# Agro-biodiversity and natural resource management in traditional agricultural systems of northeast India


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## Abstract

Physiographically, the North-eastern region of India can be categorized as the Indian Eastern Himalaya covering about 52% of the total Eastern Himalayas. The Eastern Himalaya is recognized as a 'Centre of Plant Biodiversity'; 'Eastern Asiatic Regional Centre for Endemism' and also comprises one of the 'global biodiversity hotspots'. Moreover, the region is culturally diverse with over 39 million people and over a hundred culturally-distinct ethnic communities. Rain-fed agriculture is the main livelihood source supplemented by gathering of wild edible fruits and vegetables form nearby forests and farm fallows. The traditional ecological knowledge (TEK) associated with these practices is preserved in the form of stories, songs, folklore, proverbs, beliefs, rituals, community laws, local languages and other forms of oral traditions.

Traditional agriculture in NE India follows mixed cropping pattern through multi-cropping, crop rotation, use of multipurpose N-fixing trees, along with protection of semi-domesticated and wild biodiversity, including medicinal plants, wild edible fruits and vegetables, fodder plants and other useful species. Presently, there has been a gradual shifting from subsistence cultivation to commercial agriculture driven by market forces and modernization, leading to transition from traditional agriculture to mono-culture plantations of cash crops. This has resulted in reduced cultivation of local crop varieties and disappearance of the associated TEK. Therefore, the present study attempts to review contribution of traditional agricultural practices to agro-diversity conservation and sustainable natural resource management. Relevant traditional practices such as shifting (*Jhum*) cultivation systems, bamboo-drip irrigation, paddy-cum-fish cultivation, traditional agroforestry systems of different indigenous communities residing in different states of NE India were mentioned in this review. It is undeniable that TEK was developed by communities through many centuries by trial and error methods to conform to the local climate, topography, ecology and socio-cultural relevance to the concerned indigenous community. This knowledge, therefore, has a great scope for improvement by integration with scientific knowledge for transforming into sustainable agricultural systems in the face of climate change adaptation and mitigation of the vulnerable mountain communities of the Himalayan region.



**Key words:** Indigenous communities; Agriculture; Traditional knowledge; Sustainable farming

## 1. Introduction

Agricultural biodiversity or agrobiodiversity constitutes the biodiversity components that contribute to food and agriculture, which includes genetic resources of crops and livestock as well as of other plants, animals, microorganisms, sustaining the structure and functions of the agro ecosystems. Agrobiodiversity contributes to agricultural productivity and food security as well as stability of farming systems by reducing pressure of agriculture on fragile areas, forests and endangered species. Maintaining high agrodiversity can offer different kinds of benefits including goods of direct usefulness to the people, i.e., flora and fauna as well as goods which may not be useful at present but may prove to be useful in future, e.g., traditional crops and wild varieties of grains that may serve as sources of genes for desirable characters in crops. Another benefit of high agrodiversity is the heritage value that some floral and faunal elements may have, that even though they may not be directly useful to people yet the present generation would like to preserve for posterity.

Traditional agriculture (TA) has been known to be a storehouse of rich biodiversity including agrobiodiversity. Different TA practices has been developed over many centuries by different rural communities or indigenous communities by taking cognizance of the local biodiversity, topography, climate and socio-cultural set up. In these agroecosystems, farmers employed numerous practices for utilization, enhancement and conservation of the biodiversity in their traditional farming systems. Till today, we can find many of these practices being employed such as use of particular species for pest control, agroforestry systems and conservation of semi-domesticated and wild useful plants into farming systems. In TA systems, traditional varieties and landraces are maintained in their natural surroundings, thus enhancing more diversity in production systems which is conducive to sustainable agricultural development. Such practices are a basis of survival and livelihood for millions of people. The importance of TA systems in maintaining agrodiversity and natural resource management has been highlighted in several studies. Armitage (2003) identified that maintaining traditional agroecological systems and the associated adaptive resource management strategies used by local groups is one of the opportunities to enhance conservation. Coeto et al (2019) indicated the higher ecological and cultural resilience of agroecosystems of Mexico were higher when there is sufficient transmission of the biocultural legacy from the ancestors and the attachment of peasant families to it. Similarly, in the Indian Himalayan Region (IHR) Chandra, et al (2020) suggested that agorecosystems with traditional crops are more ecologically and economically viable and important for food security, thus contributing to long-term sustainability of agroecosystems and conservation and management of the surrounding landscape. Anthropological and ecological research conducted on traditional agriculture showed that most indigenous modes of production exhibit a strong ecological basis, and contribute towards the regeneration and preservation of natural resources (Denevan 2001).

