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Traditional oak agroforestry practices in Mima village of Kohima district, Nagaland state, Northeast India

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ABSTRACT

Traditional agroforestry refers to variant of conventional agroforestry systems practiced by indigenous people in different parts of the world. Such practices are indispensable source of food, medicine, firewood, fodder, cultural needs and livelihoods. The present study, which was conducted from March 2016 to December 2018, aims to document the traditional knowledge of oak-based agroforestry practices in Mima village. Management of jhum fallow and trends in agroforestry practices of Angami tribes are also discussed. Fields observation, group discussions and semi-structured interview of small holder farmers were employed to collect data. Oak (*Quercus serrata*) has been selected as common fallow tree at lower altitude $\leq$ 1000m above sea level. Oak-based agroforestry can serve as sustainable agroecosystem which has the potential to augment production of foods, fodder and firewood without adverse impacts on environment. This system can sustain in different agroclimatic zones of hilly regions. It is the primary repository of biodiversity particularly traditional varieties of plants genetic resources which can form valuable source of novel traits for our conventional crops. There have been changes in the Angami agroforestry practices with introduction of high-yielding crop varieties resulting in erosion of valuable gene pool of folk crop varieties. It needs an extensive documentation of agrobiodiversity before it is lost to science. Such study can be useful, among other issues, in recognition of contribution of indigenous farmers and protection of their intellectual property and biodiversity conservation.

1. Introduction

Agroforestry is a sustainable land-use and natural-resource management system in which there is purposeful growing or deliberate retention of trees with crops and/or animals in interacting combinations for multiple products or benefits from the same management unit (Bammanahalli 2016; Singh *et al.,* 2017; Quandt *et al.,* 2018). Agroforestry has the multifunctional role of agro-ecosystems (Dagar *et al.,* 2014). These systems contribute towards increased food production, economy (Jemal *et al.,* 2018; Quandt *et al.,* 2018), biodiversity conservation (Sistla *et al.,* 2016; Mattalia *et al.,* 2018), soil conservation (Limon *et al.,* 2018; Pe´rez-Flores *et al.,* 2018) and poverty alleviation (Raj and Chandrawanshi 2016; Amejo *et al.,* 2018; Shukla *et al.,* 2018). Traditional agroforestry refers to variant of conventional agroforestry systems practiced by indigenous people in different ecological regions of the world, for example agrisilviculture, silvopastoral, agrosilvopastoral and homegarden. The vegetation of agroforestry systems shows stratification of three or more different canopy layers, *viz.* main canopy, shrub and herb layer. Main canopy layer is dominated by multipurpose woody trees. Shrub layer is dominated by coffee and small fruit trees. Herb layer is composed of agricultural crops such as rice, pumpkin, cucumber *etc.* (Elevitch *et al.,* 2018; Umrao *et al.,* 2018).

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In such systems, multipurpose traditional tree species are managed along with diverse crop varieties. Besides source of timber and firewood, the trees help to maintain soil fertility and reduce soil erosion. There is recent global interest to investigate the management of firewood tree species in the traditional agroforestry systems for mitigating the energy crisis (Bennett *et al.,* 2018; Githiomi *et al.,* 2012; Iiyama *et al.,* 2014). Some reports described the distinct economic, environmental, social and historical characteristics of oak-agroforestry systems (Dagar and Tewari 2017; Chaturvedi *et al.,* 2018; Pantera *et al.,* 2018).

Shifting cultivation or jhum associated with alder (*Alnus nepalensis*) trees is one of the major forms of traditional agroforestry systems practiced by different ethnic groups in Nagaland State, Northeast India (Nakro 2011). Alder-based farming is the common practice for amelioration of jhum land in the state (Cairns 2007; Dhyani 1998; Rathore *et al.,* 2010). Alder, which can fix atmospheric nitrogen into the soil (Dhyani 1998), helps to improve soil fertility and reduce soil erosion with its root system. Such farming system augments crop production and also provides firewood and timber. Changkija (2014) reported that this system concentrates only in the regions of higher altitude ≥ 1000m above sea level (asl). There is one report on the management of Macaranga sp. in jhum fields at altitude less than 1000m asl by the Konyak tribes of Nagaland. Leaves of Macaranga sp. which shed profusely in winter, help to retain the soil moisture and in the early summer it can be mulched with the soil as fertilizers (Changkija 2014).

A review of various reports revealed scant information of the management of trees in jhum fields at lower altitude. During ethnobotanical study in Kohima district, Nagaland by the authors, other forms of agroforestry involving trees such as Quercus serrata, Albizia lebbeck, Melia azedarach, Phyllanthus emblica and Schima wallichii have been observed in areas with altitude less than 1000m asl. Particularly management of oak tree in jhum system has not been studied earlier. In the daily village life in Nagaland where there are no alternative sources of energy, fuel wood is one of the most important needs of a family's existence. Firewood is not only used in cooking but also for heating homes during cold winter, making charcoal and other utilities. Next to food security, firewood is the most important resource in the life of a farming family in Angami villages (Nakro 2011). The study aims to document the traditional knowledge of oak-based agroforestry practice in Mima village preceded by brief introduction to Angami agroforestry. Management of jhum fallow and trends in Angami agroforestry practices are also There is a sincere need for investigation of the complex interactions of various multipurpose tree species with crops in oak-based agroforestry to augment the production of foods, timbers and firewood without significant negative bearings on environment.

2. Materials and Methods

2.1 The study area and the people

The Kohima district of Nagaland state is considered as the homeland of the Angamis, one of the 14 Naga tribes of the state (Basic facts Nagaland 2018). This study was conducted in Mima village (25.59˚ N Latitude and 94.11˚ E Longitude) which is one of the southern Angami villages located in Jakhama circle of Kohima district at altitude of 700m-1450m asl (Figure 1). The residential areas of the village are located at altitude ≥ 1000m asl while the agroforestry fields are found at an altitude below 1000m asl. There are 403 households and the population is 2149 (Census of India 2011). The traditional religion of the Angami Naga is animism which includes belief in multiple deities and ancestor worship. Under the influence of missionaries, majority of the Angamis have embraced Christianity and today their animistic religion remains confined to a few Angami groups only. Agriculture is the main occupation and rice (Oryza sativa) is their staple food.

2.2 Collection of information and analysis of data

Permission for field study and interview was obtained from the chairperson of Village Council, Mima village. Extensive field study was conducted from March 2016 to December 2018 in the Angami agroforestry fields. Data collection methods like group discussion, semi-structured interview and field observations were included in the study design. Thirty elderly knowledgeable farmers who have experiences of more than 10 years were selected for group discussions on oak management, soil management, fallow management and pests and weeds management. Ten households were randomly selected to document the yields of 13 selected crops through semi-structured questionnaires. Average yields of crops of 10 households was calculated using Microsoft excel 2016. A checklist of plants growing in Angami agroforestry fields was prepared through group discussions and personal observations in the field. Plant specimens were collected from agroforestry fields with the help of informants and identified with the help of local floras (Kanjilal *et al.,* 1934, 1938, 1939, 1940). Nomenclature and family delimitation for the recorded plants were updated using online database The Plant List (www.theplantlist.org).

discussed.

