

# Impacts of Land Degradation on Rainfed Maize Yield: The Northeast Thailand Experience

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## INTRODUCTION

Land degradation due to soil erosion is a major problem that certainly affects the sustainability of agricultural production on the sloping Kandiustalfts and Ustults of northeast Thailand. These uplands have considerable area with moderate (5–15%) and steep (>15%) slopes which are susceptible to erosion. While farmers recognize soil erosion as a problem, they are not willing to invest their scarce resources in adopting soil conservation-effective farming.

In 1999, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) started a project to enhance and sustain the productivity of the medium- to high-water holding capacity soils in the intermediate rainfall ecoregion in Asia. In collaboration with Khon Kaen University (KKU), Department of Agriculture (DOA) and Land Development Department (LDD), studies in Thailand were conducted in Tad Fa subwatershed in the sloping land area of Nam Chern River Basin in the northeast. In this area, maize is grown intensively and since the cropping history of the area is only 80 years old [with a break for about five years], the soils of the watershed are reasonably fertile and productive. But the farmers are already noticing that in order to maintain the yields of maize above 2.50–3 t ha<sup>-1</sup>, they have to apply an additional topdressing of fertilizers around 'silking' stage to the maize crop, particularly on the steeplands (>15% slopes).

This paper attempts to quantify the impact of land degradation primarily due to soil erosion on maize crop yields in Tad Fa subwatershed. The time for the maize yields to drop to uneconomical levels, if soil degradation carries on at the present rate was predicted by modelling. Topics for future research were also suggested.

