GRASSROOTS JOURNALS

ISSN 2581-6853

Grassroots Journal of Natural Resources, Vol. 4 No. 2 (June 2021)
ISSN 2581-6853 | CODEN: GJNRA9 | Published by The Grassroots Institute
Website: http://grassrootsjournals.org/gjnr | Main Indexing: Web of Science

OPEN ACCESS Freely available online

M – 00222 | Research Article

Integrated Management of Land, Water and Bioresources for Sustainable Agriculture in North Eastern Region of India

Sanjay-Swami
School of Natural Resource Management, College of Postgraduate Studies in Agricultural Sciences, Central Agricultural University Imphal, Umiam (Barapani) – 793103, Meghalaya, India.
Email: sanjayswamionline@gmail.com | *ORCID: 0000-0001-8961-4671*

How to cite this paper: Sanjay-Swami (2021). Integrated Management of Land, Water and Bioresources for Sustainable Agriculture in North Eastern Region of India. *Grassroots Journal of Natural Resources*, 4(2): 136-150. Doi: https://doi.org/10.33002/nr2581.6853.040210

Received: 02 November 2020
Reviewed: 15 December 2020
Provisionally Accepted: 11 January 2021
Revised: 20 April 2021
Finally Accepted: 11 May 2021
Published: 05 June 2021

ISSN 2581-6853
04210
9 772581 685006

Abstract

The ecosystem approach is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way. There is no single way to implement the ecosystem approach, as it depends on local, provincial, national, regional or global conditions. The North Eastern Region (NER) of India represents three geographies (East Himalayas, Brahmaputra Valley, and North East Hills) and covers about 7.7 percent of the total geographic area of India. Around 56 percent of the cultivated area of the NER is under low altitude (valley or lowland), 33 percent under mid-altitude (flat upland), and the rest under high altitude (upland terrace). The environment, local conditions, socio-economic and socio-cultural life of different tribal communities and the rituals associated with agricultural practices have developed many Indigenous farming systems, which have in-built eco-friendly systems for conservation, preservation and utilization of natural resources. However, with the passage of time, some of these practices have been further refined and modified to cater the location specific present day needs for conservation of natural resources, particularly soil and water resources. The present article is to discuss some important ecosystem approaches/traditional practices followed in the North Eastern Region with recent innovations to make agriculture more efficient and more sustainable.

Keywords

Ecosystem approach; Principles; Operational guidance; North Eastern region; Sustainable agriculture

Introduction

The challenges arising from global economic and population growth, pervasive rural poverty, degrading natural resources in agricultural land use, and climate change are forcing ecological sustainability elements to be integrated into agricultural production intensification. Chemo-centric technological advancement during Green Revolution period boosted the production potential and provided food security to the nation. However, over a period of time, this production system has started exhibiting its carrying capacity as reflected by production plateau in green revolution belt (Sanjay-Swami, 2017). This version of agriculture wherein the soil structure, soil life and organic matter are mechanically destroyed every season, and the soil has no organic cover, is no longer adequate to meet the agricultural and rural resource management needs and demands of the 21st century (Kassam and Friedrich, 2012). The future farming must be multifunctional, and, at the same time, ecologically, economically and socially sustainable, so that it can deliver ecosystem goods and services as well as livelihoods to producers and society. The farming needs to address effectively the local, national and international challenges. These challenges include food, water and energy insecurity, climate change, pervasive rural poverty, and degradation of natural resources. All these challenges can be addressed by adopting integrated management of land, water and bioresources.

The ecosystem approach is a strategy for the integrated management of land, water and bioresources that promotes conservation and sustainable use in an equitable way. It is based on the application of appropriate scientific methodologies focused on levels of biological organization, which encompasses the essential structure, processes, functions and interactions among organisms and their environment. It recognizes that humans, with their cultural diversity, are an integral component of many ecosystems. During its fourth meeting of Conference of the Parties (COP4) in Bratislava in May 1998, the Convention on Biological Diversity (CBD) acknowledged the need for a workable description and further elaboration of the ecosystem approach, and requested the Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA) to develop principles and other guidance on the ecosystem approach. Based on the work of SBSTTA, which had a mandate of operationalizing the ecosystem approach, the fifth meeting of the members of the Conference of the Parties (COP-MOP5) endorsed a description of the ecosystem approach and recommended 12 principles for application of the ecosystem approach. It also suggested 5-points operational guidance for the ecosystem approach (SCBD, 2004).

Methodology

Both primary and secondary data were used to document some important ecosystem approaches/traditional practices followed in the North Eastern Region of India along with the recent innovative modifications to make these practices more efficient in the present agricultural scenario. The primary data/observation/ pictures were collected during multiple field visits/survey, whereas the secondary data were collected from relevant research papers published in various journals, articles, books and searching google search engine with the appropriate key words like ecosystem approach, traditional practices, North Eastern Region of India, etc.

North Eastern India's Regional Perspective

India's North Eastern Region (NER) represents three geographical entities (East Himalayas, Brahmaputra Valley, and North East Hills) and covers about 7.7 percent of the total geographic area of India. Around 56 percent of the cultivated area of the NER is under low altitude (valley or lowland), 33 percent under mid-altitude (flat upland), and the rest under high altitude (upland terrace) (Sanjay-Swami, 2019a). Nearly 22 percent land area is under crop cultivation in the region leaving 78 percent without cultivation. Majority of the fields in the region are situated across the hilly slopes (Sanjay-Swami, 2019a). Traditionally, farmers in both upland terrace and valleys practice mono-cropping under rainfed agriculture, where rice (*Oryza sativa*) is the major crop occupying more than 80 percent of the cultivated area followed by maize (*Zea mays*). The cropping intensity of the NER is 130 percent. The "slash and burn" agriculture (shifting cultivation or *Jhum*) is practiced on about 0.88 million ha. Soil health/fertility is the most crucial factor in deciding the agricultural productivity. Approximately, 84 per cent of the soils in the NER are acidic in nature, having low available phosphorus and zinc with toxicity of iron and aluminum.