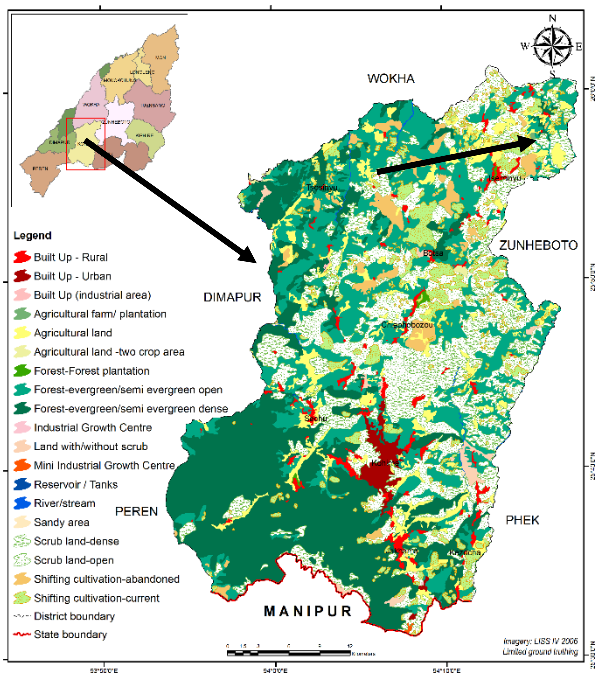

Figure 1. Land use map of Kohima district showing study area (arrows) Source: Nagaland GIS and Remote Sensing Centre Planning and Co-ordination Department, Government of Nagaland, 2018

3. Results and Discussions

3.1 Angami agroforestry- a general appraisal

Jhum or shifting cultivation associated with multipurpose trees is the major form of agroforestry practices among the Angami Nagas. They maintain home gardens of small or large area for household consumption of food, vegetables, medicines and other requirements (Singh and Teron 2015). But the composition of tree species in Angami agroforestry varies with altitudes. From 1000m and above farmers cultivate alder whereas below 1000m tree species, namely *Q. serrata*, *M. azedarach*, *Toona* sp., *A. lebbeck*, *P. emblica*, *Parkia timoriana* and *S. wallichii* are cultivated. Alder-based farming has been well studied and described from Khonoma village, Kohima district (NEPED and IIRR 1999 Cairns 2007; Chase and Singh 2014). In such system farmers cultivate crops for two years followed by a fallow period of two years. In the first cropping year farmers start slash and burnt operation and till the soil with crude implements for cultivation. New seedlings of alder, whether self-grown or intentionally planted, are established. Farmers grow rice and other secondary crops such as vegetables. On maturity the crop is harvested, processed and stored for new season. Surplus produce is sold in return for cash benefit. The same crop operation is repeated in the second year. After the harvest of second year crops the field is left fallow. After two or three jhum cycles the alder trees are pollarded horizontally with a sharp dao (knife) at a height of 2.13-2.44m above the ground without forming any crack on the main trunk. The fresh cut ends are plastered with mud to prevent it from drying and cracking. A stone slab is then placed at the top of cut trunk to ensure that new coppices will sprout from all the sides and spread in horizontal direction (Figure 2a). During the first eight to nine years alder grows faster reaching 0.7-0.8m in diameter and 10m in height. In lower altitudes alder does not grow well. So, to meet household demands of firewood farmers maintain other tree species, namely *Q. serrata*, *A. lebbeck, P. emblica, M. azedarach, P. timoriana, Toona* sp. *and S. wallichii* in place of alder in their *jhum* fields. As an exception, in Rusoma and Mima villages alder is managed in the colder ravine sides of the mountains where *jhum* practice is not suitable by pollarding the tree at about 0.61-0.91m above the ground or closer (Figure 2b). Particularly in Mima village there is intensification of oak cultivation in *jhum* fields for economic benefit and household consumption of firewood.

3.2 Oak-based agroforestry in Mima village

In the region lower than 1000m asl, agroforestry involving other trees like *Q. serrata, A. lebbeck, P. emblica, M. azedarach, P. timoriana, Toona* sp. *and S. wallichii* have been observed. Except oak however, there is no proper management of other tree species. The Angamis of Mima village have been practicing oak-based agroforestry since many years with significant investment of labour for its management. In the beginning Angamis managed oak trees in the forest by pollarding to produce coppices. Its introduction in *jhum* fields has only been a decade or so.

Efforts by farmers to grow alder in *jhum* fields was not successful. So after initial years of positive returns with oak, farmers adopted oak-based agroforestry practice as an alternative to alder tree to meet the increasing demand of firewood without compromising crop yields. In the following sections oak agroforestry operations in Mima village is described. Major stages of the oak-based agroforestry is presented in Figure 3a.

Selection of agroforestry sites

Angami Nagas practice *jhum* in permanent ancestral village lands; they rotate *jhum* cultivation from one site to another within this ancestral land. There is no further expansion of *jhum* fields beyond the permanent ancestral land. The entire community collectively decide to select new *jhum* site, leaving the preceding field to lie fallow. But in the Mima village each household is responsible for the selection of new sites for cultivation. Further, no land is owned by the *khel* or village. In the month of October, after completion of wet or terrace cultivation, household elders venture out to look for new cultivation sites. Area abundant with mature trees that is about 10-20 years with gentle slope and receives sunlight is usually selected for agroforestry. The choice of a site for growing a crop depends upon the types of soil, temperature and economic needs. For example, hard and clayey soil with abundant sunlight is said to be suitable for rice; soft and blackish soil for potato (*Solanum tuberosum*) and vegetable crops; warmer places for growing *Musa* sp. and potato. As per traditional belief, their selection is said to be validated in dreams; if it is negative a new site is selected. Today, however, most farmers have embraced Christianity; they only perform prayers to Jesus before an agroforestry site is selected.