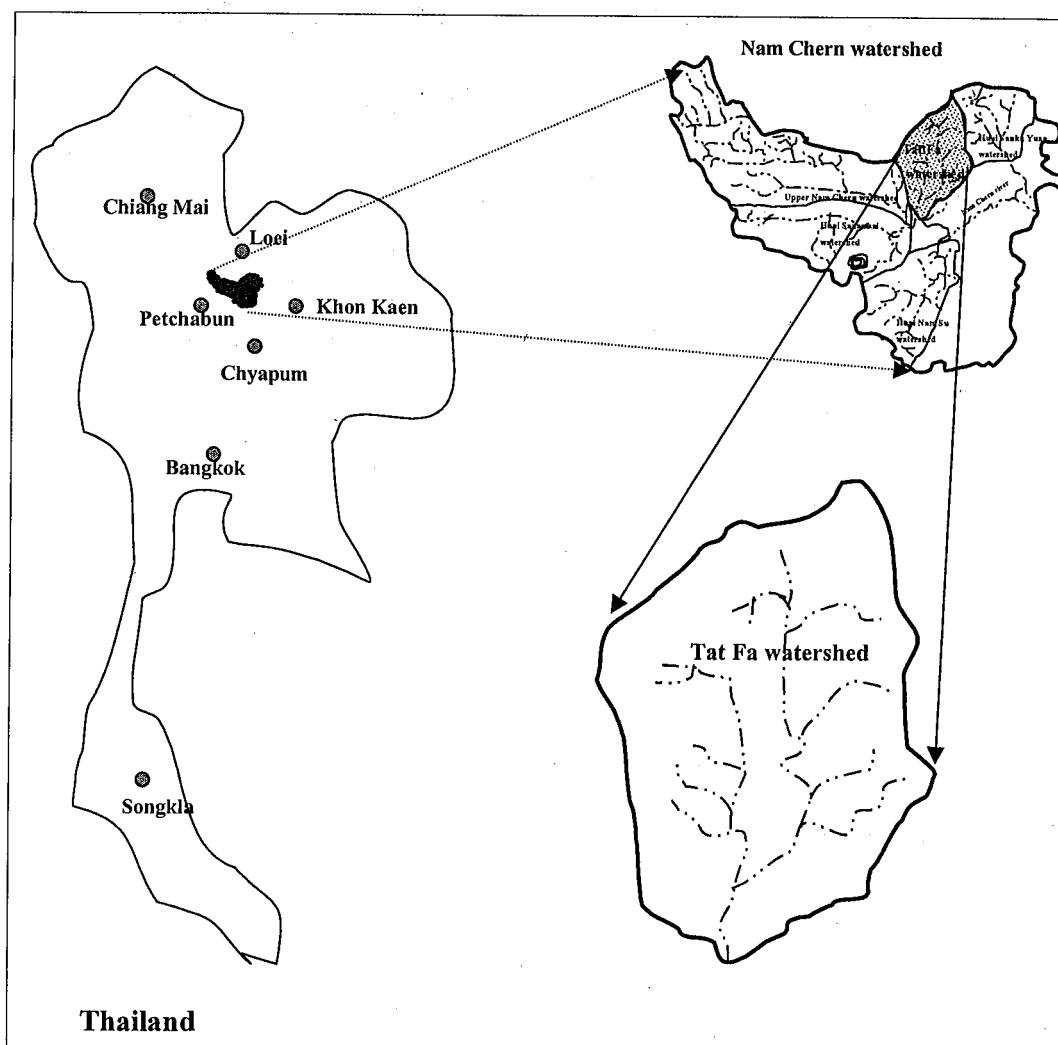
## METHODOLOGY

The study was conducted in Tad Fa subwatershed located about 150 km northwest of Khon Kaen at the top of the mountain range dividing north and northeast Thailand (Figure 1). At an elevation of 400–600 m asl, Tad Fa subwatershed covers an area of 2,300 ha out of which 700 ha to the east of Tad Fa village were selected for the study. The ecology of the upland areas was studied through a detailed socioeconomic survey of one village, Dong Sakran.

The yield of maize across the toposequence was evaluated through a series of on-farm experiments conducted in 11 farmers' plots in 1999. Three plots represent the steep slope (>15%), six plots represent the moderate slope (5–15%), and two plots represent the slight slope (2–5%). The yield of maize was then measured. Simulation studies were also carried out (using the INDPERFECT Model) to assess the soil loss in a typical (average rainfall) season from soil located on varying slopes in the toposequence.

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**Figure 1.** Location of Tad Fa Watershed.

## RESULTS AND DISCUSSION

### Site characteristics

#### *Topography*

Tad Fa subwatershed has a hilly topography with 30% of the area having slopes of more than 30%. About 50% has slopes ranging between 5–15%, and 20% with a slope of less than 5%. Based on the toposequence, the Tad Fa Watershed can be subdivided into three zones: upper, middle, and lower zones. The upper zone is comprised of four villages where upland agriculture predominates. Upland subsistence crops (e.g. upland rice) and maize (a cash crop) are mainly grown; some ginger is also grown in one of the villages. The middle zone has two villages in which both upland (rice and maize) and lowland (rice) crops are grown. The lower zone, where lowland rice is mainly grown comprises one village. Tad Fa subwatershed consists mainly of the upper and middle toposequences.

### ***Village settlement***

In Tad Fa village, there are 207 households comprised of ethnic people who have been living there for the past 80 years, according to available records. Around 1990–1992, these households were moved, in order to bring the Tad Fa area under complete forest cover. At that time each family owned some 15–20 ha of land (both forested and agricultural). However, after long and hard protests by the displaced Tad Fa dwellers, between 1993–1995, they were allowed to return to the Tad Fa area with the proviso that they were to clear the land, plant a substantial number of trees on the agricultural land, and adopt soil conservation practices, as the uplands of the Tad Fa Catchment were subject to massive soil erosion. Some 120 families returned and settled in three hamlets (now about 5–7 years old). Each family was allocated 4 ha of land (25 *rai*) for cultivation. The total population of the three hamlets is 460. In December 1998, the government officially recognized this group of (120) households as a village.

