Issues Concerning the Adoption of Direct Seeding Mulch-Based Cropping Systems in Southern Xayabury, Lao PDR

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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 crops. This development, by way of intensification, depends on local market accessibility, transfer of technologies from Thailand and the increasing financial capacities of local enterprises. Thai inputs, heavy mechanisation and technical skills are imported and cropping is largely opportunistic, following Thai market demand. 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. As a result of this development, combined with land allocation and increasing population density, fallow periods are disappearing. Such ‘resource-mining’ agriculture generates land erosion - leading to destruction of roads and paddy fields – and is also responsible for fertility loss, yield decline and chemical pollution.

To rehabilitate the areas most degraded by these practices, combinations of multicropping, animal husbandry and off-farm activities can provide a balanced distribution of farming activities over time and space. Such strategies reduce climatic and economic risks in a fragile ecosystem. In light of this, the Lao National Agro-Ecology Programme has implemented a holistic research approach which emphasises generation and adaptation of direct seeding mulch-based cropping (DMC) systems with village communities and groups of smallholders. 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 various conditions are presented in this paper: yields, labour inputs, costs, net income and labour productivity are all observed.

Positive results are evident from DMC on residues. Despite agronomic and economic successes, however, various constraints limit the dissemination of these systems. 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. The major limiting factors appear to be: i) drudgery of labour for land preparation, so limiting cultivated area; ii) access to inputs (market and financial constraints); iii) problems of appropriate equipment for sowing; iv) technical skills required; and v) calendar flexibility.

Keywords

Xayabury province, iterative approach on soil conservation, residue management, adoption of DMC systems, limiting factors for dissemination.

Introduction

Since the 1990s, traditional farming systems in southern Xayabury province have changed drastically through extensive agricultural development based on cash crops such as maize, rice-bean (*Vigna umbellata*), peanuts, Job's tears (*Coïx lacryma*), sesame and black cowpeas (*Vigna unguiculata*). This development is mainly the result of technology transfer from Thailand (inputs, heavy mechanisation and technical skills), along with increased local financial capacity and market accessibility.

In response to Thai market demand and due to the low labour requirements of the crop, maize monocropping now dominates production in the area. Land preparation, based on ploughing steep slopes, has allowed maize cultivation across large upland fields. This development, along with land allocation and increasing population density, is leading to dwindling fallow periods. Despite very good soils and high potential for agricultural development, arable land can be quickly degraded, in which case negative social and economic impacts will follow. 'Resource-mining' agriculture generates land erosion - causing destruction of roads and paddy fields – and is also responsible for fertility loss, yield decline and chemical pollution.

Increasing use of pesticides (herbicides and insecticides) is another major aspect of this agricultural intensification. In the most degraded areas, increasing weed pressure and rapidly declining soil fertility reflect the limitations of current land preparation practices. Farmers are thus shifting from conventional land preparation (slash-and-burn, ploughing) to increased use of herbicides such as Atrazine, Paraquat and Glyphosate. These are now widely used in the southern districts of Xayabury: it is estimated that more than 90% of smallholders in Pak Lai district used Atrazine after ploughing and maize sowing in 2005. Lack of knowledge, misuse of pesticides (handling of highly concentrated solutions) and widespread chemical use can have rapid and dramatic consequences for health and the environment as soils and water sources become polluted.

In order to convert this 'resource-mining' production to a more stable plant-soil system, an iterative approach has been implemented by the National Programme of Agro-Ecology (PRONAE) to analyse, for each step, the technical and socio-economic viability of direct seeding mulch-based cropping (DMC) systems. The programme's work is founded on the main objectives of local smallholders, i.e. (i) increasing cash income by increasing cultivated area; (ii) optimisation of labour; and (iii) decreasing the drudgery of labour.

