Agrobiodiversity and Natural Resource Management in Traditional Agricultural Systems of Northeast India

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Abstract
North-East India, which falls under the Indian Eastern Himalayan region and forms part of two global biodiversity hotspots, is well-known for its rich diversity of flora, fauna, cultures and traditional knowledge systems. Agriculture is the main occupation of the communities living in this region supplemented by utilization of wild useful species from the nearby forests. Traditional agriculture in North-East India follows mixed cropping pattern through multi-cropping, crop rotation, use of multipurpose nitrogen (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 to intensive agriculture and monoculture of cash crops. This has resulted in reduced cultivation of local crop varieties and disappearance of the associated traditional ecological knowledge (TEK). Therefore, the present study attempts to review the contribution of traditional agricultural practices to agrobiodiversity 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 North-East 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 communities. 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.

Keywords
Indigenous communities; Agriculture; Traditional knowledge; Sustainable farming; Conservation
1. Introduction

Agricultural biodiversity or agrobiodiversity has been defined by the Food and Agriculture Organization (FAO) as “The variety and variability of animals, plants and micro-organisms that are used directly or indirectly for food and agriculture, including crops, livestock, forestry and fisheries. It comprises the diversity of genetic resources (varieties, breeds) and species used for food, fodder, fibre, fuel and pharmaceuticals. It also includes the diversity of non-harvested species that support production (soil micro-organisms, predators, pollinators), and those in the wider environment that support agroecosystems (agricultural, pastoral, forest and aquatic) as well as the diversity of the agroecosystems” (FAO, 1999). In short, 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, and microorganisms sustaining the structure and functions of the agroecosystems. Agrobiodiversity has been reported to contribute to agricultural productivity and food security, stability of farming systems and reduce pressure of agriculture on fragile areas, forests and endangered species (Thrupp, 2000) and can enhance human food diversity and nutrition (Remans et al., 2014). Recent works reported that food crops obtained from traditional cultivars and non-cultivated plants gathered from diverse ecosystems which compose many local diets globally, contain higher nutrient content (FAO, 2010). In addition to providing food and livelihood, agrobiodiversity is also a source of other material requirements such as clothing, shelter, medicines, new breeding varieties, and ecosystem services including maintenance of soil fertility and biota, soil and water conservation (CBD, 2018). For example, wild relatives of crops have been found to provide several desirable traits such as disease resistance, abiotic stress tolerance, quality improvements and yield increases which have proved to be valuable in agriculture breeding programmes (Tyack et al., 2020). The use of cover crops in agroecosystems can provide regulating ecosystem services such as nutrient cycling, water storage, improvement of water quality, decreased erosion, weed and pest control and carbon sequestration (Dabney et al., 2001; Schipanski et al., 2014; Frasier et al., 2016; Pinto et al., 2017). Additionally, there may be a heritage and cultural value of traditional agroecosystems and the species contained in them in different parts of the world (Qiyi et al., 2009), that even though they may not be directly useful to people now; yet the present generation would like to preserve them for posterity.

Cochrane (1975) defined traditional agriculture as “the customary methods of earning a living from the land that have been handed down to posterity by word of mouth or by practice and have, therefore, withstood the test of time”. Traditional agricultural practices have been developed over many centuries by local communities taking cognizance of the local biodiversity, topography, climate and socio-cultural set up, and has been a source of livelihood for people in many regions of the world (Pulido and Bocco, 2003; Koohafkan and Altieri, 2010). The Indigenous knowledge evolved from these agricultural systems is usually very rich and detailed comprising of knowledge on plants use, soil types and land use classification, micro-climate and being developed by local communities not only through observation of nature but also through ‘trial-and-error’ experimentations in the field. Even with the advancement of modern agriculture, many of these traditional agricultural (TA) practices are still in existence today in many parts of the world. Traditional agricultural (TA) systems have been known to contribute to conservation of biodiversity including agrobiodiversity (Altieri, 2004) and were also considered as being of paramount importance for preventing species loss (Eriksson, 2021). In TA systems, farmers employed numerous Indigenous practices for utilization, enhancement, and conservation of the biodiversity (Altieri, 2004; Koohafkan, 2012).
Traditional varieties and landraces of many major and minor crops are cultivated by farmers, thus, enhancing more diversity in production systems, which is conducive to sustainable agricultural development. TA systems maintain high genetic diversity that occur due to natural interspecific and inter-varietal breeding among crop plants (Elias et al., 2001).

