कृषि एवं किसान
कल्याण मंत्रालय
MINISTRY OF
AGRICULTURE AND
FARMERS WELFARE

सत्यमेव जयते

भाकृअनुप
ICAR

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CAFRI

Promising Agroforestry Models for Nagaland

ICAR-Central Agroforestry Research Institute

Jhansi-284003, Uttar Pradesh, India

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Contribution

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Disclaimer

The document has been prepared fully in academic spirit for educational and ready reckoning purposes. The information in the document is based on primary observations and secondary information from published sources. The information provided in this document is to best of our knowledge, accurate although we do not guarantee the information not are we liable for any damages arising from use of information.

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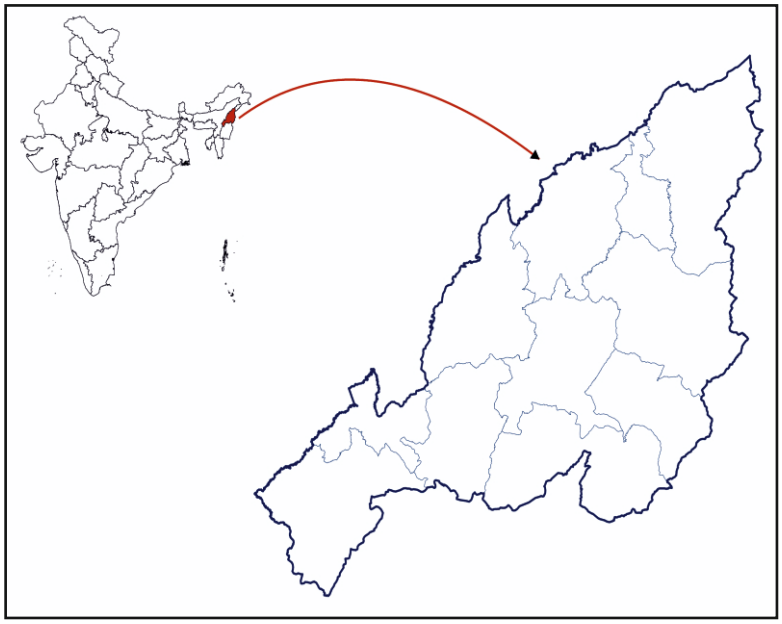
Promising Agroforestry Models for Nagaland



Nagaland is a land of transition, a fusion of hill tribes' styles and cultures. One of the smaller hill states of India, Established in 1866 as the Naga Hills district under the Bengal Presidency, it later became a district in Assam. In 1957, a new administrative unit was formed in Assam, named Naga Hill Tuensang Area. On the 1st December 1963 Nagaland inaugurated as the 16th state of India, with its capital at Kohima. It is a largely mountainous state and it is bounded by Assam, Myanmar, Arunachal Pradesh, parts of Assam, and Manipur. Geographically, the state extends 93°20' E and 95°15' E Longitude and between 25°6' and 27°4'N Latitude (Ministry of Tourism, 2003).

Physiography

Nagaland is characterized by a narrow strip of hilly terrain running from the northeast to the southwest, with the Assam plains lying to its north and northwest. The Barail range enters the state at the southwest corner, extending northeastward nearly to Kohima. In the vicinity of Kohima, the Barail range converges with mountain ranges stretching towards Manipur, causing the main range to shift towards a more northerly direction. This main range is significantly higher than the Barail, featuring peaks such as Saramati at 3,826.15 meters and Mataung Kien at 3,420 meters in the extreme east.

Between Mao and Kohima, there are several notably high peaks, including Japvo. North of Kohima, the main range decreases in height, with the Japukong range in Mokokchung district reaching an average elevation of 750 meters. Overall, 94% of Nagaland's area consists of hilly and rugged terrain, while only 6% comprises plains, predominantly along the western boundary adjacent to the Assam plains. The state's landscape is marked by low hills densely covered with vegetation (Government of Nagaland).

