The Adaptation of Upland Rice Cropping to Ever-Shorter Fallow Periods and its Limit

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Abstract

Rotational shifting cultivation in the mountainous land of Northern Laos is responding to population pressure by intensification of land use. In many areas the rotational cycle has been shortened to an unsustainable three to five years. With shorter rotations weed infestation becomes the major constraint in upland rice cultivation, particularly where only manual labour is used. This study is part of the MSEC programme (Managing Soil Erosion Consortium), present in seven countries in southeast Asia since 1998. MSEC deals with soil erosion under land use change. The Lao study site, Houay Pano watershed, is located 10 km from Luangprabang.

The study, conducted between 2001 and 2003, addresses the question of how, in shifting cultivation, cultivation practices have been adapted to shorter fallow periods. Particular attention is paid to the progressive invasion of weeds in fields and the subsequent extra work to clean these fields in order to continue upland rice farming. It also indicates the conditions where upland rice cropping is no longer possible. The study combined interviews with farmers, direct observations in fields, and field experiments.

Four successive stages were identified in the shifting cultivation system. Changes from one stage to the next typically involved a switch in tools, more work lost in weeding, changing priorities in the cropping calendar, and more and more drastic tillage techniques. Weeding and land clearing induce tillage erosion, which is the process of downhill soil movement caused by agricultural tools and gravity. Soil losses due to tillage were assessed experimentally in farmers' fields. Regression analysis demonstrated increased erosion of between 1 and >5.5 t/ha/year as cropping rotations shortened from over eight years to three years on very steep slopes. In Houay Pano watershed, upland rice cropping is progressively being abandoned and replaced by less labour demanding crops (e.g. Job's tears). The farmers in the watershed actively experiment with alternative land uses and cropping patterns, with and without the assistance of the MSEC programme.

Introduction

Shifting cultivation has long been a dominant feature in the highlands of southeast Asia and still is in the hills and mountains of Laos, Thailand and Vietnam. Shifting cultivation is largely subsistence-based, providing food, fibre, medicine and a variety of other needs from cropped, fallow and forested land. Over the last forty years a number of changes have affected shifting cultivation systems and the situation now includes the following three important factors: (i) a higher population pressure, mainly due to forced relocation and resettlement as well as spontaneous migration; (ii) the development of markets, together with the opening of roads and other infrastructure; (iii) a lack of suitable conditions for developing sustainable agricultural alternatives. Typical responses to and effects of this situation have been: (a) the shortening of fallow periods to less than that required to suppress weeds and rebuild soil fertility, leading to productivity decline; (b) an increase in soil erosion and infertility, leading to lower yields and consequently, (c) an even greater pressure on slash-and-burn to produce acceptable yields. In shifting cultivation the shortage of good land, due to an increased ratio of cultivation to fallow, has become a crisis. However, it should be noted that shifting cultivation, whatever the rotational area, is a system where labour is the limiting factor. A study on shifting cultivation should therefore include estimates both of the productivity of the land and of the required labour.

Weed pressure has rapidly increased due to the shortening of the fallow period and farmers now consider weeding to be the most difficult task for upland rice (Roder *et al.* 1997). On steep slopes, these operations can induce tillage erosion, which is the process of downhill soil movement caused by the force applied by agricultural tools and gravity. The limited attention paid to tillage erosion probably originates from its slow and inconspicuous nature compared to the more spectacular gullies and rills resulting from overland water flow. In northern Laos, soil losses due to runoff, as measured at the plot scale under traditional farmer practices, are 5.7 t/ha/year mean over five years (Phonmasack *et al* 2001). However, soil losses due to tillage remain largely unknown - hence the urgent need to quantify soil losses for each operation disturbing the topsoil surface. This is all the more pressing because shifting cultivation has developed from an essentially no-till system under long term fallowing into systems that depend heavily on tillage to control weeds.

This study is part of MSEC (Management of Soil Erosion Consortium), which is a scientific research programme based on a participatory, interdisciplinary approach and works at the watershed scale. The MSEC programme has been active in six Asian countries since 1998.

The aim of the study was to retrace all major changes in the shifting cultivation system in one area, starting from a period with no apparent land shortage and ending with a period in which shifting cultivation is progressively abandoned because the land becomes unsuitable for upland rice cropping. Secondly, this study estimates on-farm, and on the prevailing steep slopes, the quantity of tillage erosion induced by intensification of the shifting cultivation cycle.