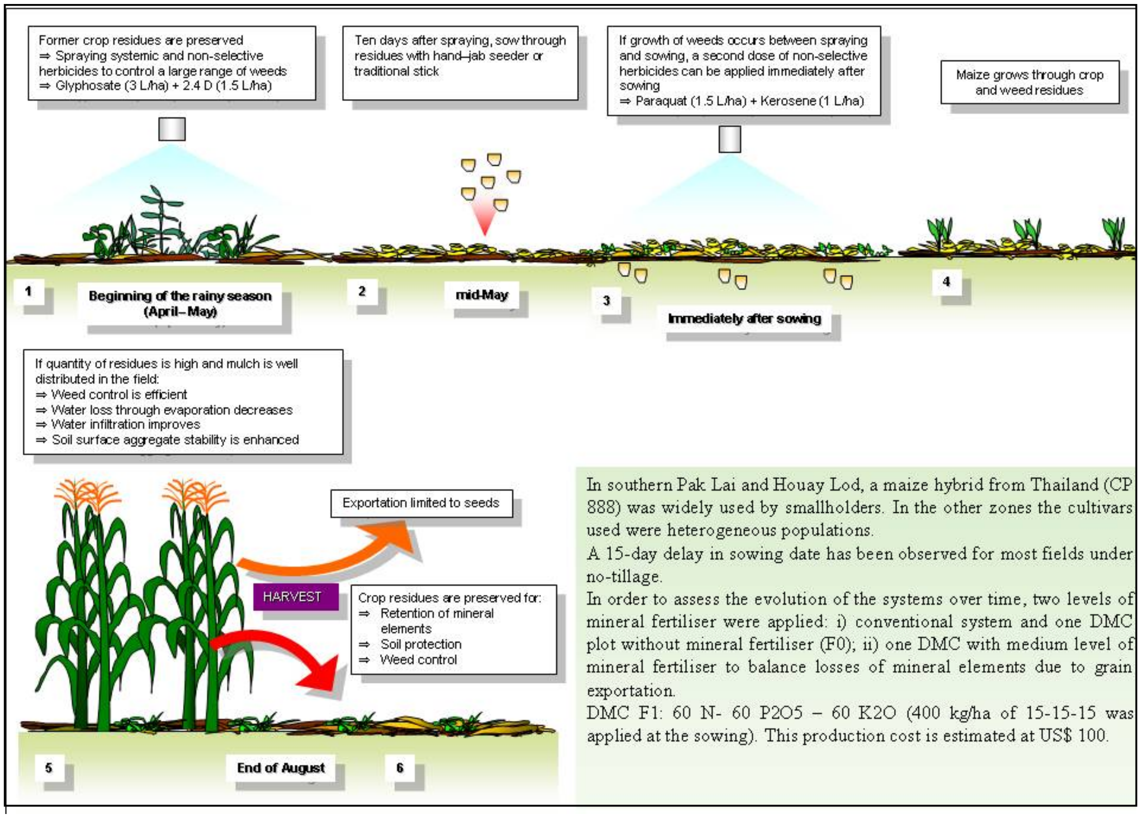
The aim of this paper is to highlight (i) the results of comparisons between DMC systems and conventional practices, as made during on-farm experiments with village communities and groups of smallholders since 2003 in three districts of southern Xayabury; and (ii) the factors limiting adoption of these technologies.

Methodology

On-Farm Experiments

Experiments were carried out on farmers' fields, on plots of at least 4,000m^2. The performances of conventional and DMC systems for different crops (choice of crop depends totally on farmer) were assessed under conditions matching those found on farms in the region. These experiments involved 35 smallholders located in five villages, with a total area of 14 ha. Results presented in this paper concern maize, the main crop produced in this region. Fields were chosen for the study according to morphopedological units, access to market and farmers' strategies, with 4, 5, 11, 6 and 2 fields used in Kengsao, Bouamlao, Paktom, Nahin, Houay Lod and Nongphakbong respectively: these 28 plots were sown with maize. A description of the different steps followed for DMC system land preparation is given in Figure 1.

Figure 1: Steps followed for land preparation under DMC systems with residue management. Choices of herbicide depend on weed pressure and on the specific weeds in each field.



