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# ENVIRONMENTALLY SUSTAINABLE HILL AGRICULTURE FOR SOIL AND WATER CONSERVATION IN NORTH EASTERN HILLS REGION

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## ABSTRACT

The prevalent of shifting cultivation (jhum) and growing of crops along the hill slopes in the north eastern hills region have resulted the degradation of land resources caused by loss of vegetative cover without protection in the last century as a result of exponential population growth. Jhum is the main cause for the loss of forest cover and its continuous short cycle with low biomass production, during abandoned period decreased the status of natural build up of soil fertility caused by loss of top fertile soil through running water on hill slopes. The cultivation of crops (mainly tuberous and vegetables) along the hill slopes on raised bun system has also compounded the soil fertility degradation. The land degradation has resulted the loss of topsoil quality and exposed the unfertile acidic soil and some hills with exposed rocks and putting continuously pressure on fragile mountain resources. Depending on the availability of infrastructures, location specific requirement of household/community, mixed cropping, perennial plantation and field crops, cropping practices on sloppy land, adoption of biological means of soil protection with traditional system of agriculture and mixed farming are the viable production systems for the sustainability of hill agriculture, discussed in this article.

## INTRODUCTION

The north-eastern hills (NEH) region of India comes under warm per-humid agro climatic region and geographical features have been classified into following broadly homogeneous sub regions.

1. Himalayan hills comprising Sikkim and Darjeeling hills of West Bengal,
2. North eastern hills consisting Arunachal Pradesh, Nagaland, Karbi Anglong and North Cachar hills of Assam,
3. Southern hills and valleys include Manipur, Tripura and Mizoram and
4. Southern plateau of Meghalaya.

The region is marked by the geo-morphological development of a series of ridges and valleys, terraces, scraps, several planar surfaces at different elevations (15-6000m and above) etc. the total geographical area of the region is 2.12 lakhs sq.km, and out of which 69,672 sq.km are at an altitude over 1200 m. the climate varies from tropical in the foot hills and plains to alpine in the high elevations of Sikkim and Arunachal Pradesh. The traditional land use pattern developed in historical period that characterized subsistence agriculture in various regions.

In northeastern region hill agriculture exists in many forms according to latitude, longitude, and social groups. The hill agriculture has been defined for the agricultural practices for production on hill slopes exceeding above 36% slope (200). Almost every system is basically a form of mixed farming, including arable cultivation of cereals and tubers, livestock and intensive use of forests. Food crops

usually taken in valley, terraces and hill slopes, supplemented by some animal products, satisfy the basic energy intake of rural population. Over the past several centuries, there was the close relationship between human population growth, expanding area under subsistence crops, and increase in livestock number. These have intensified the demands on the forest to supply animal fodder, timber fuel wood and land for agriculture. The mountain and hills are highly vulnerable to degradation caused by over use or rapid changes extend to physical land surface, vegetative resources, and even delicate economic life support systems of mountain tribes of different ethnicity. The hill tribes through trial and errors over generations have evolved their own adaptation mechanism. They either modified the mountain characteristics (e.g., terracing, plantation crops, etc.) to suit their needs or used the system as such in different forms of shifting cultivation relying on the regeneration of soil productivity through natural vegetation without any out side inputs excepting seeds and human labours.

The deterioration of the soil productivity of mountain environment has now been defined as a function of deterioration in the vegetative cover of uncultivated land. The loss of top fertile soil through erosion during monsoon season as suspended sediment in the main drainage river Brahmputra is higher as compared to western Himalayas origin Ganga. Dibang, Teesta and Lohit tributaries of Brahmputra have reflected the high rates of upliftment and denudation in the Himalayas and are extremely high in sedimentation load ( Table 1). Teesta has the highest silt load as compared to any rive of the world. The major causes of the high rate of silt load in these rivers are the result of shifting agriculture on hill slopes (jhum0, which is the major cause of deforestation. This is a challenge for us to maintain the ecosystems of the hills without harming fragile mountain environments to meet the food security of the region.

The alleviation of poverty and the extent to which we can improve mountain environmental conditions will greatly depend upon a comprehensive understanding of the constraints and opportunities prevailing in this region. At present, there is a need to develop the sustainable hill agriculture in humid hilly ecosystem to meet the human basic needs and protect the natural resources.