The study site

The study site, Houay Pano watershed, comprises 73 ha and is located near the village of Lak Sip, about 10 km south of Luangprabang town along national road No.13. The population density in the village territory is 55 persons per km^2, which is quite high when compared to the mean density of 23 persons per km^2 in Luangprabang Province (NSC 1998). However, this density does not reflect the actual availability of land. Due to the land allocation and forest classification scheme introduced into Lak Sip village in 1995, only 136 ha or 31% of the village territory can be used for rotational cropping. With only this area of rotational land, the population density is then 98 persons per km^2 of arable land. The entire Houay Pano watershed falls within the category of rotational land and thus the study area reflects the real pressure on available cropland in the region. Farmers in the village practice upland rice-based cultivation in rotations of one to three years of bush fallow, and one year of rice or Job's tears (*Coix lacryma-jobi* L.). The average household is comprised of five people and has three hectares of rotational land at its disposal. Most of the farmers cultivating the watershed also have fields and fallow plots outside the watershed. Khmou constitute 92% of the village population and 97% of household heads are engaged in farming as their major source of livelihood and income. Because of more intense cropping and reduced fallow period, farmers reported that crop yields have declined, leading to recurrent rice shortages. To compensate for these rice shortages, farmers resort to the sale of secondary crops, livestock, firewood and non-timber forest products.

The cultivated soils in the catchment are of medium fertility. Alfisols cover 71% of the catchment, with Entisols and Ultisols at 14% and 12% respectively (MSEC 1999).

From April 2001 onwards, a team of Lao and European students and staff stayed permanently in the village conducting studies in agronomy, soil science, hydrology and socio-economy. Senior scientists supported and monitored all the field team activities through extended stays in the village at monthly intervals.

Study of cultivation practices: methods

Three sources of information were combined: *1*. interviews with farmers; *2*. observations and experiments in farmers' fields; *3*. publications, including maps.

Instead of group interviews in the village, farmers were questioned individually in the field. Interviews with farmers were conducted frequently and can be considered as a continuous process over the years 2001-2003.

Field observations were carried out each year at regular intervals in 30-60 permanent plots of 9 m^2, in order to follow crop performance, weed development and vegetation regrowth. Within the watershed, where rotations are short, the monitored plots covered the range of upland crops (rice, Job's tears, maize), soil types, topographic position and fallow length. Outside the watershed, examples of rice cropping under long-term fallowing were studied in a similar way (10-20 years of fallow). In addition, the cropping calendar, labour input and use of hand tools were determined. The extensive biophysical and socio-economic inventories produced in the MSEC programme were also used, i.e. annual land use maps, topographic, soil, and land tenure maps (MSEC 1999-2003).

Changes in cultivation practices: results

With fallow length diminishing gradually and the number of rotations increasing one by one, upland rice cultivation has become more labour intensive and difficult. Confronted with these problems, farmers have been forced to adapt their practices in a stepwise manner. Combining field observations and interviews, four successive stages of adaptation were identified in upland rice cultivation, as summarised in Table 1.

Stage 1: In the hilly country of northern Laos, on soils of moderate fertility, the development of fallow vegetation is such that after eight years or more of undisturbed growth the standing forest has to be cleared with an axe. The burning of the debris is sufficiently intense to produce a clean seedbed where rice can be sown with the first substantial rains. One or two weeding rounds are carried out, both with a small curved hoe. The weed cover is composed of a relatively few large individual weeds. These are pulled out and, where this is not possible, stems are cut off with the sharp edge of the curved hoe. Farmers avoid disturbing the soil, as they are aware that tillage triggers the germination of new seeds and thus increases the weed pressure. The technique of sowing the rice, by dibbling the seeds in holes, is also an operation which reduces soil disturbance to a minimum.

Stage 2: In fallow vegetation less than seven to eight years old, the machete replaces the axe as a tool for land clearing. The quantity of slashed material is still large enough to provide an overall burn and a clean seedbed, allowing timely rice sowing. The distinguishing feature of stage 2 is the introduction of some tillage. Just after sowing, the weeds that appear are so numerous and so small that they cannot be pulled out individually or cut off. The first weeding operation - superficially scraping the soil with the curved hoe to uproot the weeds - disturbs the soil. The second weeding generally does not require tillage: the larger weeds are pulled out or the stems are cut off above the soil surface. The

Table 1: Caracteristics of the four stages in shifting cultivation, Luangprabang

In bold, the distinguishing feature best remembered by farmers.

Operation	Stage 1	Stage 2	Stage 3	Stage 4
Field preparation	**Clearing with axe**	Clearing w/ machete	Clearing w/ machete	Clearing w/machete
Burning	One burn	One burn	Burn, piling, re-burn	Piling, burn
Second clearing before sowing	None	None	**Tillage with small curved hoe**	Tillage with medium-sized hand hoe, this causes delay in sowing
1st weeding	Hand pulling and chopping with machete	**Tillage with small curved hoe**	Tillage with small curved hoe	Tillage with small curved hoe
2nd weeding	Hand pulling and chopping with machete	Hand pulling and chopping with machete	Tillage with small curved hoe	Tillage with small curved hoe
3rd weeding	None	Hand pulling and chopping with machete	Hand pulling and chopping with machete	Hand pulling and chopping with machete
4th weeding	None	None	None	Hand pulling and chopping with machete

Stage 1. Rice cultivation without major constraints due to fallow periods >8 years and rapid forest cover after cultivation.