The region has several unique features: fertile land, abundant water resources, evergreen dense forests, high and dependable rainfall, mega biodiversity and agriculture-friendly climate, yet it failed to convert its strengths optimally into growth opportunities for the well-being of the people. It has diversity in cropping pattern, livestock management and diversity in culture and socio-economic life. The size of land holdings is small that varies with state to state within the region. The mainstay of livelihood is only the agriculture, which is predominantly traditional and CDR (complex, diverse and risk prone), with a very backward industrial sector. The environment, local conditions, socio-economic and socio-cultural life of different tribal communities and the rituals associated with agricultural practices have developed many Indigenous farming systems, which have in-built eco-friendly systems for conservation, preservation and utilization of natural resources. However, with the passage of time, some of these practices have been further refined and modified to cater the location specific present day needs for conservation of natural resources, particularly soil and water resources (Sanjay-Swami, 2019a).

The following sections deal with some important ecosystem approaches/traditional practices followed in the North Eastern Region along with recent innovations to make agriculture more efficient, more sustainable.

Shifting Cultivation

The agricultural system, which is characterized by a rotation of fields rather than of crops, by short period of cropping (one to three years) alternating with long fallow periods (up to 20 or more years, but often as short as 6-8 years) and clearing of forest by means of slash and burn is known as “slash and burn” agriculture or shifting cultivation or *jhum*. This system involves cultivation of crops on steep slopes. Land is cleared by cutting of forests, bushes, etc. up to the stump level during December-January months leaving the cut plant materials for drying and final burning to make the land ready for sowing of seeds of different crops before the onset of rains. Upland rice is the main crop grown in mixtures with maize, finger millet, foxtail millet, beans, tapioca, yam, banana, sweet potato, ginger, chilies, sesame and vegetables. All these crops are grown as rainfed without tilling the land. Harvesting starts from August onwards. Maize and cucurbits are first available for consumption. Rice harvesting starts with maturity of panicles, which are picked up in time, leaving behind stubbles in the *jhum* field to decompose. The *jhum* practice has an in-built mechanism of sustenance, conservation and renewable system of resource management (Sanjay-Swami, 2018).

Traditionally, *jhum* cultivation was productive and sustainable. However, over the past four decades, due to increasing human population, the *jhuming* cycle in the same land, which extended to 20-30 years in older days, has now been reduced to 3-6 years (Sanjay-Swami, 2018). Deforestation and biomass burning in *jhum* aggravate soil erosion and ecosystem degradation. Annual soil erosion on steep slopes (44-53%) under shifting cultivation can be as much as 40.9 Mg/ha along with attendant losses (in kg/ha) of 702.9 of soil organic carbon (SOC), 63.5 of phosphorus (P) and 5.9 of potassium (K). Soil erosion, during the 1^{st} and 2^{nd} years on the abandoned land has been estimated at 147, 170, and 30 Mg/ha, respectively (Saha, Mishra and Khan, 2011). Similar observation was also made by Ray *et al.* (2020) who reported that shifting cultivation is the primary source of livelihood for farmers in the hilly tracts of North East India. However, the *jhumias'* (farmers involved in shifting cultivation) livelihoods are at stake due to low productivity and low profit due to detrimental effects of soil erosion, loss of soil nutrients and biodiversity. Steep slopes, cultivation along the slope, with negligible nutrient replacement and high rainfall are among the major causes of land degradation in Meghalaya state. The annual soil loss and carbon content in different land use systems are presented in table 1.

Table 1: Soil loss and carbon content in different land use systems

S. No.	*Land use system*	*Soil loss (ton/ha/yr)*	*Organic carbon (%)*
1.	Shifting cultivation	30.20-170.20	1.24-2.54
2.	Agriculture	5.10-68.20	1.96-2.70
3.	Livestock based land use system	0.88-14.28	1.80-2.94
4.	Natural fallow	0.37-1.83	2.84-3.25
5.	Agri-horti-silvi-pastoral	0.38-1.22	2.01-3.22
6.	Natural forest	0.04-0.52	2.92-3.05

Source: Saha, Mishra and Khan (2011)

Figure 1: Burning of hill side for *jhum* cultivation
Source: Field trip, 2014

Figure 2: Making bunds to reduce soil loss
Source: Field trip, 2014

Figure 3: View of *jhum* field after germination
Source: Field trip, 2014

Modified Shifting Cultivation Ensuring Soil Conservation

Bun cultivation is a modification of shifting cultivation and is mostly followed in the Meghalaya plateau for last four decades. In this system, the crops are grown on a series of raised beds of 0.15-0.30 m height having 0.75-1.0 m width with almost equal width under sunken area made along the slopes, locally referred to as “Bun”. While preparing buns, biomass is burnt under the soil, and the land is abandoned after two or three years. It provides an improved production system, helps conserve soil moisture, and prevents land degradation and soil erosion. In this system, bench terraces are built on the hill slopes running across the slopes. The gap between each bun is levelled using the cut and fill method. The vertical break between each terrace is 1 meter. Such measures help in preventing erosion and retaining maximum rainwater within the slopes. It also helps in safely disposing-off the additional runoff from the slopes to the lower areas.

