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कल्याण मंत्रालय
MINISTRY OF
**AGRICULTURE AND
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Promising Agroforestry
Models for Odisha

ICAR-Central Agroforestry Research Institute
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Contribution:

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Remunerative Agroforestry Models for Odisha

The modern state of Odisha is surrounded by West Bengal in the northeast, Bihar and Jharkhand in the north, Andhra Pradesh in the southeast, Chhattisgarh in the west and Bay of Bengal in the east. It is located between the parallels of 17.49'N and 22.34'N latitudes and meridians of 81.27'E and 87.29'E longitudes (Odisha Profile, 2018).Covering an area of 1,55,707 km^2, Odisha has a coastline of about 480 km on the Bay of Bengal. Geologically, Odisha is located on the eastern fringe of Indian Peninsula.

Physiography

The state is mainly divided into four physiographic zones namely Coastal Plains, Central Table Land, Northern Plateau and Eastern Ghats (Odisha Profile, 2018). The coastal plain is characterized by numerous deltas largely created by the rivers Subarnarekha, Mahanadi, Brahmani and Baitarani. Central Table Land consist mainly of the Mahanadi basin with the rivers Jira, Ong and Tel. Northern plateau is a continuation of Chhotanagpur plateau of Jharkhand. Eastern Ghat is a region of hilly ranges which belong to the main lines of the Eastern Ghats along with some plains and valleys (Singh et al., 2002). This is the largest among the four physiographic regions of Odisha. Mahanadi (494 km) is the major river of the state. Other important rivers of Odisha include Brahamani, Baitarani, Budhabalanga, Subarnarekha, Rushikulya, and Bahuda. Chilika Lake is one of the world's largest brackish water lagoons.

Climate

Odisha enjoys the tropical climate. The climate of state is characterized by high temperature, high humidity, medium to high rainfall and short mild winters, and this climate can be divided into four major seasons including (i) winter season (December to February), (ii) pre-monsoon or hot weather season (March to May), (iii) monsoon season (June to September), and (iv) post-monsoon season (October to November). The normal annual rainfall of the State is 1,451.2 mm (OSDMA, 2023). A major portion of the rainfall in the state is obtained from South-West Monsoon. The mean summer and winter temperatures are 30.3°C and 21.3°C, respectively (Sahu and Mishra, 2005).

Land use pattern

Land use is an important statistic for agricultural growth. Out of the total geographical area (155.7 lakh ha) in the State, a major portion of land is covered by forest (37%). Land use pattern in Odisha for 2021-22. In 2021-22, the net sown area in Odisha was 54.1 lakh ha (35% of the total geographical area) and it has increased by 1.5% over the previous year.
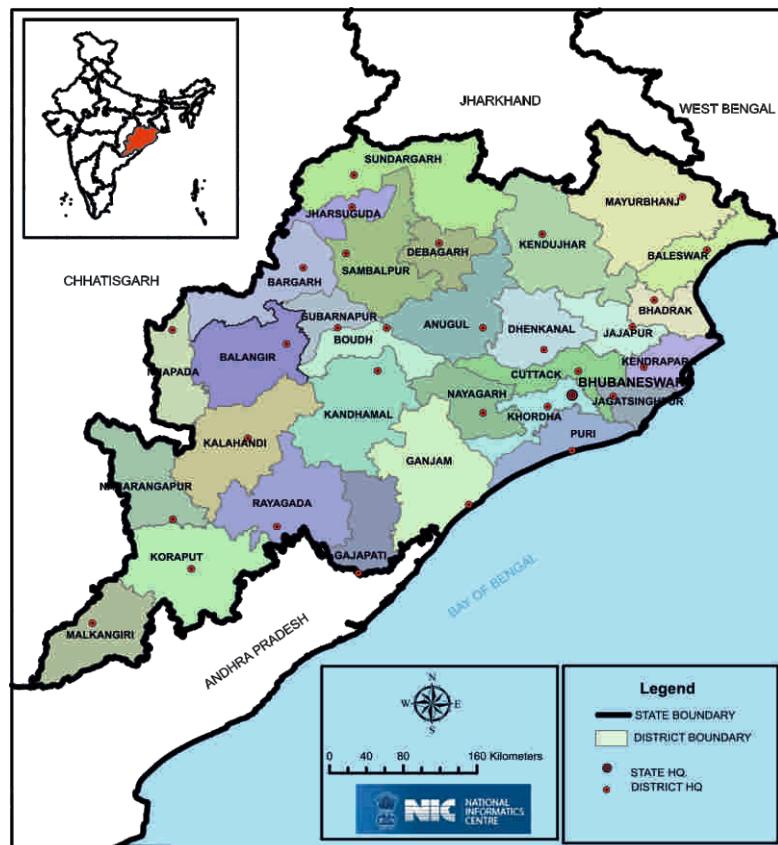
Forest and Tree Resources