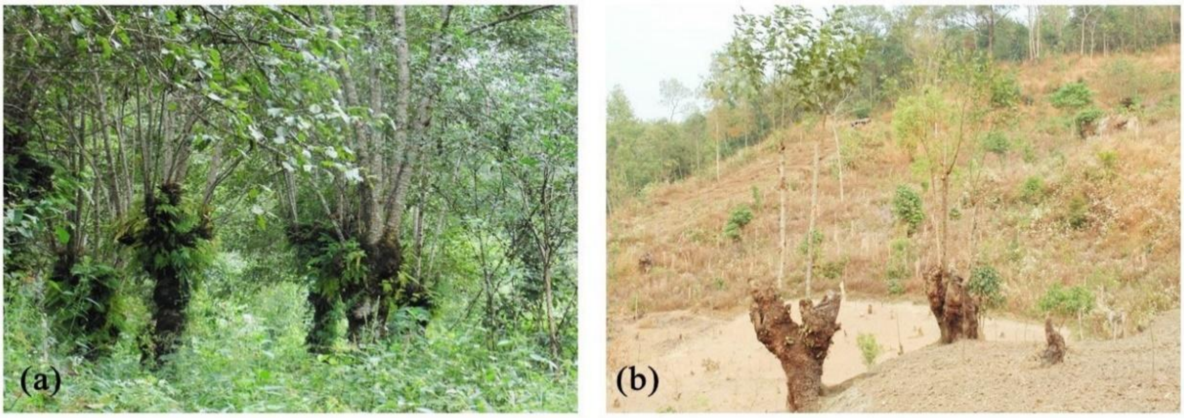

Figure 2. Alder (*Alnus nepalensis*) management (a) pollarded at the height of 2.13-2.44m above the ground in Khonoma village and (b) pollarded at the height of 0.61-0.91m above the ground in Mima village, photo (a) taken on in 2016 and photo (b) taken in 2018

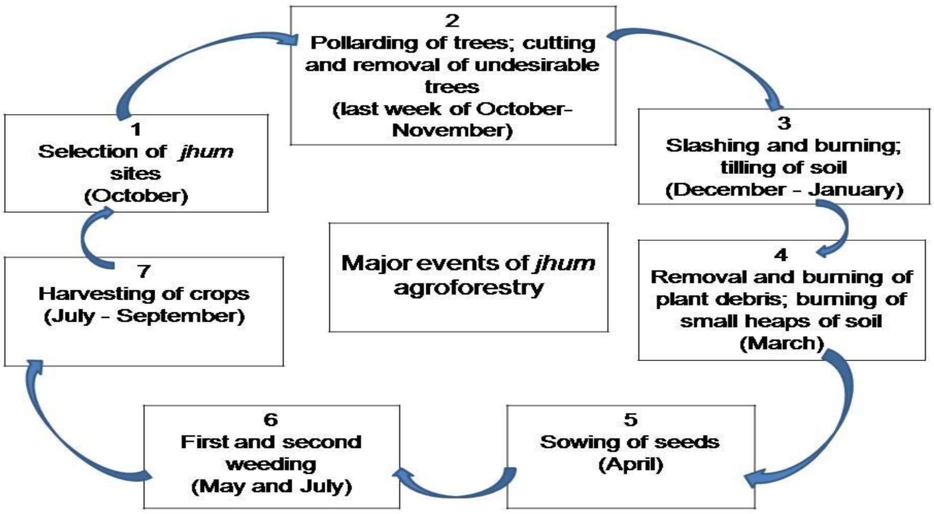

Figure 3. Major stages of oak-based agroforestry

Table 1. Inventory of plants cultivated in Angami Agroforestry fields

Plants [Family]	Angami name	Part used	Propagation	Uses			
				Food	Medicine	Economy	Others
Albizia lebbeck (L.) Benth. [Leguminosae]	*Ze/melü*	Stem	Seed	No	No	No	Firewood and timber
Alnus nepalensis D. Don [Betulaceae]	*Rüpro*	Stem	Seed	No	No	No	Firewood and timber
Allium ascalonicum L. [Liliaceae]	*Themera*	Bulb	Bulb	Yes	Yes	Yes	No
Allium chinense G. Don [Liliaceae]	*Khova*	Buld and leaves	Buld	Yes	Yes	Yes	No
Allium sativum L. [Liliaceae]	*Chümeyie*	Buld and leaves	Buld	Yes	Yes	Yes	No
Benincasa hispida (Thunb.) Cogn. [Cucurbitaceae]	*Serümo*	Fruit	Seed	Yes	No	Yes	No
Capsicum annuum L. [Solanaceae]	*Chüsi*	Fruits	Seed	Yes	No	Yes	No
Coix lacryma- jobi L. [Poaceae]	*Kesi*	Seed	Seed	Yes	Yes	No	No
Colocasia esculenta (L.) Schott [Araceae]	*Abibicho/dzümo*	Corm	Corm	Yes	No	Yes	Pig feeds
Cucurbita maxima Duchesne [Cucurbitaceae]	*Rümo/rümosisi*	Fruit	Seed	Yes	No	Yes	No
Cucurbita pepo L. [Cucurbitaceae]	*Lemosi*	Fruit	Seed	Yes	No	Yes	No
Cucumis sativus L. [Cucurbitaceae]	*Tsütuo/pitüshey*	Fruit	Seed	Yes	No	Yes	No
Glycine max (L.) Merrill [Leguminoceae]	*Chüja*	Seed	Seed	Yes	No	Yes	No
Helianthus annuus L. [Asteraceae]		Seed	Seed	Yes	No	No	No
Hibiscus sabdariffa L. [Malvaceae]	*Gakhro*	Leaves	Seed	Yes	No	No	No
Lagenaria siceraria (Molina) Standl. [Cucurbitaceae]	*Mesü*	Fruit	Seed	No	No	Yes	Container for water and rice beer
Lycopersicon esculentum Miller [Solanaceae]	*Bengenuo/benyieno*	Fruit	Seed	Yes	No	Yes	No
Melia azedarach L. [Meliaceae]	*Khosa/khousie*	Stem	Seed	No	No	Yes	Timber
Ocimum tenuiflorum L. [Lamiaceae]	*Nhietso/ Nietso*	Leaves	Seed	Yes	Yes	No	No
Oryza sativa L. [Poaceae]	*Pelulha*	Seed	Seed	Yes	No	No	No
Parkia timoriana (de Candolle) Merrill [Leguminosae]	*Miakrürucü/kuinyümero*	Pod	Seed	Yes	Yes	Yes	No
Perilla frustescens (L.) Britton [Lamiaceae]	*Kenyie*	Seed	Seed	Yes	No	No	No
Phaseolus vulgaris L. [Leguminosae]	*Cükha*	Seed	Seed	Yes	No	Yes	No

Plants [Family]	Angami name	Part used	Propagation	Uses			
				Food	Medicine	Economy	Others
Phyllanthus emblica L. [Phyllanthaceae]	*Tseihusi/ciehu*	Fruits, stem	Seed	Yes	Yes	Yes	Firewood and charcoal
Quercus serrata Murray [Fagaceae]	*Phibo/phrie*	Stem	Seed	No	No	Yes	Firewood and charcoal
Schima wallichii Choisy [Theaceae]	*Mecho*	Stem	Seed	No	No	No	Firewood and timber
Setaria sp. [Poaceae]	*Tsütienuo*	Seed	Seed	Yes	No	No	No
Solanum annuum C.V. Morton [Solanaceae]	*Chüsi*	Fruit	Seed	Yes	No	No	No
Solanum melongena L. [Solanaceae]	*Pfhüdisi*	Fruit	Seed	Yes	No	No	No
Solanum tuberosum L. [Solanaceae]	*Luyi*	Tuber	Tuber	Yes	No	Yes	No
Toona sp. [Meliaceae]	*Tezu/zuna*	Stem	Seed	No	No	Yes	Timber
Zea mays L. [Poaceae]	*Shüko*	Corn	Seed	Yes	No	Yes	Pig feeds
Zingiber officinale Roscoe [Zingiberaceae]	*Kevü*	Inflorescence and rhizome	Rhizome	Yes	Yes	Yes	No

