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WORKSHOP

RESEARCH AND APPLICATION OF TECHNOLOGICAL ADVANCES FOR THE SUSTAINABLE UPLAND AGRICULTURAL PRODUCTION

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RESEARCH AND APPLICATION OF TECHNOLOGICAL ADVANCES FOR SUSTAINABLE UPLAND AGRICULTURE PRODUCTION IN NORTHERN VIETNAM

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Abstract

The rainfed uplands occupy about one-third area of northern Vietnam and are threatened with destruction of natural habitat due to improper land use practices. Agricultural technologies practiced on these lands are exacerbating soil loss and destruction of the natural habitat as the soils are deeply weathered, poor in nutrients, and highly vulnerable to erosion. The loss of humus rich topsoil leaving behind the subsoil devoid of vital plant nutrients is leading to rampant infertility and poor water holding capacity of soils. The upland ecosystems have much lower carrying capacity and respond to crop intensification by rapid declines in productivity, even total collapse if not managed properly.

Remoteness and inaccessibility, low biological productivity, environmental degradation, disease and health problems, population increase, and lack of a development paradigm tailored to the special conditions are the key constraints. Growth in population densities, combined with deforestation and environmental degradation, has created a veritable crisis in the upland ecosystems. Sustainable farming on these lands in the perspective of a seriously deteriorated ecology and environment is not an easy task. Through proper understanding of constraints and development of appropriate technologies with focus on soil, water and nutrient management will help optimize food production and combat further resource degradation. Research and application of watershed based integrated natural resource management technologies offered excellent opportunities for crop diversification to meet market orientation, sustain food production at higher levels, improve soil health, recharge of aquifers, and enhanced household incomes for better rural lively hoods in the upland ecoregions of the northern Vietnam.

The Scenario

The rainfed uplands compose approximately one-third land area of the northern Vietnam consisting most of the provinces of Vinh Phuc, Ha Bac, and Bac Thai, some parts of Tuyen Quang, Yen Bai, Hoa Binh, Ha Tay, and Quang Ninh, and a small part of Ninh Binh Topography varies from densely packed hills to plains with isolated knolls. . Hill slopes are the dominant landform. Hills are rounded, with level tops and convex slopes of between 5 and 40^0. Most are between $20\text{-}25^0$ with elevations ranging between 15 and 200 meters above the sea level.

A number of specific challenges should be addressed for development to be carried out successfully in the upland ecoregions. Very poor material and technical infrastructure; seriously damaged environment; poorly developed economy; low level of

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knowledge; high population increase; unemployment; and poor education and training for local professional staff and administrators are the main constraints (Chu Huu Quy, 1995).

Remoteness and inaccessibility, low biological productivity, environmental degradation, disease and health problems, population increase, ethnic relations, and the lack of a development paradigm tailored to the special conditions of the upland ecoregions are the key constraints for development (Terry Rambo, 1995).

Resource degradation and production constraints in the rainfed uplands

More than 50% of the area has slopes above 20 degrees (Bui Quan Toan et al. 1993). Little level land is available for cultivation forcing farmers to clear fields on steeply sloping hillsides. Until late 1950s, rainfed uplands were sparsely populated by the tribal groups. However, the population has increased rapidly as the Vietnamese government began a program to resettle people from the delta to uplands in the year 1954. The Kinh constitute the majority population of the rainfed uplands. To the lowland Kinh, who are by age-long tradition skilled paddy farmers, dry-land farming on sloping terrain is unfamiliar, and they are not especially skilled in this kind of agriculture, for which there is really no precedent, even in the hills. Adoption of the traditional shifting cultivation employed on hill land by the ethnic minorities is not feasible. The Kinh people have, therefore, brought their lowland production technology to the rainfed uplands, exacerbating soil loss and destruction of the natural habitat.

Rainfall is seasonal with much of the annual total concentrated in a few short events. Inadequate distribution of rainfall during the year causes intermittent and prolonged droughts leading crop failures or fall in crop yields and food production.