### ***Agroclimate***

The annual rainfall of the area is 1,600–1,800 mm, but it is quite variable, with a range of 1,100–2,600 mm. The rainy period begins in March/April and ends in October/November. Soils of coarse Alfisols intergrades of Ustults and Kandiusalfs are commonly found. These are medium to heavy soils and possess medium (150 in the root profile) to high (? 200 mm) available water holding capacity. Soil depth ranges between 0.5 to over 2 m. The soils are sandy loam at the surface and exhibit clayey loam to loamy texture at the subsurface. The underlying D horizon is rich in broken rocky material, mostly comprised of shale; some slate is also found.

### ***Cropping systems and water management***

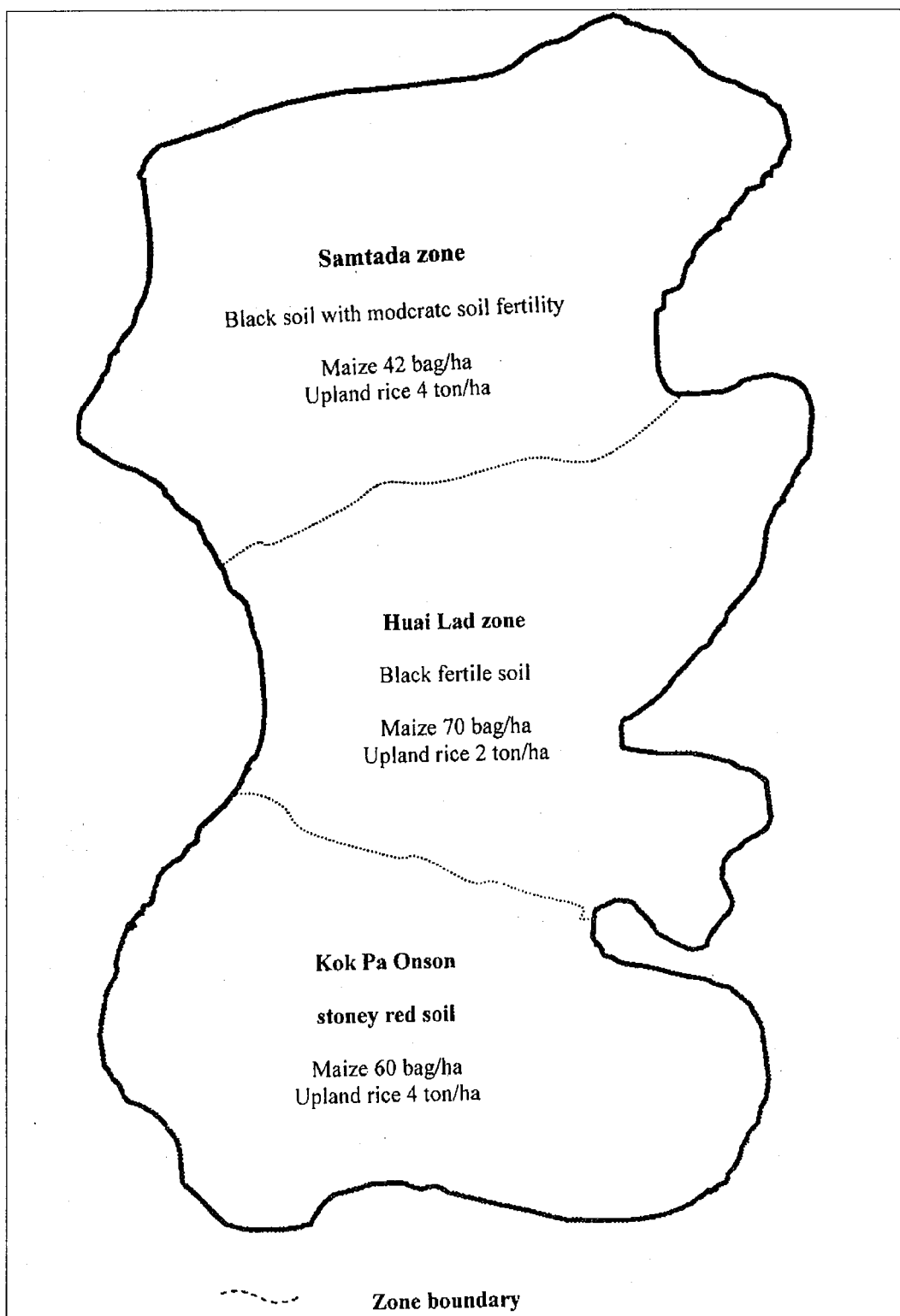
Upland rice is the main crop grown for home consumption, while maize is grown as a cash crop. Rice is planted in June and harvested in October. Two crops of maize are grown: the first crop is planted in March–April and harvested in July–August, while the second crop is sequentially planted and harvested in October–November. The establishment of the first maize crop is risky. It fails one in three years. The second maize crop is more secure; 8–9 good harvests are possible in 10 years. Ginger, another market crop, is sown in March–April and is harvested in December. For maize, farmers apply 150 kg ha<sup>-1</sup> of 15:15:15 fertilizer, while for ginger the dose of fertilizer application is rather heavy: 600 kg ha<sup>-1</sup> of 15:15:15. Fruit trees are mostly planted on relatively flat lands (with 2–5% slope) and as far as possible, adjacent to the houses or residential areas.