Agroforestry operations

After selection of a site, preparation of field starts with clearing of vegetation usually with dao (knife) from the last week of October and continue till the end November. Care is taken to maintain natural population of oak trees and saplings and other useful plants. Instead such trees are pollarded at a height of 0.61 to 0.91m above the ground. Trees with no known use are usually cut closer to the ground and even removed completely. The plant debris are burnt in the month of December. Terrace is barely constructed. However, soil bunds are constructed across the slope to check erosion. Farmers use poles, logs and rocks to construct soil bunds. Long trench is constructed at the foot of soil bund to drain water across the slope. The trench can reduce significantly the volume of surface run off water along the slope and thus helps to minimize soil erosion (NEPED and IIRR 1999). There is no irrigation system and the agricultural practice is purely rain fed. Farmers start to till soil manually with the help of adzü, a traditional hoe, to expose the soil for weathering by sunlight. In the month of January-February big clumps of soil are broken into smaller pieces by using a wooden tool known as nokoson. During tilling smaller herbs are mulched with soil to enrich soil fertility. Plant debris like smaller twigs, stems, roots *etc.* and other aggressive weeds are removed from the soil with the help of a wooden hook known as charuo/phawo or directly with hand and pile up together on the side or inside the field; on drying it is burnt in March. Further, farmers make small heaps of dried plant debris on which small mounds of soil are deposited. These heaps are burnt to roast the deposited soil. Such practice of roasting soil is done randomly at different sites inside the tilled field in such way that the roasted soil along with ashes can be spread uniformly. Burning of plant biomass is a common approach to eliminate waste after harvesting and emits gases like sulphur dioxide, oxides of nitrogen, carbon dioxide, carbon monoxide, black carbon, organic carbon, methane, volatile organic compounds, non-methane hydrocarbons, ozone, and aerosols *etc.* which affect the global atmospheric chemistry and climate (Tripathi *et al.,* 2013). Farmers consider burning of plant debris and weeds as the cheapest and easiest method of land clearing and pest control. Small mounds of soil are made at regular intervals in some fields for growing crops like potato, taro (*Colocasia* sp.), garlics (*Allium sativum*), Allium chinense *etc.* Such mounds make easier and faster to bury corm, rhizome or bulb in the soil while growing. No such mounds are made in the area designated for rice and maize (Zea mays) cultivation. Generally, crops-cultivation continues for two years at a particular site followed by fallow period of 10 – 15 years. Figure 4 shows the schematic representation of oak agroforestry. Crops cultivated in the first year are different from those grown in the second year. Seed sowing starts in April. In the first year farmers sow rice as dominant crop along with seeds of other crops, namely, maize, chillies (*Capsicum annuum*), cucumber (*Cucumis sativus*), pumpkin (*Cucurbita maxima*), tomato (*Lycopersicon esculentum*), *Perilla frustescens* etc. After germination, plantlets of different crops are transplanted at suitable places in the field with proper spacing. Pumpkin and cucumber are transplanted at the edge of the plot so that they will not interfere with growth of rice.

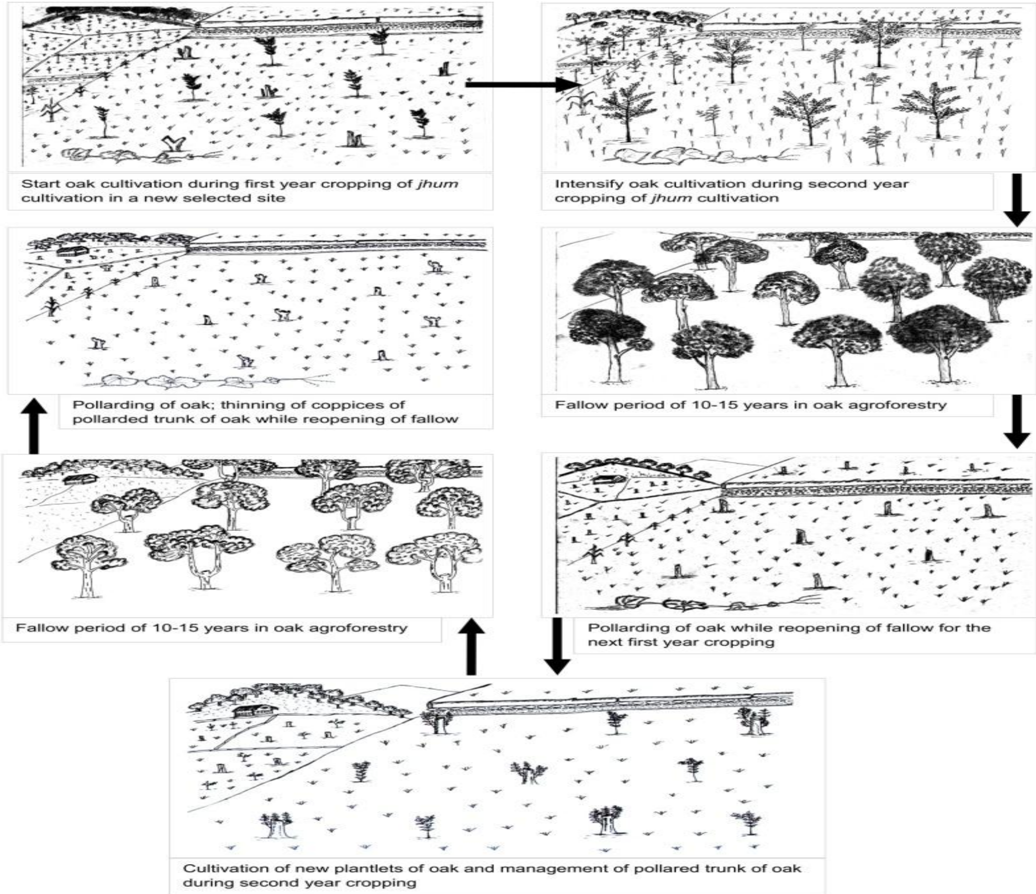

Figure 4. Schematic representation of oak-based agroforestry system in Mima village of Kohima district

Beans (*Phaseolus vulgaris*) which need support are grown near pruned small trees inside the field. Maize are planted along the foot path inside the field or at the edge around the plot. Sometimes, they are also grown among the rice crop. Farmers do first weeding in May and second weeding in July. Harvesting of cucumber, chilli, early maize, tomato *etc.* starts from late July to August. Early harvest of traditional rice, namely okie commences in September. In the second year, farmers grow rice of shorter duration, namely, the kelha along with other vegetables or rise nurseries of paddy for wet terrace located nearby the agroforestry fields. Sometimes, farmers also grow millets (*Setaria* sp.) in the second year along with maize and other important crops, such as chillies and *Solanum melongena*. Farmers cultivate *Zingiber officinale*, maize, taro *etc.* in fertile soil while *Pisum sativum* and Glycine max can grow in less fertile soil.