In present days, TA is facing different kinds of threats such as low economic viability, people’s migration, climate change as well as replacement by modern extensive agriculture. Consequently, there is gradual abandonment of these practices leading to loss of valuable Indigenous crop varieties and the associated traditional knowledge embedded within these practices. Responding to these global threats, the FAO in 2002 launched a programme known as GIAHS-Globally Important Agricultural Heritage Systems, aimed to conserve and help in adaptive management of TA systems having outstanding values (FAO, 2018). Nevertheless, TA is receiving significant attention nowadays as a sustainable alternative to industrial farming (Fraser et al., 2015) especially for developing a climate-smart food production system (Singh and Singh, 2017). In comparison to modern extensive agriculture, which is mainly focused on maximizing production, TA has been considered as more sustainable practice since it involves use of local knowledge and locally available resources, minimal use of external inorganic inputs, recycling of agricultural and other wastes through composting and adaptive measures to extreme climatic events (Altieri et al., 1987, 2015; Schiere and Kater, 2001; Naylor et al., 2005; Anex et al., 2007; Ellis and Wang, 1997; Denevan, 1995). Use of organic inputs enhances soil health through nutrient enrichment and diversity of soil microbiota (Koohafkan and Altieri, 2010). Crop residue management and reduced tillage characteristic of TA systems improve C sequestration in soils (Aguilera et al., 2013) that can potentially contribute to mitigation of GHGs emission (Sanz-Cobena et al., 2017). Moreover, mixed cropping practiced in TA diversify the food systems and reduces risks due to crop failure, insect and pest attacks (Patel et al., 2019; Sauerborn et al., 2000). Armitage (2003) identified that maintaining traditional agroecological systems along with the associated adaptive resource management strategies used by local groups is one of the opportunities to enhance conservation. Coeto et al. (2019) indicated that the 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. (2010) suggested that agroecosystems 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 lies between 22° to 29°5’N latitudes and 88°E to 97°30’ E longitudes and covers an area of about 262,379 sq. km. It is composed of 8 states, viz., Assam, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Tripura and Sikkim and shares international boundary with 4 countries, viz., Bangladesh, Myanmar, Bhutan and China (Figure 1). Physiographically, the region can be categorised as the Indian Eastern Himalayas covering about 52% of the entire Eastern Himalayas. The Eastern Himalayan region has been recognised as a ‘Centre of Plant Biodiversity’ and ‘Eastern Asiatic Regional Centre for Endemism’ (Wikramanayake, 2002). The convergence of the Indo-Malayan and Palearctic biogeographical realms in the landscape has resulted in rich flora and fauna (CEPF, 2005; Hua, 2012). The North-Eastern region of India comprises both the Himalayan and Indo-Burma global
biodiversity hotspots. About 50% of the total flowering plants found in India have been known to occur here, out of which 40% are endemic species. Moreover, it was reported that the region is a place of origin of wild relatives of 132 economically important species including important and notable species of citrus, banana, rice, sugarcane, and pulses (Mao et al., 2009). Therefore, the region has been recognized by the ICAR-National Bureau of Plant Genetic Resources (NBPGR) as being rich in wild relatives of crops. The region has been identified by the Indian Council of Agricultural Research (ICAR) as a ‘centre of rice germplasm’. The region harbours a wide range of rice diversity estimated at 9,650 varieties and their wild relatives adapted to different environments such as upland, lowland, deep-water (Hore and Sharma, 1995). It was reported that a total 2,639 accessions of rice germplasms, including their wild relatives, have been collected from the region between 1985 to 2002 (Hore, 2005).