In Dong Sakran village, three zones were identified with different productivity levels. The middle zone is most fertile (for upland crops), the upper zone is definitely less fertile, while the lower zone suffers from frequent water congestion (Figure 2).

Over 40% of the seasonal rainfall disperses as runoff. There are nearly 80 farm ponds (big and small) in Tad Fa, out of which only four store water through the dry season; others dry up and mainly recharge the groundwater. The subsoil is very porous and seepage from the ponds is very high.

## **CONSTRAINTS TO SUSTAINABLE UPLAND FARMING**

A rapid rural survey showed that farmers identified the following problems (in order of priority): permanent land tenure, lack of capital (especially for agriculture), education of children, housing, poor water resources, high cost of agricultural inputs, wide price fluctuation of agricultural produce, insufficient government support, poor transportation facilities, severe weed problems, soil erosion (and land degradation), and forest fires. When questioned, the farmers told the survey teams from Khon Kaen University that soil erosion is a long-term problem. They would rather accord high priority



**Figure 2.** Relative productivity of three zones in Dong Sakran village.

to short-term immediate problems like tenure of their land, education of their children, better and more secure housing, and capital for agriculture. Because of the relatively small size of their farms, they have low incomes, and thus capital formation is negligible. The farmers concurred with the university scientists that inappropriate and too much up-and-down ploughing of sloping lands by heavy-duty tractors (mainly to suppress weeds) was a major cause of high soil erosion. Under the current socioeconomic circumstances, they said that they cannot easily change their farming methods. However, they are willing to try new technology that could be adopted within their 'limited resource environment'.

## Maize yields

It is difficult to maintain adequate plant population on the steep slopes (in the toposequence) due to erosion and consequent washing-off of seeds, if rains occur within a day or two of planting. The steeper parts of the toposequence are located next to the forestlands. The rodent damage to the young seedlings is high in this area. Some years the damage can be as high as 50%. The recommended plant population for sole maize is 50,000 plants  $\text{ha}^{-1}$ . Stem borers are a common problem.

The effect of land degradation on maize yields is evident. Even though farmers apply same dosage of inputs all over the watershed, the yield of maize in the steeper parts of the toposequence is at least 1 t  $\text{ha}^{-1}$  less when compared to yield obtained from the crop grown on the area with slight slope.

The grain yield of the maize crop was 3.12 t  $\text{ha}^{-1}$  in fields situated on steep sloping areas (>15% slope); it was 3.65 t  $\text{ha}^{-1}$  on the midlands (5–15% slope), while the yields recorded from lands that were level or with slight slope (2–5%) were of the order of 4.10 t  $\text{ha}^{-1}$  (Table 1). It is thus evident that land degradation that has occurred over the past six cropping seasons has reduced the yield of maize on the steep sloping areas by 25% or about 175 kg  $\text{ha}^{-1} \text{y}^{-1}$  when compared with the maize productivity of the 2–5% mildly sloping flat lands. On the midslopes, the loss of productivity is estimated at 10% or 70 kg  $\text{ha}^{-1} \text{y}^{-1}$ . Similar observations on the relative loss in the productivity of the rice bean crop were also noted in a toposequential experiment.

