Example of an Iterative Approach Conducted with Smallholders in Northern Laos for the Adoption of Direct Seeding Mulch-Based Cropping Systems

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Abstract

Since the 1990s, in the southern districts of Xayabury province in the Mekong corridor, traditional farming systems have changed through extensive agricultural development based on cash-crop production. This development, by way of intensification, depends on local market accessibility, transfer of technologies from Thailand and the financial capacities of local enterprises. Thai Inputs, heavy mechanisation and technical skills are imported and cropping is largely opportunistic, following Thai market demand. Land preparation, based on burning residues and ploughing on steep slopes, has allowed for cultivation of large upland areas. As a result of this development, combined with land allocation and increasing population density, fallow periods are disappearing. Furthermore, this ‘resource-mining’ generates land erosion, fertility loss, yield decline and chemical pollution as well as destruction of roads and paddy fields. In light of this, the Lao National Programme of Agroecology has implemented a holistic research approach in order to propose various systems for integrating crops and livestock production to farmers. From a large range of technologies that were tested, maize production using direct seeded grain on former crop residues under no-tillage systems has been implemented. Results achieved under the various conditions are presented in this paper: the yields obtained are close to and sometimes even higher than those obtained in conventional systems. Labour, costs, soil erosion, net income and labour productivity are also all observed.

Media summary

Direct seeding mulch-based cropping systems are compared with conventional practices in southern Xayabury through on-farm experiments. Promising results are obtained with this first level of DMC systems, mainly based on use of available technologies for smallholders. Feedback from farmers also identifies the main constraints of these systems.

Keywords

Xayabury province, iterative approach to soil conservation, residue management, labour productivity, key factors for scaling-up.

Introduction

Traditional farming systems have drastically changed over the last fifteen years in the southern districts of Xayabury province, with considerable agricultural development based on the production of cash crops such as maize, rice-bean (*Vigna umbellata*), peanuts, Job’s tears (*Coix lacryma*), black cowpeas (*Vigna unguiculata*) and sesame. This development, by way of intensification, depends mainly on local market accessibility, transfer of technologies from Thailand and the financial capacities of local enterprises (to fund inputs, heavy mechanisation and technical skills from Thailand). Due to its low labour requirements and high labour productivity, maize is widely sown and spreads to new areas every year (more than 15,000 ha was sown in southern Xayabury in 2004), while crop rotation tends to be abandoned. Land preparation based on burning residues and ploughing on steep slopes has allowed for cultivation of large upland areas.

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As a result of this development, associated with land allocation and increasing population density, fallow periods are disappearing and agricultural systems are not conserving soils and nutrients. Even arable land with very good soils and high potential for agricultural development can be rapidly degraded, in which case negative social and economic impacts follow. Initial assessment of this 'resource-mining' agricultural development shows dramatic land erosion, and destruction of roads and paddy fields. In many degraded areas of southern Xayabury, smallholders have modified conventional land preparation and are shifting from ploughing to herbicides. Residue burning, followed by spraying before sowing, is common. Increasing use of pesticides is also one of the major issues of this agricultural intensification. Herbicides such as Atrazine, Paraquat and Glyphosate are now widely used in southern Xayabury for land preparation after burning or ploughing (sometimes up to $10l.ha^{-1}$ of Paraquat or Glyphosate) and for post-emergence application (Atrazine) on maize. It is estimated that in 2004 more than 90% of smallholders in Parklai district used Atrazine.

Theses changes in agricultural practices emphasise the great reactivity, good or bad, of smallholders, who cite three main objectives in their development goals: (i) cash income and increasing the area cultivated, (ii) labour optimisation and (iii) decreasing the drudgery of labour. In order to convert this 'resource-mining' production to a stabilising plant-soil system, an iterative approach has been implemented to analyse, for each step, the technical and socio-economic viabilities of direct seeding mulch-based cropping (DMC) systems. The aim of this paper is to compare maize production under direct seeding on crop residues with production through conventional land preparation, mainly based on ploughing. Since 2002, the Lao National Programme of Agroecology has implemented a holistic research approach which emphasises generation and adaptation of DMC systems with village communities and groups of smallholders.

