in order to evaluate each component's influence on system performance and to match smallholders' strategies in adopting technologies. In different experimental units, soil and crop management sets are conducted under different levels of fertiliser in order to assess the evolution of the different systems under time. Moreover, these units provide an excellent opportunity for researchers to analyse short, medium and long-term biological and physicochemical processes in stabilised systems.

Photo 2: Experimental unit with conventional land preparation (right side) and different levels of DMC systems (left side)

Modification of Land Preparation and Crop Management

An iterative generation of DMC systems is followed in both locations. The first step is based on modification of land preparation with crop and weed residues management. Cash crops like Job's tears (*Coix lacryma Jobi*) and rice-bean (*Vigna umbellata*) can be considered as key crops for implementing this first level of DMC systems. These crops, with long-cycle durations, produce a large amount of dry matter (over 20t.ha^{-1} for Job's tears) and degradation of these residues is relatively slow due to a high rate of lignin. This provides good soil protection, reducing evaporation, soil erosion and weed pressure (Photo 3). Moreover, the strong rooting system of Job's tears improves soil structure, making it a useful former crop. The second step integrates soil and crop management (association, rotation and/or annual crop sequence) in order to diversify the production (grain production, rational use of forages by grazing and/or cut and carry), and so reduce agronomic, economic and climatic risks while optimising the main functions of DMC systems through adequate use of main and relay crops.

Photo 3: Maize direct seeded on rice-bean residues (residual dry matter > 4t.ha^{-1}). Southern Xayabury May 2005

Use of Cover Crops

Many options are available when using additional crops (cover crops) but in the case of smallholders, who usually lack of market access, an integrated cropping and livestock production system is more suitable. Many systems are being tested in experimental units or with smallholders in both locations:

- Rotations with direct-seeded grain crops (maize, Job's tears) followed by forage production for grazing (Kluthcouski *et al.* 2000). Species like *Brachiaria ruziziensis* are sown at the first weeding stage by seed broadcasting in order to limit labour input. After two or three years, depending on the farmer's strategy, crops can be direct seeded on forage mulch.

- Association of cash crops (maize or Job's tears) with living cover crop (*Centrosema pascuorum*, *Desmodium uncinatum*).
- Mixed system between edible crops and *Brachiria ruziziensis*, frequently slashed and imported in the row to protect the soil, control weeds and improve nutrient availability for the main crop via mulch mineralization.
- Regeneration of grasslands (altitude plains in Xieng Khouang province) by use of forage species (*B. ruziziensis*, *B. mulatto*, *B. brizantha*). One of the main functions of *Brachiaria* sp. is to improve soil structure and recycle nutrients leached deep in the soil through strong and deep root systems. After two or three years of biological improvement, upland rice can be direct seeded on forage mulch.
- Grain production based on two crop sequences: a main short-cycle crop (e.g. peanuts, sesame, soybeans) followed by a relay crop for small animal feeding (sorghum, finger millet, oats in winter in mountainous areas). The aim of this system is to use annual species which can produce grain and a high amount of dry matter at the end of the rainy season.

Location and systems	**Crop management: rotations, associations and crop successions**		**Main products**	**Advantages**	**Weak points**
Grain production in southern Xayabury and Xieng Khouang	Annual cropping	Maize / Maize	Grains for agro-industry	- Lower production - Higher net income	- Weed control and soil erosion
Southern Xayabury – Large scale rainfed grain production	Rotational sequence, two years	Maize / rice-bean		- Higher net income, yields and labour productivity - Control of weed and soil erosion	- Erratic grain production of rice-bean
	Rotational sequence, three years	Job's tears / rice-bean / upland rice	Grains for agro-industry and home consumption	- Control of weeds and soil erosion - Soil structure and fertility - Higher net income, yields and labour productivity	- Small market for Job's tears - Erratic grain production of rice-bean
Mountainous area in Xieng Khouang	Mixed system	Maize / Legumes or upland rice – *B. ruziziensis* (slashed and imported in the row)	Grains for home consumption and integration with livestock production	- Control soil erosion and weeds - Improve soil fertility - Integration with livestock production - Forage seed production	- Need fertiliser to compensate for nutrient exportation by forage - Labour inputs
Altitude plains of Xieng Khouang	Rotational sequence, three to four years	*Brachiaria* sp. (2-3 years) / upland rice (1-2 years)	Edible crop for home consumption and integration with livestock production	- Regeneration of waste lands - Added output with forage seeds production - Livestock production	- Need economic incentives - Inputs and specific tools (direct sowing machine for hand tractor)
Mountainous area in Xieng Khouang	Rotational sequence, three years	Maize / Soybean – oats in winter / upland rice	Grains for agro-industry, livestock production and home consumption	In progress	
Southern Xayabury		Job's tears - *B. ruziziensis* - *C. Cajun* / rice-bean / upland rice			
Southern Xayabury and mountainous area in Xieng Khouang	Living mulch	Maize - *Centrosema pascuorum* or *Desmodium uncinatum*	Grains for agro-industry and for livestock production		

Table 1: Example of some DMC systems generated in southern Xayabury and Xieng Khouang province.