Bamboo Drip Irrigation System

Meghalaya is well-known for having the highest rainfall in the world with about 11,500 mm rainfall recorded annually (Sanjay-Swami, 2021). This makes Meghalaya the wettest places on Earth. Though, the state gets plenty of rainfall during the monsoon season, a well-managed irrigation system is required during the dry spell. Hill farming is subject to a number of serious constraints such as undulating topography, steep-slopes, poor and shallow soils (prone to erosion). Majority of the fields in the region are situated across the hilly slopes. Therefore, the water-retention capacity of the terrain is poor and bringing water from distant water sources to the fields is a big challenge for the farmers in the rural areas. Ground channeling is also impractical due to the harsh landscape. Confronted with such adverse conditions for irrigation, the traditional farmers of Meghalaya have come up with an innovative way. The farmers of the Jaintia and Khasi hills have developed unique bamboo drip irrigation system of trapping springs and stream water

Grassroots Journal of Natural Resources, Vol.4, No.2 (June 2021), pp.136-150 | ISSN 2581-6853 | CODEN GJNRA9
Doi: https://doi.org/10.33002/nr2581.6853.040210 OPEN ACCESS Freely available online

normally to irrigate the betel leaf or black pepper crops planted in areca nut orchards or in mixed orchards (Sanjay-Swami, 2021).

Figure 4: Buns ready for sowing
Source: Field trip, 2019

Figure 5: Vegetable cultivation on buns
Source: Field trip, 2019

Figure 6: Larger view of bun cultivation
Source: Field trip, 2019

The bamboo drip irrigation system is based on gravity and the steep slopes that facilitate in implementing it. Water from an uphill source is trapped and brought to the plantation by a main bamboo channel. Usually, these water sources are far off from the plantations and the main bamboo channel runs hundreds of meters - in some cases even few kilometers. The water is then regulated through a complex bamboo network of secondary and tertiary channels to all the parts and corners of a plantation, right up to the bottom of the hill.

Bamboos of varying diameters are used to build the channels, support structures, diversion pipes and strips. Channels are held above the ground by bamboo or wooden *Y* shaped sticks. About a third of the outer casing in length and internodes of bamboo pieces have to be removed while fabricating the system. One stretch of channel is lashed to another by thin bamboo strips. Indigenous tools like a *dao*, a type of local axe, and chisels of various shapes and design are used to build the bamboo network. Two labourers can construct a network covering 1 hectare of land in 15 days. They are built with such skill that water wastage by leakage is minimal. The construction is based on a simple thumb rule that the ratio of diameter of primary channel to tertiary channel determines the quantity of water which will reach the trees. It is a subtle skill that comes with years of observation and experience. It is so perfect that about 18-20 litres of water entering the bamboo pipe system per minute gets transported over several hundred metres and finally gets reduced to 20-80 drops per minute at the site of the plant (Sanjay-Swami, 2021).

The cost involved in building the system is minimal. Bamboo is available freely in this region. Usually, the farmer himself sets up the system in his plantation with some help from 1 or 2 labourers (Sanjay-Swami, 2021). The region gets heavy rain and, as a result, each installation lasts for about 2-3 years. After the rainy season the undergrowth is cleared, and reinforcements are provided. Old bamboo is left to rot, which, over the time, returns to the soil as humus. Cooperatives are formed and each farmer provides his skill and labour to build and maintain the system. The distribution of water from one plantation to another is done by diverting water at fixed timings. This avoids the occurrence of conflicts between various farmers. By this method, the whole community works harmoniously sharing the limited resources judiciously (Sanjay-Swami, 2019b).

Grassroots Journal of Natural Resources, Vol.4, No.2 (June 2021), pp.136-150 | ISSN 2581-6853 | CODEN GJNRA9
Doi: https://doi.org/10.33002/nr2581.6853.040210 OPEN ACCESS Freely available online