Crop yield is maintained following traditional practices of soil and weed management. Angami farmers do not apply manures or fertilizers in the oak-based agroforestry fields. Instead they add ashes and charcoals obtained from the burning of plants debris and weeds, in the fields for neutralizing the acidic soil. They believe that burning of vegetation releases nutrients stored in the forest biomass onto the soil which crops absorb (Changkija 2014). The nutrient content of ash markedly increases the nutrient supply, providing a two-fold increase in exchangeable Ca and Mg and a threefold increase in Modified Oslen-extractable P (Smyth and Cassel 1995). Many farmers reported plants grow well in those places where the soil is burnt. Burning of soil helps to release fixed nutrients, such as potassium and phosphorus from the soil to the crops (NEPED and IIRR 1999). Herbicides, insecticides and fungicides are seldom used. Seeds and other perennial underground vegetative parts of weeds are expected to die while burning of soil during its preparation. Regular practice of manual removal of weeds is considered the most essential approach of controlling weeds. Burning of slash helps to drive away rodents far from the field and many pests, including insects existing in the soil are expected to die. Burning of slash is effective in controlling soil-borne pest, insects and other pathogens. It was also reported that addition of ashes and charcoal to soil effectively controls different types of pest insects (for examples locusts, caterpillars, grasshoppers *etc.*). Farmers construct scarecrows or guard the fields to evade birds like parrots and wild pigs in the fields. Manual removal of diseased plants from fields and burning separately are another ways of controlling diseases of crops.

Angamis follow strict cultural tradition relating to agroforestry operations. Villagers select an elderly man known as tsaki – u who cannot do any physical work, to perform all the rituals of sowing seeds. He inaugurates the seed sowing in a small plot which is fenced around with bamboo to avoid any trespasser. Strong taboo is imposed on sowing seeds in agroforestry fields and wet terrace before observing ritual by tsaki – u. A small hut is constructed at any place in the village where tsaki – u has to stay after sowing seeds for 5 days. For first 5 days he is not allowed to return to his house. He is prohibited to meet or talk to any stranger during this period. While staying in the hut he performs prayers and other rituals for the protection and higher yield of crops. After sowing seeds farmers celebrate the küyünyü festival; family members share rice beer among themselves for the success of sowing seeds. This festival also marks the time of opening terrace fields. An elderly woman known as Liedüpfü inaugurates the first harvesting of crops. She harvests a small huddle of mature paddy plants or millet and hangs the bundle in a corner of the house. Other farmers then harvest their crops, but it is prohibited to harvest any crops before inauguration by Liedüpfü. However, there is lacking of such traditional practice among the modern Angamis due to acculturation.

Agrobiodiversity

Inventory of oak-based fields recorded diverse agroforestry products that included 33 species belonging to 28 genera under 15 families (Table 1). The most widely cultivated plants belong to Cucurbitaceae and Solanaceae (5 species) which is followed by Leguminaceae and Poaceae (4), Liliaceae (3 each), Lamiaceae and Meliaceae (2 each) and the rest of the families are represented by one species only. Primary utility of these products are food. Six species have single use (*i.e.* food) while 21 other species have uses in addition to food (for example medicine, fodder and other purposes). Six tree species are important sources of firewood, charcoal and timber. There was less fluctuation in the crop yields of the last 3 consecutive years (2016, 2017 and 2018). Yield of rice and other crops in oak-based agroforestry was normal as opposed to the notion that nothing grows well underneath oak trees (Figure 5). However, Nakro (2011) reported, maize under oak plantations is not suitable. The pattern of cropping in oak-based agroforestry is similar to mixed cropping. Farmers perceive that such pattern of cropping helps to augment the yields of crops. Crops such as maize, tomato, cucumber, pumpkin, beans and A. chinense in oak-based agroforestry are sufficient for household consumption (Table 2). However, rice productivity is insufficient since the area of cultivation is small. As a result farmers mainly rely on the yield of rice from wet terrace for annual household consumption. Crop productivity is also adversely affected by pests like parrots and wild pigs.

Management of oak trees

The oak tree is referred to phibo/phrie in Angami dialect. It is a fast-growing deciduous tree and produces many coppices after pollarding. Farmers have reported young oak plantlet grows to a diameter of 0.026 to 0.038m in 2 years, 0.051 to 0.076m in 4 to 5 years and 0.17m and height of more than 4.6m in 7 years. Sufficient mature oak trees are found growing in Mima, Rusoma and Dihoma villages areas in natural habitats such as road sides and forests. In Mima village oak trees are found growing from the altitude of 1450m to 700m asl.

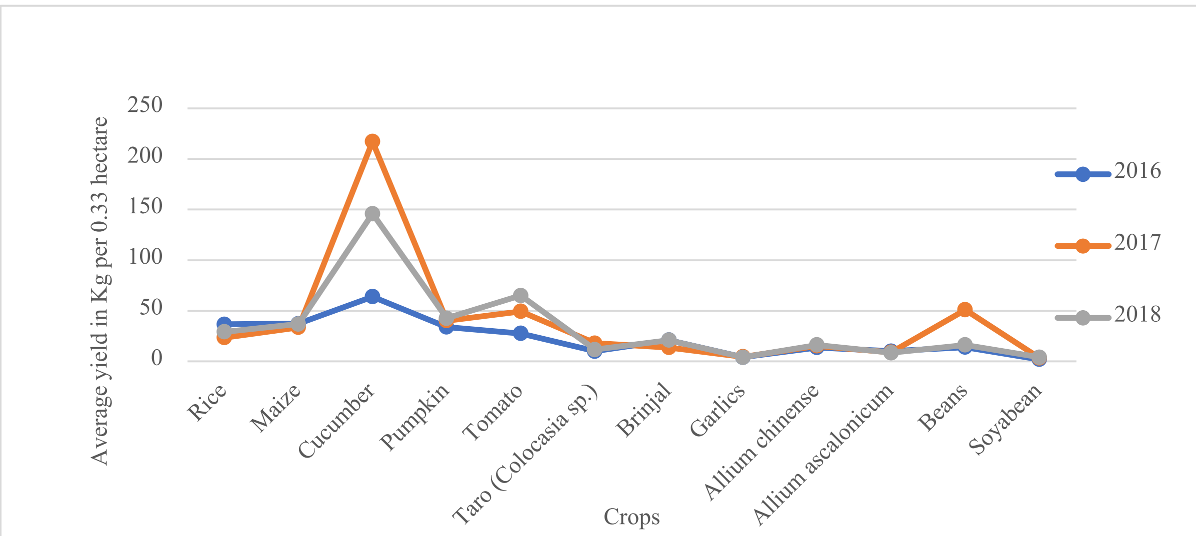

Figure 5. Comparison of crop yields of three years in oak-based agroforestry of Mima village