Adaptation and Adoption by Smallholder Groups through a Community-Based Approach in Southern Xayabury

Adaptation and Validation at Farm Level

The third component of this holistic approach uses on-farm adaptation and validation of the first level of DMC systems that match smallholders' conditions and strategies. In this region, agricultural developments copied from Thailand: crop residues and weed mulch are usually burned, thereby increasing mineral losses and erosion on bare soil. This generates land erosion, fertility losses and yield decrease. In addition, because of the environmental and financial costs of land preparation, farmers are shifting to herbicides, which are sprayed before and/or after crop emergence, and so lead to chemical pollution. These developments are leading to the destruction of paddy fields and even roads, as the degradation of agricultural land has serious knock-on effects downstream. Many farmers have now requested technical support to modify land preparation.

Experience has shown that organisation of farmers through groups is crucial for the adaptation and adoption of DMC systems, which modify mostly conventional agriculture (Landers 1998). Farmers groups were organised for a total of 42 families in southern Xayabury (six villages) to validate technical options aimed at decreasing production cost and labour, and limiting rainfed area erosion. DMC systems for crop residues are implemented for cash crops such as maize, Job's tears and rice-bean. A few modifications to cropping systems are proposed to smallholders in order to set-up, adapt and validate each step using current crops and cultivars. DMC systems for crop residues can exhibit very good results (Photo 4) in terms of net income, yield and labour productivity (Tivet et al. 2004; Tran Quoc et al. 2005). Referring to feed-back from smallholders, every constraint is notified during the process of adaptation and adoption and taken into account into the experimental unit. Tran Quoc et al. (2005) give a review of the main constraints identified by men and women in farmer groups.

Photo 4: Left, direct seeding of maize on former crop residues; right, maize after ploughing. Southern Xayabury, 2004

Community-Based Approach

Dealing with community land management is essential in order to scale-up DMC systems. Maintaining crop residues or cover crops on fields is a difficult process where land management modification has to occur during the dry season. Wild fires that are started by farmers and spread to the land of other farmers are common. One option proposed by the programme, as suggested by Sain and Barreto (1996), is to enhance the attractiveness of mulch, linking this component to other technological changes that tend to decrease production costs while increasing cash income and labour productivity. In four villages where farmer groups have been constituted, a research development programme has been set up to work along the following lines recommended by Chazée (1994):

- Analysing the short- and medium-term strategy of the village.
- Analysing needs relating to the work developed by the programme and others needs.
- Formalisation of a research and development programme with the community.
- Definition of the activities which will be implemented with the community.
- Encouraging, from the beginning, the continuation of this research-development process with farmers, headmen, and district and provincial agricultural services after the end of the programme.

This framework seems essential to understanding the effects and impacts of our activities, and particularly to understanding the whole *problematique* at the village level. At this time, ninety-seven smallholders are adapting DMC systems (over approximately 78ha) based on residue management in the context of the constraints of their farming systems and overall environmental and economic conditions. Others technologies, such as regeneration of pasture lands with improved forage species (*Brachiaria* sp.), have been adopted by sixty families and cover more than 65ha.

Issues and Challenges in Scaling-Up DMC systems in Laos

Economic Incentives

Economic incentives such as provision of credit have to be promoted. As observed in southern Xayabury and reported also by Petersen et al. (1999), one of the major limiting factors to adoption may be that the practice promoted was first perceived as being closely associated with a need to use cash income for equipment and inputs. In southern Xayabury, traders give ploughing and seed credit at the beginning of the season. For many smallholders, even if high interest rates (50% over eight months) are used, this function is positive as it gives them the opportunity to not use any cash. In mountainous areas and altitude plains, new farming systems based on DMC integrated with livestock and forestry products could be stable and profitable if, at the same time, economic incentives (access to market, inputs, credit, agriculture and forestry product processing) are promoted to allow this development.

Mechanisation

It should be noted that labour force is one of the main limiting factors in agriculture, and smallholders cite three main objectives in their development goals: i) increasing cash income and cultivated area, ii) labour optimisation and iii) decreasing the drudgery of labour. Specific tools, such as the hand-jab seeder, the direct sowing machine for hand tractors, and low-volume application sprayers, can reduce drudgery and labour inputs. Smallholders are currently highly dependent on traders who own tractors, and their choice of land preparation is somewhat dictated by the burden of borrowing. Increased mechanisation in the area, with an increase in the number of hand tractors and tractors, would increase the ability of farmers to farm their land on a more sustainable basis.

Biomass Management at Community Level

As mentioned above, rules must be defined at the community level for management of cover crops and residues during the dry season. Managing the interface between animal and crop components is crucial to the success of these systems. Overgrazing of cover crops or crop residues during the dry season may leave too little mulch for sowing the following wet season crop, thereby affecting the main functions of the DMC systems. Specific forage use and control of wild fires must be defined by the community.