Out of the 16 major forest types in India, 4 forest types exist in Odisha including Tropical Dry Deciduous Forests (57.87 %), Tropical Moist Deciduous Forests (39.88 %), Tropical Semi Evergreen Forests (0.68 %) and Littoral& Swam Forests (0.48 %) (OSDMA, 2023). As per the ISFR (2021), total recorded forest area of the state is 52155.95km^2 which is 33.50% of the total geographical area. The area of very dense forest (VDF), moderately dense forest (MDF), and open forest (OF) is 7212.80 km^2, 20994.90km^2 and 23948.25 km^2, respectively (ISFR, 2021). Gajapati district has the highest forest cover (60.65% of geographical area).
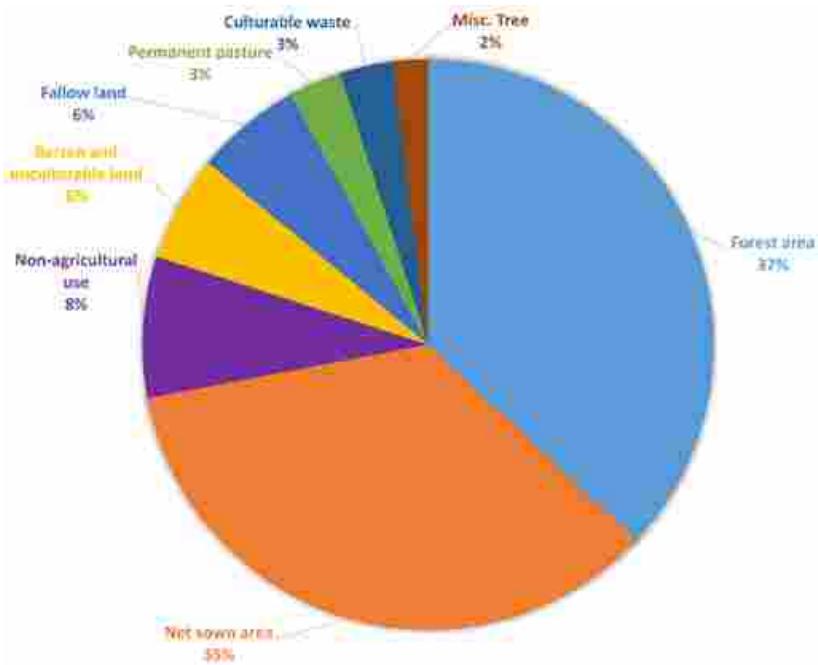
Distribution of land use pattern in Odisha during 2021-22
(*Based on*Odisha Economic Survey 2022-23)

Forest cover inside the Recorded Forest Area (RFA) is 32686 km^2 whereas forest cover outside RFA is 19470km^2. Tree cover in Odisha has increased from 4648km^2 (2019 assessment) to 5004km^2 (2021 assessment). Extent of Trees outside Forests (TOF) in Odisha is 24474 km^2. TOF is the summation of Forest Cover outside RFA and Tree Cover. Based on relative abundance, the top five tree species in TOF (Rural) in Odisha are *Shorearobusta* (9.49%), *Mangifera indica* (7.63%), *Butea monosperma* (5.39%), *Azadirachta indica* (5.29%) and *Madhuca latifolia* (5.25%). The top five tree species in urban TOF include *Mangifera indica* (10.63%), *Cocus nucifera* (8.73%), *Azadirachta indica* (6.59%), *Moringa species* (5.80%),and *Tectona grandis* (5.70%). Total carbon stock of forest in the state including TOF patches which are more than 1 ha in size is 444.83 million tonnes which is 6.17% of the total forest carbon of the country. *Shorearobusta, Madhuca indica, BuchananiaLanzan, Schleicheraoleosa, and Semecarpus anacardium* are major NTFP species in Odisha (ISFR, 2021).