Table 2. Average yields of six selected crops of three years (AY = Average yield) in ten households

(a) Households	Average area of cultivation of 3 years (2016, 2017, 2018) in Hectare	Rice	Maize	Cucumber	Pumpkin	Taro (*Colocasia*sp.)	Tomato
		AY of 3 years in Kg	AY of 3 year in Kg	AY of 3 years in Kg	AY of 3 years in Kg	AY of 3 years in Kg	AY of 3 years in Kg
1	0.3	20	40	30	4	-	32
2	0.1	13	18	21	22	-	6
3	0.16	19	40	61	25	20	33
4	0.31	70	53	152	60	-	45
5	0.49	30	50	120	15	-	10
6	1.47	29	32	64	45	11	25
7	0.56	30	-	1500	150	-	325
8	0.3	31	35	40	39	-	10
9	0.25	25	45	35	35	10	20
10	0.36	30	45	80	40	15	30

As a result, oak trees can be managed in jhum fields of different agroclimatic zones. In the month of October-November seeds are collected from forests and immersed in water for a few minutes. Floating seeds are discarded while those settled at the bottom are selected for sowing as such seeds are considered viable. These seeds are spread over the ground near the house. Germination starts in March (Nakro 2011). Many farmers even maintain nursery of oak for growing in the agroforestry fields. In the first year of crops cultivation farmers start transplantation of oak seedlings or randomly bury 2 or 3 seeds at a place at different sites of the field. Natural population of oak trees of about 7-10 years (considered as most desirable age) are pollarded horizontally at the height of 0.61 to 0.91m above the ground (Figure 6a). Thinning is done for small and young trees which are less than 7 years. Farmers believe that oak pollarded at this height develops stronger coppices which could not be broken by strong winds. Above 15 years oak trees hardly produce coppices or even die. In the second year, as many as 20 to 30 coppices develop from the lateral side of the stem which is usually thinned to 2 coppices. Intense cultivation of oak commences in second year with spacing of about 1.52m randomly throughout the entire field (Figure 6b). During the fallow period of 10 to 15 years, coppices of the pollarded stems grow to decent size which is harvested for firewood. Two more species of oak, namely, *Quercus griffithii* and *Lithocarpus polystachyus* are prevalent in Mima village. But they are slow grower and produce profuse lateral branches at lower height which increases undesirable shading effect to crops. Further thinning the branches of *Q. griffithii* and *L. polystachyus* involves intense physical labour. As a result, farmers do not favour these trees for their agroforestry. *Q. serrata* is preferred the most as it grows faster, and produce more coppices than other oak species. It produces long and erect stem with lesser lateral branches at lower height and thus there is no shading effect. Oak produces quality firewood and charcoal better than alder trees.

Fallow management

In higher altitudes, alder is a common fallow tree whose successful management in jhum fields of Khonoma village has been reported elsewhere (Cairns 2007) whereas in Mima village alder is not suitable for fallow because of its restricted distribution in lower altitude. Many farmers observed that dry and warmer climatic conditions of Mima village are the factors for their failure to introduce alder in jhum fields. Selection of suitable local tree species for fallow can be considered as the challenge to farmers since it involves long process of field trial and observations (NEPED and IIRR 1999). Farmers observed that oak (*Quercus serrata*) could satisfy some of the desirable properties of fallow trees, such as wider adaptability, less shading effect, good quality firewood and charcoal, and producing profuse coppices after pollarding. Oak trees shed their leaves profusely in winter, which mulch with soil and help to enrich soil fertility and reduce soil erosion with its root systems. As a result oak had been selected as the most popular fallow tree in Mima village. Other components of management of oak is similar to that of alder. Farmers maintain fallow regeneration for a period of 10-15 years during which the pollarded stump increases its diameter and develops large number of bigger coppices. Farmers regularly thinned selected coppices at an interval of 5 years for firewood even during the fallow period. Thinning of coppices is practiced in the month of September. While reopening of the fallow for the next jhum cycle farmers log most of the oak trees and maintain

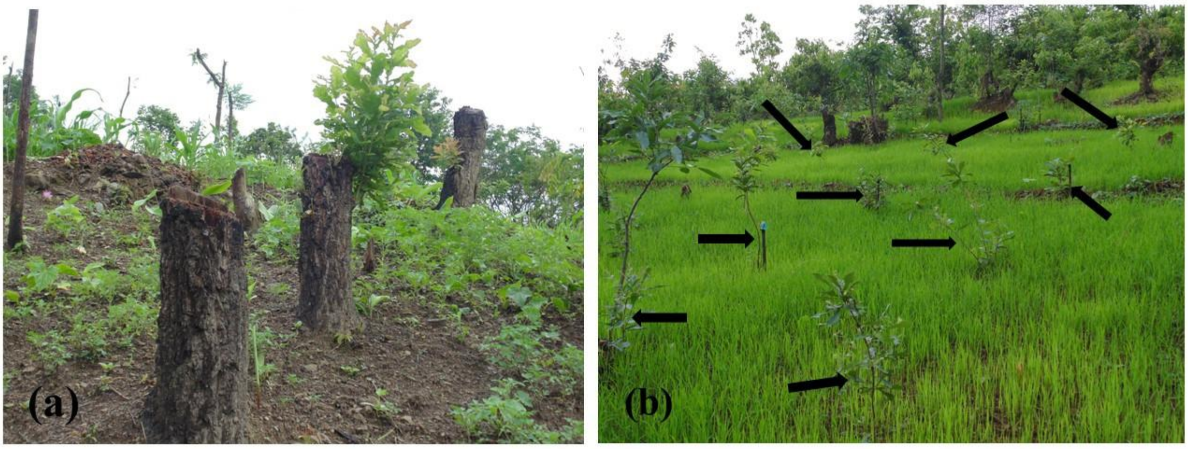

Figure 6. Oak (*Quercus serrata*) management (a) oak pollarded at the height of 0.61-0.91m above the ground (b) intense cultivation of oak in second year *jhum* field (arrows) Photo (a) and (b) taken in 2018

Table 4. Comparison of fallow management in three Angami villages

Trees associated with the fallow management	Fallow management	Villages		
		Mima	**Rusoma**	**Khonoma** (Cairns, 2007)
Alnus nepalensis D. Don	Pollarding time	October	October-November	November
	Pollarding age	6-7 years	7-10 years	8-9 years
	Pollarding height	0.61-0.91m	0.61-0.91m	2.13-2.44m
	Period of crop cultivation	2 years	1 year	2 year
	Fallow period	10-15 years	15-20 years	2 years
	Status of the tree	Rare	Abundant	Abundant
Quercus serrata Murray	Pollarding time	October	No report	No report
	Pollarding age	7-10 years	No report	No report
	Pollarding height	0.61-0.91m	No report	No report
	Period of crop cultivation	2 years	No report	No report
	Fallow period	10-15 years	No report	No report
	Status of the tree	Abundant	No report	No report

only a few trees in the field as many crops do not grow well under oak trees. In the second year of cropping farmers restart growing of many young oak trees and replace the older unhealthy ones with new young plants. Farmers claim oak trees grows well producing more coppices till about 30-40 years.