In addition to its rich biodiversity, the region is also culturally diverse with over 46 million people (Census of India 2011) belonging to more than 200 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 falls for self-consumption or additional income. The traditional ecological knowledge (TEK) associated with these practices is preserved in the form of stories, songs, folklore, proverbs, beliefs, rituals, customary laws, and other forms of oral traditions. The TA practices of this region varies from one community to another depending on the inherent TEK, socio-cultural set up and environmental and topographical conditions of the place. A number of TA practices such as paddy-cum-fish cultivation of Apatani tribe of Arunachal Pradesh, Zabo system and Alder-based agriculture in Nagaland, large cardamom agroforestry in Sikkim, Bamboo drip irrigation in Meghalaya are still prevalent till the present days indicating that they are sustainable, viable as well as cost-effective (De, 2021). However, with the advent of modernization and rush towards a cash economy, a large number of TA systems have been converted to intensive agriculture, 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 conservation of biodiversity. Therefore, the present study attempts to emphasize the importance of traditional agricultural systems of Northeast India for the conservation of agrobiodiversity as well as conservation and management of natural resources such as soil, water, and land. 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, also known as slash-and-burn, swidden or rotational bush fallow agriculture, is one of the most ancient farming systems believed to have originated in the Neolithic period 8,000 B.C. This practice is prevalent mostly in the mountainous and hilly regions of Central Africa, Latin America and Southeast Asia (van Vliet et al., 2012). It is a process of cultivation in which a patch of forest is cleared completely, the debris is left to dry and then burnt after which the land is used for cultivation for 1-2 years. At the end of the cropping period, the land is left fallow for a certain number of years ranging from 3-5 years to over 10-15 years or more, during which natural regeneration of vegetation takes place. After the fallow period is over when sufficient growth of forest is obtained the same land is again cleared for cultivation and the cycle is repeated. Shifting cultivation involves rotation of fields rather than rotation of crops. The important features of this agricultural practice include no tillage, use of primitive tools like dribbling sticks and hoes, dependence on manual labour, absence of manuring and irrigation and short-term use of land followed by long fallow period. It is a form of subsistence agriculture whereby a farmer grows different types of food crops mostly for household consumption while the surplus produce is either bartered for other goods or sold for a little cash income. The merits and demerits of Jhum cultivation have been a subject of debate among the scientific community worldwide for a few decades now (Fox, 2000; Mertz, 2002; Mertz et al., 2009; Pedroso-Junior et al., 2009). However, no clear consensus has emerged so far regarding its sustainability or ecological influences (Ribeiro Filho et al., 2013).

In North-East India, shifting cultivation, is popularly known as Jhum cultivation and is prevalent in the states of Arunachal Pradesh, Nagaland, Manipur, Meghalaya, Tripura and hill districts of Assam (Figure 2). It is an inseparable part of the socio-cultural life of the local communities and most of their religious rites and rituals and community festivals revolve around this practice (Teegalapalli and Datta, 2016; Priyadarshni, 1995). It is practiced in community land on hilly forest tracts. The traditional head of the village along with village elders are responsible for allotment of Jhum plots to each household. It involves the usual process of forest clearing, burning, cultivation and fallow. Land clearing, sowing and harvesting are generally carried out with community participation, except in rare occasions where activities were done by the members of family to which the particular plot is allotted. The cultivation pattern involves mixed cropping where different types of crops are grown on the same plot. The type of crops grown varies among tribes and locations. Commonly, staple food grains like paddy, maize, and millets are grown along with legumes, root and tuber crops and leafy vegetables. These crops have different harvesting seasons, thereby, providing a
continuous source of food supply throughout the year. The abandoned fallow fields continue to provide different resources intermittently in the form of residual crops, wild and semi-domesticated edible fruits and vegetables, medicinal plants, etc. Therefore, Jhum cultivation has been a source of sustenance and livelihood for the people in the region especially those living in the remote areas where there are limited means of communication and market linkages.