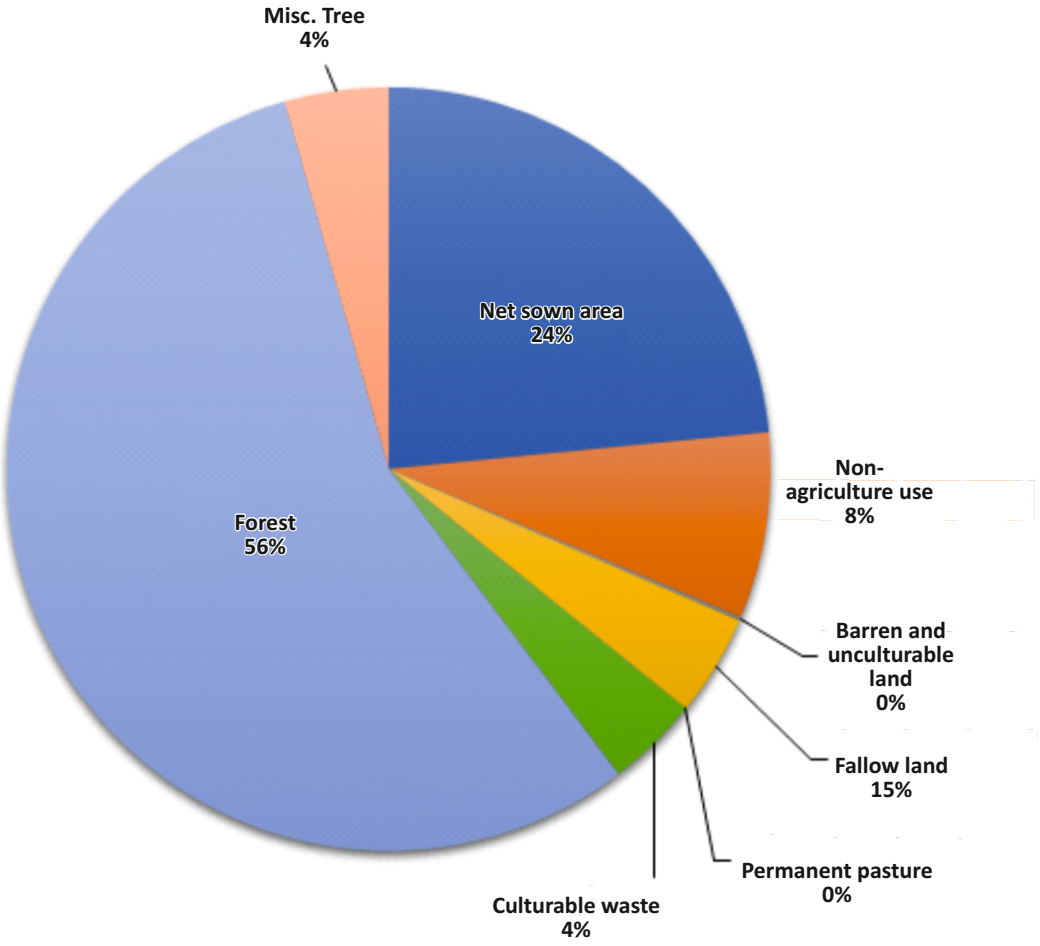
Climate

Nagaland's climate is pleasant due to its abundant vegetation and hilly terrain. Winters are cold, with areas like Kiphire, Phek, and Pfutsero experiencing little snowfall due to their high elevation. Summers can be slightly hot and humid in towns like Dimapur, Tuni, and Tizit. The region receives ample rain 1,800–2,500 millimeters during the monsoons from May to September and the average temperature ranges between 21 to 40 °C, with temperatures generally not dropping below 39 °F. The shortest season is summer, lasting for a few months. The summer temperature remains between 61 to 88 °F (16 to 31 °C). Winter often arrives early, with extreme cold and dry weather attacking certain areas. The extreme temperature in winter is 75 °F (24 °C). Sturdy northwest breezes blow across the state through February and March. Snowfall occurs in high elevations, but is infrequent and most of the state does not observe snow (Government of Nagaland, 2003).

Land use pattern

Land use is an important statistic for agricultural growth. In Nagaland, with a total geographical area of 16,579 km^2 a major portion of land is covered by forest 73.90%. The net sown area in Nagaland was

3624.32 km^2, which accounts for 21.86% of the total geographical area. There was a decrease of 5.89% in the net sown area compared to the previous year.