Data Collection, Economic Analysis and Survey of Conditions for Adoption of DMC Systems
Labour requirements and production costs were recorded for all activities (land preparation, sowing, weeding, harvesting), while yield and overall performance were recorded for each treatment. In addition, the philosophy under which the experiments were carried out allows for qualitative analysis in order to evaluate the socio-economic viability of these systems and also to have better arguments for extension. A gender-disaggregated survey was carried out with all groups of smallholders (total of 90 respondents) to identify the limiting factors of this first level of DMC systems on residues. During the survey, interviewers asked men and women to express three advantages and three constraints of DMC systems.

Results and Discussion

Yield
Maize grain yield variations, according to site characteristics (landscape, soil units) and cultivars, are important for each treatment (Table 1). Such results reflect differences in soil erosion and fertility. For example while Paktom and Bouamlao have the same geological substratum (green stones), large differences in yield are observed. In southern Pak Lai (Kengsao and Bouamlao) and northern Kenthao (Houay Lod), which are recent areas for maize production, yields recorded under DMC systems exceed 5.2t.ha^{-1}. With DMC systems, yield levels were generally close to or even higher than those obtained in conventional systems. In these areas, use of fertiliser allows a production profit of 600 to 1,000 kg/ha which is not enough

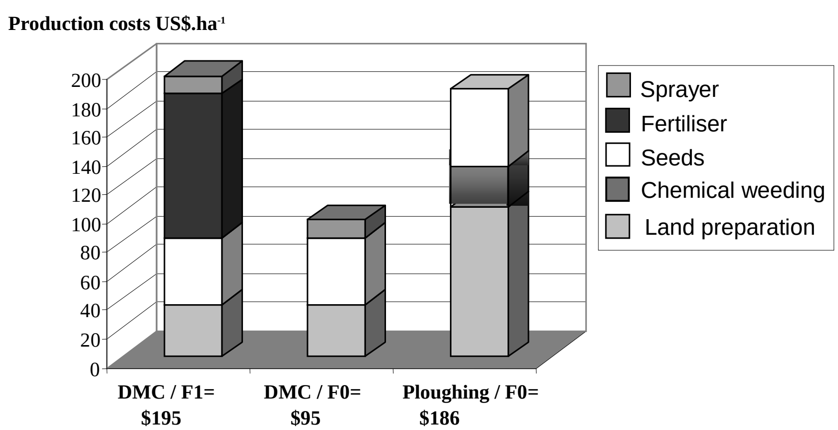
to counterbalance production cost. Neither does use of fertiliser appear to be economically viable for degraded areas (Nongphakbong, Paktom), where maize price is significantly lower. In these areas, mean yield recorded with no-tillage oscillates between 3.1 and 3.7 $t.ha^{-1}$ (without fertiliser) with maize hybrid, while mean yield with conventional tillage is $3.3t.ha^{-1}$.

In Nongphakbong, poor soil structure due to compaction and crusting seems to be the main yield limiting factor under DMC and conventional systems. Erenstein (2003) reported that short-term yields 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.

Production Cost and Net Income

For DMC systems production costs ranged from US$ 65 to $95 per ha, while ploughing costs ranged from $135 to $226 per ha depending on the slope, field accessibility and rate charged by the tractor owners. Savings of $40 to $130 per ha are possible under DMC systems (Table 1). Nowadays, production costs with conventional tillage increase considerably with use of herbicides for chemical weeding (figure 2). In southern Pak Lai and northern Kenthao, net income per ha presents mean value of US$ 415 per ha for no tillage system and US$ 275 per ha for conventional tillage system. In these areas, high net incomes obtained under DMC systems result by low production costs combined with high yields and higher maize price. It is also interesting to observe that in degraded areas such as Paktom and Nongphakbong, net income per hectare can be improve rapidly after two or three years of practicing no tillage.