2.1.1 Agrobiodiversity 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, Colocasia, pumpkin, cucumber, and other food crops (Dollo et al., 2005). In Nagaland, the alder based Jhum cultivation is well-known. In this system the nitrogen fixing Alnus nepalensis trees are maintained in the Jhum plots and pollarded at 1-2 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 millets, Job’s tear, maize, potato, tomato, chilli, cabbage, cauliflower, squash, cucumber, ginger, French bean, soybean and pea. 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 and Teyang, 2015). Teegalapalli and Datta (2016) estimated that around 7 varieties of rice, 2 types of millets and 30 different types of vegetables along with yam, sweet potato, corn and sugarcane were grown by the Adi tribe of Upper Siang district of Arunachal Pradesh. Bhuyan et al. (2012) reported 39 crop species from 14 families cultivated in Jhum fields of Adi tribe residing in East Siang district, Arunachal Pradesh. Similarly, Nocte tribe of Arunachal Pradesh were cultivating up to 20 species in their Jhum field (Tangjang, 2009). Additionally, one study in certain Jhum fields of North-East India reported rich diversity of as many as 12 species of Solanum, 9 species of chillies and 18 species of Cucurbitaceae (Asati and Yadav, 2004) while another recorded about 22 important crop species (Dikshit and Dikshit, 2004).

Figure 2: A freshly cleared and burned shifting cultivation patch in Nagaland (Photo credit: Anup K. Das)
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 alike. 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 and Raman, 2016). They also 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 actinorhizal N-fixing trees enrich the soil with nitrogen, thus maintaining fertility of the soil. 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 method of soil management in *Jhum* cultivation is an indigenous technique of soil erosion control by farmers in Wokha district of Nagaland by construction of a structure known as *Echo* in the local language (Figure 3). *Echo* consists of short bamboo barricades strategically placed horizontally across the slope in *Jhum* fields to reduce water runoff and check soil erosion. The structure generally lasts up to 3 years or sometimes up to 5 years. Scientific studies carried on efficiency of *Echo* for soil erosion control revealed that the structure 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 (Singh *et al.*, 2016). Application of traditional knowledge and skills on *Echo* along with scientific improvisation of the technique can be a good option for sustainable management of land and soil resources in the vast *Jhum* area of the state as well as the whole region. The technique can also be adopted in other agricultural areas with steep topography.

![Figure 3: Echo, a traditional method of soil erosion control in shifting cultivation fields in Wokha district of Nagaland (Photo credit: Anup K. Das)]
Traditional practice of soil erosion control in shifting cultivation locally called Paneng or Panpeng is unique to Adi tribe of Arunachal Pradesh. Adi is one of the largest tribal communities of Arunachal Pradesh inhabiting the districts of East Siang, Upper Siang, West Siang and Western part of Lower Dibang Valley. They trace their origin from Tanii, ‘the first human being’ which they regarded as Abo Tanii (Abo meaning ‘father’ in their local dialect). They are comprised of more than 30 sub-tribes. Historians, anthropologists, and scholars believed that the tribe has migrated from Tibetan province. Paneng or Panpeng is a traditionally developed method of using logs of wood to reduce surface runoff during rainy season and check soil erosion. In this method, unburnt or half-burnt logs felled and burnt during the slashing of field were laid parallel to each other against the slope gradient to reduce the force of water flow and prevent the topsoil from being washed away. The structure is strengthened by wooden poles locally called Sipit/Hipit or wooden stumps called Hiir. Uprooted weeds from the field were also dumped alongside the logs which further enhance the efficacy of controlling soil erosion. In addition, the Panpeng also help block any stone or gravel falling from upper slope that may damage the crops (Samal et al., 2019).