Source: Nagaland Statistical Handbook (2023)

Forests and its resources

Nagaland has six of India's 16 main forest types: Northern Tropical Wet Evergreen Forest, Northern Tropical Semi Evergreen Forest, Northern Sub-Tropical Broad Leaved Wet Hill Forest, Northern Sub-Tropical Pine Forest, Northern Montane Wet-temperate Forest and Alpine Forest (Department of Environment, Forest& Climate Change, 2024). Nagaland has a total forest cover of 12,251.14 km², accounting for 73.90% of the entire geographical area. Nagaland's forest cover is categorized into very dense forest (1,272.04 km²), moderately dense forest (4,449.07 km²), and open forest (6,530.03 km²). Peren, a tribal hill district, boasts the largest forest coverage, with forests covering 85.30% of its total geographical area (ISFR, 2021). Nagaland has 8,628 km² within the Recorded Forest Area (RFA) and 3,623 km² outside of it. The tree-covered area in Nagaland has slightly increased, from 362 km² in 2019 to 365 km² in 2021. Trees outside forests (TOF) span 3,988 km², including both forest and tree cover. In rural Nagaland, the top five tree species in TOF are *Schima wallichii* (8.46%), *Alnus nepalensis* (5.71%), *Duabanga grandiflora* (5.69%), *Macaranga* spp. (4.37%), and *Livistona jenkinsiana* (4.27%). In urban areas, the top five TOF tree species are *Areca catechu* (12.53%), *Mangifera indica* (11.22%), *Tectona grandis* (5.72%), *Artocarpus heterophyllus* (3.22%), and *Cocos nucifera* (2.67%). The overall carbon store of Nagaland forests, including TOF patches bigger than 1 hectare, is 134.93 million tonnes, or 1.87% of the country's total carbon pool. Major Non-Timber Forest Produce (NTFP) species in Nagaland include *Thysanolaena maxima, Phyllanthus officinalis, Rhus semialata, Oroxylum indicum* and *Litsea citara* (ISFR, 2021).

Forest types

S.No.	Type of Forest	Area (in sq.km)	% of the total mapped area
1.	Assam Valley tropical wet evergreen forest (Dipterocarpus)	82.82	0.63
2.	Pioneer Euphorbiaceous scrub	639.37	4.86
3.	Eastern alluvial secondary semi-evergreen forest	2353.38	17.90
4.	Secondary moist bamboo brakes	546.69	4.16
5.	East Himalayan moist mixed deciduous forest	5030.79	38.26
6.	Khasi subtropical wet hill forest	2148.80	16.34
7.	Assam subtropical pine forest	735.33	5.59
8.	Naga hill wet temprate forest	1446.16	11.00
9.	Montane bamboo brakes	9.16	0.08
10.	TOF/Plantation	129.39	0.98
	Total (Forest Cover & Scrub)	13121.89	100

Source: ISFR (2021)

Soil

Nagaland's soils are classified into four orders, seven sub-orders, 10 great groups, 14 sub-groups, and 72 soil families.

- Alfisols, found in semiarid to humid areas under hardwood forest cover, are moderately leached soils with high native fertility and are widely used for food and fiber production. They occupy 10.1% of the global ice-free land area and support about 17% of the world's population.
- Entisols, defined as soils that do not show any profile development other than an A horizon, are the second most abundant soil order, occupying about 16% of the global ice-free land area. They are found on the western flank of the State bordering Assam and are deep and well drained of fine to fine loamy texture.
- Inceptisols, more developed than Entisols but lacking features characteristic of other soil orders, are soils that exhibit minimal horizon development and are widely distributed across a wide range of ecological settings. They are often found on steep slopes, young geomorphic surfaces, and on resistant parent materials. Land use varies considerably with Inceptisols, with a sizable percentage found in mountainous areas and used for forestry, recreation, and watershed.
- Ultisols, strongly leached, acid forest soils with relatively low native fertility, are found primarily in humid temperate and tropical areas of the world. They have a subsurface horizon in which clays have accumulated, often with strong yellowish or reddish colors resulting from the presence of Fe oxides. Due to their favorable climate regimes, Ultisols often support productive forests. However, their high acidity and relatively low quantities of plant-available Ca, Mg, and K make them poorly suited for continuous agriculture without the use of fertilizer and lime.
- Inceptisols dominate the soils of the State with 66%, followed by Ultisols 23.8%, Entisols 7.3%, and Alfisols 2.9% of the total 16.6 million ha of the State Geographical Area (Humtose, 2013).