## CAUSES OF RESOURCE DEGRADATION

Once this region was full of forest cover with small cluster of forest dwellers, which met their basic demand of food through shifting agriculture and food gathering and hunting of animals in forests. With passage of time, they started shifting as well as settled agriculture for their sustenance, mostly dependent on recycling of nutrients through the available biomass. After independence, the population of the north-eastern hills region has increased tremendously in the last century as compared to All India Population Growth rate (Fig.1) The population density per unit arable land is more than some of the plain states. This exponential population growth has resulted the over exploitation of the natural resources to meet the basic needs. Still forest and its produce have a major role in contributing the well being of rural masses (70% of the total population) as well as urban needs. The rapid loss of tree cover from the hills has rendered them susceptible to accelerated soil erosion, landslides and loss of habitat and genetic diversity. The unprecedented degradation of the mountain ecosystem is probably the foremost threat to the ecological safety and security of the population living in the watersheds of the rivers originating from them.

The shifting agriculture (Jhum), which is prevalent in this region, has resulted maximum loss of forest cover (Table 2). The continuous short cycle of jhum in some areas left the hill barren without soil and badly degraded fields are often abandoned to imperata grass [Imperata cylindrical (L) Raeuschel ] infestation. It has been observed that the amount of biomass burned for jhum has the direct positive relationship with productivity (Fig.2). Farmers cannot afford the luxury of long fallow period that allow the recovery of secondary forest and rejuvenation of exhausted soil nutrients and ultimately resulted marginalized the living of standard of the involved communities.

The practices of jhum and hill agriculture accelerate the soil erosion by running water on hill slopes. Erosion adversely affects the crops productivity by reducing the availability of water, nutrients, organic matter as the top enriched nutrients soil gets thin, which ultimately restrict the rooting depth of plants. Erosion is slight from soil well covered by dense grasses or forest but is enormous from steep, poorly covered and jhum lands that are exposed to heavy rainfall (Table 3). The accelerated erosion results the loss of high quality topsoil and exposed the unfertile acidic subsoil. It is not uncommon in this region during monsoon, moving the soil particles by surface creep, salutation, and suspension downhill by running water. Soil erosion affects crop production principally because of its effects (i) soil nutrients, (ii) infiltration of water and air into the soil, (iii) soil water holding capacity, (iv) soil tilth, and (v) the configuration of soil. Mannering (1981) estimated the permissible tolerance rate of soil loss through erosion under the different soil depths are given in table 4. It has been estimated that under ideal conditions 25 mm of soil can form in 100-300 years and under normal agricultural practices 100 years. If soil renewal rate is 0.2 mm/year, for the soil depth of 1.4m deep depth, then the permissible soil loss should never exceed 2mm/year. The tolerable soil loss is calculated as 1.38mm/year or about 14t/ha/year. In this region frequently most sloppy lands do not have the effective rooting depth more than 1 m, if the loss of soil through erosion is exceeding more than 10t/ha, ultimately going to affect the soil productivity in short term as well as in long- term leading wastelands.

## ENVIRONMENTALLY SOUND HILL AGRICULTURE

The land resources, water and soil are responsive to human interventions and its better or bad conditions depend on users. The interaction between climate and soil are particularly important for land use. The economic production in traditional hill agriculture has the relationship with inputs and outputs and in turn human or land resources. The 1992 United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro, Brazil (Rio Conference or Earth Submit) contains 115 programmed areas relating to socio-economic aspects, natural resource conservation and management, the role of major social groups and the means of implementation. The chapter 13 dealing with agricultural sector of Managing Fragile Ecosystems: Sustainable Mountain Development highlighted vital role for supplying food essential for human survival. The sustainability of agriculture is one that, over the long-term enhances environmental quality and the resource base on which agriculture depends, provides basic human food and fiber needs, is economically viable and enhance the quality of farmers life and community as a whole (American Society of Agronomy News, 1989). The sustainability of agriculture may not be the ultimate or highest end on the means-ends ladder (Schaller, 1990). It can be thought of means to the sustainability of society- as a whole and well being of all the mountain living community. Sustainable system must be resource conserving, environmentally sound, socially supportive, and commercially competitive. The concept of sustainable development is based on the belief that human progress must confirm to basic ecological percepts and human need in order to endure.