2.2. Paddy-cum-fish Cultivation

2.2.1 Agrobiodiversity in paddy-cum-fish cultivation

Paddy-cum-fish cultivation is an Indigenous organised farming method of the Apatani tribe of Arunachal Pradesh locally known as Aji-ngyii: Aji meaning cultivation and ngyii meaning fish (Figure 4). The practice was considered to be one of the most productive and efficient agricultural systems of the region (Nimachow et al., 2010). The practice involves integration of wet-rice cultivation with Indigenous millet (Eleusine coracana) and fish rearing on the same field. While paddy is grown on the field, millet is grown along the bunds surrounding the rice fields. Houttuynia cordata, an edible herb growing wild on the lower sides of bunds is not weeded out, but retained, to act as soil binder to further strengthen the bunds. About 16 local varieties of rice and 4 millet varieties, classified into early- and late- maturing varieties, have been reported to be grown in the wet-rice farming systems (Kala, 2008; Dollo et al., 2009) (Table 1). Different types of fish were also reared on the standing water of the rice fields. Additionally, shallow trenches were dug inside the paddy terraces. During monsoon season when water supply is abundant, the water in the paddy field is maintained at about 5 to 10 cm and fishes can move all over the rice fields. During the drier period when water is scarce, water remains only in the trenches where fishes retreat and continue to grow. Manuring of paddy fields also act as nutrition source for the fishes, as such there is no requirement for additional fish feeds. In this system, both paddy and fishes are produced together by proper management of rainwater (Rai, 2004). Different species of Indigenous fishes such as tali ngiyi (Channa spp.), papi ngiyi (Puntius spp.), ngilyang ngiyi (Schizothorax spp.), tabu ngiyi (eels), ribu (Nemaucheilus), ngiyi papi (dorikona or weed fish) were found naturally occurring in the stream draining the paddy fields are raised in the system. Other commercial species were introduced by the state government such as common carp (Cyprinus caprio), silver carp (Hypophthalmichthyes molitrix), grass carp (Ctenopharyngodon idella), Labeo gonius and Barbonymus gonionotus. However, the common carp remains the most reared species and the success rates is also found to be higher than the other varieties of fish (Nimachow et al., 2010).
Figure 4: Paddy-cum-fish cultivation, Indigenous farming method of the Apatani tribe of Arunachal Pradesh (Photo credit: Tilling Rinya)

Table 1: Different landraces of paddy and millet cultivated by Apatani of Arunachal Pradesh (Source: Kala 2008; Dollo et al., 2009)

| Land races (Oryza sativa) | Early maturing variety | Late maturing variety |
|--------------------------|------------------------|-----------------------|
| **1. Eamo**              | **Ampu Ahare** (most commonly cultivated) | **Ampu Hatte** (rarely cultivated) |
|                          |                        | **Radhe Eamo** (rarely cultivated) |
|                          |                        | **Eylang Eamo** (most commonly cultivated) |
|                          |                        | **Ampu Puloo Hatte** (extinct) |
| **2. Mipyre**            |                        | **Kogii Pyate** (commonly cultivated) |
| (i) Pyate Mipyre         |                        | **Zeehe Pyate** (rarely cultivated) |
|                          |                        | **Pyate Pyapu** (rarely cultivated) |
| (ii) Pyaping Mipyre      | **Tepe Pyaping** (most commonly cultivated) | **Pyapu Pyaping** (rarely cultivated) |
|                          | **Kogii Pyaping** (rarely cultivated) | **Zeehe Pyaping** (rarely cultivated) |
|                          | **Pyare Mipyre** (cultivated near settlements) | **Mishang Mipyre** (rarely cultivated) |
| Land races | Early maturing variety | Late maturing variety |
|------------|------------------------|-----------------------|
| Mithu Mipye (commonly cultivated) | | |
| Eylang Mipye (rarely cultivated) | | |
| Millet (*Eleusine coracana*) | Surpu Ahare (commonly cultivated) | Sartii (rarely cultivated) |
| Sarse | | Ahki sarse (rarely cultivated) |
| | Surpu Latha (most commonly cultivated) | |