Water Resources of Nagaland

Groundwater is a crucial resource for irrigation, domestic, and industrial use. It is available in the active recharge zone, which is replenished annually and in-storage conditions, which are deeper zones below water level fluctuations. Dynamic groundwater resources are regularly used, and there are large reservoirs in deeper zones and confined aquifers. In-storage groundwater resources can only be developed during extreme drought conditions, mainly for drinking water supply. Monsoon season resources assessment is calculated by multiplying water level fluctuation with the assessment area and

specific yield. Non-monsoon season recharge is calculated using the Rainfall Infiltration Factor (RIF) method. The state of Nagaland has a total annual groundwater recharge of 78,548.63 Ham (Hectare meter), with an annual extractable groundwater resource of 70,693.74 Ham after deducting natural discharge. Current gross groundwater extraction is 2,044.19 Ham, and the net groundwater availability for future use is estimated to be 68,530.17 Ham. The over-all stage of ground water development of the state is 2.89%. All the districts of the state fall under safe category.

Comparison between ground water resources estimation for Nagaland for 2020 and 2022 (based on GEC'15)

S.No	Item	GEC'15 (2020)	GEC'15 (2022)	Comparison (Hectare meter)
1.	Recharge worthy area	1409148	385507	Decreased by 1023641 Ham
2.	Total annual ground water recharge	216653.51	78548.63	Decrease by 138104.88 Ham
3.	Annual extractable ground water resource	194988.14	70693.74	Decrease by 124294.4 Ham
4.	Current annual gross ground Water extraction for all uses	2023.18	2044.19	Increase by 21.01 Ham
5.	Annual allocation of ground water for domestic water supply as on 2025	1970.08	1961.80	Decrease by 8.28 Ham
6.	Net Ground water availability for future use	192805.80	68530.17	Decrease by 124275.63 Ham
7.	Stage of Ground Water extraction	1.04%	2.89%	Increase by 1.85%

Source: CGWB (2022)

Agriculture

Nagaland's economy is predominantly agricultural. The state's agro-climatic conditions are favorable for commercial floriculture and horticulture. It is home to 650 indigenous species of medicinal and aromatic plants. The state has the potential to produce 15,000 metric tons of honey and 100 metric tons of wax annually, which could generate approximately US$ 100 million. In 2016-17, honey production was recorded at 0.45 thousand tons. Agriculture supports over 70% of Nagaland's population. The primary crops include rice, millet, maize, and pulses, with rice being the staple diet and dominant crop, accounting for about 84.4% of the gross cropped area under food grains. Cash crops like sugarcane and potato are gaining popularity. Coffee, cardamom, and tea are cultivated as plantation crops. Oilseeds, including rapeseed and mustard, are also significant crops. The principal crops grown in Nagaland include arums, yams, millet, maize, potatoes, and sugarcane. Vegetable crops include melons, cucumbers, spinach, mustard, onions, chilies, carrots, tomatoes, and eggplant (brinjal). Naga tribes practice two main cultivation methods: jhuming (slash-and-burn agriculture) and terrace cultivation. Approximately 87,339 hectares are under jhum cultivation, while about 62,091 hectares are under terraced cultivation (STINER, 2024). The state has a potential of approximately 30,000 hectares for fisheries, encompassing lakes, ponds, and other terrestrial water bodies. The fisheries sector is crucial to the state's economy. In 2022-23, fish production reached 928 metric tonnes (Nagaland Economic Survey, 2024).

Major crops in Nagaland (in Metric tonnes)

Crops	Production
Jhum Paddy	179227
Maize	88931
Jowar	299

Small Millet	11120
Jobstear	1326
Bajra	880
Ragi	374
Wheat	2570
Tur/Arhar	630
Urd/Moong	740
Ricebean/Nagadal	6650
Cowpea	1270
Beans	4780
Horsegram	110
Pea	6269
Lentil	195
Gram	488
Blackgram	255
Rajma/Kholar	17203
Groundnut	2059
Soyabean	17010
Perilla	1926
Castor	1
Sesamum	886
Sunflower	190
Rapseed/Mustard	15978
Linseed	3030
Sugarcane	108489
Cotton	2
Jute	5667
Tea green	36788
Ramie	95
Mesta	1794
Tapioca	62035
Colocasia	61532
Yam	8514
Sweet potato	17391
Oil palm	7533
Ginger	48928
Potato	51760.05
Broccoli	71.56
Cabbage	119269.92
Green chilli	34064.3
Mushroom	1642.54
Okra	1508.06