Trends in Angami agroforestry practices

Traditionally a period of 10 to 15 years is given for fallow regeneration during which sufficient biomass for productive re-cultivation. But the operation varies from one village to another in respect of management of trees (Table 4). In the present days however, there has been changes in fallow management with fallow period as less as 2 to 3 years, while in other villages the fallow period has increased. Causes for increase or decrease in fallow period differ from one village to another.

For example, in Rusoma the increase in fallow period is attributed to farmers giving up jhum practices and mainly focusing on wet terrace agriculture whereas in Kigwema the decrease in fallow period is due to increasing population pressure. In recent times, there is high market demand for P. timoriana because of the medicinal and nutritional properties and palatability of the pods. Though the pod is recently introduced into traditional Angami food practice (Singh and Teron 2017), farmers of Mima village are aggressively cultivating P. timoriana in their agroforestry fields to meet the increasing market demands. Farmers have started cultivation of many local tree species, namely *Q. serrata*, *A. lebbeck*, *M. azedarach*, *S. wallichii, Toona* sp. and *P. emblica* in jhum fields to meet the increasing need of firewood and timbers. Many families have been focusing on permanent terrace cultivation as jhum cultivation involves intense physical labour.

As a result, there is rapid decrease in the number of farmers who practice jhum cultivation. As folk varieties of crops are less productive and cannot meet the increasing demand of food, it is gradually replaced with the so called high-yielding varieties. Traditional cultivars of jhum rice are also gradually disappearing today. Farmers have reported about twelve traditional cultivars of jhum rice but today they cultivate only four, namely pelulha/khathuo, ketei, lhaya - e and kekra. A traditional cultivar of jhum rice known as the kelha which is cultivated only in the second year is found to be very rare. Many farmers do not prefer to grow this variety because of its smaller seeds which pose difficulty in winnowing; moreover, its productivity is less. In Rusoma village, farmers cultivate the kelha in home gardens mainly for the purpose of conservation. Changes in traditional agroforestry practices seem natural rather than imposed. Decrease in number of individuals in a family who practice jhum cultivation due to migration to urban areas in search of jobs; change in life style of the people due to financial improvement; realisation of involvement of lesser manual works, labourers and time in wet terrace cultivation compared with the jhum practice are major drivers of changes in Angami agroforestry.

Another recent development in Angami agroforestry was the establishment of the Nagaland Environmental Protection and Economic Development (NEPED) project, partnering with the Government of Nagaland, International Development Research Centre and India-Canada Environment Facility with the objectives of improving land use systems of *jhum as* (shifting cultivators) (NEPED and IIRR 1999). In 1995 NEPED began to work at the community level to encourage adoption of agroforestry by cultivating multipurpose local tree species in *jhum* fields. However, during the field survey of the present study it was found that the initiatives of NEPED for the improvement of *jhum* fields could not reach out many Angami villages, namely, Kigwema village, Mima village, Rusoma village and Dihoma village in Kohima district of Nagaland state. In these villages farmers hardly manage tree in their *jhum* fields. Cultivation of trees in *jhum* fields depends upon the interest and economic needs of the owners. This may result in serious problem of soil erosion including frequent landslides in many parts of Kohima district. There is a need for intervention of the authorities and policy makers to extend their supports to renovate *jhum* fields of these villages as sustainable agroecosystems by encouraging to cultivate suitable multipurpose fallow trees for different agroclimatic zones.

Conclusions

The Angami traditional agroforestry practices have developed as result of long-term interactions of the people with local environment. The successful integration of selected multipurpose local trees with diverse traditional crop varieties to meet requirement for food, fodder, firewood, timber and other essential commodities is a display of sound traditional ecological knowledge of management of trees, soil, water and pests. Global initiatives to encourage large-scale adoption of agroforestry in *jhum* fields need adaptive approaches that are consistent with locally relevant model of land use systems. Cultivation of oak trees in *jhum* fields helps to maintain soil fertility and reduces soil erosion. Oak-based agroforestry can serve as sustainable agroecosystem which has the potential to augment production of foods, fodder and firewood without adverse impacts on environment. This system can sustain in different agroclimatic zones of hilly regions and serve as an important alternative source of firewood to meet the increasing energy crisis in both rural and urban areas without compromising crop yields. It is the primary repository of biodiversity particularly traditional varieties of plants genetic resources which can form valuable source of novel traits for our conventional crops. This system infers as a viable tool for conservation of agrobiodiversity and natural forest resources by reducing pressure on forests from firewood and timber extraction.

However, in recent time there has been many changes in Angami agroforestry particularly with the introduction of high-yielding crop varieties resulting in erosion of valuable gene pool of folk crop varieties. There is a need to encourage the cultivation of more multipurpose trees capable of biological nitrogen fixation, namely *Albizia lebbeck* and *Parkia timoriana* (Hammer and Khoshbakht 2015) which helps to enhance the sustainability of agroforestry practices in Mima village of Kohima where oak-based agroforestry dominates. It needs an extensive documentation of agrobiodiversity before it is lost to science. Further investigation of the impact of oak agroforestry on climate change is needed. Scientific investigations can help to validate sustainability and potentials of traditional agroforestry systems. Such study can be useful, among other issues, in recognition of contribution of indigenous farmers and protection of their intellectual property and biodiversity conservation.

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References

Amejo AG, Gebere YM, and H Kassa (2018). Integrating crop and livestock in smallholder production systems for food security and poverty reduction in sub-Saharan Africa. *African Journal of Agricultural Research* 13(25): 1272-1282

Bammanahalli S (2016). Productivity and carbon storage in prevalent agroforestry systems in sub-tropical region of Himachal Pradesh. PhD Thesis, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Solan, Himachal Pradesh, India

Basic Facts Nagaland (2018). Basic facts of Nagaland, Directorate of Information and Public Relations, Government of Nagaland, Kohima, pp 7

Bennett A, Cronkleton P, Menton M, and Y Malhi (2018). Rethinking fuelwood: people, policy and the anatomy of a charcoal supply chain in a decentralizing Peru. Forests 9: 533. https://doi.org/10.3390/f9090533

Cairns M (2007). The alder managers: The cultural ecology of a village in Nagaland, N.E. India. PhD Dissertation. Australia National University, Canberra, Australia

Census of India (2011). District census handbook, Kohima District, Village and Town Directory, Series 14, Part XII A. Directorate of Census Operations, Nagaland, pp 86

Changkija S (2014). Biodiversity of Nagaland. Department of forest, ecology, environment and wildlife. Government of India, Kohima, pp 39-41