**Table 1.** Maize yields and components in a toposequence in on-farm studies (1999).

| Toposequence        | # of plots | Maize population ( $\times 1000 \text{ ha}^{-1}$ ) | Plant ht. (cm) | Yield stand (%) | Grain yield ( $\text{t ha}^{-1}$ ) |
|---------------------|------------|--|----------------|-----------------|------------------------------------|
| Steep slope (>15%)  | 3          | 33.5   | 186            | 98              | 3.12                               |
| Moderate (5–15%)    | 6          | 37.6   | 197            | 96              | 3.65                               |
| Slight (2–5%) slope | 2          | 36.3   | 197            | 96              | 4.10                               |

## Soil erosion estimate and its impact on maize yield

The simulation study showed that soil erosion from cultivated steeplands (>15% slopes) is estimated at about 300 t  $\text{ha}^{-1}$ ; from midlands (5–15% slope) at 150 t  $\text{ha}^{-1}$  and from the level to mildly sloping lands (<5% slope) at about 20–50 t  $\text{ha}^{-1}$  in an average rainfall year (1,330 mm annual rainfall). The annual runoff is estimated at about 300 mm. There are two peaks noted in the annual cycle of soil erosion and runoff. The first peak occurs in March/April, when the land has been freshly cultivated or just seeded. There is little or no canopy cover and the soil loss may be 5–45 t  $\text{ha}^{-1}$  from mildly to steep sloping lands at this time. The second peak in soil erosion occurs in September/October, when the crops are harvested and the land is ploughed to suppress weeds. The loss of soil at this time is very intense: 10–50 t  $\text{ha}^{-1}$  on the mild slopes (2–5% sloping land) and as much as 150 t  $\text{ha}^{-1}$  from the lands with steep slopes.

If soil conservation measures are **not adopted**, simulation results showed that maize yields in another five years' time (by 2005–2006) will be reduced to less than 2 t ha<sup>-1</sup> on the steeplands and to less than 2.5 t ha<sup>-1</sup> on the midlands, assuming that the maize yields are maintained at around 4 t ha<sup>-1</sup> on the relatively flat or moderately mildly sloping lands. Translated into yield loss, if the current rates of soil erosion continue, on the steep slopes these would amount to 400 kg ha<sup>-1</sup> y<sup>-1</sup> on a compound yield loss basis. Since about 1,500 kg maize productivity per ha is the required minimum of the economic threshold, it is evident that in another six years' time the production of maize on the steeplands will be rendered uneconomical as a result of the land degradation. Unfortunately the lands at that time would also be degraded to an extent that they would need significant profile modification for the establishment of any horticultural plantation.

## SUGGESTED STEPS FOR SUSTAINING PRODUCTIVITY

The possible approaches for sustaining productivity of sloping lands in northeastern Thailand include the following:

**For steep sloping lands:** no up-and-down cultivation of land. Minimum cultivation techniques should be adopted. As far as possible such lands should be planted to perennial agricultural land uses, e.g. fruit trees. Chemical + mechanical weed control systems that least disturb the soil surface should be employed. Water storage reservoirs may be built for supplemental irrigation so that irrigation water is available for horticultural production during the dry season.

**For midlands:** minimum cultivation, establishment of Vetiver grass live barriers along the contour, permanent or perennial agriculture, and legumes may be planted in replacement of the first maize crop as opportunity crops. Chemical weed control should be encouraged. Water storage reservoirs may be built for supplemental irrigation of fruit trees and for post-rainy season vegetable production.