Methodology

On-Farm Experiments

The main characteristics of this region are given in Bounthong et al. (2005). Farmers' field experiments are carried out on plots of at least $4,000m^2$. Comparisons between conventional and DMC systems are assessed on large demonstration plots under conditions that match those found on farms in the region. Wherever possible, conventional land preparation is replicated on both sides ($1,000m^2$ x 2) of the direct seeding plots ($2,000m^2$) and arranged on landscape slopes in order to take fertility gradients into account. These experiments involve 42 smallholders located in six villages with a total area of 16.8ha. Comparisons are also carried out between DMC systems on residues and conventional cropping systems for different edible and cash crops. The results discussed in this paper concern maize, the main production crop in this region. The number of fields differed according to zone (with varying morpho-pedological features, access to market and farmer strategies) with six, four, eleven, three, five and five fields used in Kengsao, Bouamlao, Paktom, Nahin, Houay Lod and Nongphakbong respectively. A description of the different steps followed for land preparation for DMC systems is given in Figure 1.

Data Collection and Economic Analysis

Labour requirements and production costs were recorded for all activities (land preparation, sowing, weeding and harvesting). Yield and overall performance is recorded for each treatment. However, the philosophy under which the experiments were carried out allows for qualitative analysis in order to evaluate the socio-economic viability of these systems.

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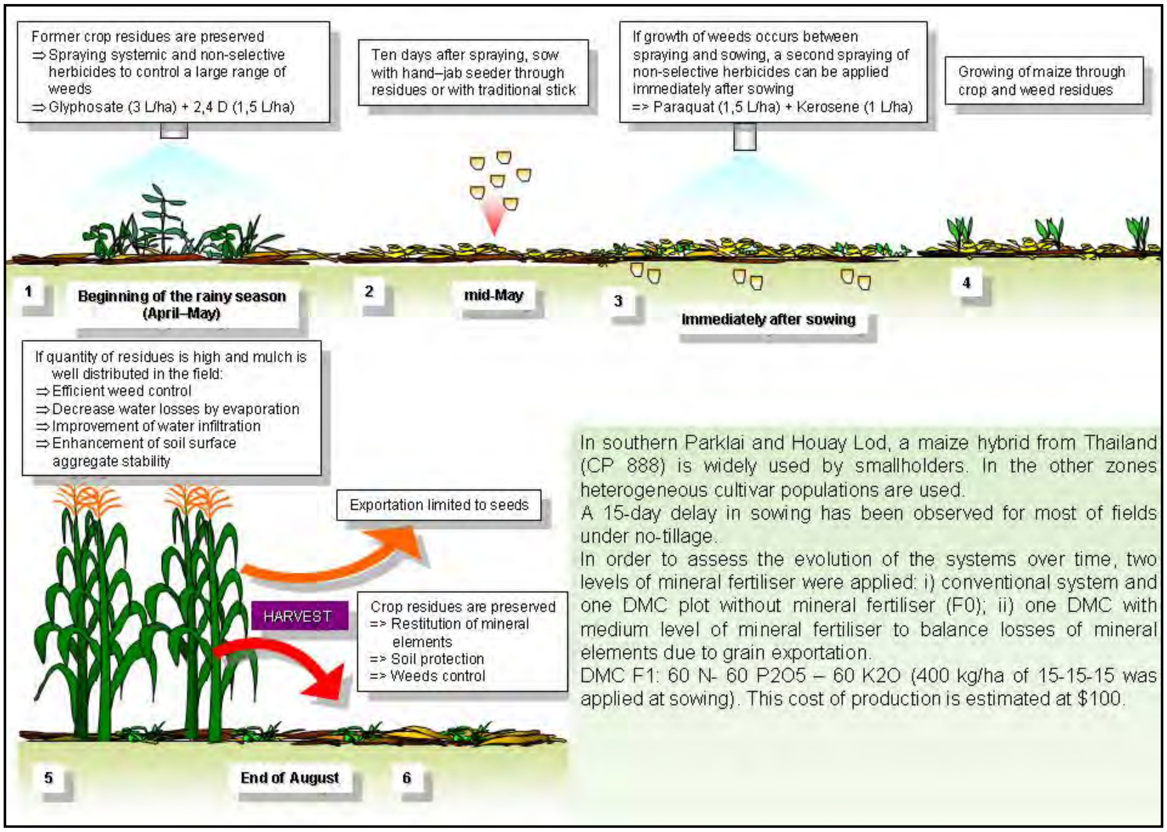