Figure 2: Production costs analysis in southern Pak Lai. Based on mean of data from 11 replications



Labour Requirements and Labour Productivity

When the amount of mulch layer before sowing is sufficient (at least 3 $t.ha^{-1}$) and its distribution homogeneous, weed pressure can be greatly reduced under DMC systems. In Kengsao for example, where quantity of remaining crop residues is superior to $3t.ha^{-1}$, the labour required for weeding is only three $days.ha^{-1}$ with no tillage and 31 $days.ha^{-1}$ with tillage. However, the degree of weed pressure and the labour input required depend greatly on the nature of the former crop. Results show that in most cases of maize mono-cropping with no tillage, weed pressure cannot be controlled efficiently because of the short duration of maize and rapid mineralization of maize straw. Indeed, after harvest and during intercropping (six months), weed proliferation and seeding occur.

Table 1: Data ± SE from on-farm experiments conducted between 2003 and 2005 in southern Xayabury. Mean value, yield, production cost, net income, labour inputs and labour productivity are presented for five situations. Data is from two to eleven on-farm trials of 1000 m^2 per treatment.

Components	Treatment	Villages: Kengsao			Bouamlao			Houay Lod		Paktom			Nongphakbong	
	Year (Replications)	2003 (3)	2004 (6)	**2005 (5)**	2003 (5)	2004 (4)	**2005 (4)**	2004 (6)	**2005 (6)**	2003 (8)	2004 (11)	**2005 (11)**	2004 (4)	**2005* (2)**
Yield (kg/ha)	**DMC F0**	5481 ± 167	4583 ± 325	**6355 ± 735**	5044 ± 379	3727 ± 379	**5220 ± 1045**	4976 ± 435	**5965 ± 440**	2563 ± 329	3383 ± 714	**3150 ± 945**	2270 ± 434	**3725**
	DMC F1	7542 ± 693	6106 ± 338	**7330 ± 950**	7413 ± 451	5657 ± 827	**6380 ± 995**	6779 ± 437	**6565 ± 480**	3616 ± 268	5356 ± 214	**5370 ± 950**	3960 ± 91	**5300**
	CV F0	4332 ± 691	5215 ± 588	**5190 ± 660**	5073 ± 281	4629 ± 394	**5330 ± 1105**	4726 ± 518	**5950**	2787 ± 316	3477 ± 42	**3310 ± 850**	3305 ± 811	-
Production cost (US$/ha)	**DMC F0**	116 ± 13	100 ± 12	**90 ± 13**	93 ± 3	90 ± 3	**77 ± 12**	94 ± 0.5	**95 ± 4**	52 ± 5	89 ± 9	**95 ± 10**	59 ± 14	**64**
	DMC F1	220 ± 13	200 ± 12	**203 ± 13**	198 ± 3	190 ± 3	**192 ± 11**	194 ± 1	**208 ± 5**	145 ± 11	189 ± 9	**210 ± 10**	189 ± 14	**182**
	CV F0	169 ± 39	201 ± 40	**201 ± 52**	142 ± 23	185 ± 46	**159 ± 59**	194 ± 61	**226**	88 ± 8	111 ± 16	**135 ± 32**	86 ± 28	-
Net income (US$/ha)	**DMC F0**	227 ± 19	243 ± 53	**423 ± 71**	222 ± 23	236 ± 67	**392 ± 78**	280 ± 73	**429 ± 28**	82 ± 17	123 ± 8	**161 ± 64**	33 ± 41	**215**
	DMC F1	252 ± 53	258 ± 53	**403 ± 70**	265 ± 27	305 ± 145	**367 ± 84**	315 ± 73	**386 ± 42**	43 ± 11	146 ± 17	**199 ± 64**	- 27,4 ± 25	**215**
	CV F0	102 ± 53	190 ± 84	**234 ± 93**	175 ± 39	190 ± 86	**306 ± 138**	100 ± 41	**288**	57 ± 19	107 ± 16	**146 ± 75**	52 ± 66	-
Labour inputs (days/ha)	**DMC F0**	62 ± 5	51 ± 8	**60 ± 8**	55 ± 9	49 ± 13	**51 ± 6**	65 ± 10	**56 ± 3**	61 ± 4	40 ± 12	**40 ± 9**	31 ± 1	**38**
	DMC F1	65 ± 2	54 ± 7	**71 ± 8**	65 ± 9	51 ± 13	**64 ± 9**	65 ± 10	**69 ± 3**	67 ± 5	55 ± 9	**58 ± 8**	55 ± 13	**57**
	CV F0	75 ± 7	93 ± 32	**94 ± 42**	70 ± 6	64 ± 18	**50 ± 11**	78 ± 24	**51**	74 ± 7	41 ± 7	**35 ± 6**	64 ± 4	-
Labor productivity (US$/day)	**DMC F0**	3.7 ± 0.1	4.8 ± 0.9	**7.1 ± 1.5**	4.0 ± 0.8	4.9 ± 1.0	**7.8 ± 2.1**	4.2 ± 0.9	**7.7 ± 0.6**	1.3 ± 0.2	3.2 ± 1.4	**4.0 ± 1.4**	1.0 ± 0.8	**5.7**
	DMC F1	3.9 ± 0.8	4.8 ± 0.8	**5.7 ± 0.9**	4.1 ± 1.4	5.8 ± 1.5	**6.0 ± 2.1**	4.7 ± 1.0	**5.6 ± 0.7**	0.6 ± 0.2	2.8 ± 0.4	**3.5 ± 1.2**	-0.5 ± 0.5	**3.7**
	CV F0	1.4 ± 0.7	2.2 ± 1.3	**3.2 ± 2.6**	2.5 ± 0.7	3.0 ± 1.5	**5.8 ± 1.6**	1.3 ± 0.1	**5.7**	0.8 ± 0.3	2.6 ± 0.5	**3.9 ± 2.0**	0.8 ± 0.6	-