The North-eastern region of India (Fig. 1) forms the Indian part of the Eastern Himalayas covering about 52% of the total area of Eastern Himalayas. It comprises the Himalayan and Indo-Burman global biodiversity hotspots. The convergence of the Indo-Malayan and Palearctic biogeographical realms in the landscape has resulted in rich flora and fauna (CEPF 2005, 2007; Hua 2012). It is also recognised as a 'Centre of Plant Biodiversity'; 'Eastern Asiatic Regional Centre for Endemism' (Wikramanayake 2002). The region has been identified by the Indian Council of Agricultural Research (ICAR) as a centre of rice germplasm and ICAR-National Bureau of Plant Genetic Resources (NBPGR) has highlighted the region as being 'rich in wild relatives of crop plants. Moreover, the region is culturally diverse with over 39 million people and over a hundred culturally-distinct ethnic communities. Rain-fed agriculture is the main livelihood source of these communities supplemented by gathering of wild edible fruits and vegetables from nearby forests and farm fallows. The traditional ecological knowledge (TEK) associated with these practices is preserved in the form of stories, songs, folklore, proverbs, beliefs, rituals, community laws, local languages and other forms of oral traditions. With the advent of modernization and rush towards a cash economy, a large number of TA systems have been converted to monoculture cultivation and cash crop plantations. Moreover, traditional crops including local varieties of grains and vegetables are being slowly replaced by high yielding varieties leading to gradual disappearance of many indigenous crops. From the above review of literature, it is clear that TA has the potential to contribute towards sustainability and resilience of ecosystems as well as in regeneration and conservation of natural resources. Therefore, the present study attempts to highlight the richness of agrodiversity in traditional ecosystems in northeast India and their role in conservation and management of natural resources. The traditional ecological knowledge involved in TAs has a great scope for improvement by integration with scientific knowledge to develop sustainable agriculture especially for the climate change adaptation and mitigation of the vulnerable mountain communities of the Himalayan region.

## 2. Traditional agricultural systems

### 2.1. Shifting (*Jhum*) cultivation systems

Shifting cultivation or slash and burn agriculture is the most prevalent form of agricultural practice of the ethnic people, and is one of the most ancient systems of farming believed to have originated in the Neolithic period around 7000 B.C. It was estimated that about 350,000 people practice shifting cultivation on about 4,160 km² of unsurveyed land. A wide variety of land is use for shifting cultivation and the important feature being that the land is cleared and agricultural crops are grown for a limited period, which may range from one to over ten years, after which the cultivation is moved to a new site. The cultivated site is left fallow for a certain number of years to allow regrowth of vegetation. After the fallow period is over, the area is again cleared and cultivation is resumed. Therefore shifting cultivation involves rotation of fields rather than rotation of crops. In northeast India, shifting cultivation, popularly known as *Jhum* is prevalent in the states of Arunachal Pradesh, Nagaland, Manipur, Meghalaya, Tripura and hill districts of Assam (Fig. 2).

#### 2.1.1. Agrodiversity of Shifting cultivation systems

Jhum cultivation systems follow multi-cropping pattern with minimum tillage. Paddy, maize and millets are the major crops grown along with pulses, colocasias, pumpkin, cucumber, and other food crops (Dollo et.al 2005). In Nagaland, the alder-based Jhum cultivation is well-known. In this system the N-fixing *Alnus nepalensis* trees are maintained in the jhum plots and pollarded at 2-3 m above the ground level. The lopped branches and leaves are burned on the field after which the soil prepared for cultivation. The major crops/vegetables grown are potato, tomato, chilli, cabbage, cauliflower, squash, cucumber, ginger, French bean, soybean, pea, millets (Job's tear) and maize In the jhum cultivation of the Nocte and Wancho tribes of Arunachal Pradesh a total of 60 species of crop plants were reported belonging to 25 families, the maximum number of crops being from the families Cucurbitaceae, Poaceae, Solanaceae, Apiaceae and Dioscoreaceae (Bhuyan & Teyang 2015). Similarly other studies have recorded high diversity of crop plants in the Jhum systems of different communities of Northeast India ranging from 22 to 39 crop species (Bhuyan et al. 2012; Tangjang 2009; Asata & Yadav 2014; Dikshit & Dikshit 2004).