Soil resources

The soils of Odisha have developed predominantly through the interplay of relief, parent material and climate (Singh et al., 2002). The soil of Odisha can be divided into 8 broad soil groups. Taxonomically these 8 broad soil groups under 4 orders, 10 suborders and 18 great groups (Sahu and Mishra, 2005). These eight soil groups include Red Soil, Mixed red and Yellow Soil, Black Soil, Laterite Soil, Deltaic alluvial Soils, Coastal Saline and Alluvial Soil, Brown Forest Soil, and Mixed red and black soil (Table).

Soil types in Odisha

Soil groups	Districts covered	Area covered (m.ha)	pH	Features
Red Soil	Koraput, Rayagada, Nawrangpur, Malkanagiri, Keonjhar, Ganjam, Kalahandi, Nuapada, Bolangir, Dhenkanal and Mayurbhanj	7.14	5.6-6.5	Moderately acidic with low to medium organic matter, deficient in nitrogen and phosphorus, poor water retentive capacity.
Mixed red and Yellow Soil	Sambalpur, Bargarh, Deogarh, and Sundargarh	5.5	5.6-6.5	Slight to moderately acidic. The upland soils are low in nitrogen and phosphorous, low land soils are medium in phosphate and high in potassium.
Black Soil	Puri, Ganjam, Malkangiri, Kalahandi, Nuapada, Bolangir, Sonepur, Boudh, Sambalpur, Bargarh and Angul.	0.96	6.6-7.3	Neutral alkaline. The soil is rich in calcium but deficient in phosphorus, potassium, zinc and boron
Deltaic alluvial	Balasore, Bhadrak, Jajpur, Kendrapara, Jagatsinghpur, Cuttack, Puri, Gajapati and Ganjam	0.67	7.4-8.4	Slight to moderately alkaline. Available nitrogen and phosphate are low and potash is medium.
Laterite Soil	Khurda, Nayagarh, Cuttack, Dhenkanal, Keonjhar, Mayurbhanja and Sambalpur	0.70	4.5 to 5.8	Acidic to neutral; soils are deficient with N, P, K and Sulphur.
Coastal Saline and Alluvial Soil	Balasore, Bhadrak Jagatsinghpur, Kendrapara, Puri, Khurda and Ganjam.	0.25	6.0 to 8.0	Acidic to neutral. The soils are rich in nitrogen, potassium and low to medium in phosphorus
Brown Forest Soil	Phulbani, Kandhamal, Rayagada and parts of Ganjam and Nayagarh	0.17	5.6-6.5	Slight to moderately acidic. Organic matter, nitrogen, phosphorus and potash contents are medium
Mixed red and black soil	Sambalpur, Bargarh, Sonepur and Bolangir	0.16	6.6-7.3	Neutral; Black soils are rich in calcium and red soils are dominant with iron.