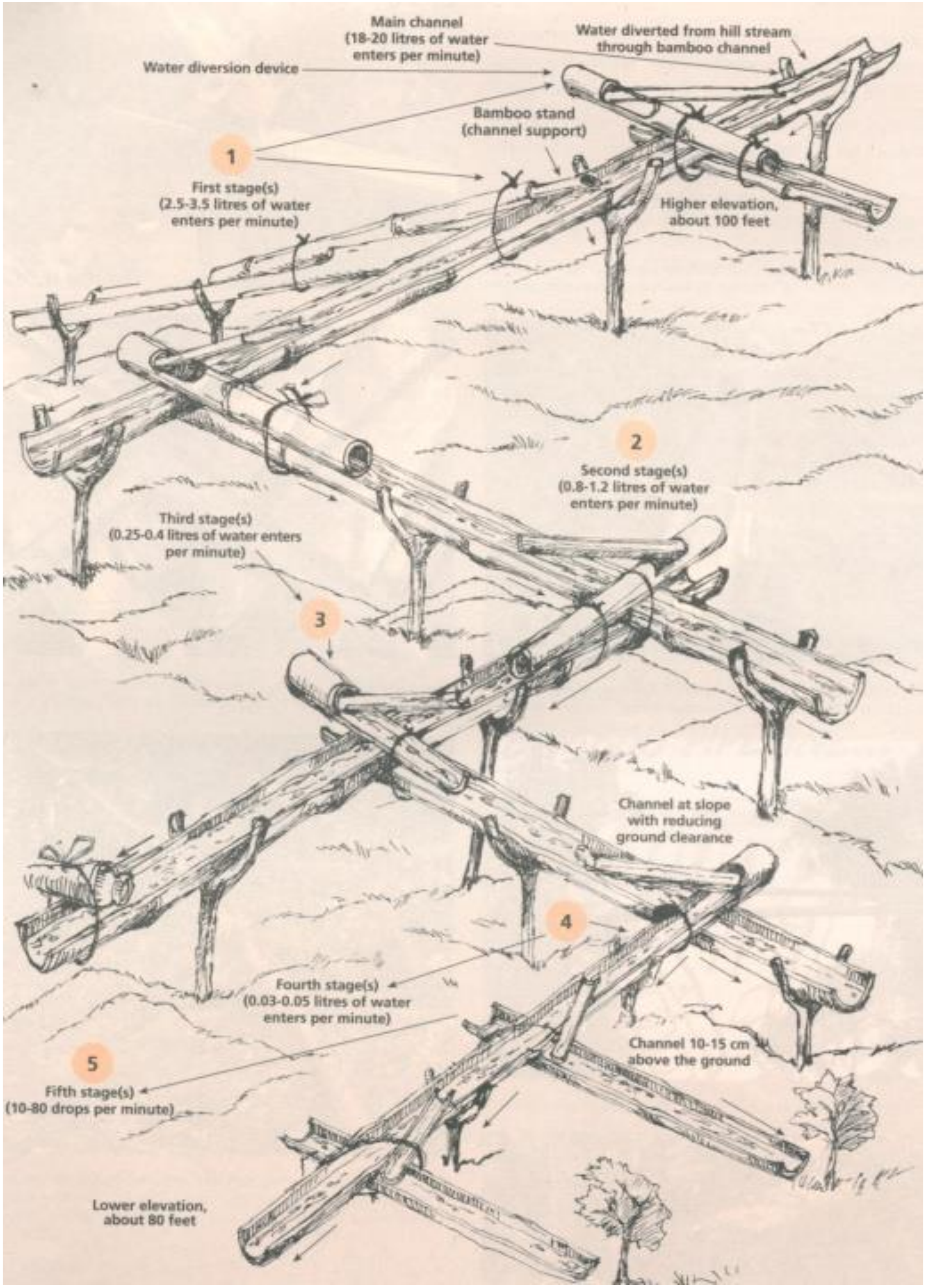

Figure 7: Different stages of water distribution in bamboo drip irrigation system. *Source:* CSE (2021)

Modified Bamboo Drip Irrigation System

The bamboo drip irrigation system, traditionally used for irrigating plantation crops from stream water, has been further refined and modified to increase water use efficiency and to irrigate field crops apart from plantation crops. Since the region faces lot of water scarcity during dry period, and as most of the crops are cultivated on upland topography, water harvesting tanks (*Jalkunds)* at the top of the hills can be the solution for water scarcity (Sanjay-Swami, 2019b). During wet period, water can be collected by making small ponds or tanks and can be saved for dry spell. Since water in bamboo drip irrigation is actually conveyed from higher elevation to the downstream with the help of gravity up to plantation crops, water harvesting tank should also be constructed at the top of the hills or above the cultivated crops so that water can easily be transported through bamboo.

Bamboos are laid down from the water source, which is the mainline, and from there lateral line bamboos are connected. Bamboos are laid just above the properly spaced crop plants. Bamboo has a hole above the plant so that water can just drip on the particular plant only. The height of bamboo placed above the plant should be enough for the farmers to move under it for inter-culture operations like manual weeding. The end of the mainline should be closed. Holes in the mainline convey the water to the laterals. The laterals also consist of small holes just above the individual plant to drip water. For efficient utilization of water, tying of some woolen thread with the cap in the holes of the laterals is also recommended to manage the speed of drip or to irrigate only the desired crop area. If the wetting is completed, it can be pulled down for seizing the flow of water for its efficient utilization. In the mainline, holes can be either closed with the help

Figure 8: Modified bamboo drip irrigation system suitable for field crops. *Source:* ICAR Research Complex for NEH Region (2018)

of mud or thread just like in the laterals for seizing the flow with respect to particular plant. It leads to better utilization of rainwater which would have been washed out if not harvested during rainy season. It has also been observed that about 25-30% water can be saved by modified bamboo drip irrigation followed by straw mulching, although it is cost effective only for cash crops like potato, capsicum, tomato, strawberry, etc., which are grown with definite spacing (Sanjay-Swami, 2019b).

Rice-Fish System of Apatani Plateau

It is a multipurpose water management system, which integrates land, water and farming system by protecting soil erosion, conserving water for irrigation and paddy-cum-fish culture. It has been practiced in a flat land of about 30 km^2 located at an altitude of about 1,525 m above m.s.l. in the humid tropic climate of Lower Subansiri district of Arunachal Pradesh. Local tribe "Apatani" who developed this system dominates the area; every stream rising from the hill is trapped soon after it emerges from forest, canalized at the rim of valley and diverted by network of primary, secondary and tertiary channels. The first diversion from the stream takes off at a short distance above the terraces. Central irrigation channel of 0.61 x 0.61 m size and embankment of the same size in each of the paddy plots are constructed. The water into the plots is drawn from irrigation channel and has a check gate made of bamboo splits (huburs) at the inlet for regulation of entry and exit of water through the outlet. The farmers drawn off the water from the rice fields twice, once during flowering and finally at maturity on an average 10 cm water level is maintained in the plots by adjusting the height of outlet pipes. For fish culture, a vertical pit is dug in the middle of the plot, so that the water remains in these pits even when it drains away from the surrounding fields. To prevent trashes or migration of fish, a semicircular wooden/bamboo net is installed at the inlet to reduce beating action of flowing water regulating in soil erosion; wooden strikes or planks are put at the outlet. The huburs are installed about 15 cm x 25 cm above the bed level. They are made of plank or pine tree trunk or bamboo stem of different diameters. The water from terraces is finally drained into the river, which flows in the middle of valley.