Diversity of soil is great. Yellow red feralitic soils are the most widespread type (Be Viet Dang, 1993). Soils are deeply weathered, poor in nutrients, and highly vulnerable to erosion when cleared of vegetative cover and are subjected to various forms of degradation. Loss of humus rich topsoil leaves behind the subsoil devoid of vital plant nutrients leading to rampant infertility and poor water holding capacity. Unterraced fields are highly subject to erosion with estimates of annual soil losses ranging from 150 - 350 t ha^{-1} (Bui Quang Toan et al., 1993). Micronutrients are frequently limiting.

Forced by weather-related uncertainties and low incomes, farmers in upland eco-regions are generally resource poor and cannot invest adequately in crop husbandry. Thus uplands are threatened with destruction of natural habitat due to improper land use practices. These ecosystems have much lower carrying capacity and respond to crop intensification by rapid declines in productivity, even total collapse. Growth in population densities, combined with deforestation and environmental degradation, has created a veritable crisis in the upland ecosystems.

Why do we need to sustain production in the upland ecologies?

There are 10 million agricultural and forestry households in Vietnam with agriculture as the main component of the rural production structure (> 70% of households). In mountainous provinces this is further higher (> 80%) implying that other professions account for a smaller percentage. Surveys of farmer income show that, on an average, household earns their income mainly from agriculture (>72% of total income) and very small from other professions (<12%).

There are only 7 m ha of cultivated land compared with 20 m ha of forestland (with 9 m ha under dense forests). In mountainous provinces, the flat lands are only 10% and sloping lands in the remaining 90%. Farmers in several areas have been exploiting uplands using backward and unsustainable methods like slash and burn cultivation, uncontrolled exploitation of forest products, free animal grazing resulting in continuous degradation of soil and environment. The economic status of ethnic families who live in these areas is getting badly affected resulting in migration to new areas and repeating the cycle. During 1991 and 1995, 172,000 households (832,000 persons) immigrated to 8 provinces of west high plateau and eastern part of the south and destroyed more than 100, 000 ha of pristine forests.

Population growth is rapid and will continue to be so for at least for next 20 years. The population densities are expected to double over the current levels by 2015. In general upland agro-ecosystems have much lower carrying capacity and respond to intensification by rapid declines in productivity, even total collapse.

Growth in population densities, combined with deforestation and environmental degradation, has created a veritable crisis in upland ecosystems. The unfavorable shift in the people to land ratio has forced a dramatic shortening of the fallow cycle. The conservation of land and water resources in these eco-systems has been neglected for too long. There is an urgent need for development of sustainable land and water management strategies suitable for these eco-regions (Long and Ramakrishna, 2001)..

Integrated Participatory Watershed Research and Application: An Appropriate Way to Meet the Challenge!

Integrated participatory watershed research offer excellent opportunities to meet the challenges. Soil and water conservation technologies can be best practiced on a watershed, which is a natural hydrological unit. Watershed enjoins biophysical, social and economic inputs for optimal management, lead to diversified and high production, control environment degradation and provide a mechanism for the recharge of ground water aquifers. The research partnership between the Vietnam Agricultural Science Institute (VASI) and the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) precisely address these concerns in the Asian Development Bank's (ADB) Regional Technical Assistance # 5812 began in April 1999. The project "Improving Management of Natural Resources for Sustainable Rainfed Agriculture" in Vietnam is addressing primarily two issues:

- Enhance and sustain crop production and
- Combat degradation of natural resource base

With specific objectives:

- Introduce improved soil, water, nutrient soil, water, nutrient and pest management technologies for efficient use of natural resources;
- Reduce soil degradation and increase rain water use efficiency through better infiltration, water harvesting and ground water recharging; and
- Identify and evaluate suitable cropping systems based on the agro-ecological potential of the region for sustained increases in agricultural productivity and farm income.

The approach we are taking is to encourage maximum participation of farmers' in planning and execution of all our activities. All the watershed interventions are thoroughly discussed and decided by the farmers. Researchers and extension workers aid in decision-making process and facilitate agreed activities by providing technical support. The benchmark watershed is located in Kim Boi district of Hoa Binh province. Some research highlights of the project are presented hereunder.