Pineapple	114238.24
Mango	3694.65
Banana	86616.64
Coffee	17.47
Arecanut	1226.8
Coconut	9357
Total	1146632

Source: Nagaland Statistical Handbook (2023)

Schemes of Nagaland

The Nagaland government has launched several initiatives and plans, such as the National Food Security Mission (NFSM), *Rashtriya Krishi Vikas Yojana* (RKVY), National Mission on Edible Oil-Oilseed (NMEO-OS), and National Mission on Oilseeds and Oil Palm (NMOOP). According to the 20th livestock census, Nagaland livestock population stands at 3.39 million (Ministry of Agriculture, Department of Animal Husbandry, Dairying and Fisheries, 2019).

S.No	Scheme	Objective
1.	National Food Security Mission (NFSM)	This scheme was introduced to boost the production of rice, wheat, pulses, coarse cereals, and nutrient-rich cereals by expanding the cultivated area and enhancing productivity in a sustainable manner within the targeted districts. Additionally, it aims to restore soil fertility and productivity at the individual farm level.
2.	National Mission on Edible Oil-Oilseed (NMEO-OS)	The NMEO-OS scheme aims to enhance oilseed production nationwide. In the state, oilseed cultivation spans approximately 3,000 hectares. Currently, the emphasis is on three main oilseed crops: rapeseed and mustard, soybean, and groundnut.
3.	*Pradhan Mantri Krishi Sinchayee* (PMKSY): "Per Drop More Crop"	Launched on July 1, 2015, this scheme aims to converge investments in the irrigation sector at the field level. In Nagaland, during 2022-23, PMKSY-O. It was implemented across 50 clusters encompassing all districts and subdivisions, resulting in the development or procurement of 4,692 hectares of land.
4.	Mission Organic Value Chain Development for North East Region (MOVCD-NER)	The Ministry of Agriculture and Farmer Welfare launched the MOVCD-NER for the period 2020-21 to 2022-23, aiming to enhance marketing access under the management of growers' organizations. The Department of Agriculture has identified 140 clusters, covering 173 villages and benefiting 7,339 farmers.
5.	*Rashtriya Krishi Vikas Yojana* (RKVY)	The scheme aims for a 4 percent annual growth in the agriculture and allied sectors by offering financial assistance to states for various agricultural and rural development activities. For the period 2023-24 to 2024-25, it covers 89 villages in clusters across all districts and subdivisions.

6.	Agriculture Technology Management Agency (ATMA)	The primary goal is to provide technical training to farmers. ATMA, a society comprising key stakeholders at the district level, focuses on sustainable agricultural development within the district.
7.	Mission for Integrated Development of Horticulture (MIDH)	During the 2022-23 program, a total of 760 hectares was designated for cultivating fruits such as kiwi, dragon fruit, persimmon, and citrus. Additionally, 800 hectares were allocated for vegetable cultivation. For spices, the state initiated area expansion with 50 hectares for Zanthoxylum and 100 hectares for large cardamom.
8.	Sub-Mission On Seeds And Planting Material (SMSP)	Implemented in the state since 2014-15, the SMSP program encompasses the entire seed production chain, from producing nucleus seeds to supplying quality seeds to farmers. It also supports the creation of infrastructure that promotes the development of the seed sector.
9.	Seed Production Programme (RKVY)	Seed production has been a priority sector for the department. Since the inception of the RKVY program, seed production activities have been conducted in all areas under RKVY projects. This program is implemented during both the Kharif and Rabi seasons. In 2016-17, 87.5 metric tons of certified potato seeds were distributed, covering 35 hectares and expecting a production of 245 metric tons. Additionally, 30 training sessions on seed production techniques have been conducted across all seed production areas.
10.	*Paramparagat Krishi Vikas Yojna* (PKVY)	*Paramparagat Krishi Vikas Yojna* (PKVY) is a scheme under National Mission for Sustainable Agriculture (NMSA). It aims at development of sustainable models of organic farming through integrating traditional and modern science to ensure long term soil fertility, resource conservation and address climate change.
11.	Green India Mission (GIM)	This is a Centrally Sponsored Scheme of Green India Mission (GIM) is one of the eight Missions identified under the National Action Plan on Climate Change (NAPCC). The GIM aims to address key concerns related to Climate Change in the forest sector, namely: Adaptation, Mitigation, Vulnerability and Ecosystem Services. GIM is significant for increasing the forest/tree cover and to improve the quality of existing forest.
12.	Nagaland Bee and Honey Mission	The mission focuses on three major areas namely- I. Research Studies ii. Apiculture Development & Promotion iii. Industry Service and Marketing
13.	Nagaland Bamboo Development Agency	Promoting bamboo-based industries to utilize available resources for income generation. Revitalizing and enhancing local traditional bamboo crafts and art with advanced technology and design, and adding value for export through industrialized production methods.