Stage 2. The massive germination of weeds requires a superficial scraping of the soil - this becomes necessary after two successive cycles of moderate duration (4-8 years).

Stage 3 . Tillage prior to sowing becomes a neccessity after three to four cycles of moderate duration (4-8 years) or short duration (<4 years).

Stage 4. Deeper tillage is needed to extract the rhizomes of grasses. Rice cultivation stops as weeds are impossible to control without the use of herbicide after five to nine cycles of short duration (<4 years).

(Note: cycle duration and number of cycles depend on soil conditions and topographic position).

smallest weeds are left undisturbed because they are considered harmless to the now well-developed rice crop.

Stage 3: With shorter fallow times the standing biomass of natural fallow vegetation becomes reduced, and so the burning phase of the process produces only scanty fires. Subsequently patches of soil surface remain unburned. Unburned patches, combined with the progressive invasion of weeds, create the need for additional clearing prior to sowing. Farmers are well conscious of this change because a new and heavier tool, the medium-sized hand hoe, had to be introduced into the system. This situation occurs after a succession of short rotations of about three to four years. Once this stage is reached, two or three weeding rounds are necessary after sowing. Only the last round does not involve tillage with the curved hoe.

Stage 4: After slashing the vegetation, the material does not cover the ground sufficiently to produce a burn. Instead, the debris is gathered and burned in heaps, and only these burned areas are weed free. The entire remaining field surface has to be tilled with a hoe before the rice sowing can start. More and deeper tillage is required to remove the rootstocks of perennial grasses that tend to invade the field. As farmers have to perform this preparatory cultivation, sometimes twice, they are naturally late with planting. Weeding after sowing is quasi-continuous, requiring up to four rounds. The last weeding round does not disturb the soil.

Most of the fields in the study site have been cultivated five to eight times with rice over the last 40 years. Over the same interval, average fallow periods have gradually reduced from about eight years to three. Most of the land has presently reached stage 4 of adaptive practice or has gone even beyond this, meaning that farmers are no longer cropping upland rice but are producing less labour-demanding crops instead.

The study of tillage erosion: methods

Tillage erosion under on-farm conditions was assessed in Houay Pano watershed during the cultivation seasons of 2001 and 2003. Soil losses were estimated, with three replications for different tools (clearing tools versus weeding tools), as well as for nine slope gradients ranging from 30 to 85%. For each measurement, 100 aggregates of 1-2 cm were taken from the soil surface, dried, painted and used as tracers. They were placed along a contour line marked by a string. A clearing or weeding operation was then performed and the distance between each displaced aggregate and this benchmark line was measured, enabling both the calculation of the soil flux caused by the tillage pass, and of the annual erosion rate per hectare (Dupin *et al.* 2002; Turkelboom *et al.* 1997).

Tillage erosion: results

Regression analysis of the experimental data produced the following conclusions and graph. In Figure 1, the results of tillage erosion under stage 4 of adaptation are presented. Firstly, soil losses increased exponentially with the slope, whatever the tool used. Secondly, tillage erosion depended on the type of operation: clearing with the medium-sized hand hoe works the soil down to 1-2 cm and generates more soil loss than weeding with the small curved hoe, which scrapes the topsoil to a depth of only 1-2 mm. Thirdly, soil losses due to tillage depended on the moment in the growing season. The more the rainy season advances, the more the soil is covered by the rice crop. Hence the chance of de-

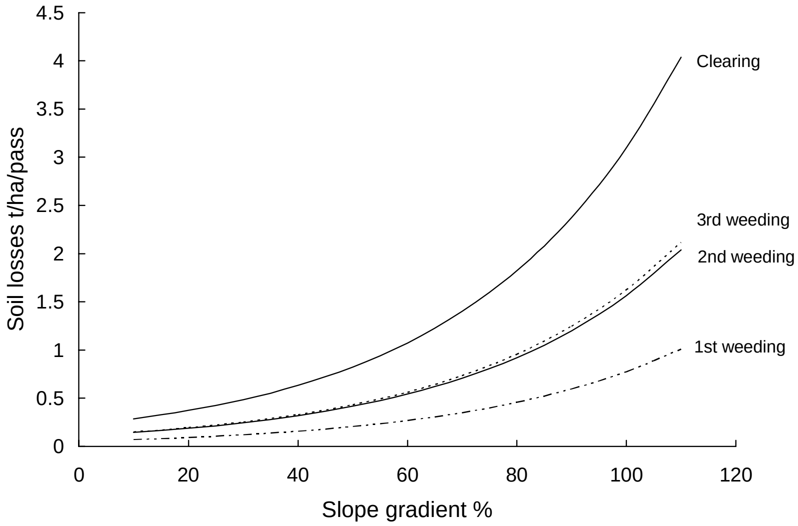

Figure 1: Tillage erosion due to hoeing during clearing and weeding, as influenced by slope gradient. Shifting cultivation in Houay Pano watershed, Luangprabang.

tached soil aggregates 'meeting' a rice plant and subsequently getting trapped increases. These obstacles limit tillage erosion later in the season.