Soil and Water Conservation

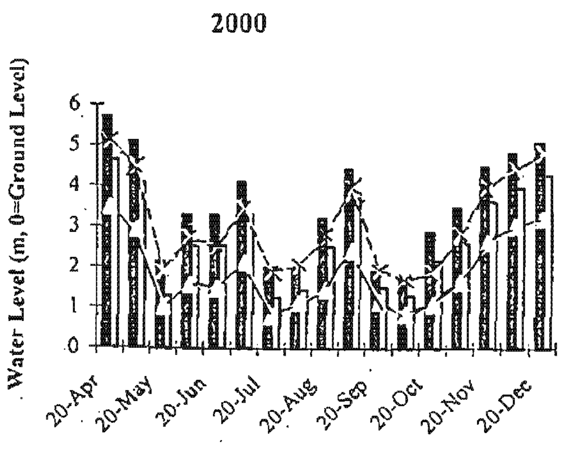
For increased water and soil conservation in the benchmark watershed we have undertaken various measures such as

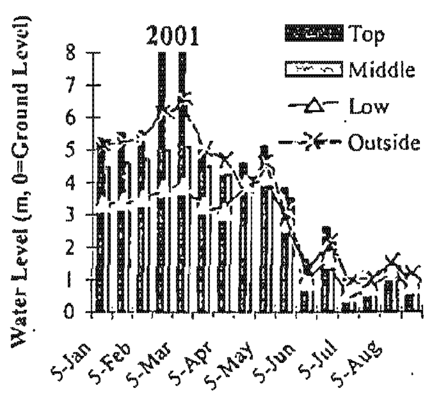
- Land form treatments (ridge and furrow, contour planting)
- Grassed waterways and drainage channels,
- Field bundling
- Biological and mechanical barriers across the slope on contours
- Trenches, and silt traps to reduce the rain water velocity and increase opportunity time for infiltration
- Percolation tanks (40 cubic meters capacity) to store excess water
- *Glyricidia sepium* planting on the property bunds and contours etc. were undertaken.

Ground water monitoring

Ground water level in 10 open wells (8 inside and 2 outside the watershed) on the toposequence (top, middle and lower part of the landscape watershed) was monitored at fortnightly intervals to observe ground water fluctuations and water yield to quantify the influence of improved soil and water conservation practices undertaken in the benchmark watershed. There was about 2.5-3 m rise in the water level in the benchmark watershed open wells compared to those in the outside the watershed during the entire observation period. Secondly, the groundwater level fluctuations were less pronounced with stable water yield particularly in the dry season (Fig 1).

Fig 1. Ground water level in the open wells in the benchmark watershed.

