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Rejuvenation of Jhum Lands through Bio-terracing

In the hilly regions of Northeastern India, shifting cultivation, locally known as jhum or slash/burn agriculture, has been the predominant form of farming, relying on traditional knowledge. However, this practice has led to a significant decline in soil fertility, rendering it unsustainable, particularly with increasing population and subsequent rise in food demands. To address this issue, implementation of bio-terracing with the use of green-manuring species serves as a restorative measure to sustain soil fertility for agricultural purposes. It is important to note that soils in jhum areas are not only depleted of nutrients but also lack sufficient moisture, necessitating comprehensive soil conservation and improvement strategies.

JHUM lands face a grave issue where burning of forests results in the loss of organic matter, nutrients, and microbial life, leading to soil heating. However, this problem can be significantly addressed through implementation of diverse bio-terracing model. These models can effectively enhance organic matter content, micronutrient levels, moisture conservation within soil. Nonetheless, local communities, known as *Jhumia*, have played a crucial role in preserving agro-biodiversity through their adherence to traditional rules, practices, and informal networks for seed exchange and knowledge sharing. It is important to note that tribal people in these regions possess a strong aversion to use of chemical fertilizers, which has contributed to degradation of soil quality in *Jhum* areas. Therefore, implementation of various bio-terracing models, which include leguminous green manuring shrubs, emerges as most suitable approach for improving soil health & enhancing crop productivity. Green manuring crops are typically incorporated into soil when they are still green or during early flowering stage (~40-50 days after sowing) to conserve soil, nutrients, and moisture. This investment during the specified period proves beneficial for subsequent two crop seasons, leading to improved production. Addition of organic material enhances soil structure (tilth) and simultaneously conserves and returns nutrients utilized by plants back to the soil, thereby enhancing soil fertility. While almost any crop can be used for green manuring, legumes are preferred due to their ability to fix atmospheric N (sesbania, cowpea, greengram, clovers, lentil).

Practice of growing legume crops to be incorporated into the soil is an age-old agricultural technique that is gaining popularity once again. Furthermore, soil N content is closely associated with organic matter, and decomposition of organic matter significantly influences availability of soil nutrients. Therefore, it is important to discuss the quantity and sources of organic matter in soils, as well as factors that contribute to its increase and its role in soil health. Soil organic carbon plays a vital role in improving the physical, chemical, and biological properties of soil. In hills where perennial water sources are present, cultivation of green manure crops has proven highly successful in enhancing soil health of Jhum land, which suffers from deficiencies in organic matter, N, P & other micronutrients. Consequently, incorporating green manuring practices becomes a viable alternative for maintaining the productivity, profitability, and sustainability of Jhum land.

Land use patterns

There is significant disparity in agricultural growth pattern across country, characterized by variations among the regions, sectors, and farming communities. The Northeastern Hills (NEH) region, comprising states i.e., Assam, Arunachal Pradesh, Manipur, Mizoram, Tripura, Nagaland, and Meghalaya, lags despite its abundant natural resources. The region faces challenges in achieving high productivity due to various factors, including the prevalence of shifting cultivation, rugged terrain, unpredictable climate changes, low levels of input utilization, and inadequate infrastructure. Shifting cultivation remains a prominent practice in NEH region and is extensively employed by over 100 tribal ethnic minorities. This traditional form of agriculture involves clearing of land by cutting down and burning natural vegetation for cultivation purposes. Tribal people engaged in this agricultural practice are known as "*Jhumias*,", they possess unique linguistic and cultural identities. The NEH region exhibits a vast array of geographical features. Out of its total geographical area of 26.2 m ha, ~10.8% lies within an elevation range of 300-600 meters, 17.9% between 600-1200 meters, and 28.3% above 1200 meters. The region receives an average annual rainfall ranging from 2000-4000 mm, primarily during southwest

monsoon. Interestingly, world's highest rainfall area, Mawsynram, is also situated within this region. Region experiences significant temperature variations throughout the year, with summer temperatures ranging from 15 to 32 °C and winter temperatures ranging from 0 to 26°C. In contemporary scientific research, various regional models are being utilized to study and analyse local climate changes. Agricultural yields in this region display greater instability in rainfed areas compared to irrigated ones due to unpredictable nature of climate changes. It is estimated that ~3.5 m ha of land is used for rainfed cultivation, accounting for ~30% of total area. Rainfed lands encounter numerous biophysical and socioeconomic challenges, including low and erratic rainfall, limited input utilization, insufficient availability of draft power, land degradation, resource-poor farmers and inadequate access to credit. Moreover, hilly terrain characterized by steep slopes, uneven topology, and limited flat land areas contributes to poor crop yields. On average, an estimated 38.7 thousand hectares of land are subjected to shifting cultivation each year, sustaining livelihoods of ~ 443,336 families.