Figure 9: Rice-fish system of Apatani plateau

ZABO System of Farming

"Zabo" is an Indigenous farming system of Nagaland state. This system has its origin in Kirkuma village of Phek district of Nagaland, located at an altitude of 1,270 m above m.s.l. The word "Zabo" means impounding of water. It has a combination of forest, agriculture and animal husbandry with well-founded soil and water conservation base. It has protected forest land towards the top of hill, water harvesting tanks in the middle and cattle yard and paddy fields for storage for the crops as well as for irrigation during the crop period. Special techniques for seepage control in the paddy plots are followed. Paddy husk is used on shoulder bunds and puddling is done thoroughly.

Alder Based Farming

In some pockets of Nagaland, the farmers use *Alnus nepalensis* (alder) tree for agriculture. In this system, the alder seedlings are planted on the sloppy land intended for cultivation and the alder grows fast till it attains 6-10 years age. At this stage, initially the trees are pollarded, the leaves and twigs are burnt, and ash is mixed with soil to prepare it for raising crops. Subsequently, pollarding is done once every 4-6 years. Under this process, coppice is cut except 5-6 on top of the main trunk and crop schedule is followed including fallow period of 2-4 years. The bigger branches stripped of leaves are used for firewood, while the root of the tree develops nodules (colonies of *Frankia*) increasing the fertility of soil. Spreading nature of the roots helps in preventing soil erosion on slopes. Nitrogen fixation in *Alnus nepalensis* takes place through a symbiotic relationship between *Alnus* with nitrogen fixing actinomycetes of the genus *Frankia* and is, therefore, able to improve degraded *jhum* lands. The symbiotic microorganism *Frankia* (actinomycetes) is located in specialized structures, or nodules, along the root system of the host plants. The root nodules are analogous to those induced by *Rhizobium* in legumes, and they provide an environment where *Frankia* can grow and prosper, while providing the host plant with fixed atmospheric nitrogen. Unlike

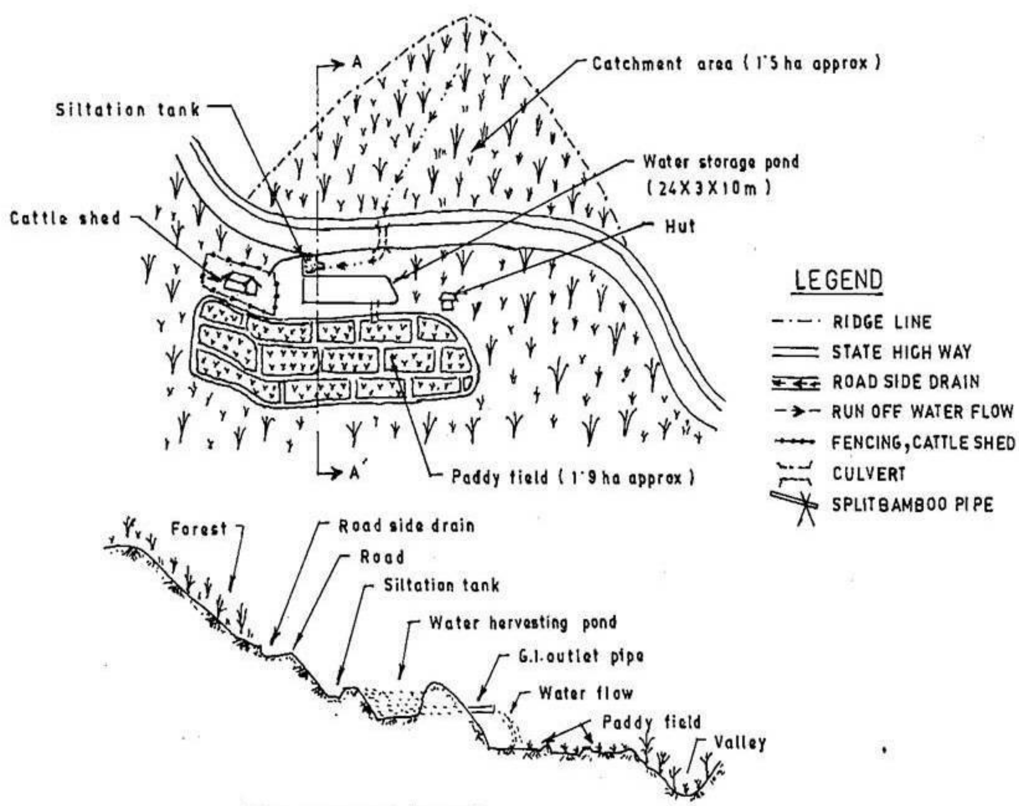

Figure 10: Land management under Zabo farming system. *Source:* Sanjay-Swami *et al.* (2021)

the *Rhizobium*-legume symbiosis, where most of the host plants belong to a single large family, *Frankia* can form root nodules in symbiosis with actinorhizal plants. The ability of the alder trees to develop and retain fertility of the soil has been fully utilized by farmers in Angami, Chakhesang, Chang, Yimchunger and Konyak area in Nagaland at varying altitudes.