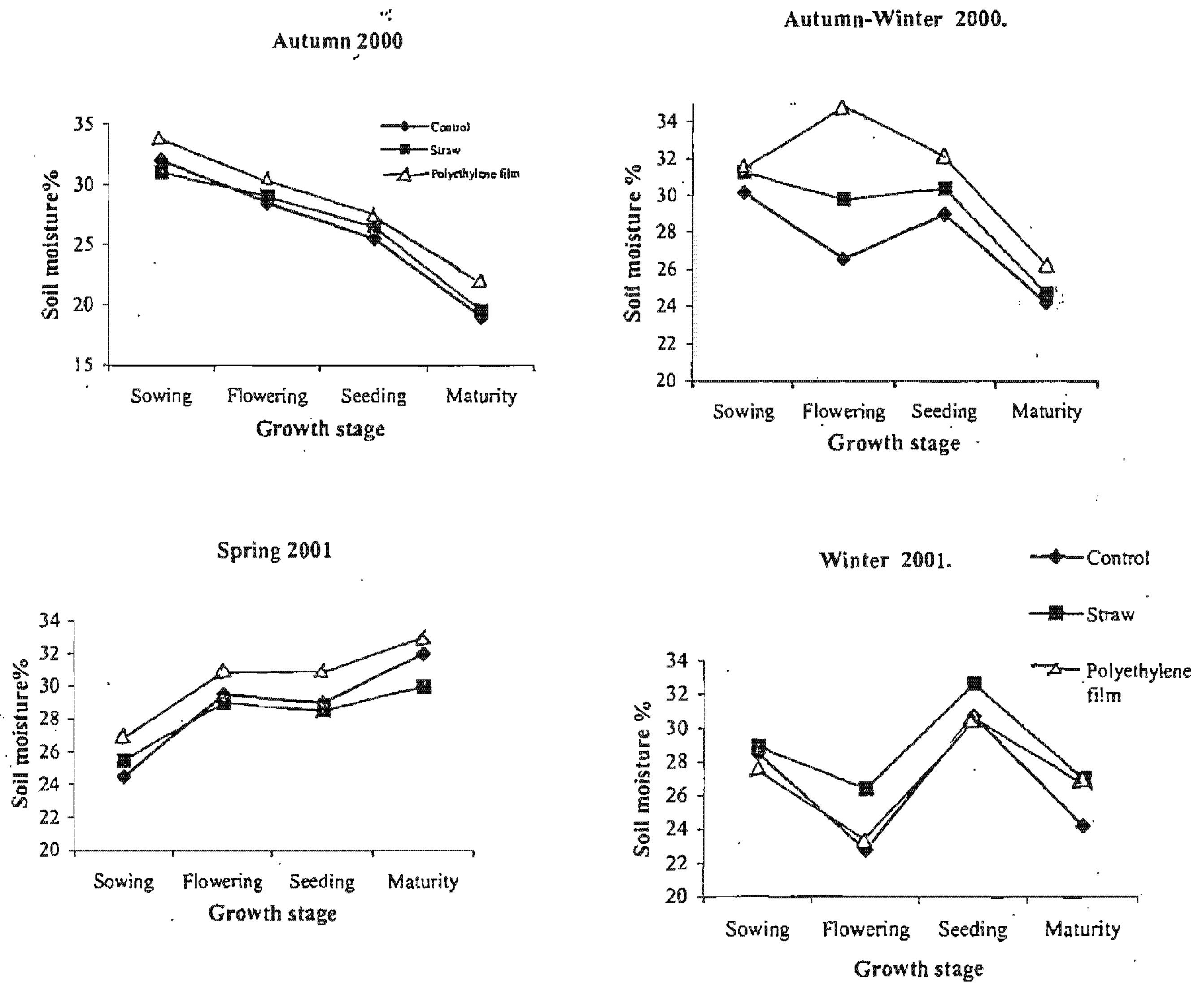




Moisture Conservation

In northern Vietnam, the important production constraints for the groundnut crop are low temperature at maturity in autumn-winter and low temperature at germination and moisture stress at maturity in spring season that hold back the potential yields. Trials were therefore, initiated to evaluate the effect of straw and polyethylene mulch on soil moisture, temperature and pod yields of groundnut. Polyethylene mulch increased soil temperature by 2-3 ^0C in autumn-winter and 1-2 ^0C in spring seasons with associated conservation of soil moisture. Increase in soil temperature in spring helped for early (about 2-3 days) and better germination with high seedling vigor while in winter, good pod development and early maturity was noticed.

Fig 2. Changes of soil moisture (0-30 cm) and temperature (10 cm) in mulch and



Application of polyethylene mulch resulted in doubling the groundnut yield (1.5 t ha^{-1}) than the control (0.7 t ha^{-1}) treatment in autumn-winter season in the year 2000. The straw mulch treatment, which is environment-friendly, and also economical increased groundnut, yields by 71 per cent over the non-mulch control treatment (1.2 t ha^{-1}) (Table 1). Application of both the mulch treatments increased number of pods $plant^{-1}$, pod weight and biomass.

Table 1. Effects of straw and plastic mulch on groundnut yields parameters in Thanh Ha watershed, summer 2000.