Bio-terracing models

Shifting cultivation is often referred to as a "cafeteria system of cultivation" where a wide variety of cereals, vegetables, and tree crops are grown together in a single field. The development of agricultural food production in region is heavily influenced by the customs, culture, and dietary preferences of tribal people. *Jhumias* continue to rely on less productive forms of cultivation, not because they are backward or ignorant, but because they lack viable alternatives for alternative livelihoods. The land-to-person ratio in the region, at 0.68 ha per person, is considerably higher than national average of 0.32 ha per person. Additionally, it has been observed that there has been a gradual decrease in net land per family for shifting cultivation and an increase in permanent agricultural land per family, with figures decreasing from 1.1 to 0.7 ha per family for shifting cultivation and increasing from 0.35 to 0.74 ha per family for permanent agriculture. Despite covering 8.8% of country's total geographical area, region continues to be a net importer of food grains, contributing only 1.5% to country's total food grain production. The growing population in many regions has necessitated a transition towards settled cultivation.

From 1970-71, net land under shifting agriculture decreased from 87,220 ha to 84,002 ha in 1995-96. Conversely, land under permanent agriculture increased from 28,006 ha in 1970-71 to 81,281 ha. Renovation crops and pastures are cultivated with primary goals of improving soil fertility, reducing weed pressure, and increasing soil organic matter. A similar concept has been tested in lowland areas to generate biomass on-site for soil fertility management and decrease reliance on external inputs like fertilizers. Hedge row species such as *Tephrosia spp*, *Cajanus cajan*, and others are grown on raised bunds in alternate patterns within lowland rice field. This practice generates substantial amount of biomass to supplement nutrient requirements of rice. It involves intercropping arable crops in spaces between

Maize cropping view between *Tephrosia* hedge rows production system

two rows of hedge or leguminous shrubs. The width of these alleys varies from 2-5 m depending on factors like slope and plant species involved. In Northeastern region of India, suitable leguminous shrubs for alley cropping include *Crotolaria*, *Tephrossia*, *Casia*, Acacia, *Cajanus cajan*, *Flemingia*, *Indigofera* spp., among others. Ginger, turmeric, maize, and similar crops are cultivated within alleys. The height of the hedge rows is typically maintained at~1 m through regular pruning. Pruned biomass is either used as mulch or incorporated into soil as a nutrient source. Intercropping in spaces between hedgerows is a proven & sustainable technology for the NEH region. Hedgerows grown along contours contribute to development of natural terraces within a few years. Green biomass, including leaves and twigs, of these hedge row species is rich in essential nutrients, particularly N, P, and K. This cultivation system effectively reduces erosion, conserves soil moisture, and retains nutrients within the soil. On average, pruning of N-fixing hedgerow species adds ~20-80 kg/ha/year of N, 3-4 kg/ha/year of P, and 8-38 kg/ha/year of K. Addition of leaf biomass from hedge row species significantly improves fertility status of soil.

CONCLUSION

Renovation crops and pastures play a crucial role for enhancing soil fertility, reducing weed pressure, and increasing soil organic matter. In Northeast region of India, leguminous shrubs such as *Crotolaria*, *Tephrossia*, *Casia*, *Acacia*, *Cajanus cajan*, *Flemingia*, *Indigofera* spp., and others are well-suited as alley crops. Ginger, turmeric, maize, and other crops are cultivated within alleys created by these shrubs. Height of alleys is typically maintained at ~1 m through regular pruning, and pruned biomass is either utilized as mulch or incorporated into soil to provide essential nutrients. Intercropping in spaces between hedgerows has proven to be a sustainable and effective technology for NEH region of the country.

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