Key: DMC: direct seeding with residue management; CV: conventional – ploughing; F0: without mineral fertiliser; F1: 400 kg.ha^{-1} of 15-15-15. Nongphakbong 2005*: all conventional plots were managed with crop residues

In contrast, local species like rice-bean and Job’s tears are ideal for starting a direct seeding system. With long-cycle duration (seven months), these species produce high amounts of dry matter (>20 $tDM.ha^{-1}$ for Job’s tears), have low residue degradation due to high lignin content, present low levels of animal exportation owing to the unpalatability of both species, and also compete fiercely (especially rice-bean) with weeds during the rainy season.

Commonly, a decreasing number and a change of weeds are observed in the second year of direct seeding. For example in southern Pak Lai and northern Kenthao with no tillage, field observations showed that *Ageratum conizoïdes* and *Melampodium divaricatum* become the dominant species and *Mimosa invisa*, the major weed associated with ploughing and burning, is significantly reduced.

Labour productivity increases with residue management and was highly significant in Bouamlao, Kengsao and Houaylod (Table 1), ranging from \$7.1 to \$7.8 per day with DMC F0 and from \$3.2 to \$5.8. In the most degraded areas (Nongphakbong), labour productivity can be highly improved if crop rotation (maize-leguminous) is practiced. In 2005, mean labour productivity among survey respondents reached \$5.7 under DMC systems, thanks to very low production costs and good management of crop residues.

Dissemination of DMC Systems: Positive Results and Limiting Factors for Adoption of these Innovations

The degree of dissemination of DMC systems differs greatly among the five villages according to their environmental and socio-economic conditions. Results show a rapid adoption of these technologies in Houaylod, Nongphakbong and Paktom (tables 2 and 3). Clearly farmers adopt DMC systems firstly because of socio-economical advantages and not for environmentally positive effects, and secondly when conventional cropping systems are no more productive or economically efficient (table 4).