Treatment	Pods $plant^{-1}$	Pod mass (g)	Test weight (g)	Pod yield (t ha^{-1})	Total dry matter (t ha^{-1})	Shelling (%)
No mulch	11.9	109.9	41.2	0.7	5.38	66.8
Straw mulch	14.5	113.7	43.8	1.18	5.88	65.8
Plastic mulch	13.6	118.1	46.2	1.54	6.32	68.3
NA1	15.7	107.1	42.6	1.03	6.14	66.7
NA 5000	14.3	108.7	41.5	0.97	6.9	65.7
SEM	0.62	1.97	0.91	0.12	0.25	0.5
CV %	9.9	3.9	4.7	22	9.9	1.5

However, in spring 2001, only polyethylene mulch gave significantly higher yields (3.23 t ha^{-1}) over control ((2.74 t ha^{-1}). The beneficial effects of straw mulch appear to be masked by the increased incidence of pod rot, a fungal disease.

We are monitoring the runoff and soil loss in the benchmark watershed to quantify the advantages due to improved soil and water management practices. The watershed is equipped with digital recorders to monitor runoff and sediment samplers to measure nutrient loss. With the annual rainfall of 1349 mm (seasonal rainfall was 1009 mm), the runoff as a percent of rainfall was 29.5% and the total soil loss from the developed watershed was 6.8 t ha^{-1} in the year 2000.

Land Degradation

In order to quantify the effect of land degradation in terms of reduced productivity we studied the effect of field location on a toposequence in the watershed on crop productivity. Soil samples up to a depth of 105 cm were collected for detailed biophysical-chemical characterization for identifying the suitable indicators of land degradation.

Soil biological activity parameters such as microbial biomass, soil respiration, dehydrogenate, alkaline and acid-phosphates activities are the direct measures that indicate the soil health. These biological properties are directly associated with transformations of various elements in soil which are needed for plant growth. Soil biological parameters varied significantly on a toposequence. Biomass C and respiration values for top 10 cm samples from top of the toposequence were similar to the values of the 10 – 20 cm samples of the mid of toposequence.

The results indicated a wide variation for all the parameters along the location on a toposequence. The organic C content was high (8517-9633 mg C kg^{-1} soil). Similarly, soil respiration also showed the same trend. Further, analysis of results reveal that the samples from a top of the toposequence showed more soil C, microbial biomass C and N, and respiration than the samples from middle and lower positions on a toposequence.

These results point out that in Thanh Ha watershed as the farmers grow fruit trees on hills (top of a toposequence) the soils are not degraded on top, whereas, the agricultural systems followed on middle and lower positions of a toposequence which are cultivated have caused degradation. The results in Table 2 also suggest a direct relationship between rainfall and soil organic C content. Further detail analyses of these data sets will reveal detail understanding of relationships between environmental, management factors and land degradation.

Table 2. Variation in soil biological properties along the toposequence

Soil property/ toposequence	Soil depth (0-105 cm)
Microbial biomass C (mg C kg^{-1})	
Lower	107.5
Middle	112.2
Top	124.9
Microbial biomass N (mg N kg^{-1})	
Lower	11.16
Middle	10.14
Top	16.35
Mineral N (mg N kg^{-1})	
Lower	18.96
Middle	17.62
Top	11.83
Net N mineralization (mg N kg^{-1} soil 10 d^{-1})	
Lower	9.18
Middle	7.81
Top	10.31
Organic C (mg C kg^{-1})	
Lower	8517
Middle	8233
Top	9633

Nutrient Management

Improved nutrient management in maize: Farmers in the benchmark watershed over the years have increased the quantity of nitrogenous fertilizer (600 to 750 kg urea ha) in maize crop to maintain the yields. This has resulted increased incidence of pest and diseases and in erosion of household incomes. Improved nutrient management practice (180 N: 90 P_2O_5: 90 K_2O; 10 t FYM; and 400 kg lime) was compared with farmers' practice (275-300 N: 80P_2O_5: 45 K_2O) in maize with an objective to wean the farmers away from high dependence on inorganic fertilizers, encourage balance fertilization and to reduce cost of cultivation as maize cultivation. Higher grain yields were obtained with improved practice in all the three years and the results have clearly indicated good scope for savings on N fertilizer to the tune of 95 to 120 kg ha^{-1} (Table 3).