Biodiversity

India is one of the world's 17 Mega biodiversity countries, accounting for 7–8% of all documented species. Nagaland is rich in Biodiversity, comes under the Indo-Burma (Myanmar) Biodiversity hotspots of the world. The state's rich floristic and faunal diversity is influenced by its location. The world's tallest Rhododendron tree, discovered in 1993, stands at the base of Japfü Peak and is featured in the Guinness Book of World Records. The Protected Area Network includes 1 National Parks and 04 Wildlife sanctuaries as well as 114 Community Reserves 2 Elephant Reserves important role in in-situ conservation of biodiversity (ENVIS Nagaland).

Groups	Number of species in Nagaland
Total crops Cultivated and crops of Jhum fields	231/105
Wild edible fruits	248
Wild edible vegetables	More than 128
Wilde edible flowers	52
Wild edible mushrooms	58
Domesticated fruits	More than 26
Edible roots and tubers	42
Edible seeds and nuts	54
Medicinal plants	More than 656
Bamboo species	57
Orchid species	More than 345
Cane species	7
Lichens	346
Ferns	280
Lesser known Indigenous spices	More than 46
Indigenous local useful trees species	560
Commercial timber plants	147
Animals & butterflies	183
Mammals	67
Aves	More than 541
Amphibian	32
Fish	149
Snake	More than 35
Lizard and geckos	More than 6
Mollusca (Snail)	50
Eatable insects	78

Source: Department of Environment, Forest & Climate Change (2024)

Agro-climatic Zones

Nagaland can be categorized into three distinct agro-climatic zones based on various criteria, including rainfall patterns, soil types, texture, depth, physicochemical features, elevation, terrain, and the dominant crops and vegetation. These zones are: Foothills & Lower Hills, Mid-hills and High-hills.

S.No.	Agro-Climatic Zones	Elevation Range	Important Horticulture crops that can be grown	Important growing areas
1	Foothills & Lower Hills	500 – 2500 ft.	Sub- tropical crops like pineaaple, mango, ber, guava, citrus, banana, date, coconut, etc.	Dimapur, Jalukie, Tizit, Medziphema, Peren, Baghty, Bhandari, Meluri, Tuli, Tsurangkong, Wakching, etc.
2	Mid-hills	2500 – 5000 ft	Stone fruits like plum pear, peach, almond, aonla, mango, banana, passion fruits, etc.	Kohima, Peren, Mon, Wolkha, Tseminyu, Changtolemba, Kiphere, Mangkolemba, etc.
3	High-hills	5000 – 9000 ft	Temparate fruits like apple, cherry, walnut, chestnut, pear, plum, persimmon, apricot, kiwi, etc.	Pfutsero, Chentang, Zunheboto, Helipong, Aboi, Longkhim, Chenmolo, Shanmatore, etc.

Source: Horticulture Development in NEH Region (2009)

Demography

According to the 2011 Indian Census, Nagaland has a population of approximately 1.97 million people. This population is comprised of 1.02 million men and 0.95 million women, making up about 0.16% of India's total population, which stands at 1,210.19 million. Nagaland's population density is 119 people per km^2. Although this density is lower than the national average of 382 people per km^2, the state's demographic features are notable in other respects. Nagaland boasts a literacy rate of 79.55%, reflecting a relatively high level of education among its residents. However, the state's sex ratio, which is 931 females for every 1,000 males, is slightly below the national average of 943 females per 1,000 males. These figures highlight both the educational achievements and the demographic challenges facing Nagaland, underscoring the unique social and cultural dynamics within the state (Nagaland Statistical Handbook, 2023).