Figure 1: Description of the different steps followed for land preparation under DMC systems with residue management. Choice of herbicide depends on weed pressure and the nature of weeds in the field.

Results and Discussion

Mulch Remaining before Sowing

A layer of mulch, even a thin one, limits soil erosion by decreasing the kinetic energy of raindrops and run-off intensity (Abrahams et al. 1994). Moreover, run-off intensity is decreased because of the sinuous pattern that is generated by residues. This wavy pattern increases the path and decreases the effective slope met by the run-off. Findeling (2001) reported that 4.5t.ha^{-1} of dry matter can represent a 30% slope reduction and reduce run-off intensity by 20%. At the beginning of the rainy season in 2004, dry matter ranged from 2.0 to 3.5t.ha^{-1}. However, this figure refers only to large particles of residue and ignores small aggregates of soil and straw, which also greatly reduce run-off intensity. After harvesting, large amounts of dry matter are obtained with these different cash crops (maize, rice-bean and Job's tears). For example, on average the dry matter reaches 16t.ha^{-1} with Job's tears, 8t.ha^{-1} for maize, and 6.5t.ha^{-1} for rice-bean under good soil potential. Mulch remaining at the beginning of this season (2005) represented at least 45% of the dry matter recorded after harvesting, with no exportation by animals occurring during the dry season.

Crop residue management can be a first step towards reducing losses of soil and mineral elements, as well as a way of saving money. In southern Xayabury, Job's tears and rice-bean are useful crops for starting DMC systems on residues because of: i) their low residue degradation due to a high lignin content, which enhances soil protection by reducing both evaporation and weed pressure (particularly for rice-bean); ii) the low rate of C/N for rice-bean residues, minimising mineral nitrogen competition between the crop and micro-flora at the beginning of the rainy season; and iii) the low level of animal exportation owing to the low palatability of both species. Below-ground dry matter was not measured, but biological improvement of soil structure by rooting systems is crucial. A crop of Job's tears with long duration and a strong rooting system is a good companion crop for ensuring this function.

Yield

For each treatment, grain yield variations for maize, according to site characteristics (landscape, soil units) and cultivars are significant (Table 1). Such results reflect differences in soil erosion and fertility. For example, while Paktom, Nahin and Bouamlao have the same geological substratum, large differences in yield are observed. In southern Parklai (Kengsao and Bouamlao) and northern Kenthao (Houay Lod), areas which began maize production recently, yields recorded under DMC systems reach 5t.ha^{-1}. With DMC systems, yield levels were generally close to or even higher than those obtained in conventional systems, with no substantial difference observed. In Northern Kenthao, the use of fertiliser can increase yield by up to 73%, which can counterbalance production cost. In contrast, the use of fertiliser does not appear to be economically viable for degraded areas like Nongphakbong and Nahin. However, use of fertiliser under direct seeding tends to boost not only yield but also biomass production, thus indirectly enhancing soil biological activity. In these degraded areas, the mean average yields recorded with no-tillage oscillate between 2.4 and 3.4t.ha^{-1} with maize, while mean yield with tillage is 3.3t.ha^{-1}. In Nongphakbong, poor soil structure due to soil compaction and soil crusting seems to be the main limiting factor of yield under both DMC and conventional systems. Erenstein (2003) reported that short-term yield effects often depend on the mulch, crop and site characteristics. Therefore a number of seasons are necessary to stabilise the system. As described by Séguy et al. (1998), soil characteristics must be improved in order to generate a conservative system for water and nutrients with good organic composition to restructure the soil. Moreover, enhancement of soil biological activity is crucial as below-ground insect and microbial populations improve soil structure and plant nutrition. Because of the great modifications of the soil by conventional agriculture, these main functions can be completed under medium and long-term processes.