Environmental damage from agricultural perspective is largely a matter of lost biological diversity caused by spread of human habitat, impinging on forest that accounts for the most profound losses in biodiversity. Environmental protection according to the consumption perspective requires the calculation of maximum sustainable yield for renewable resources and long-term conservation strategies for the management of nonrenewable resources. The apparent improvement in economic welfare at the expense future generations is going result the loss of NEH natural wealth as opined by Repetto (1990)" A country could sell of its timber and minerals, erode its soil, pollute its aquifers, deplete its fisheries, and the national accounts would treat all the proceeds as current income. Mistaking a decline in wealth for a rise in income is confusion likely to end in bankruptcy". Sustainable development of mountain ecosystems, which are fragile and already stressed to the limits of their recuperative capacity are of utmost importance for regulating the water in rivers and streams that originate from them. The rapid loss of tree cover from

these hills have rendered them susceptible to accelerated soil erosion, land slides and loss of habitats and genetic diversity, which are the far most threat to the ecological safety and security of the hill people. The hill people have deep rooted cultural ties with the forest. Erode hills once covered with forest, extensive deforestation and shifting agriculture left bare ground, has not only resulted thousands of species to extinction every year with little prospect of improving their lot

The management of soil crop systems includes (a) Crop Device, hybrid or variety choice, resistant to insect pests, tolerance to stress conditions, (b) maintenance of soil fertility, (c) pest management strategies (d) bring soil loss through running water on hill slopes below tolerance level, (e) tillage operation for minimizing soil loss, and (f) crop rotation, and (g) system design. The concept of land husbandry is more acceptable to farmers for managing and improving the present use of land for productive purposes on a sustainable basis. To check the degradation occurring under hill agriculture for sustained productivity within the permissible loss of soil through erosion following steps are necessary.

1. Comprehensive inventory of the land
2. Assessment of soil health / condition
3. Planning and
4. Technical feasibility of the know how

The development of mountain or hill agriculture is based on the integrated rural development concept involving agro forestry, horticulture, applied research to increase productivity of hill crops, soil and water conservation, reforestation and development of more efficient pasture production. The conservation effective technologies directly or indirectly contribute to the maintenance and enhancement of soil productivity and prevent land degradation of hill agriculture.

## CROPPING PRACTICES ON SLOPPY LAND

In these regions, most of the farmers are growing food crops in mixed cropping system to cover the natural risk caused by heavy rain, abundant weed growth and insect pest and diseases. The utilization of 75% natural slope for maize and 25% lower area under bench terraces is more productive in terms of grain yield, loss of rain water through run off and soil loss through erosion as compared to soil cropping of either maize or rice on 100% terraced lands (Table I) . The decrease of the yield of both crops on 100% terraced lands is caused by loss of gross cultivated area for terrace development. The yield of both crops grown on natural hills slope decreased with increasing the years of cropping even after the application fertilizers, whereas the application of fertilizers on terraced land showed the increasing tendency. The decreasing the yield of crops on sloppy hills was the result of soil loss above the critical level (<30 t/ha), which ultimately reduced the soil available nutrient reserves and exposure of hard, acidic and poor nutrients subsoil.

The mild sloppy land can be changed to terraces in time by adopting the contour bunds with grass vegetation on contour lines and growing of crops to change the soil erosion. The Mizoram government has developed the contour trenching as an alternative of mechanical conservation to rehabilitate the jhum lands (Thansanga, 1997). Trenches are dug along the contour across the slope about 30cm deep and 15cm wide. The interval of trench lines varies according to steepness on higher slopes (50-20 m). The main aim of creation of the contour trench is to break the hill slopes, allow the surface water to be absorbed in the sub soil. The topsoil deposited in the trench during cultural operation and surface run off with decayed bio mass is utilized as manure for the next crop. Erosion permitting crops like cassava, sweet potato, ginger turmeric, potato etc can be safely cultivated in this system within the permissible soil loss (0.4 to 15 t/ha/yr). This system in time can replace the shifting cultivation by conserving soil and water to attain sustainable agriculture.

## MIXED/INTERCROPPING

Mixed cropping is the characteristic of the most jhum, which was evolved to meet food requirement of growers throughout the year by the nature of crops, temporal maturity and able to utilize the subsoil moisture during off rainy season. By planting together a number of crops with varying planting and harvesting times and growth habits, plant nutrients in different soil layers are better exploited and light energy is most effectively intercepted. The risk caused by diseases, pests, and climatic vagaries can be reduced. It provides an insurance against complete failure and it reduces soil erosion particularly if one of the two associated crops has a trailing habit, Inter planting with tuber crops provides an ideal famine reserve crop. It is well known that species diversity in multiple cropping reduces most insect pest problems.