2.2.2 Water resource management in paddy-cum-fish cultivation

The whole Apatani plateau is devoid of any big river or water body and depend on few small rivulets or streams for irrigating agricultural fields. As the community practices wet rice cultivation along with fish rearing, stagnant water is essential in their agricultural field for a period of 4-5 months. This has made the community to search for an ingenious way to utilize the water of existing springs and streams efficiently and also to harvest and store the rainwater. With local skills and knowledge, the community has developed a well-designed system of channelizing the water from streams and rainwater to their agricultural field. The water from stream is blocked at an appropriate elevation with barriers (*Borang*) made of locally available wood and bamboo. The stored water is then channelized through canals locally called *Sugang* into each and every agricultural field. Maintenance and repair of the *Sugangs* were done by the beneficiaries of the community. The water thus brought to the fields is retained with the help of bunds called *Agber*. In each field, water is retained at a desired level, above which an outlet made of bamboo pipe is built to drain the excess water into the adjacent field situated at a lower level. The stepwise distribution of water to all the field is maintained, and the excess water drained out from each field blocks are further channelized towards a common final outlet.

Paddy-cum-fish cultivation is also practiced in other northeastern states, mainly in the valley area of Manipur. In this system, trenches called “*Kom*” with a width of 4-5 metres (depending upon size of the paddy field) were dug in one side or along 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 Homestead Gardens

The Intergovernmental Panel on Climate Change (IPCC) has recognised agroforestry systems as one among the potential land uses important for food security and carbon sequestration contributing to climate change mitigation and adaptation (IPCC, 2019). 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*, *F. hookeri*, *Nyssa sessiliflora*, *Osbeckia paniculata*, *Viburnum cordifolium*, *Litsea...
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 Arunachal Pradesh was 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-storied, 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 pineapple and vegetable crops. In addition to these, wild herb species used as food and medicine such as Ageratum conyzoides, Spilanthes sp. and other Asteraceae species also form part of the ground vegetation.

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), 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. Tynsong et al. (2018) reported rich plant diversity species in this agroforestry system comprising of 94 tree species, 17 species of shrubs and 48 herb species.

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. The ponds are being used for pisciculture and during the lean season, the pond water is used for irrigation of crops and fruit trees. Rearing of animals such as cow, pig, buffalo or goat as well as farming local poultry is also practiced. Vegetable waste from the nearby garden and home are either made into compost or added to the pond as feed for the fishes like grass carps. Paddy is then cultivated in the lowland areas.

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

2.4 Bamboo Drip Irrigation

The Bamboo drip irrigation system (Figure 5) is an ingenious method of irrigation by the Indigenous communities residing in the War Jaintia areas in Jaintia Hills district of Meghalaya. The people here practice agroforestry system of arecanut, black pepper and betel leaf (Piper betel). Irrigation is needed for the betel vines and black pepper crops during the winter season when water is scarce. 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 construct ground irrigation channels. This method utilizes the water from the uphill streams and springs and directs
it to the fields till it reached the base of the plant where water reduce to drops. Usually, water sources are distant from plantation sites and so the main bamboo channel runs several meters, sometimes even a couple of kilometres. The water is tapped from the upper slopes which are then diverted to various parts of the field located in the lower hill slopes through a system of secondary and tertiary bamboo channels. Channel sections are made of bamboos of varying 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 considered so efficient that it was estimated that water entering the bamboo pipe at about 18-20 litres per minute gets transported over several hundred metres through the intricate network of channels till it finally gets reduced to about 20-80 drops per minute at the root 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 (Ryngnga, 2016).