Production Cost and Net Income

High variations are observed in economic components such as production costs, net income and labour productivity, mainly dependent on the number of replications and on site characteristics (Table 1). An example cost production analysis for southern Parklai is given in Figure 2. For ploughing, production costs ranged from US$40 to $150 per ha depending on the slope, distance from the main road, and amount of stones and/or stumps in the field. In comparison, the cost of land preparation with DMC systems is about $30 per ha. Production costs can therefore be reduced by 30%-100%, representing a gain of $35-$100 per ha (Table 1). In southern Parklai (Kengsao, Bouamlao) and northern Kenthao (Houay Lod), net income per ha was highly significant with a mean value close to US$ 250 per ha for direct seeding. The difference in income between this method and the conventional approach varied from $45 to over $150 per ha. Furthermore, results emphasise that in these zones the use of mineral fertiliser is economically viable because of good soil fertility and lower weed pressure.

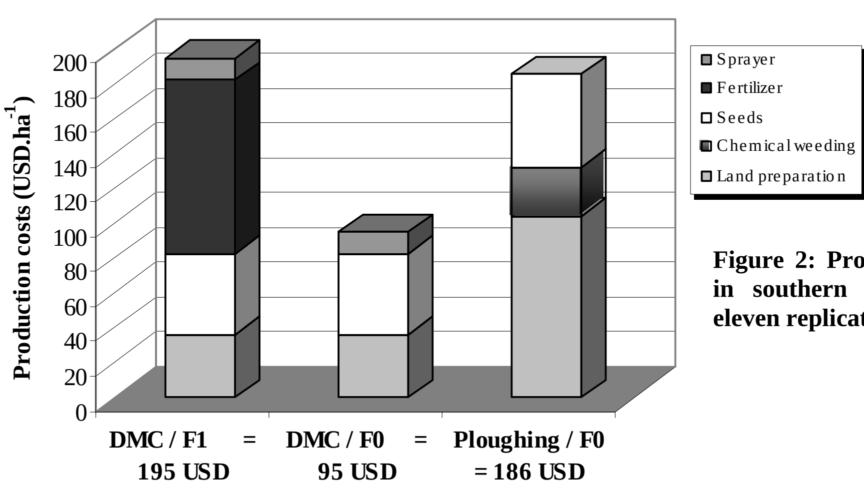

Figure 2: Production costs analysis in southern Parklai. A mean of eleven replications is given

Labour Requirements and Labour Productivity

With direct seeding technologies and a reasonable mulch layer before sowing (at least $3t.ha^{-1}$), weed pressure was lower than in conventional situations. Figure 3 shows that labour inputs required for weeding is only 3 $days.ha^{-1}$ with no tillage and 31 $days.ha^{-1}$ with tillage. A total mean gain of 39 days/ha was recorded during the season for DMC systems. Labour inputs for weeding depend greatly on the history of the field and on the nature of the former crop. Local species like rice-bean and Job's tears are ideal crops to start a direct seeding system. With long-cycle duration (seven months), both species compete fiercely with weeds during the rainy season and produce a high amount of biomass.