Table 3. Influence of improved nutrient management practices on grain and stover yields of maize t ha^{-1}).

Practice	1999 Autumn		2000 Spring		2000 Autumn		2001 Spring	
	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover
Farmer's Practice	4.50	8.84	5.32	11.80	4.90	8.8	5.57	9.58
Improved Practice	4.81	9.67	5.70	11.85	5.37	11.82	6.62	11.26
SE±	0.12	0.20	0.13	0.16	0.12	0.21	0.25	0.28
CV%	9	17	10	5.7	9.8	10.7	5	9

Evaluation of micronutrient requirements

The soil analysis of the benchmark watershed indicated that the soils are deficient in micronutrients like boron, zinc, sulphur and molybdenum. Trials were initiated on maize, groundnut and soybean to quantify economic advantage due to addition of these nutrients. Application of rhizobium resulted in CAPut!'.8% higher pod yields (2.1t ha^{-1}) over no rhizobium application (1.7 t ha^{-1}) in groundnut.

Nutrient budgeting

In order to develop sustainable nutrient management options for the selected farming systems in the target eco-region balanced fertilization is essential. We are evaluating on-farm nutrient budgeting approach as an effective tool to empower the farmers to take informed decisions for applying the nutrients. These studies will also enable us to collect the data sets for N inputs and losses from various processes under farmers' field situation that will help us to devise the options to harness the maximum benefits through adoption of improved nutrient management options. We are using N-difference and ^{15}N isotope dilution method to quantify BNF contributions of legumes using non-fixing control plants.

Green manure, compost and mulching

Farmers have planted 40,000 *Gliricidia* saplings on farm bunds, propriety bunds and near the mechanical structures in the benchmark watershed. The growth of the plants was very fast with ample biomass production. In Vietnam, *Gliricidia* can be cut 5 times in a year with an estimated biomass production of 25 - 50 t ha^{-1}. This rich organic matter containing 3-5% N can meet 100 to 200 kg N requirements of crops when applied *in-situ*.

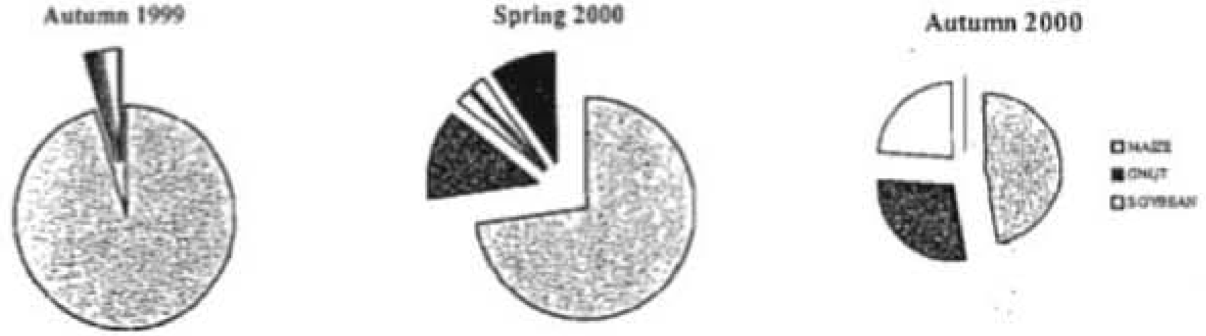
Farmers used to burn maize straw after spring season to get the fields quickly prepared for autumn-winter cropping as the turn around time is limited. Demonstrations were held to discourage straw burning and farmers were given training on minimum cultivation, mulching *in-situ* soil incorporation and composting.

Improved Cropping Systems for Sustainability and High Systems Productivity

Cereal mono-cropping (spring maize-autumn maize) was predominant in the watershed resulting in decline in soil fertility and increase in input costs. Trials to evaluate/identify improved cropping systems with soybean; groundnut and mungbean were taken up. All the new cropping systems were profitable over the traditional maize-maize cropping system indicating considerable scope for productivity gains and efficient use of natural resources.