3. Discussions

This review presented a few of the unique TA practices of different communities of North-eastern India that are still sustained till the present day. The probable explanation for their continued existence is that the knowledge and practices have been constantly evolved and modified by the concerned communities through their inherent TEK to adapt to the ever-changing environment, climate, demography, resource availability and various other natural and anthropogenic changes occurring around them.

Shifting cultivation though often regarded as unproductive and unsustainable, several researchers in NE India have revealed its positive role on the environment. Studies suggested that, in the shifting cultivation regime, there is optimal utilization of natural resources, which is conducive to the stability and sustainability of agriculture in the mountain ecosystems (Ramakrishnan, 1992). Bhuyan and Teyang (2015) opined that
Jhum cultivation of Nocte and Wancho tribes of Arunachal Pradesh is well adapted to the local environment and ecological balance is maintained by mixed cropping of cereals and tree crops in the same field. In Nagaland, Chase and 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 this agricultural system 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.

In spite of the positive reviews, many scholars have also pointed out the negative impacts of shifting cultivation mainly due to the shortened fallow period. In some parts of the region, 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 of soil quality, etc., which might have been aggravated due to shortened fallow periods. Therefore, it is imperative to document the good practices involved in this form of agriculture such as mixed cropping, high agrobiodiversity, traditional methods of soil erosion control such as the Echo practised by some communities in Nagaland and Paneng/Panpeng in Arunachal Pradesh. Technical and scientific innovation to transform the system and reduce its negative impact should be built around the existing traditional skills and knowledge so that the changes can be easily adopted by the farmers. 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 (Kumar et al., 2016). In spite of certain crises that this agricultural system faces, proper scientific research and appropriate policy supports can encourage this farming system to provide adequate food and economic security for the peoples and motivate them to conserve and enhance local crop diversity in the traditional environment (Bhuyan and Teyang, 2015).

The traditional paddy-cum-fish agriculture of the Apatani tribe of Arunachal Pradesh reflected the tribe’s ingenuity in achieving optimum utilization and management of natural resource such as land, water and bioresources (Kala et al., 2008). The system also has replication potential in other places with similar micro-ecological conditions (Dollo, 2009). The integration of rice with fish along with other crops such as millets enables low-cost practice needed for food security and nutritional security and good income from a limited area (Baruah et al., 2019). In addition, cultivation of different Indigenous varieties of rice and millets leads to the conservation of this valuable genetic diversity. Rai (2005) reported that this agroecosystem is very advanced and has exceptionally high economic and energy efficiency. In present days, there is gradual modification of the traditional practices such use of iron and plastic pipes, and concrete instead of locally available materials like bamboo and wood to build irrigation canals and check dams, which may pose a threat to the health of the agroecosystem and disappearance of community TEK (Dollo, 2009). Observations mentioned in table 1 revealed that, out of the 16 Indigenous varieties of paddy reported from this agricultural system, only 5 varieties were commonly cultivated, while the rest were rarely or not cultivated at present. Similarly, out of the 4 varieties of millets only two were commonly
cultivated while other 2 were rarely cultivated. These changing preferences in cultivation of certain crop varieties over others may gradually decrease the number of varieties cultivated in the TA system which may eventually lead to their extinction and loss of a valuable genetic diversity.

Agroforestry, a type of land use where trees are grown alongside non-woody crops in the same land (with or without livestock), has been adopted by the traditional communities of North-East India to fulfil their multifarious needs of food, fodder, fuel, medicinal plants as well as to generate income and ensure optimised use of land resources. Large cardamom-based agroforestry systems of Sikkim have been found to harbour a rich agrobiodiversity, increased farmers’ income as well as provide different types of ecosystem services (Sharma et al., 2007). On the other hand, the pond-based agroforestry of the plain areas of Assam, Manipur, South Garo hills of Meghalaya and Tripura revealed the local knowledge of integrated farming system combining agriculture, forestry, fishery and water management (Das et al., 2012). The practice exhibited an efficient cycling of nutrients within the system through composting of crop residues and vegetable wastes that are added back to the soil; vegetable waste is also used as feed for fishes while the pond water is also used for irrigation during dry periods. Similarly, the Indigenous arecanut, betel leaf and black pepper-based agroforestry of Meghalaya have been found to be fairly sustainable with minimal impact on plant diversity (Tynsong et al., 2018). In a study conducted in southern India, Hombegowda et al. (2015) concluded that depleted soil organic carbon (SOC) stocks brought about by the conversion of forest to agricultural land can be recovered by converting the same land to agroforestry.