Chase P, and PO Singh (2014). Soil nutrients and fertility in three traditional land use system of Khonoma, Nagaland, India. *Resour Environ* 4(4): 181-189

Chaturvedi OP, Dagar JC, Handa AK, Kaushal R, and VC Pandey (2018). Agroforestry potential for higher productivity from degraded ravine watersheds. In: JC Dagar, A Singh (eds) Ravine lands: greening for livelihood and environmental security. Singapore: Springer. Doi: 10.1007/978-981-10-8043-2_14

Dagar JC, Pandey CB, and CS Chaturvedi (2014). Agroforestry: a way forward for sustaining fragile coastal and island agro-ecosystems. In: JC Dagar, AK Singh, A Arunachalam (eds) Agroforestry systems in India: livelihood security & ecosystem services, advances in agroforestry 10. Springer India 2014, pp 185-232. Doi: 10.1007/978-81-322-1662-9_7

Dagar JC, and VP Tewari (2017). Evolution of agroforestry as a modern science. In: JC Dagar, VP Tewari (eds) Agroforestry. Singapore: Springer Natural Pte Ltd. https://doi.org/10.1007/978-981-10-7650-3-2

Dhyani SK (1998). Tribal alder: an agroforestry system in the northeastern hills of India. *Agro Today* 10(4): 14-15

Elevitch CR, Mazaroli DN, and D Ragone (2018). Agroforestry standards for regenerative agriculture. Sustainability 10: 3337. Doi:10.3390/su10093337

Githiomi JK, Mugendi DN, and JB Kung'u (2012). Analysis of household energy sources and wood fuel utilisation technologies in Kiambu, Thika and Maragwa districts of Central Kenya. *Journal of Horticulture and Forestry* 4(2): 43–48

Hammer K, and K Khoshbakht (2015). A domestication assessment of the big five plant families. *Genetic Resources and Crop Evolution* 62(5): 665-689.

Idumah FO, and AO Akintan (2014). Contribution of agroforestry to food production and income generation in Sapoba forest area, Edo State, Nigeria. *Journal of Horticulture and Forestry* 6(8): 64-71. https:/doi. org/ 10.5897/JHF2014.0357

Iiyama M, Neufeldt H, Dobie P, Njenga M, Ndegwa G, and R Jamnadass (2014). The potential of agroforestry in the provision of sustainable wood fuel in sub-Saharan Africa. *Current Opinion in Environmental Sustainability* 6: 138–147

Jemal O, Callo-concha D, Van noordwijk M (2018). Local agroforestry practices for food and nutrition security of smallholder farm households in southwestern Ethiopia. Sustainability 10: 2722

Kanjilal UN, Kanjilal PC, Das A, and C Purkaystha (1934). Flora of Assam, Vol. 1: Assam Government. Press, Shillong

Kanjilal UN, Kanjilal PC, and A Das (1938). Flora of Assam, Vol. 2: Assam Government. Press, Shillong

Kanjilal UN, Kanjilal PC, Das A, and RN Dey (1939). Flora of Assam, Vol. 3: Assam Government. Press, Shillong

Kanjilal UN, Kanjilal PC, Das A, and RN Dey (1940). Flora of Assam, Vol. 4: Assam Government. Press, Shillong

Limon SH, Hossain M, and H Spiecker (2018). Nutrients leaching from green leaves of three potential agroforestry tree species. *Agroforestry Systems* 92: 389. https://doi.org/10.1007/s10457-016-9996-x

Mattalia G, Calvo A, and P Migliorini (2018). Alpine home gardens in the Western Italian Alps: the role of gender on the local agrobiodiversity and its management. Biodiversity. doi: 10.1080/14888386.2018.1504692

Nakro V (2011). Traditional agricultural practices and sustainable livelihood. A thematic report 2009. Department of planning and Coordination. Kohima: Government of Nagaland, pp 43-46

NEPED and IIRR (1999). Building upon Traditional Agriculture in Nagaland, India. Nagaland. Philippines: Environment Protection and Economic Development, Nagaland, India and International Institute of Rural Reconstruction, Silang, Cavite

Pantera A, Papadopoulos A, and VP Papanastasis (2018). Valonia oak agroforestry systems in Greece: an overview. Agrofor Syst. https://doi.org/10.1007 /s10457-018-0220-z

Pe´rez-flores J, Pe´rez AA, Sua´rez YP, Bolaina VC, and AL Quiroga (2018). Leaf litter and its nutrient contribution in the cacao agroforestry system. Agrofor Syst. https://doi.org/10.1007/s10457-017-0096-3

Quandt A, Neufeldt H, and JT Mccabe (2018). Building livelihood resilience: what role does agroforestry play? Clim Dev. doi: 10.1080/17565529.2018.1447903

Raj A, and S Chandrawanshi (2016). Role of agroforestry in poverty alleviation and livelihood support in Chhattisgarh. *South Indian Journal of Biological Sciences* 2(3): 339-343

Rathore SS, Karunakaran K, and B Prakash (2010). Alder based farming system a traditional practices in Nagaland. *Indian Journal of Traditional Knowledge* 9(4): 677-680

Shukla S, Pandey VV, and V Kumar (2018). Agroforestry Systems as a tool in sustainable rural development, food scarcity and income generation. Indian for [S.l.] 435-441

Singh AB, and R Teron (2015). Diversity of wild edible plants used by the Angami Nagas in Kohima district of Nagaland, India. *Pleione* 9(2): 311-324

Singh AB, and R Teron (2017). Ethnic food habits of the Angami Nagas of Nagaland state, India. *International Food Research Journal* 24(3): 1061-1066. http://www.ifrj.upm.edu.my ; Accessed 7 February 2019

Singh NR, Arunachalam A, Bhusara JB, Dobryal MJ, and RP Gunaga (2017). Diversification of Agroforestry Systems in Navsari District of South Gujarat. *Indian Journal of Hill Farming* 30(1): 70-72

Sistla SA, Roddy AB, Williams NE, Kramer DB, Stevens K, and SD Allison (2016). Agroforestry practices promote biodiversity and natural resource diversity in Atlantic Nicaragua. Plos One 11(9): e0162529. doi: 10.1371 / journal. pone.0162529

Smyth TJ, and DK Cassel (1995). Synthesis of long term soil management – research on ltisols and oxisols in the Amazon. In: Lal R, Stewart BA (eds) Soil management: experimental basis for sustainability and environmental quality. Lewis Publisher, Boca, raton, Boca Rston, Florida.

Tripathi S, Singh RN, and S Sharma (2013). Emissions from Crop/Biomass Residue Burning Risk to Atmospheric Quality. *International Research of Earth Sciences* 1(1): 24-30.

Umrao R, Mehera B, Khare N, and H Kumar (2017). Structure and floristic composition of existing agroforestry systems in Fatehpur district of Uttar Pradesh, India. *Current World Environment* 12(1): 124-131. http://dx.doi.org /10.12944/CWE.12.1.15