Organic Cultivation

The concept of organic cultivation/farming builds on the idea of efficient use of locally available resources as well as the usage of adapted technologies e.g., soil fertility management, closing of nutrient cycles as far as possible, control of pests and diseases through management and natural antagonists. It is based on a system-oriented approach and can be a promising option for sustainable agricultural intensification, as it may offer several potential benefits such as: (i) a greater yield stability, especially in risk-prone tropical ecosystems, (ii) higher yields and incomes in traditional farming systems, once they are improved and the adapted technologies are introduced, (iii) an improved soil fertility and long-term sustainability of farming systems, (iv) a reduced dependence of farmers on external inputs, (v) the restoration of degraded or abandoned land, (vi) the access to attractive markets through certified products, and (vii) new partnerships within the whole value chain, as well as a strengthened self-confidence and autonomy of farmers.


Figure 11: Alder based farming in *Jhum* land


Figure 12: Field after crop harvest


Figure 13: Pollarding of alder tree

The organic farming is based on following four basic principles:

Principle of Health: Organic agriculture should sustain and enhance the health of soil, plant, animal and human as one and indivisible entity.
Principle of Ecology: Organic agriculture should be based on living ecological systems and cycles, work with them, emulate them and help sustain them.
Principle of Fairness: Organic agriculture should build on relationships that ensure fairness regarding the common environment and life opportunities.
Principle of Care: Organic agriculture should be managed in a precautionary and responsible manner to protect the health and well-being of current and future generations and the environment.

These basic principles provide organic farming with a platform for ensuring the health of environment for sustainable development, even though the sustainable development of mankind is not directly specified in the principles (Sowmya, 2014).

The NER has much strength for organic farming. The region is home to many niche crops like large cardamom, ginger, turmeric, Assam lemon, Joha rice, medicinal rice, Naga chilly (Bhoot Jolkiya), areca nut and passion fruit with high market demands. Farmers can fetch premium prices for organic produce along with conserving local crops, which are common for farmers in their localities as local crops are more resistance to biotic and abiotic stresses (Sanjay-Swami, 2017). Sikkim has become the first state in India to go fully organic in terms of production and consumption of food. The changeover is already apparent in local markets where organic produce seems to be trumping non-organic. Approximately, 75,000 acres of chemically fertilized farmland have been converted to organic farming in Sikkim state. NER is the fourth largest producer of oranges in India. Best quality ginger (low fibre content) is produced in this region and an Agri-Export Zone (AEZ) for ginger is established in Sikkim. Sikkim is the largest producer of large cardamom (54 percent share) in the world.

Meghalaya, being organic by default, provides an ample scope for expanding and exploiting the potential for this sector in right direction. The new policy of the state government also aims at building brand Organic Meghalaya, which will produce organic certified food and products, link organic food to ecotourism, cleaner and greener environment through lower carbon regime and build consumer awareness and demand for safe and healthy food. Meghalaya Department of Agriculture has successfully initiated pilots during 2010, which began with tea and, thereafter, cauliflower in Ri-Bhoi and East Khasi Hills district. "MEG" Tea is presently marketed as Organic Certified Tea and is available in three variants - Green, Oolong and Black Tea. All the organic tea variants are USDA and NPOP certified, which were certified by M/s Control Union India. In Garo Hills, organic certification of pineapple and cashew nut are ongoing and are presently in C_1 and C_2 stage (*Shabong*, 2015).

Organic farming, without doubt, is one of the fastest growing sectors of agriculture production in Meghalaya. The Meghalaya state aims to convert at least 200,000 hectares into organic farmland by 2020 (*Shabong*, 2015). The process to convert a portion of agricultural land to become fit for organic cultivation takes at least three years. The agricultural land is being selected area wise to be converted into organic farmland, and the land is put under observation for three years. After the third-year conversion period, the land is certified as fit for organic farming or not. So far 1,410 hectares of agricultural land have been certified for organic farming in the Meghalaya. The agricultural land, in which some crops have been organically cultivated, includes 150 hectares for tea plantation, 380 hectares for cashew nut and 80 hectares for turmeric. The process to convert around 16 hectares land under ginger cultivation has entered its second year (Sanjay-Swami, 2019b).

Biochar for Soil Acidity Management

Approximately, 84 per cent of the soils in the North Eastern Hill (NEH) region of India are acidic having low available phosphorus (P) and zinc (Zn) and toxicity of iron and aluminum (Lyngdoh and Sanjay-Swami, 2018). To overcome the problem of soil acidity, farmers adopt variety of soil amendments like ash, manures, lime, compost and bio-sorbents. Although, liming is good practice to overcome the soil acidity problem, yet the latest, cheap and good organic source is biochar as the availability of biomass is much more in NEH region (Yadav and Sanjay-Swami, 2018). The usefulness of biochar increases when it is applied in combination with organic manures like farm yard manure (FYM), vermicompost, poultry manure, pig manure, etc. (Yadav and Sanjay-Swami, 2019).