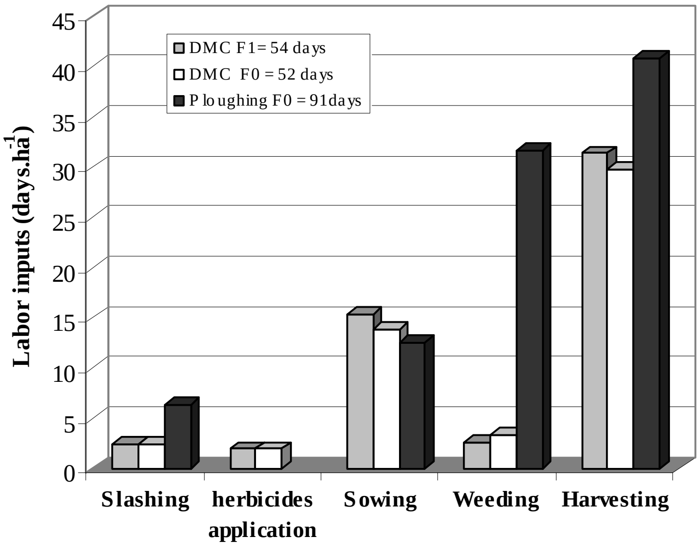

Figure 3: Labour inputs in southern Parklai and northern Kenthao. A mean of seven replications is given (quantity of remaining crop residues is superior to $3t.ha^{-1}$). Labour inputs for threshing and transport are not represented. Sowing was carried out without the use of a hand-jab seeder.

Little data was recorded in the field, but both a decreasing number and a change in species of weeds is common in the second year of direct seeding. In southern Parklai, with residue management, *Ageratum conizoïdes* become the dominant species and *Mimosa invisa*, which is the major weed associated with ploughing and burning, is significantly reduced. Dominance of this species in the conventional system is mainly related to the fact that burning tends to boost seedling emergence (Lao-IRRI 2000).

In all fields, labour productivity increased with residue management. This was most notable in Bouamlao, Kengsao and Houaylod (Table 1), where the increase ranged from \$4.2 to \$4.8 per day (DMC F0). In contrast, in the most degraded areas like Nongphakbong, very low labour productivity (<$\$1/day^{-1}$) is recorded under both DMC systems and conventional land preparation. These results are mainly due to the combination of low yields and the very low selling price of maize in this area.

Main Constraints for this First Step, Based on Residue Management

In southern Parklai, where area of maize cultivated per labourer can reach 2.5 ha, land preparation through large-scale herbicide application represents a considerable labour drudgery for men. Women meanwhile are more concerned about labour during sowing, and the risks of men becoming poisoned when using herbicides. Traders and/or tractor-owners give ploughing and seed credit at the beginning of the season. For many smallholders, even if higher interest rates are practiced (50% over eight months) such loans offered a good opportunity to avoid using any cash at the beginning of the season. The current lack of cash was identified as one of the major constraint, and was also cited by both men and women in Houay Lod, where no-tillage practice is common. Problems relating to labour input are also frequently emphasised following the drastic increase of cultivated area in this village. On the other hand, in degraded sites like Nongphakbong and Paktom, constraints relating to sowing through crop residues seem to be more important (including soil compaction induced by former ploughing, and difficulty in making holes and in seeing them through the residue crops). A presentation of the gender-disaggregated surveys conducted in Kengsao is given in Figure 4.