**For level or mildly sloping lands:** intensify cultivation of maize-maize or upland rice-cereal systems. Include legume crops in the rotation. Plant on beds, with furrows acting as drainage channels. Establish Vetiver grass vegetative barriers to control soil erosion. Build water storage reservoirs for supplemental irrigation and for recharging groundwater aquifers for fruit tree and vegetable production.

## SUGGESTED TOPICS FOR FUTURE RESEARCH

**Socioeconomics:** tenure, minimum size of land holding for adequate food supply, income security at household and village levels, the location of a water recharging structure in the landscape watersheds, and farmers' group size for encouraging group action for soil conservation among land holders in a watershed are important social and socioeconomic issues for future research.

**Hydrology:** adequate information on the performance of different sections of the toposequence for soil water balance is not available. New methods of evaluation of soil water changes in a variable and mixed-slope terrain in the watershed need to be tested, evaluated, and verified.

**Land management and use:** these are situation specific. Basic principles of land use on sloping toposequences need revised evaluation in the context of sustainable agriculture. Land management techniques for sloping lands of different grades need critical evaluation particularly with regard to the application of minimum cultivation methods and chemical weed control.

**Soil and water conservation:** use of Vetiver grass bunds has proved useful for the control of soil erosion. Similarly storage of water in the reservoirs for water recycling and recharge of groundwater aquifers needs to be implemented on landscape scale watersheds.

**Policy issues:** farmers believe that soil erosion is a slow, land degrading process and can be reversed. They need to be educated on the irreversible nature of soil degradation and the economic and environmental costs associated with it. Land revenue and green farm taxation policies need to be introduced so farmers are encouraged to adopt soil and water conservation techniques and environmentally clean methods of sustainable farming.

## SUMMARY AND CONCLUSION

The results of a toposequential study on a soil farmed for six years continuously after land clearing showed that maize yields were: 3.12 t ha<sup>-1</sup> on the steeply sloping areas of the subcatchment of the watershed; 3.65 t ha<sup>-1</sup> on the moderately sloping midlands, and 4.10 t ha<sup>-1</sup> on the mildly sloping portion. The results clearly demonstrate that steeplands, which are exposed to severe land degradation, showed a marked reduction in maize yields. The performance of midlands was intermediate.

In the bimodal rainfall areas of northeast Thailand (annual rainfall ca. 1,600 mm) simulation studies showed that most of the soil erosion takes place in March–April (almost with the onset of the rainy season) when the land has been prepared for sowing of crops or the crop has been freshly sown. This accounts for almost one-third of the total annual soil erosion. Another two-thirds of the annual total soil erosion takes place in September–October after the harvest of the crops. The total soil loss due to soil erosion may be as high as 300 t ha<sup>-1</sup> on steeplands (slope >15%), about 150 t ha<sup>-1</sup> on midlands (slope 5–15%), and 20–50 t ha<sup>-1</sup> on mildly-sloping lands (2–5% slope) in an average rainy season. The runoff generally accounts for 34–35% of the total rainfall (ca. 400–500 mm).

The simulation modelling results also revealed that if the farmers on the sloping lands do not adopt conservation-effective methods, then their maize yields would not be economical in another five years' time. The reduction in maize productivity would be of the order of 400 kg ha<sup>-1</sup> y<sup>-1</sup> on a compound yield loss basis provided the fertilizer rates are maintained at the current levels.

Based on these preliminary results, topics for future research were also identified. These include studies on socioeconomic aspects of the sloping lands, hydrologic water balance, land management and use, soil and water conservation, and policy issues for enabling the farmers to progressively adopt environmentally clean conservation farming techniques.

## ACKNOWLEDGMENT

The INDPERFECT Soil Erosion Model has been used to simulate soil erosion scenarios. The erosion, yield reduction, and runoff rates predicted are indicative. More complete studies are underway. Thanks are due to Dr. K.P.C. Rao, Senior Scientist and Mr. S. Srinavas of ICRISAT for their assistance in using the model.

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