Besides crop diversity, Jhum fallows also serve as a habitat for wildlife as well as wild useful species such as medicinal plants, wild edible plants, fodder plants and the like. Studies in and around the Dampa Reserve Forest in Mizoram revealed that the diversity of bird species in Jhum sites were more similar to rainforest than were monocultures. Mandal & Raman (2016) argued that rapid recovery of dense and diverse secondary bamboo forests during fallow periods makes the shifting agricultural landscape mosaic a better form of land use for bird conservation than monocultures.

### 2.1.2. Resource management in shifting cultivation systems

In Alder-based jhum cultivation of Nagaland, the alder trees were not cut completely but managed in the jhum field for several years. These actinirhizal N-fixing trees enrich the soil with nitrogen, thus maintaining fertility of the soil during ongoing cultivation as well as in the fallow period. Studies have found that these soils were rich in nutrients and harbour very high active microbial populations making the soil more productive (Giri et al 2018). Besides, the trees are also multipurpose, the pollarded branches being used for timber and fuel while the fallen leaves enrich the soil with organic matter and helps in recovery of soil during the fallow period.

Another practice of soil resource management in jhum fields is known as *Echo*, which is an indigenous technical practice of soil erosion control practiced by farmers in Wokha district of Nagaland (Fig. 2). Soil erosion problems cause due to jhum cultivation could be solved through mechanical measures, but the cost will be very high. *Echo* consists of short bamboo barricades strategically placed horizontally across the slope in jhum fields to reduce run-off and check soil erosion. The structure generally last up to 3 years or sometimes up to 5 years. Studies carried on *Echo* with scientific method showed that it could retain soil about 229.5 t/ha/yr in the first year, about 153.0 t/ha/yr in the second year and about 91.8 t/ha/yr in the third year. *Echo* with scientific method could save vast jhum area of Wokha, Nagaland and will help to bring it to sustainable agriculture (Singh et al. 2016).

Traditional practice in shifting cultivation locally called *Paneng* is unique to Adi tribe. *Paneng* is a traditional practice of placing unburnt or half-burnt logs of wood horizontally against the slope of land to reduce surface run-off and check soil erosion. Chemical fertilizers are still not in use in the area.

## 2.2. Paddy-cum-fish cultivation

### 2.2.1. Agrodiversity in paddy-cum-fish cultivation

Paddy-cum-fish cultivation is an indigenous farming method of the Apatani tribe of Arunachal Pradesh locally known as *Aji- ngyii*, *Aji* meaning cultivation and *ngyii* meaning fish (Fig. 4). Their system of Aji cultivation, using a combination of Paddy and fish together is thought to be one of the most productive and efficient agricultural systems of the region. Along with paddy, millets were grown on the bunds of paddy field while fish-mint (*Houttuynia cordata*) is grown on lower sides of bunds. About 16 local varieties of rice and 3 millet varieties were reported grown in the wet-rice farming systems (Kala 2008; Table 1). Commonly, two species of carps were reared along with the paddy cultivation, viz., *Cyprinus caprio* (Common carp) and *Hypophthalmichthyes molitrix* (Silver carp). For fish rearing, a small pit is dug in each terrace where paddy is grown. When water supply is sufficient in monsoon season, the paddy field is kept under shallow submergence of 5 to 10 cm and fishes come out of the pits and move around the whole submerged area of the terrace field. During the period of water scarcity, when water remains only in the pits, fishes run back to the pits and grow. Fishes get better nutrition due to manuring of paddy fields and their growth is better due to availability of larger surface area during full submergence of paddy fields. In this system both paddy and fishes are produced together by proper management of rainwater (Rai, 2004).