Land Tenure and Amount of Cultivated Area per Household

This approach, based on soil conservation technologies and integration of systems (livestock and perennial crops), can be efficient in the uplands if land tenure per household is defined under specific conditions. Obviously, land allocation must be flexible, taking into account the diversity of livelihoods in the uplands. Maintaining and protecting soil resources and biodiversity will be effective if enough land is allocated to smallholders for the integration of forestry area and natural resource uses.

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Improvement of the "Smallholders, Researchers, Extension Agents, Decision-Makers and Private Sector" Continuum

The different components of this approach generate a strong training environment for smallholders, research and extension officers, and all of the stakeholders involved in development. However, this continuum has to be improved in order to share experience and to efficiently disseminate DMC systems. The main limiting factors are a lack of extension officers at provincial and district level; lack of human resources to give the available technical information in a way that is understandable for each stakeholder; and a low level of coordination between all the stakeholders. The Lao government and its Ministry of Agriculture and Forestry recently recognised that this approach should be scaled up at nationally in order to protect natural resources, maintain soil potential and increase livelihoods. Moreover, it has been proposed that a specific degree course on DMC systems be developed in the agricultural schools where the country's extension officers are trained.

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References

Chazée L (1994). Guide pratique pour le développement des communautés rurales du Laos. Amélioration des systèmes de production basée sur l'approche participative, l'aménagement des terroirs et la conservation de la biodiversité. Projets de « Modernisation des petits périmètres irrigués dans les provinces d'Oudomxay et de Luang Namtha ». Document FENU-PNUD. p. 76.

Fujisaka S (1991). "A diagnostic survey of shifting cultivation in northern Laos: targeting research to improve sustainability and productivity". Agroforestry Systems 13, 95-109.

Government of Lao PDR. The National Growth and Poverty Eradication Strategy 2004. Ministry of Foreign Affairs, Vientiane, Lao PDR. 151 pp.

Hansen PK and Sodarak H (1996). *Environment, socio-economic conditions and land-use in Ban Thong Khang Sub-district, Northern Laos*. Shifting cultivation research sub-programme. Technical report 2. National Agriculture and Forestry Research Institute, Vientiane, Lao PDR.

Kluthcouski J, Cobucci T, Aidar H, Yokohama LP, Oliveira IP, Costa JLS, Silva JG, Vilela L, Barcellos AO and Magnabosco CU (2000). "Integração lavoura/pecuária pelo consórcio de culturas anuais com forrageiras, em áeras de lavoura, nos sistemas direto e convencional". *Embrapa Arroz e Feijão, Circular Técnica* 38, p.28.

Landers JN (1998). Technology transfer mechanisms for the new direct sowing techniques in the savannahs of Central Brazil. In "Gestion Agrobiologique des sols et des systèmes de culture", Rasolo F and M Raunet (Eds.), International Seminar proceedings, Antsirabe, Malagassy, 23-28 March 1998.

Maclean J, Dawe D, Hardy B, and Hettel G Eds (2002). Rice Almanac. Los Banos, Philippines: International Rice Research Institute. Bouake, Côte d'Ivoire : West Africa Rice Development Association. Cali, Columbia: International Center for Tropical Agriculture. Rome, Italy: Food and Agriculture Organization. p. 253.

Ministry of Agriculture and Forestry (1999). The government's strategic vision for the agricultural sector. A Discussion Paper prepared for the Donor Round Table Conference. Ministry of Agriculture and Forestry. Vientiane, Lao PDR. 8-9 November 1999.

Ministry of Agriculture and Forestry (2003). Agricultural Statistics, Department of Planning. Vientiane, Lao PDR.

Petersen P, Tardin J and Marochi F (1999). Participatory development of no-tillage systems without herbicides for family farming: the experience of the center-south region of Paraná. Environment, Development and Sustainability 1, 235-252.

Roder W, Phengchanh S and Maniphone S (1997a). “Dynamics of soil and vegetation during crop and fallow period in slash and burn fields of northern Laos”. Geoderma 76, 131-144.

Roder W (1997b). “Slash and burn rice systems in transition: challenges for agriculture development in the hills of Northern Laos”. Mountain Research Development 17, 1-10.

Sain G and Barreto H (1996). The adoption of soil conservation technology in El Salvador: linking productivity and conservation. Journal of Soil Water Conservation 51, 313-321.

Séguy L, Bouzinac S, Trentini A and Côrtes NA (1998). “Brazilian frontier agriculture”. Agriculture et Développement. Special issue.

Tivet F, Tran Quoc H, Khamxaykhay C, Chantharath B, Julien P, Sosomphou T and Panyasiri K 2004. On-farm validation of direct seeding on crop residues, south of Xayabury Province. Workshop on Poverty Reduction and Shifting Cultivation Stabilization in the Uplands of Lao PDR: Technologies, approaches and methods for improving upland livelihoods. Luangprabang, Lao PDR. 27-30 of January 2004.

Tran Quoc H, Tivet F, Khamxaykhay C, Chantharath B and Séguy L (2005). Example of an iterative approach conducted with smallholders in northern Laos for the adoption of direct seeding mulch-based cropping systems. Third World congress on Conservation Agriculture Proceedings. Nairobi, Kenya. 3-7 October 2005.