In the most degraded areas (Nongphakbong and Paktom), where soil fertility has decreased rapidly because of soil nature (sandstone in Boten district) and erosion induced by former ploughing, crops tend to be diversified (maize, peanuts, rice-bean) in order to limit risk due to soil and climatic factors. In these areas, maize yields and labour productivity under conventional tillage systems are low and ‘resource-mining’ systems had already shown their limitations. Furthermore, in order to increase cash income, most small and medium households are shifting to DMC systems to cultivate wastelands infested by the *Imperata cylindrica* weed with rice-bean. Such areas cannot be farmed through conventional tillage systems because of the high labour requirements for weeding.

Recently, new maize production areas in northern Kenthao district (Houaylod), where there is access to the Thai market, have contributed to a drastic increase in total cultivated area (+50% per household). Common land preparation is based on slash-and-burn practice and DMC systems are spreading rapidly as farmers attempt to increase the area cultivated. The men and women surveyed are also convinced that the benefits obtained through no-tillage systems are higher than those received through ploughing, as maize production costs are reduced (table 4).

Table 2: Dissemination of DMC systems according to surface (%) between 2003 and 2005 in 5 villages.

Villages	Houaylod			Paktom (North)			Nongphakbong			Kengsao			Bouamlao		
Total Smallholders	169			131			101			134			383		
(Replications)	(90)			(90)			(74)			(90)			(155)		
Land preparation / Year	**2003**	**2004**	**2005**	**2003**	**2004**	**2005**	**2003**	**2004**	**2005**	**2003**	**2004**	**2005**	**2003**	**2004**	**2005**
Slash & Burn	72.2	54.5	**17.6**	16.6	13.7	**6.8**	35.1	33.3	**38.1**	16.4	5.6	**1.5**	7.6	2.5	**0.1**
Ploughing	19.7	21.7	**26.8**	78.4	81.1	**83.1**	57.2	56.1	**42.3**	79.3	67.4	**37.0**	81.6	68.8	**31.6**
Ploughing & Herbicide	2.3	1.7	**11.7**	1.7	0.8	**0.9**	1.1	0.8	**0.8**	4.3	26.5	**58.0**	10.8	28.7	**68.3**
DMC	5.8	22.1	**43.9**	3.3	4.4	**9.2**	6.6	9.8	**18.8**	0	0.5	**3.5**	0	0	**0**

Key: DMC: direct seeding with residues management; Ploughing & Herbicide: Herbicides (Paraquat or Atrazine) are applied after sowing. Source: Data from a survey carried out by PASS Project (Point d'Application du Sud de la province de Sayabouri) in 2005.

Table 3: Dissemination of DMC systems according to number of smallholders (%) between 2003 and 2005 in 4 villages.

Villages	Houaylod		Paktom (North)		Nongphakbong		Kengsao	
Total Smallholders	169		131		101		134	
Year	2003	**2005**	2003	**2005**	2003	**2005**	2003	**2005**
% of smallholders	4	**50 [45]**	8	**[50]**	5	**22 [27]**	0	**2 [1.5]**

[ ]: Data from a survey carried out by PASS Project in 2005.

Table 4: Advantages of DMC systems as identified by smallholders in 5 villages.

Villages	Nongphakbong		Houaylod		Paktom		Kengsao & Bouamlao	
Gender / Replications / Advantages	Men (10)	Women (10)	Men (10)	Women (10)	Men (15)	Women (15)	Men (10)	Women (10)
Low Production Costs	++	+++	++++	++++	++	+	+++	+++
Land Preparation Rapidity	+++	++	++++	++++	++	+	0	++
Decreasing Erosion	++	++	+	+	+++	++	++++	+++
Increasing Soil Fertility	+	+++	+	+	++++	+	+++	+
Soil Moisture	+++	++	+	+	+	++	++++	++++
Weed Control	+	+++	+++	++++	++	+++	+	++

0: No respondents; +: 0–25 % of respondents; ++: 25–50% respondents; +++: 50–75% respondents; ++++: 75-100% of respondents.