Meghalaya is known for a large array of vegetables, both sub-tropical and temperate. Tomato (*Lycopersicon esculentum* Mill.) is one of the most important vegetable crops supporting the livelihood of many vegetable growers. Hence, for optimization of biochar dose with vermicompost and recommended dose of fertilizers to maximize the yield of tomato in acid soil, a field experiment was conducted at School of Natural Resource Management, College of Postgraduate Studies in Agricultural Sciences, Umiam, Meghalaya during winter season of 2017. Tomato cv. Megha tomato-2 was used as test crop with three doses of biochar (B) @ 2, 3 and 4 t/ha, vermicompost (VC) @ 2.5 t/ha and two graded recommended doses of NPK fertilizers (RDF) @ 75 and 100%. Sixteen combination of treatments as T_1 - Control, T_2 - B @ 2 t/ha, T_3 - B @ 3 t/ha, T_4 - B @ 4 t/ha, T_5 - 75% RDF + B @ 2 t/ha, T_6 - 75% RDF + B @ 3 t/ha, T_7 - 75% RDF + B @ 4 t/ha, T_8 - 75%

RDF + B @ 2 t/ha + VC @ 2.5 t/ha, T_9 - 75% RDF + B @ 3 t/ha + VC @ 2.5 t/ha, T_{10} -75% RDF + B @ 4 t/ha + VC @ 2.5 t/ha, T_{11} - 100% RDF + B @ 2 t/ha, T_{12} - 100% RDF + B @ 3 t/ha, T_{13} - 100% RDF + B @ 4 t/ha, T_{14} - 100% RDF + B @ 2 t/ha + VC @ 2.5 t/ha, T_{15} - 100% RDF + B @ 3 t/ha + VC @ 2.5 t/ha, T_{16} - 100% RDF + B @ 4 t/ha+ VC @ 2.5 t/ha were tested. The trial was laid out in RBD and replicated thrice. The results indicated that plant height, number of fruits/plant, fruit size and fruit yield of tomato was superior with the application of biochar @ 4 t/ha with vermicompost @ 2.5 t/ha and 100% RDF and the soil pH also improved significantly over control. Hence, the combined application of biochar @ 4 t/ha with vermicompost @ 2.5 t/ha and 100% RDF may be recommended for Meghalaya farmers to enhance tomato productivity coupled with managing their acidic soils (Sanjay-Swami *et al.*, 2018).

Figure 14: Biochar
Source: ICAR Research Complex for NEH Region, 2017

Figure 15: Application of biochar in experimental field
Source: Experimental Plot, 2017

Figure 16: Mixing of biochar in soil for managing acidity problem
Source: Experimental Plot, 2017

Figure17: Experimental plots with different treatments
Source: Experimental Plot, 2018

Figure 18: Fruiting stage of tomato
Source: Experimental Plot, 2018

Das *et al.* (2012) also attempted to document the various indigenous techniques of soil and water conservation in the North-eastern region of India linked with traditional farming practices like Alder (*Alnus nepalensis*) based farming system, *Zabo* farming, *Panikheti* in hills and pond based farming system in plains of the region developed by local farmers using their ingenuity and skills over the centuries and reported that some components of these farming systems have good scientific base for resource conservation like nutrient cycling through *in situ* residue management, green leaf manuring, soil and water conservation and maintenance of forestry whereas there are few components like burning of biomass in *jhuming* needs a relook.

Conclusion

The future farming must be multifunctional and, at the same time, ecologically, economically and socially sustainable so that it can deliver ecosystem goods and services as well as livelihoods to producers and society. The environment, local conditions, socio-economic and socio-cultural life of different tribal communities of the North Eastern Region of India, and their rituals associated with agricultural practices have developed many Indigenous farming systems, which have in-built eco-friendly systems for conservation, preservation and utilization of natural resources. Shifting cultivation or *jhum*, bun cultivation, bamboo drip irrigation system, modified bamboo drip irrigation system, rice-fish system of Apatani tribe**,** ZABO system of farming in Nagaland, alder-based farming**,** organic cultivation, and use of ash, manure, composts, biochar, etc. for managing soil acidity are just some of the hundreds of traditional eco-friendly practices performed by the farmers of North Eastern Region. The uniqueness of these practices is their suitability to the local conditions, their economic feasibility and easy implementation.

References

CSE (2021). Bamboo drip irrigation. Centre for Science and Environment, India. Available online: https://www.cseindia.org/bamboo-drip-irrigation-2839 [Accessed 22 March 2021]

Das, A., Ramkrushna, G.I., Choudhury, B.U., Munda, G.C., Patel, D.P., Ngachan, S.V., Ghosh, P.K., Tripathi, A.K., Das, S. and Kumar, M. (2012). Natural resource conservation through indigenous farming systems: Wisdom alive in North East India. *Indian Journal of Traditional Knowledge*, 11(3): 505-513. Available online: http://nopr.niscair.res.in/handle/123456789/14393 [Accessed on 27 May 2021]

Kassam, A. and Friedrich, T. (2012). An ecologically sustainable approach to agricultural production intensification: Global perspectives and developments. *Field Actions Science Reports (Facts Reports): The Journal of Field Actions*, Special Issue 6: 01-06. Available online: http://journals.openedition.org/factsreports/1382. [Accessed 22 March 2021]

Lyngdoh, E.A.S. and Sanjay-Swami (2018). Phytoremediation effect on heavy metal polluted soils of Jaintia Hills in North Eastern Hill Region. *International Journal of Current Microbiology and Applied Sciences*, 7(11): 1734-1743. DOI: https://doi.org/10.20546/ijcmas.2018.711.199.