Administrative profile

After India's independence, the Naga Hills region was initially made a Centrally Administered Territory, known as the Naga Hills, in 1957. During this period, the area was under the administration of the Governor of Assam. Eventually, on December 1, 1963, Nagaland was established as a separate state of the Indian Union. This transition marked a significant milestone in the region's history, as the Naga Hills district and the Tuensang Area were merged to form the new state of Nagaland. Kohima is the capital of the state and the rural self-government entities in Nagaland include 3 Municipality, 41 Town Panchayat, 74 Blocks and 1428 village, 01 Lok Sabha Constituencies, and 60 Assembly Constituencies and the Nagaland is divided into 16 administrative districts: Chümoukedima, Dimapur, Kiphire, Kohima, Longleng, Mokokchung, Mon, Niuland, Noklak, Peren, Phek, Shamator, Tuensang, Tseminyü, Wokha and Zünheboto (Government of Nagaland, 2024).

State symbols

Nagaland's state symbols include several distinctive species that represent its rich biodiversity. The state animal is the Mithun, also known as the Cattle of Mountain (*Bos frontalis*). The state bird is Blyth's Tragopan (*Tragopan blythii*), locally referred to as Gun by the Angami Naga, Agha by the Sema Naga, and Aogho by the Chang Naga. The state flower is the Tree Rhododendron (*Rhododendron arboreum*) also called the Rose Tree, Lal Buransh in Hindi, Dieng-tiw-saw in Khasi, Nithu in Angami, and Lindai in Mao. The state tree is the Alder Tree, also known as the Himalayan Alder (*Alnus nepalensis*). The state fish is the Copper Mahseer, also known as the Chocolate Mahseer (*Neolissochilus hexagonolepis*). In 1967, the Nagaland Assembly declared Indian English as the official language of the state, and it serves as the medium of instruction in Nagaland's educational institutions. Besides English, Nagamese, a folk language derived from Assamese, is also widely spoken (Government of Nagaland).

Promising Agroforestry Models for Nagaland

S.No.	Agroforestry models	Tree component	Crop component	Economic returns/ Benefit Cost Ratio (BCR)
1.	Bamboo-based Agroforestry Model	Bamboo spp.	Wheat, Mustard, Pulses, Ginger and Turmeric	Net income of Rs. 95,000 to 2,00,000 ha^{-1} yr^{-1} after 4 years under irrigated conditions (Handa *et al.*, 2020)
2.	Mulberry-based Agroforestry Model	*Morus alba*	Napier-Bajra hybrid or *Setaria anceps* grass, Pulses, Beans, Soybean and Wheat	Net income of Rs. 14 000 ha^{-1} yr^{-1} in the initial years to Rs. 50 000 ha^{-1} yr^{-1} after establishment of the system (Handa *et al.*, 2020)
3.	Agar-based Agroforestry Model	*Aquilaria malaccensis*	Patchouli Sugandh mantra Kalmegh Gathion Pineapple, Ginger, Turmeric, Sarpagandha Pipali	From an established plantation, thus, a net income of Rs. 25-30 lakh/ha after 15 years may be generated giving an average of Rs. 1, 96,400 $year^{-1}$ ha^{-1} (Handa *et al.*, 2019)
4.	Alder-based Agroforestry Model	*Alnus nepalensis*	Tea, Coffee, Maize, Rice, Ginger, Potato, Chilli and Large cardamom	The overall net income on degraded hilly soil was Rs. 50,000 to Rs. 70,000/ha in the initial years and Rs. 1,25,000 to Rs. 1,60,000/ha on establishment of the system (Handa *et al.*, 2019)
5.	*Litsea glutinosa*-based Agroforestry Model	*Litsea glutinosa*	Bean, Groundnut and other Legumes mixed	The overall net income from *Litsea glutinosa*-based Agroforestry Model is Rs. 1,85,000/ha/year (Handa *et al.*, 2019)

Agroforestry Models for Nagaland

Bamboo-based Agroforestry Model

Scientific name: *Bambusa balloon, B. bambos, B. tulda, B. nutan, Dendrocalamus hamiltonii, D. strictus* and *D. stocksii*

Suitable spacing: 10m×8m or 12m×10m in agroforestry and 3-4m between clumps on boundary

Suitable intercrops: Wheat, mustard, pulses, etc. during the establishment phase with normal yield and shade-loving crops i.e. ginger and turmeric from the second year onwards

Productivity: 500-750 culms ha^{-1} yr^{-1}

Economics: Net income of Rs. 95,000 to 2,00,000 ha^{-1} yr^{-1} after 4 years under irrigated conditions

Source: Handa *et al*. (2020)