Components	Treatment	Villages									
		Kengsao		Bouamlao		Houay Lod	Paktom		Nahin		Nong Phakbong
	Year	2003	2004	2003	2004	2004	2003	2004	2003	2004	2004
	Replication	(3)	(6)	(5)	(4)	(6)	(8)	(11)	(2)	(3)*	(4)
Yield (kg/ha)	DMC F0	5481 ± 167	4583 ± 325	5044 ± 379	3727 ± 379	4976 ± 435	2563 ± 329	3383 ± 714	2507	2796 ± 559	2270 ± 434
	DMC F1	7542 ± 693	6106 ± 338	7413 ± 451	5657 ± 827	6779 ± 437	3616 ± 268	5356 ± 214	3769	3876 ± 98	3960 ± 91
	CV F0	4332 ± 691	5215 ± 588	5073 ± 281	4629 ± 394	4726 ± 518	2787 ± 316	3477 ± 42	3438	-	3305 ± 811
Production cost (US$/ha)	DMC F0	116 ± 13	100 ± 12	93 ± 3	90 ± 3	94 ± 0.5	52 ± 5	89 ± 9	46	44 ± 7	59 ± 14
	DMC F1	220 ± 13	200 ± 12	198 ± 3	190 ± 3	194 ± 1	145 ± 11	189 ± 9	153	172 ± 5	189 ± 14
	CV F0	169 ± 39	201 ± 40	142 ± 23	185 ± 46	194 ± 61	88 ± 8	111 ± 16	84	-	86 ± 28
Net income (US$/ha)	DMC F0	227 ± 19	243 ± 53	222 ± 23	236 ± 67	280 ± 73	82 ± 17	123 ± 8	84	166 ± 32	33 ± 41
	DMC F1	252 ± 53	258 ± 53	265 ± 27	305 ± 145	315 ± 73	43 ± 11	146 ± 17	43	119 ± 16	- 27,4 ± 25
	CV F0	102 ± 53	190 ± 84	175 ± 39	190 ± 86	100 ± 41	57 ± 19	107 ± 16	95	-	52 ± 66
Labour inputs (days/ha)	DMC F0	62 ± 5	51 ± 8	55 ± 9	49 ± 13	65 ± 10	61 ± 4	40 ± 12	64	51 ± 19	31 ± 1
	DMC F1	65 ± 2	54 ± 7	65 ± 9	51 ± 13	65 ± 10	67 ± 5	55 ± 9	65	54 ± 14	55 ± 13
	CV F0	75 ± 7	93 ± 32	70 ± 6	64 ± 18	78 ± 24	74 ± 7	41 ± 7	93	-	64 ± 4
Labour productivity (US$/day)	DMC F0	3.7 ± 0.1	4.8 ± 0.9	4.0 ± 0.8	4.9 ± 1.0	4.2 ± 0.9	1.3 ± 0.2	3.2 ± 1.4	1.3	3.4 ± 2.0	1.0 ± 0.8
	DMC F1	3.9 ± 0.8	4.8 ± 0.8	4.1 ± 1.4	5.8 ± 1.5	4.7 ± 1.0	0.6 ± 0.2	2.8 ± 0.4	0.7	2.3 ± 0.8	-0.5 ± 0.5
	CV F0	1.4 ± 0.7	2.2 ± 1.3	2.5 ± 0.7	3.0 ± 1.5	1.3 ± 0.1	0.8 ± 0.3	2.6 ± 0.5	1.0	-	0.8 ± 0.6

Table 1: Data ± SE from on-farm experiments conducted in 2003 and 2004 in southern Xayabury. Mean value, Yield, Production cost, Net income, Labour inputs and Labour productivity are presented for five situations. Data is from three to eleven on-farm trials of 1000 m^2 per treatment.
Key: DMC: direct seeding with residues management; CV: conventional – ploughing; F0: without mineral fertiliser; F1: 400 kg.ha^{-1} of 15-15-15. Nahin 2004*: all conventional plots were managed with crop residues

Different constraints limit the dissemination of these systems even if agronomic and economic successes have been highlighted. A gender-disaggregated survey was carried out with all groups of smallholders to identify the main constraints of this first level of DMC systems on residues (Figure 4). The results of this survey emphasised the main limiting factors:

- Drudgery of labour for land preparation (herbicide application), which limits cultivated area;
- Access to inputs (market and financial constraints, such as lack of cash);
- Problems of appropriate equipment for sowing;
- Technical skills required;
- Calendar flexibility;
- Risks of damage due to pests (rodents, insects);
- Risks of human intoxication by misuse of pesticides.