### 2.2.2. Water resource management in paddy-cum-fish cultivation

The whole *Apatani* plateau has few small rivulets or streams on which the whole community are dependent for irrigating agricultural fields. As the community practices wet rice cultivation, they require stagnant water in their agricultural field for 4-5 months where they also rear fish (Common

carp). This has forced the community to utilize the flowing water efficiently from streams (*Killey*) and also to store the rain water. With their local wisdom they have mastered the art of channelizing the water from *Killey* and rain water to their agriculture field. The flow of stream or *Killey* is blocked at a suitable elevation with timbers and bamboo locally available and the water thus stored in barriers (*Borang*) is channelized through channels locally called *Sugang* is brought to the agriculture fields. The multiple *Sugangs* are managed and maintained by the beneficiaries of the community since ages for the purpose and are distributed to each and every agriculture field. The water thus brought to the fields are stored in each fields by the help of bunds called *Agber.* The level of water in each field is also maintained by the outlets made of bamboo pipes in each blocks at certain height. The excess water is thus drained out from each field blocks called *Jaebe-Aji* locally and are further channelized towards the final outlet which is common for the whole *Apatani* plateau.
Paddy-cum-fish cultivation is also practiced mainly in the valley area of Manipur. In this system, trenches called "Kom" with a width of around 4-5 metres (depending upon size of the paddy field) were dug in one side or the whole boundary of paddy field. This Kom is filled with water where fish farming is carried out and the middle portion of the area is left for paddy. This practice has been carried out in almost every household since time immemorial and is very effective in terms of production and economic value.

## 2.3. Traditional agroforestry system and home gardens

The Intergovernmental Panel on Climate Change (IPCC) has recognised agroforestry systems as a potential landuse for carbon sequestration as part of climate change mitigation strategies. In northeast India, agroforestry has been an integral part of traditional agriculture of the indigenous communities. Traditional agroforestry systems can be regarded as close-to-nature ecosystems providing ecosystem services similar to the forests such as the biodiversity, provision of food and fibre, water resources and its purification, climate regulation and carbon sequestration, nutrient cycling, primary production, production of oxygen, and soil formation, and recreation and the cultural services. The large cardamom based agroforestry systems of Sikkim consist of a variety of shade tree species such as *Schima wallichii, Engelhardtia acerifolia, Eurya acuminata, Leucosceptrum canum, Maesa chisia, Symplocos theifolia, Ficus nemoralis, Ficus hookeri, Nyssa sessiliflora, Osbeckia paniculata, Viburnum cordifolium, Litsaea polyantha, Macaranga pustulata, and Alnus* nepalensis, hence, supporting conservation of tree biodiversity (Sharma et al. 1994). Sharma et al (2007) studied the large cardamom based agroforestry of Sikkim and observed that these systems accelerate the nutrient cycling, increase soil fertility and productivity, reduce soil erosion, conserve biodiversity, conserve water and soil, serve as carbon sink, improves the living standards of the communities by increasing the farm incomes and also provides aesthetic values for the mountain societies. Traditional agroforestry of the Nyshi tribe of Aruanchal Pradesh were found to harbour up to 80 species of useful plants of which 47 species were food plants, 21 species medicinal and 31 species used for other purposes (Deb et al 2009). These agroforestry systems were multi-storeyed, the top canopy comprising of *Livistona jenkinsiana, Grevillea robusta,* etc., the sub-canopy is dominated by *Artocarpus heterophyllus, Mangifera indica* while the middle storey was dominated by fruit trees such as papaya, guava and citrus species. The forest floor species mainly comprise of *Ananas cosmosus* and vegetable crops. In addition to these, weedy species used as food and medicine such as *Ageratum conyzoides, Spilanthes* sp. and other Asteraceae species were reported.