Ray, S.K., Chatterjee, D., Rajkhowa, D.J., Baishya, S.K., Hazarika, S. and Paul, S. (2020). Effects of integrated farming system and rainwater harvesting on livelihood improvement in North-Eastern region of India compared to traditional shifting cultivation: Evidence from an action research. *Agroforestry Systems*, 94: 451-464. DOI: https://doi.org/10.1007/s10457-019-00406-3.

Saha, R., Mishra, V.K. and Khan, S.K. (2011). Soil erodibility characteristics under modified land-use systems as against shifting cultivation in hilly ecosystems of Meghalaya, India. *Journal of Sustainable Forestry*, 30(4): 301-312. DOI: https://doi.org/10.1080/10549811.2011.531992.

Sanjay-Swami (2017). Organic farming: A way towards maintaining soil health, improving crop productivity and livelihood security of tribals in NE India. In: *Enhancing Socio-economic Status and Livelihood Security of Tribal Farmers of Meghalaya*, (Eds.) Ram Singh, N.S. Azad Thakur, K. Noren Singh, Rajkumar Josmee Singh, L. Devarani and Kennedy N., CPGS, CAU, Barapani, pp. 33-40.

Sanjay-Swami (2017). Organic farming: An eco-friendly approach for sustainable agriculture. *CAU Farm Magazine*, 7(2): 30-37.

Sanjay-Swami (2018). Shifting cultivation: A tribal way of life in North East India and alternative approaches for increasing productivity. *The Pharma Innovation Journal*, 7(3): 380-385. Available online: https://www.thepharmajournal.com/archives/2018/vol7issue3/PartF/7-3-34-826.pdf [Accessed on 25 May 2021]

Sanjay-Swami (2019a). Managing fragile hill ecosystems of North Eastern Region. *Soil and Water Conservation Today*, 14(1): 02.

Sanjay-Swami (2019b). Ecosystem approach to make agriculture more efficient, more sustainable in Meghalaya. *Souvenir, CAU Regional Agri-Fair 2019-20*, November 11-13, 2019: 52-57.

Sanjay-Swami (2021). Bamboo drip irrigation: Traditional way of irrigating crops in Meghalaya. *Just Agriculture: e-Magazine*, 01 (8): 18-21.

Sanjay-Swami, Singh, S., Patgiri, P., Raj, V.A. and Singh, T.D. (2021). Ecological sustainability in agricultural production intensification: NER perspective. In: *Sustainable Agriculture: Recent Advances*, (eds.) Sanjay-Swami and Singh, S. New Delhi, India: Biotech Books, pp. 1-20.

Sanjay-Swami, Yadav, O.S. and Gurjar, G.N. (2018). Use of biochar for increasing carbon sequestration in soil. In: *Souvenir*, 27th National Conference of SCSI on "Sustainable Management of Soil and Water Resources for Doubling Farmers' Income" (eds.) Bipul Deka *et al.*, October 25-27, 2018, Assam Chapter of SCSI, AAU, Jorhat, Assam, pp. 75-77.

SCBD (2004). *The Ecosystem Approach (CBD Guidelines).* Secretariat of the Convention on Biological Diversity, Montreal, pp. 50.

Shabong, C.S. (2015). Meghalaya mission organic: Moving towards safer food. Available on: http://megagriculture.blogspot.com/2015/01/meghalaya-mission-organic-moving.html#:~:text=The%20Department%20of%20Agriculture%2C%20Meghalaya,Green%2C%20Oolong%20and%20Black%20Tea. [Accessed on 22 April 2021]

Sowmya, K.S. (2014). Organic farming: Scope in India, *Global Journal of Advanced Research*, 1(2): 101-102. Available online: https://www.researchgate.net/publication/340826171_Organic_farming_A_way_towards_maintaining_soil_health_improving_crop_productivity_and_livelihood_security_of_tribals_in_NE_India [Accessed on 25 May 2021]

Yadav, O.S. and Sanjay-Swami (2018). Utilizing bio-char potential for acid soil management. *Soil and Water Conservation Today*, 13 (4): 05-06. Available online: https://www.researchgate.net/publication/332545002_Utilizing_Bio-char_Potential_for_Acid_Soil_Management [Accessed on 25 May 2021]

Yadav, O.S. and Sanjay-Swami (2019). Performance of tomato (*Solanum lycopersicum*L.) in acid soil under integrated nutrient management with biochar as a component. *International Journal of Current Microbiology and Applied Sciences,* 8(05): 793-803. DOI: https://doi.org/10.20546/ijcmas.2019.805.094

.

Author's Declarations and Essential Ethical Compliances

Author's Contributions (in accordance with ICMJE criteria for authorship)
This article is 100% contributed by the sole author. He conceived and designed the research or analysis, collected the data, contributed to data analysis & interpretation, wrote the article, performed critical revision of the article/paper, edited the article, and supervised and administered the field work.

Funding
No funding was available for the research conducted for and writing of this paper.

Research involving human bodies (Helsinki Declaration)
Has this research used human subjects for experimentation? No

Research involving animals (ARRIVE Checklist)
Has this research involved animal subjects for experimentation? No

Research involving Plants
During the research, the author followed the principles of the Convention on Biological Diversity and the Convention on the Trade in Endangered Species of Wild Fauna and Flora.

Research on Indigenous Peoples and/or Traditional Knowledge
Has this research involved Indigenous Peoples as participants or respondents? No

PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses)
Has author complied with PRISMA standards? No

Competing Interests/Conflict of Interest
Author has no competing financial, professional, or personal interests from other parties or in publishing this manuscript.

Rights and Permissions