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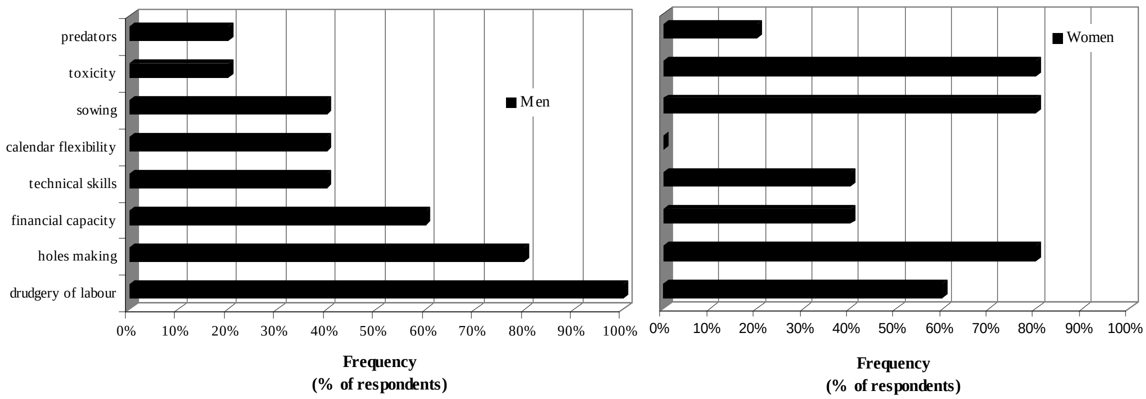

Figure 4: Factors limiting extension of DMC systems, as identified by smallholders in Kengsao

Issues and Challenges for Dissemination of DMC Systems in Southern Xayabury

Positive results from direct seeding systems based on residues are evident in southern Xayabury. The area also displays both a growing interest in and the potential for widespread adoption, with many smallholders requesting technical and financial support. However, obtaining all the biophysical and economic advantages of DMC systems involves a long process. The amount of residues remaining on fields is often relatively low due to biomass weathering, animal exportation, or even sometimes wild fires during the dry season. Small amounts of residue do not ensure good soil protection and/or weed control. In order to efficiently control weeds (through a smothering and/or allelopathic effect) and thereby generate systems that are less dependent of herbicides (Séguy 1999; Kliewer 2003), DMC systems have to be progressively improved with rational crop rotations, relay crops and cover crops.

In order to promote the extension of these systems, the limiting factors already identified by smallholders should be rapidly through a series of actions:

- Adequate equipment for DMC systems should be adapted on several scales in order to decrease labour drudgery. Diversified direct seeding equipment, such as the sowing machine for hand-tractor and medium tractor, has been designed in Brazil and could be adapted and distributed in southern Xayabury.
- Economic incentives such as provision of credit have to be promoted by decision makers and development projects.
- As knowledge is continuously generated in the field by researchers and farmers, it is essential that continuous training sessions be organised in order to share experience on the adaptation and adoption of such systems.
- As reported by many authors, the use of pesticides (herbicides and insecticides) can decrease rapidly under DMC systems with appropriate use of mulching and cover crops (Jansen 1999; Crovetto 1999; Scopel 2003). In the case of smallholders however, special attention must be addressed to the use of pesticides. Lack of knowledge leads to frequent misuse of pesticides, particularly in handling, with dramatic consequences for human health and the environment. In addition, with widespread herbicide use, large concentrations of pesticides can pollute rivers and soil. Products, which can be used as substitutes, should be researched.

Acknowledgement

The authors wish to thank the Ministry of Agriculture and Forestry of the Lao PDR, the French Agency for Development (AFD), the French Global Environment Facility (FFEM) and the French Ministry of Foreign Affairs (MAE) for financial support.

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