In Meghalaya, important horticultural crops grown in the home gardens and agroforestry systems include orange (*Citrus reticulata),* pineapple (*Ananas comosus*), lemon (*Citrus limon*), guava (*Psidium guajava*), jack fruit (*Artocarpus heterophyllus*) and bananas (*Musa* sp.). Intercropping of arecanut (*Areca catechu* Linn.), betel leaf (*Piper betle*) and black pepper (*Piper nigrum*) are the chief commercial crops commonly found in the agroforestry systems in the southern slopes of the state. The pond-based agroforestry is a type of integrated farming system followed by the farmers in plains of Assam, Manipur, South Garo hills of Meghalaya and Tripura to meet the demands for food supply and their livelihood options. This is often a very common practice in each household of these places to have a farm pond where fruit crops like banana, arecanut, vegetable garden etc are maintained in the embankment or nearby uplands of the pond and these ponds are being used for pisciculture and during the lean season, the pond water is used for irrigation to crops and fruits and fruit trees. Most households would rear at least one animal component like cow, pig, buffalo or goat etc. Local poultry or duck is accompanied to use the resources effectively. Compost pits are made around the corner of the field and in the backyard also. The ponds are generally kept in the middle of the farm for irrigation of vegetables and fish culture. Vegetable waste from the nearby garden and home are added to the pond as feed for the fishes like grass carps. Paddy is then cultivated in the lowland areas.

The Home garden is a traditional practice found to be practiced by most of the tribes of Nagaland. The home gardens is generally located close to the house and is used for growing vegetables, fruits and other food crops required for the family. A wide variety of crops are grown throughout the year in homegardens including potato, cabbage, chilli, tomato, beans, carrot, onion, garlic etc.

### 2.4. Bamboo-drip irrigation

The Bamboo drip irrigation system is an ingenious way of irrigation by the indigenous communities residing in the southern part of Jaintia Hills of Meghalaya. This irrigation system is believed to be around 200 years old. The practice has evolved to compensate with the steep and undulating topography of the area which makes it difficult to channelize water through underground channels. This method utilizes the water from the uphill streams and springs and directs it to the fields of arecanut plantations intercropped with betel leaf vines and black pepper. Usually, water sources are distant from plantation sites and so the main bamboo channel runs several meters, sometimes even a couple of kilometres. Water is thus obtained and managed through a network of bamboo system of secondary and tertiary channels to reach each part and corners of the plantation, up to the base of the hill. The water is tapped from the upper slopes which are then diverted to various parts of the field located in the in the lower hill slopes using bamboo channels of various sizes to regulate the amount of water flow. Channel sections are made of bamboos of different diameters, to control the water flow in such a way that the water reaches the site in the lower reaches, where it is circulated without spillage. The channels are supported by forked branches. The system is so perfected that about 18-20 litres of water per minute entering the bamboo pipe system gets transported over several hundred metres and finally gets reduced to 20-80 drops per minute at the site of the plant. The advantages of using bamboo are two-fold: it prevents leakage, increasing crop yield with less water, and makes use of natural, local, and inexpensive material. As water is applied locally, leaching is reduced (fertilisers/nutrients loss is minimised). Weed growth and soil erosion is highly controlled and soil infiltration capacity is increased (Rynnga 2016).

## 3. Discussions

Though often regarded as unproductive and unsustainable, several researchers in NE India have revealed the positive role of TA practices on environment. Some studies suggested that in the shifting cultivation regime there is optimal utilization of natural resources, which is helpful for the stability and sustainability of agriculture in the mountain ecosystems (Ramakrishnan, 1992). Bhuyan & Teyang (2015) opined that Jhum cultivation of Nocte and Wancho tribe of Arunachal Pradesh is well adapted to the environment where ecological balance is maintained by mixed planting of cereals and tree crops in the same field. In Nagaland, Chase & Singh (2014) reported a decline in soil fertility following conversion of natural forests to agricultural land use. However soil fertility of Alder based Jhum fallows were similar to natural forests which implied that agricultural land use with proper tree-crop management is ideal for maintaining productivity and soil health. Bhagawati et al. (2015) studied the climate change prospects of Jhum cultivation in NE India and observed that Jhum is being practised based on traditional ecological knowledge (TEK) gained through years of association with nature. This knowledge, instead of being threat to climate or environment, can provide deeper insight into the many different aspects of sustainable development and the interrelated role of local peoples and their cultures.

Hombegowda et al. (2015) in their study in southern India concluded that depleted SOC stocks brought about by the conversion of forest to agricultural land can be recovered by converting the same land to agroforestry. Pal and Dasgupta (2014) appraised the two farming systems of shifting cultivation and wet rice-cum-fish culture of the indigenous communities of Arunachal Pradesh which also support biodiversity conservation through their practice. They suggested integration of traditional knowledge with scientific methods and innovations for better sustainability of these practices. In some instances, adoption of site-specific agro-based interventions has proved to be beneficial in augmenting productivity of major crops and livestock, thus ensuring more income, employment and food security.