Intercropping is a widespread practice, which, as is generally, has some advantages over sole cropping in the tropics. Legumes are the common component of an intercrop, and their ability of fix nitrogen often assists the productivity of the intercrop or subsequent crops. A major advantage of intercropping is caused by reduced incidence of insect pests and diseases. Rerkasem and Rerkasem (1988) reported that rice bean intercropped with maize yielded up to 49 kg N/ha than the sole crop of maize. The goodness of the match between pattern of phonological development of a crop and available growing season is an important determinant of yield in both sole cropping and intercropping. Intercropping also modifies the soil environment. Improved ground cover achieved by an additive intercrop contributes to reduce soil erosion and hence better retention of soil fertility. If new crops are to be introduced to the area, acceptability of crop product, logistics for marketing, and opportunities for profitability must also be considered.

***Perennial plantation and field crops***

Moving away from the jhum towards permanent land use is the planting of perennial tropical and subtropical crops as forest under growth. It is often successful because the ecological effects of the plants are somewhat similar to those of the original vegetation they replace. The maintenance of soil fertility is not much problem as with arable food crops. The plantation tree and shrub crops include rubber, cashew, coffee, large cardamom, tea, Black pepper, beetle leaf. The perennial field crops, which can be taken depending on location and infrastructure, are bananas, sugarcane, pineapple etc. These crops may be taken on the same land over many years, provided soil fertility is maintained. These crops enhance the biological aggradations of soil, i.e., increase of organic matter content, increase in the amount of carbon from biomass and enhancement of the activity and diversity of soil fauna.

***Biological means of soil erosion protection with tradition of system of agriculture***

The objective of soil conservation is to encourage those activities which retain, and wherever possible increase soil organic matter and biological activities. Slowing the eroding water, reducing the steepness of slope, hinders soil transportation and erecting barriers such as brush dam, terraces, contour cultivation, or contour strip cropping are some of the common problem. Land that has grass or other dense perennial cover seldom needs terracing for water runoff erosion control. Terraces are costly to construct and frequent maintenance due to high intensity of rainfall during monsoon. They are only feasible where arable land is in short supply or valuable crops can be grown. Ridges formed during contour tillage on moderate slope of 2-8% are effective in reducing erosion. Contour tollage combined with terracing and/or contour strip cropping is more effective than contour tillage alone.

The biological conservation activities should precede the mechanical conservation of soil. The cultural practices that are specifically developed and adopted to conserve soil and water resources, sustain high and satisfactory return, minimize degradation of soil; and environments, and preserve soil resources. Alley cropping is a form of agro forestry in which annual food crops are grown between two adjacent hedgerows of leguminous shrubs and woody perennials. The woody perennial are regularly pruned to

minimize shading and give nitrogen-rich mulch for food crops. Contour hedges decreases runoff velocity and reduce its sediment transport capacity. Considerable amount of location specific research is needed to develop appropriate alley cropping. The traditional cropping on the contour strips of intensively cultivated crops (ginger, potato and turmeric) alternating with strips of grasses can retain the erosion sediments from the tilled strips.

There are number of techniques developed allover the world, so that forest can be cultivated for a longer period without degradation. One strategy is to integrate a wide variety of crops, which mature at different times and to grow to different heights. The creation of multi-layered garden mimics the natural forest. Soil erosion and nutrient losses are thus kept minimum and pest problems are avoided. The more crops and varieties that a farmer grows, the less the risk that has entire harvest will fail. When trees are introduced into the cycle, not only provide food in the form of fruits and nuts, but also provide fodder for animals, organic matter to enrich the soil and shade for the growing plants below. The trees reduce the impact of rainfall on the soil, to control erosion, provide humus and control weed growth.