In theory farmers adopt technologies primarily because they are economically positive. In southern Pak Lai (Kengsao and Bouamlao), although the economic superiority of the no-tillage system over conventional tillage has been proven every year, both the adoption of DMC systems by smallholders and the area managed with residues remain extremely low (tables 2 and 3). In these two villages, where the cultivated area of maize per labourer can easily exceed 2 ha, land preparation through large-scale herbicide application represents considerable drudgery of labour for men (table 5), while women are more concerned with the sowing operation. At the beginning of the rainy season, remaining dry matter reaches an average of 3.5t.ha^{-1}, which represents at least 45% of the dry matter recorded after harvesting. Making holes and seeding them through a thick mulch layer is identified by women as a real constraint. In Nongphakbong and Paktom villages, where remaining crop residues are generally low, making holes seems to be a serious constraint because of soil compaction induced by former ploughing.

Men and women in northern Kenthao (Houaylod) said that a major limitation to dissemination of DMC systems is the lack of any credit system for inputs. For many smallholders, even if extremely high interest rates are given for ploughing credit (50% over eight months), this still represents a good opportunity to avoid investing any cash at the beginning of the season.

Accessibility to inputs is also an important limiting factor for dissemination of DMC systems. The choice of products is generally limited in southern Xayabury. The only herbicides available in the Lao market are Paraquat, Atrazine, Glyphosate and 2.4-D. Furthermore, there is a lack of knowledge on the properties of each product. Local dealers cannot give accurate advice about the characteristics of the different products and so farmers have difficulties in identifying the herbicides they really need.

Due to drastic increase of cultivated area in Houaylod, constraints relating to labour input and management are also frequently emphasised by both sexes, and by the men in Nongphakbong village. Indeed, smallholders' strategy is to sow maize as soon as possible at the beginning of the rainy season. Any delay in sowing can significantly decrease maize yield due to risks of climate and pest damage. This means that all herbicide should be applied before the first major rains, thus reducing the calendar flexibility of farmers.

Finally most women expressed a fear of poisoning through use of herbicides. This observation reflects women's serious lack of information about DMC systems and poor involvement of women during training sessions and activities with the project. Without involvement of women in this first phase of DMC system extension, adoption by smallholders will be very slow.

Table 5: Limiting factors for adoption of DMC systems as identified by smallholders in 5 villages.

Villages	**Nongphakbong**		**Houaylod**		**Paktom**		**Kengsao & Bouamlao**	
Gender / Replications / Limiting factors	Men (10)	Women (10)	Men (10)	Women (10)	Men (15)	Women (15)	Men (10)	Women (10)
Financial	++	+	++++	++++	+	+++	+++	++
Drudgery of Labour	++	+++	+	0	++	++	++++	+++
Calendar flexibility	++++	++	++++	+++	+	+	++	0
Toxicity	++	+++	++	++	++	++++	+	++++
Technical knowledge	+	++	++	+++	+	++	++	++
Holes making	+++	++++	+	+	++++	+++	+++	++++
Sowing	+	+	0	+	++++	+++	++	++++
Predators (rodents. insects)	+	+	+	0	+++	++	+	+

0: No respondents; +: 0–25 % of respondents; ++: 25–50% respondents; +++: 50–75% respondents; ++++: 75-100% of respondents.

Issues and Challenges for a Larger Dissemination of DMC Systems in Southern Xayabury

Positive results are evident for direct seeding systems based on residues in southern Xayabury, where growing interest and potential for widespread adoption have been observed. Many smallholders have requested technical and financial support. However, achieving all the biophysical and economical advantages of DMC systems involves a long process.