Mulberry-based Agroforestry Model

Scientific name: *Morus alba*

Suitable spacing: 3m×3m for fodder and 2-3m between trees on Boundary/bunds

Suitable intercrops: Napier-Bajra hybrid or *Setaria anceps* grass pulses, beans, soybean and wheat can be cultivated

Tree Productivity: 8 t ha^{-1} yr^{-1} of green tree fodder and 24 t ha^{-1} yr^{-1} of green grass forage over only 6 t ha^{-1} yr^{-1} green fodder yield from degraded grassland

Economics: Net income of Rs. 14 000 ha^{-1} yr^{-1} in the initial years to Rs. 50 000 ha^{-1} yr^{-1} after establishment of the system

Source: Handa *et al*. (2020)

Agar-based Agroforestry System

Scientific name: *Aquilaria malaccensis*

Suitable spacing: For mono crop, spacing is 2.5 m x 2.5 m. However, after 10 years of growth 50 % of trees may be harvested.

Suitable intercrops: Patchouli (*Pogostemon cablin*), Sugandh mantra (*Homalomena aromatica*), Kalmegh (*Andrographis paniculata*), Gathion (*Kaempferia galanga*), pineapple, Ginger/turmeric, Sarpagandha (*Rouvolfia serpentine*), Pipali (*Piper longum*) and Kalmegh

Tree Productivity: After 10 years of planting with intensive management each infected tree may yield about 30-40 kg 'Dum type' to 'Kolasanchi' product for oil extraction, depending on infection intensity

Economics: From an established plantation, thus, a net income of Rs. 25-30 lakh/ha after 15 years may be generated giving an average of Rs. 1, 96,400 $year^{-1}$ ha^{-1}

Source: Handa *et al*. (2020)

Alder-based Agroforestry Model

Scientific name: *Alnus nepalensis*

Suitable spacing: In general 3 x 3 m spacing is recommended for gentle slopes

Suitable intercrops: Tea, Coffee, Maize, Rice, Ginger, Potato, Chilli and *Amomum subulatum* Roxb. (Large cardamom)

Tree Productivity: *Alnus nepalensis* is a fast growing tree in a fruit-based agroforestry system with annual increments of 2.7 metres in height and 2.9 cm in diameter. A mean annual diameter increment of 2 cm is common

Economics: The overall net income on degraded hilly soil was Rs. 50,000 to Rs. 70,000/ha in the initial years and Rs. 1,25,000 to Rs. 1,60,000/ha on establishment of the system

Source: Handa *et al*. (2020)

Litsea glutinosa-based Agroforestry Model

Scientific name: *Litsea glutinosa*

Suitable spacing: For mono crop, spacing is 3 m x 3 m and for mixed crop a wider spacing is adopted.

Suitable intercrops: Indian Laurel can be inter-cultivated with other species with broad leaves and a preference for light. Mixed planting of bean, groundnut and other legumes can be done in first two years. It is recommended for forest planting in mixed system/agroforestry system. Planting can be done in row mixture or cluster plantation. Management rotation is for 10-15 years.

Tree Productivity: Harvested at 7.5 years after planting, i.e., felling 15 cm above ground level enabling to regenerate the coppice shoots, and the total bark is removed. Fresh weight of the wood (without bark) =100 kg/tree; Fresh weight of the bark = 20 kg/tree; Dry weight of the bark (sun drying) = 2.8 kg/tree; Number of trees after mortality = 1000/ha; Dry weight of the bark = 2800 kg/ha; and Fresh leaf as fodder = 150 kg/tree.

Economics: The overall net income from *Litsea glutinosa*-based Agroforestry Model is Rs.1,85,000/ha/year

Source: Handa *et al*. (2020)

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Agroforestry Business Incubation Centre

ABiC

Institute Technology Management Unit (ITMU) of CAFRI facilitates incubation of new startup/entrepreneurs and enterprises for innovation technologies by providing need based physical, technical, business and networking support, facilities and services to test and validate business ventures of the incubates in agroforestry-based enterprises. Also, the IP/deemed IP are commercialized for creating an ecosystem for entrepreneurship. ABiC activities includes thematic areas like are plant nursery; semi-processed items like juice, jam, pulp, gum & resin, etc.; tree seed marketing; timber and wood-based products; fibre and flosses; biofuels and briquettes; essential oils; mini-clonal technology and agroforestry models.

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