Apart from the above-mentioned interaction between crop and soil aggregates, there is also interaction between weeds and soil particles. The calculation of tillage erosion distinguishes two aspects: the *quantity* of soil detached, which depends on the tool (e.g. the hand hoe works deeper than the curved hoe); and the *distance* the soil particles travel down the slope, which depends on steepness and on roughness and cover of the soil surface. In the case of the first weeding round (in stage 4), plants are too small to be picked up individually. Instead, thousands of seedlings get uprooted and mixed with the topsoil, forming loose mulch. This mulch stops the downward movement of aggregates and hence limits soil losses (Figure 1). In contrast, during the second and the third weeding, individual weeds are mostly gathered in the hand and put down periodically, producing a rather bare soil that is less rough. Hence, soil losses increase (Figure 1). The fourth weeding generally does not include tillage.

Tillage erosion and changes in shifting cultivation

Soil losses due to tillage were evaluated in relation to the four stages in shifting cultivation identified above (Table 1). In Figure 2, soil losses are presented for the various slope classes and the four stages of shifting cultivation adaptation. Erosion increased with each stage, because new tools are introduced and the number of weeding rounds including tillage also increased. Figure 2 demonstrates that the combination of steep slopes and tillage is extremely degrading. At the watershed scale, tillage erosion has increased markedly because steeper slopes are nowadays cultivated more frequently than before. It should be noted that erosion events under stage 1 occurred every eight years at most, whereas erosion events under stage 4 occur every three years.

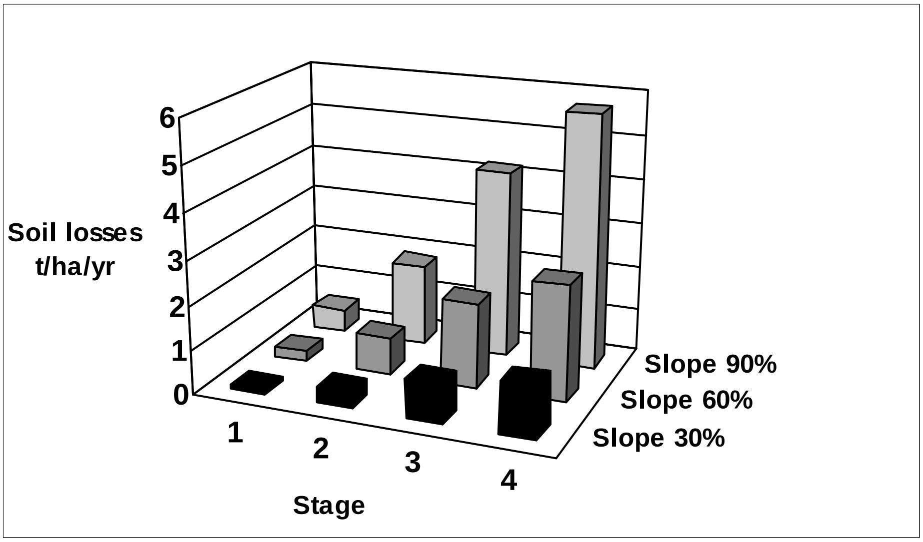

Figure 2: Tillage erosion under the various stages of shifting cultivation and as influenced by slope gradient

Conclusion

Houay Pano watershed, with its very high pressure on arable land, is approaching the limit of upland rice cropping without external inputs. Weed infestation prior to sowing seriously threatens the timely sowing of rice. Farmers are aware that late sowing of the crop directly affects its yield potential. In addition, the massive presence of weeds shortly after sowing threatens the acceptable development of the rice crop. In respect to these problems, the study site is ahead of most areas in Luangprabang province. Looking for alternatives, the farmers in the study site experiment with other upland crops as well as mixtures of crops. All of these can limit the work lost in weeding, and most of them also provide better ground cover over the rainy season (de Rouw *et al.* 2002).

Besides these spontaneous efforts of the Houay Pano farmers, since 2002 the MSEC programme has also been experimenting with improved fallows and alternative land uses to slash-and-burn, in close collaboration with other programmes (Lao-IRRI, IUARP, CIRAD). A preliminary analysis over one year demonstrated that erosion was substantially reduced under these alternative systems, though yields suffered (de Rouw *et al.* 2003).

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