Watermelon mung-groundnut, watermelon-mung-soybean, and watermelon-mung-maize cropping systems gave highest income (201 to 268%) over the traditional cropping system. More than 3/4 cropped area was under maize mono-cropping before the intervention of watershed based technologies. Technical backstopping and provision of improved seeds of the remunerative crops like groundnut, mungbean, and soybean resulted in reduction in maize area by about half during the last one year in the micro-watershed (Fig 3). Many more farmers are interested to take up groundnut cultivation but due to non-availability of improved seed further increase in groundnut area was not possible during this year.

Fig 3. Area (ha) under new cropping systems in Thanh Ha watershed



Improved production practices: Farmers in the watershed are following traditional cultural practices due to technological inaccessibility. Improved production practices (integrated nutrient, pest and disease management and agronomy) were compared with the farmers' practice in maize during autumn-winter 1999 and spring 2000. A yield increase of 8% was possible with 28% reduction in N fertilizer use. Improved cultivars of soybean, groundnut and mungbean were introduced for large-scale cultivation with improved agronomy.

Demonstration of new crops and/or improved cultivars: On-farm demonstrations were conducted with mungbean, soybean, groundnut and watermelon.

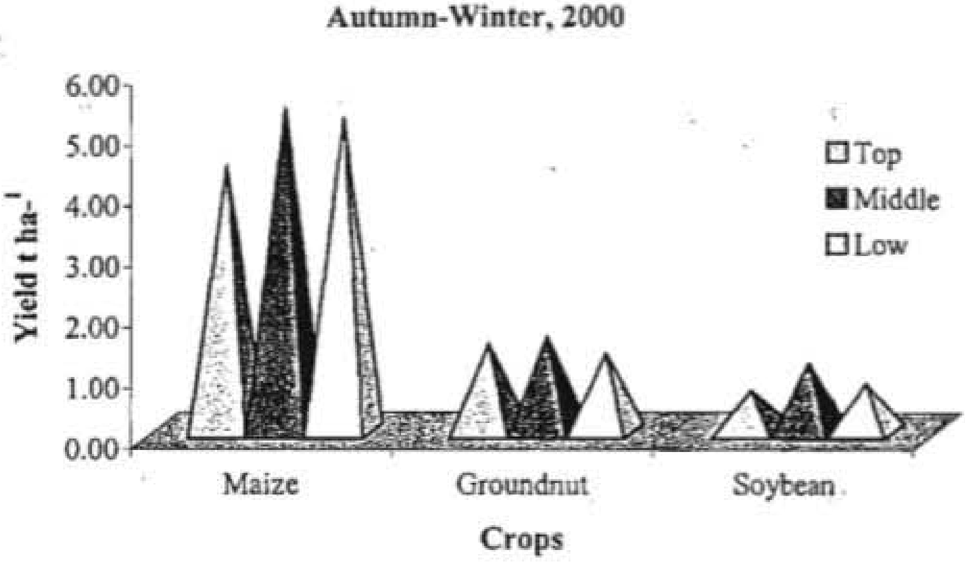
Improved mungbean cultivars (T 135) was assessed for its suitability as a catch crop in watermelon-maize cropping system. T- 135 has produced 1.12 t - 1.24 t ha^{-1} and did not pose any problem for normal maize cultivation.

An early maturing soybean cultivars TN 12 (70-75 days) was introduced to increase cropping intensity and system productivity. The new cropping system allows four crops watermelon-soybean-groundnut-sweet potato/vegetables in one year, if water is made available during the dry season.