***Mixed farming***

Integrating livestock with seasonal and perennial crops is a useful approach to providing diversity and effectively utilizing the limited resource. Almost all tribal population of the hills is meat eater and mixed farming is the appropriate means to utilize planted fallows economically and provide manure to replenish soil fertility. Creating viable unit of family farms involves the use of improved productive pastures and well-managed animal for beef, pork and meat and dairy production. Mixed farming systems provide farmers with an opportunity to reduce financial risk smooth out production cycles. The mixed farming system is also a partially closed system where the manure can be utilized on farm to build fertility, while the milk and meat produced in the system flow out to urban markets. In many respect mixed farming systems have the capacity to promote healthy ecosystems and provide economic development of the farmers however, due to human population pressure, poverty and poor infrastructure, these systems can negatively impact biodiversity and the environment at large. Stall-feeding of animal is the only way to protect the environment. Farmers should be encouraged to plant the fodder trees for the rest of the months, with lopped leaves and twigs can meet the requirement of livestock. Browsing animals (like goat) should also be encouraged which cause the least damage to ground covers of vegetation due to browsing habit. In the interest of effective feeding of livestock, the use of trees provide green leaf fodder during the winter season, should be part of the rehabilitation programme.

***Diversification of agriculture***

In this region, elevation of hills and climatic differences facilitate the growing of subtropical fruits, Vegetables and even flowers, which can be highly profitable. The slopes provide alternative areas for the cultivation of some vegetables crops (cabbage, cauliflower, radish, carrot, turnip, tomato etc.) during the rainy season. Already such type of vegetable production is in practice in Meghalaya and Sikkim in temperate zone.

***Farming system approach***

The farming systems developed in the hills are managed by a farmer's family or community to meet the needs depending on the physical, biological and socio-economic environment and in accordance with their goals, preferences and available resources. Thus farming system is the resource management strategy to achieve economic and sustainable agricultural production to the diverse requirements of the farming communities while preserving the resource base and maintaining a high environmental quality (Lal and Miller, 1990). The main objective of the farming systems is to provide healthy food and fodder and preserving the natural resource soils capacity to yield in the light of ecological, economic and social considerations over the long-term.

The hills are divided into several valleys of rivers and their tributaries. Even each tributary/valley is further divided into many natural watersheds by the prominent streams. The existing practice of land use in each watershed is of traditional types (jhum, valley and terrace rice and hill agriculture), in which various crops, vegetables and horticultural crops are grown along with livestock depending upon different agro climatic conditions. The ecological complexity of mountain agriculture can be best tackled on watershed basis with the objective of integrated management and use of mountain resources. The rational management of natural resources in the mountains depends on the integrated development of improved and diversified mountain farming systems, better infrastructure support for the hill farmers, more effective forest and pasture cover. The package of practices to be given to the farmers of a watershed should be based on the apparent productivity of the changes compared to current resource productivity, the risk from uncertainties in the outcome, the scale of resource demands in relation to farmer endowments of land, labour and cash and the managerial capacity of changes. The involvement of community and individual families in farming is the key for an effective management of natural resources in a watershed cultural norms and values, community control mechanisms, inter-household decision-making and access to resources are recognized as a central point in the adoption process.

Relevant improved technologies must include the development of new crop, livestock and tree enterprises that better match the characteristics of the land as well as improving the field management practices of existing farmers. Land suitability indicates the best way to use the land for sustained productivity, where as land capability ranks land according to its relative erosion hazards. Emphasis must be given to promote high value products (cardamom, ginger, tea, coffee, cashew, potato, vegetables, dairy products, etc.) for those watersheds with good irrigation facilities, infrastructure and access to market. The improvement of subsistence production is initiated in those areas with poor access without irrigation sources.

This region is rich in plant genetic resources to provide raw materials for development and new sustainable production systems. In view of developing variety of new crops, almost all wild or weedy floras could be considered potential genetic resources to be conserved. Plant genetic resource conservation involves managing and using resources in a manner that does not deplete them. The traditional fruit tree variety, maintained with other trees in a poly-culture by a subsistence farmer according to traditional husbandry. The ethno-botanical information includes folk names, users customs, crop management practices, technological features and ceremonies associated with plant genetic resources, and pattern of land uses, of which land tenure is particularly important. Traditional folk names and classification may provide important clues for generally unrecognized economic uses for plants. This type of information would revive the traditional system of medicine- based herbs, shrubs and trees and in turn consciousness for natural resource protection, knowledge of genetic diversity and relationship among sets of germplasm and the potential merit of the genetic diversity would be beneficial to all phases of crop improvement.