Bamboo drip irrigation is another Indigenous knowledge by the farmers of War Jaintia in Meghalaya to solve the problem of irrigation in steep hill slopes with undulating topography and manage water resource efficiently. This system has been appreciated for its environment-friendliness since it requires no cutting down of trees or shrubs in the forest area to build the irrigation channels. The irrigation system also has potential for adoption in other upland farming systems including shifting cultivation areas (Das et al., 2012). Another positive attribute of this system is its low cost of construction and use of locally available material that is bamboo, and minimal labour requirements. The system had lasted for decades which implies its sustainability and social acceptability. Ryngnga (2016) opined that there is still scope for improving the efficiency and durability of the system through use of modern scientific interventions, of course, without diluting the existing Indigenous knowledge and skills developed by the community through decades of experience.

In present day, TA still remains as a primary mean of food production system for the rural community who substantially contributed to their food and nutritional security and livelihood. On the other hand, with the aim to increase productivity of agricultural systems to meet out the needs of the growing human population and market demands to enhance farmers’ income and achieve self-sufficiency, different agricultural incentives have been offered by governments and relevant line departments at national, regional or local levels. These government schemes have motivated the people towards market-oriented agriculture such as use of high yielding crop varieties, exotic crops in horticulture and cash crop plantation and other non-farm activities. In response to the changing needs and aspirations of the people there has been a gradual transformation of TA practices to other unsustainable land uses. For instance, introduction of high yielding varieties and exotic crops has necessitated the use of inorganic fertilizers and pesticides that can pose a threat to the agroecosystem health in the long run. Similarly, increase in cash crop cultivation has given rise to monoculture plantations and slowly replacing food crop cultivation areas, thus leading to decline in agrobiodiversity and food security,
increase in risk through crop failure, pest and insect attacks and loss of ecosystem services. Mylliemngap et al. (2016) observed that, in some villages of Upper Siang district of Arunachal Pradesh, there has been gradual transition towards wet-rice cultivation/terrace rice cultivation and cultivation of Kiwi fruit and large cardamom as cash crops. This transformation has posed a threat to the agrobiodiversity 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. Pal and Dasgupta (2014) appraised the two farming systems of shifting cultivation and wet rice-cum-fish agriculture of the Indigenous communities of Arunachal Pradesh who 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.

4. Conclusion

The present review highlighted 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 systems were found to maintain a high level of agrobiodiversity along with efficient management of soil fertility, soil erosion control and supply of variable ecosystem services. On the other hand, paddy-cum-fish cultivation exhibited an advanced integrated farming of paddy, millets and fish with optimum utilization of land and an almost perfected irrigation channel system by tapping the limited rain and stream water resources available in the Apatani plateau and storing it to ensure adequate water for irrigation. The bamboo-drip irrigation revealed the excellent skills and knowledge of the farmers to design and construct an intricate irrigation system from locally available bamboo resources in the rough hilly terrains of southern Meghalaya where construction of ground irrigation channels was not feasible. The gradual transitions from TA system to modern commercial based farming would result in the loss of associated traditional ecological knowledge, agrobiodiversity along with its valuable genetic diversity and ecosystem services. 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.

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Author’ Contributions (in accordance with ICMJE criteria for authorship)
This article is 100% contributed by the sole author. She 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.

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

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Has this research involved animal subjects for experimentation? No

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