Due to the growing conception that TA is a destructive, unproductive or wasteful form of land use, governments and policy makers have tried to wean away the people from this practice by ensuring better land management options through Agro-forestry, Horticulture and encouraging other non-farm activities. Mylliemngap et al (2016) observed that in some villages of upper Siang district in Arunachal Pradesh there has been gradual transition towards wet-rice cultivation/terrace rice cultivation and cultivation of Kiwi fruit and large cardamom. This transformation has posed a threat to the agrodiversity where the cultivation of local varieties of paddy and millets has reduced greatly and there is a fear that already the region is losing of some important genetic resources in the meantime. Nimasow et al (2014) studied the sustainability of horticultural practices in West Kameng district of Arunachal Pradesh and suggested working out land suitability analysis of various crops and generating awareness of climate change and its impact on the global environment among the local people. The reduction in fallow period from the traditional 15-20 years or 8-10 years to about 3-4 years in recent times has also posed a threat to the sustainability of shifting cultivation practices since the short fallow cannot allow sufficient recovery of soil and vegetation before resuming cultivation in the same plot. Bera and Namasudra (2016) reported negative impacts of shifting cultivation in Tripura such as destruction of forest, threat of biodiversity, degradation soil quality etc., which might have been aggravated due to shortened fallow periods.

## 4. Conclusion

The present review highlights the underlying essence of different traditional agricultural practices of the indigenous communities of NE India in terms of management and conservation of biodiversity and natural resources. Shifting cultivation and traditional agroforestry were found to maintain a high level of agrobiodiversity along with efficient management of soil fertility, soil erosion control and supplies variable ecosystem services. On the other hand, the practices of bamboo drip irrigation and paddy-cum fish cultivation exhibited an almost perfected and intricate system of tapping the limited water resources available in the hilly terrains of southern Meghalaya and the Apatani plateau of Arunachal Pradesh, respectively and efficiently use it to ensure adequate irrigation for agriculture crops. The loss of agrobiodiversity and its associated traditional ecological knowledge as a result of human population pressure and the transition from traditional mixed farming systems to monoculture cash crop farming resulting in decline of species diversity. Considering that TA is closely associated with tribal livelihood prospective, specific approaches could be implemented to strengthen the existing cultivation practice instead of imposing modern intervention. Therefore, urgent concerted efforts are required to promote the sustainable use and management of traditional farming systems by integration of TEK with scientific knowledge through a multi-stakeholder approach in order to make conservation efforts successful.

**Figures and Tables with Captions**


Fig. 1. Map showing the location of North-eastern region of India (mapsofindia.com)

Fig. 2. A freshly cleared and burned shifting cultivation patch in Nagaland (Photo credit: Anup K. Das)

Fig. 3. Construction of *Echo*, a traditional system of soil erosion control in shifting cultivation fields in Wokha district of Nagaland (Photo credit: Anup K. Das)

Fig. 4. Paddy-cum-fish cultivation, indigenous farming method of the Apatani tribe of Arunachal Pradesh (Photo credit: Tilling Rinya)

Fig. 5. Bamboo drip irrigation in 'war' Jaintia area of Meghalaya (Photo credit: Vandolf Kharbhih)

Table 1: Indigenous varieties of paddy and millet cultivated by Apatani of Arunachal Pradesh

| **Type** | **Variety** |
|---|---|
| **Paddy** | |
| Eamo | a) *Ampu Ahare* |
| | b) Ampu Hatte |
| | c) Radhe Eamo |
| | d) Eylang Eamo |
| | e) Ampu Puloo Hatte |
| Mipye | |
| 1. Pyate Mipye | a) Kogii Pyate |
| | b) Zeehe pyate |
| | c) Pyate pyapu |
| | |
| 2. Pyaping Mipye | a) Tepe paying |
| | b) Pyapu paying |
| | c) Kogii paying |
| | d) Zeehe paying |
| | e) Pyare Mipye |
| | f) Mishang Mipye |
| | g) Mithu Mipye |
| | h) Eylang Mipye |
| **Millet** | |
| Sarse | a) Surpu Latha |
| | b) Surpu Ahare |
| | c) Sartii |

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