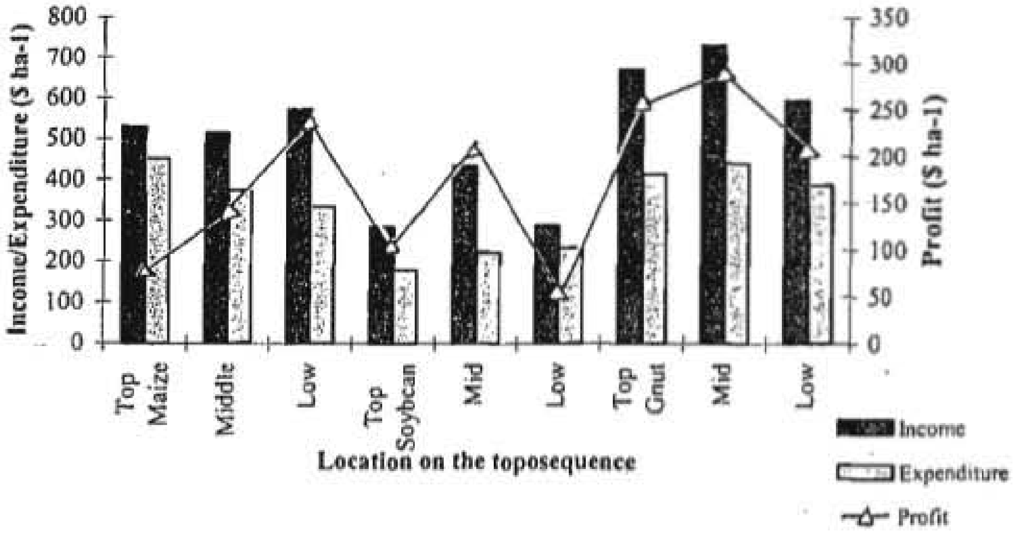
Improved groundnut cultivars (LO 2 and MD 7) with high yield potential (3-4 t ha^{-1}) and bacterial wilt and pod rot tolerance were introduced. Farmers highly impressed with groundnut and interested to plant in large areas.

Land use Planning: Grain yields of soybean, groundnut, mungbean, and maize were delineated based on the toposequence in the landscape watershed to find out the influence of land degradation/soil fertility on crop productivity (Fig 4). In general, higher grain yields were obtained in mid and lower part of the toposequence compared to top of the toposequence due to less degradation and better soil fertility. Among the crops grown, soybean suffered most due to fertility differences on the toposequence. Among crops, groundnut can be grown successfully on top, mid and lower part of the toposequence while mungbean and soybean need high level of management on top of the toposequence and for obtaining good yields. This kind of information would assist in land use planning and development of appropriate nutrient management options.

Fig 4. Influence of toposequence on crop productivity and profitability



Influence of toposequence on crop profitability, Autumn-Winter, 2000



Technology Exchange and Human Resource Development

Human resource development and technology exchange are important components of the project.

On job training: We have organized several training courses for researchers, extension workers and farmers to teach recent concepts in integrated participatory watershed management and introduce the needs of soil and water management by landscape watershed in upland agriculture. Scientists working in the watershed project were given hands on training in the design and development of efficient land and water management at watershed scale.

Public Awareness Programs: Farmers' days were conducted in each cropping season in the landscape watershed and all the farmers in the Thanh State Farm (consisting 7 Brigades/villages) were invited to get them familiarized with different components and technologies of the integrated watershed. Videos on improved production practices and watershed development were prepared for use by the extension agencies for wider adoption of technologies.

CONCLUSIONS

The conservation of land and water resources in the upland eco-regions has been neglected for too long. Sustainable farming on uplands in the context of a seriously deteriorated ecology and environment is not an easy task. Thorough understanding of constraints and development of appropriate technologies with farmer participatory approach and emphasis on land and water management will help optimize food production and combat land degradation. Watershed based integrated natural resource management technologies provided excellent opportunities for sustaining the production at higher levels to meet growing food demands, crop diversification with legumes and oilseed crops for enhanced incomes, improvement, in soil health and ground water, and reduced soil erosion and land degradation in uplands. In the coming years the strategic goal is to upscale improved technologies to other sites in the target eco-region to capitalize the benefits achieved in the benchmark watershed and consolidate the gains of improved soil, water, and nutrient management technologies and cropping systems through wider adoption for sustaining agricultural production in uplands.

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