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**Table 1. Sediment load for selected north- eastern hills rivers and Ganga**

| River | Sediment concentration ha-m/100 km2/year |
|---|---|
| Brahmputra | 7.6 |
| Buridihang | 16.6 |
| Dibang | 26.8 |
| Dikrang | 25.8 |
| Lohit | 33.7 |
| Pagladia | 31.4 |
| Teesta | 98.2 |
| Ganga | 4.0 |

**Table 2. Loss or gain of forest cover (sq.km) in 1997 assessment as compares to 1995 in the north-eastern states (States of Forest Report 1997)**

| State | Forest cover | | | Loss | | Gain | | Net | |
|---|---|---|---|---|---|---|---|---|---|
| | 1995 | 1997 | Sh.C | Others | Total | NRSC | Others | Total | Charge |
| Arunachal Pradesh | 68,621 | 68,602 | 75 | - | 75 | 56 | - | 56 | -19 |
| Assam | 24,601 | 23,824 | 257 | 159 | 416 | 163 | 16 | 179 | -237 |
| Manipur | 17,558 | 17,418 | 603 | - | 603 | 463 | - | 463 | -140 |
| Meghalaya | 15,174 | 15,657 | 75 | 2 | 77 | 20 | - | 20 | -57 |
| Mizoram | 18,576 | 18,775 | 292 | - | 292 | 491 | - | 491 | +199 |
| Nagaland | 14,291 | 14,221 | 573 | - | 573 | 503 | - | 503 | -70 |
| Tripura | 5,538 | 5,546 | - | 3 | 3 | 4 | 7 | 11 | +8 |
| Total | 164,359 | 164,043 | 1,875 | 164 | 2,039 | 1,700 | 23 | 1,723 | -316 |

*Sh.C and NRSC=Shifting Cultivation and natural regeneration in shifting cultivation.*

**Table 3. Loss of soil through erosion under different land use practices receiving 1600 mm rainfall/ year (Prasad et al. 1986)**

| Land use | Experimental plot size | Soil loss (t/ha/ye) |
|---|---|---|
| Shifting cultivation | Small | 30.2-170.2 |
| Shifting cultivation | Field | 5.1-83.2 |
| Tuber crops on raised beds(bun) | Medium | 40.0-50.0 |
| Pineapple cultivation along the slope (first two years) | Small | 24.0-62.6 |
| Homestead area | Field | 16.8 |
| Mixed crop of maize and rice | Small | 19.7-21.0 |
| Rice on slope | Small | 32.9-45.0 |
| Bare fallow | Small | 83.8 |
| Cropping systems | Medium | 51.0-83.8 |
| Planted grass cover | Medium | 10.83 |
| Natural bamboo forest | Field | 0.04-0.52 |

*Note: Area of small, Medium and field were in the range of 2-5, 16-40 and 69,000 m2, respectively.*

**Table 4. Tolerance rate of soil loss under the favourable rooting depth**

| Potential favourable rooting depth, cm | Tolerance rate of soil loss, t/ha |
|---|---|
| 0-25 | NA |
| 25-50 | 4 |
| 50-100 | 8 |
| 100-150 | 12 |
| 150-200 | 16 |
| >200 | 20 |

**Table 5. Runoff, soil loss and grain yield or crops grown on 55% in different Combinations (Rai, 1986)**

| Crop Geometry | Runoff (%) of Rainfall | Soil Loss (t/ha) | Grain yield, (q/ha) | |
|---|---|---|---|---|
| | | | Maize | Rice |
| Mixed crop of rice and maize on Natural hill slope | 5.45 | 35.00 | 4.12 | 2.63 |
| Rice on natural slope | 4.93 | 33.92 | - | 10.61 |
| Maize on natural slope | 3.62 | 30.87 | 1.061 | - |
| 75% maize on upper slope + 25% rice on bench terraced in lower slope | 0.88 | 7.25 | 11.62 | 13.73 |
| 50% maize on upper slope + 50% rice on bench terraced in lower slope | 0.56 | 5.40 | 10.37 | 13.58 |
| 25% maize on upper slope + 75% rice on bench terraced in lower slope | 0.11 | 1.10 | 9.71 | 10.77 |
| All bench terraced under rice | 0.06 | 0.67 | - | 9.23 |
| All bench terraced under maize | 0.78 | 5.85 | 10.91 | - |