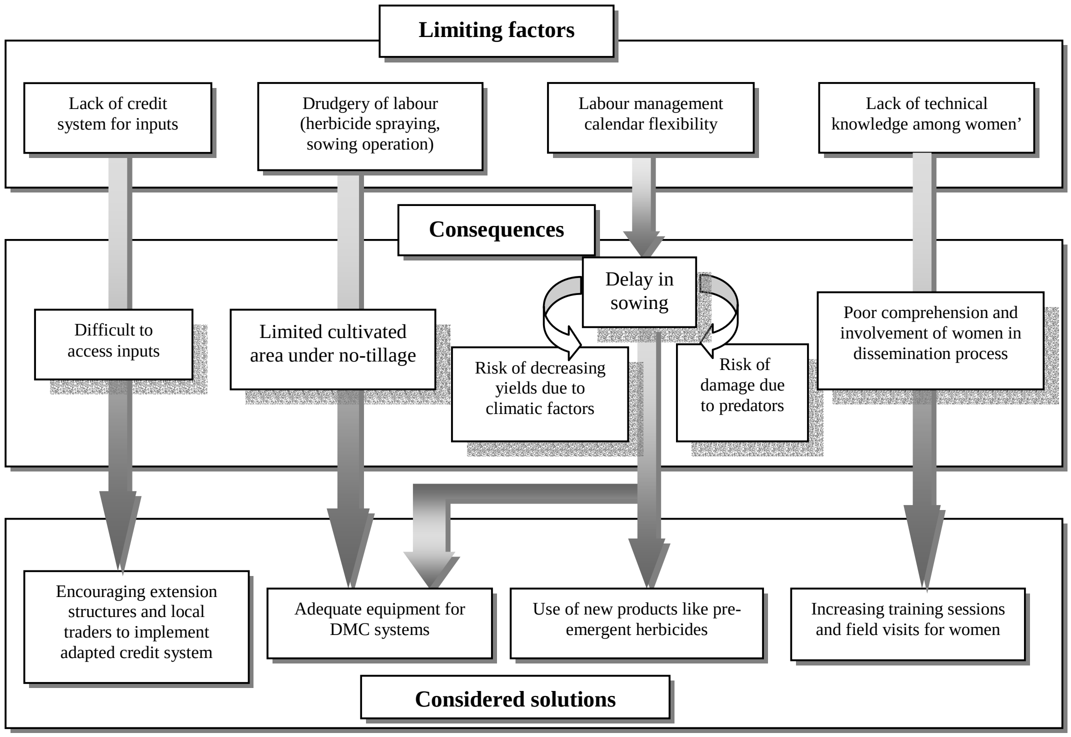
Despite rapid adoption of DMC systems (based on residue management) in some areas, no-tillage systems have to be progressively improved with rational crop rotations, relay crops and cover crops in order to reduce utilisation of herbicides and inputs costs. As reported by many authors, the use of pesticides (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 and products which can be used as substitutes should be researched.

Experience in South America has showed that in the long term, farmers who understand and practice these systems can obtain the highest economic benefits from DMC systems. Mono-cropping under no-tillage is an incomplete system in which diseases, weeds and pests tend to increase and profits tend to decrease.

Finally, in order to promote the extension of these systems, limiting factors previously identified by smallholders should be rapidly overcome through various strategies (figure 3):

- Adequate equipment for DMC systems should be adapted on several scales in order to decrease drudgery of labour (e.g. for herbicide application, sowing). Diversified direct seeding equipment, such as the sowing machine for hand-tractors and medium tractors, has been designed in Brazil and could be adapted and extended in southern Xayabury.
- Economic incentives such as provision of credit have to be promoted by decision makers and development projects.
- Women should be more informed and involved in project activities (e.g. training sessions and field visits).
- Organic systems should be progressively integrated into DMC systems in order to ensure sustainable and environmentally-friendly agriculture.
- As knowledge is continuously generated in the field by researchers and farmers, it is essential that permanent training sessions are organised in order to share experience gained through the adaptation and adoption of such systems.
- Although this may seem radical, thinking and innovating concerning agricultural methods needs to be altered among farmers, traders, technicians, extensions agents. Attitudes must be shifted from soil mining tillage operations towards sustainable production systems like no-tillage and cover crop in order to implement successful DMC systems in practical farming.

Figure 3: Limiting factors and considered solutions for adoption of DMC systems with crop residues management in the districts of Xayabury province



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