Source: Based on Sahu and Mishra (2005)
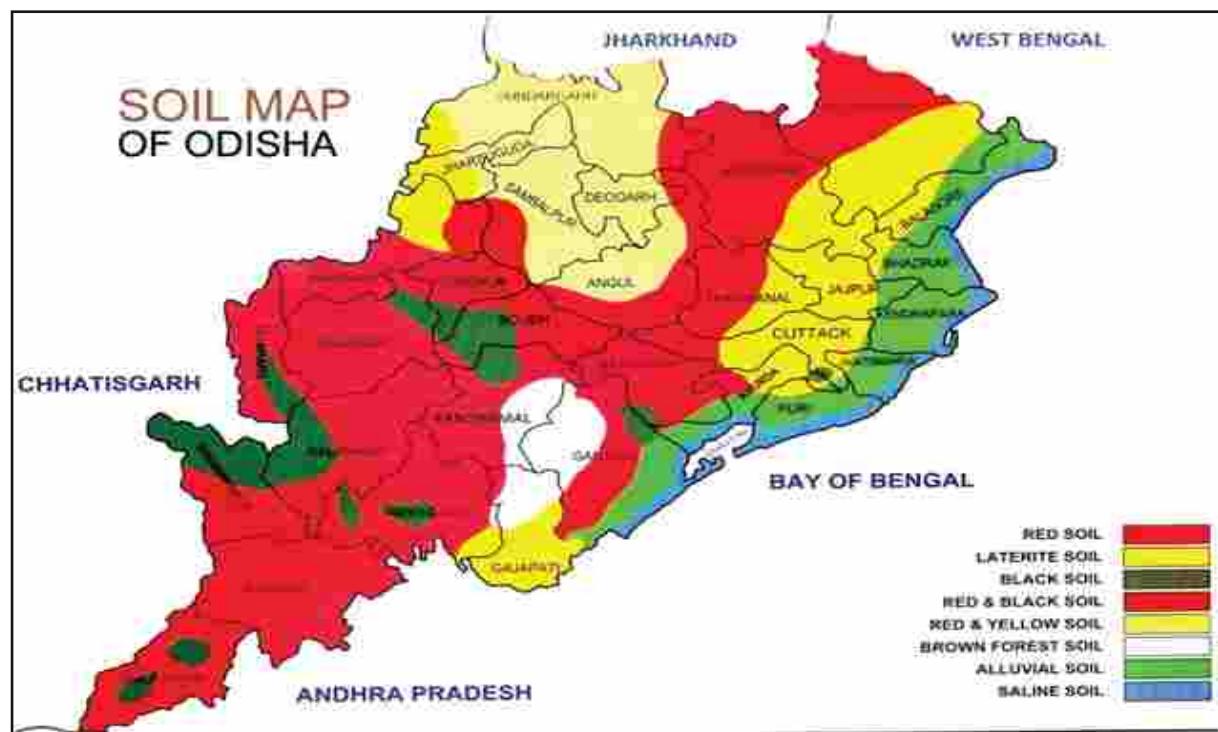
Soil Map of Odisha
(*Source:* Department of Agriculture and Farmers' Empowerment, Government of Odisha; https://agri.odisha.gov.in/media-gallery/photo-gallery/odisha-map-various-category)

Majority of the region is covered by Red and Black soil. Inceptisols are the dominant soils covering 48.8% of state area followed by Alfisols (33.52%), Entisols (10.16%), and Vertisols (5.52%) (Singh et al., 2000).

Water Resources

Odisha depends fundamentally upon monsoons for its water resources. About 78% of total annual rainfall occurs during the period from June to September and the balance 22% in the remaining period from October to May.The state is endowed with an extensive network of rivers & streams.

The state has 11 major river basins (Mahanadi, Brahmani, Rushikulya, Indravati, Kolab, Vansadhara, Baitarani, Budhabalanga, Subarnarekha, Nagavali and Bahuda). Major rivers like Mahanadi, Brahmani, and Subarnarekha originate in other states but a significant portion of their catchments lie in Odisha and they drain out to the Bay of Bengal (Pati, 2010). Mahanadi is the largest basin within the state boundary. Basin-wise surface water availability is represented in the Table.

Basin-wise availability of Surface Water (Scenario: 2001)

Basin	Average annual flow (BCM)		
	Own	Outside state	Total
Bahuda	0.438	-	0.438
Baitarani	7.568	-	7.568
Brahmani	11.391	7.186	18.577
Budhabalanga	3.111	-	3.111
Indravati	6.265	-	6.265
Kolab	11.089	-	11.089
Mahanadi	29.90	29.255	59.155
Nagavali	2.853	-	2.853
Rushikulya	3.949	-	3.949
Subernarekha	1.193	1.115	2.308
Vansadhara	5.083	-	5.083
Total	82.841	37.556	120.397

Source: Department of Water Resources, Government of Odisha

The average annual availability of surface water from the state's own drainage boundary is estimated as 82.841 BCM (DOWR, 2023). Reservoirs of Odisha have a storage capacity of 17.49 BCM in terms of completed major, medium and minor (flow) projects. Besides, 77 projects are under construction that will contribute to an additional 0.677 BCM.As per the latest assessment, the state has net dynamic ground water resources of 16.69 lakh ha.m (BCM).

Agriculture

Agriculture and allied activities constitute the main source of livelihood for a major section of population in Odisha (OES, 2023). Agriculture is the lifeline of the state's economy. The diverse agro-climatic zones of the state support the cultivation of several crop varieties of which rice, pulses, oilseeds, jute, sugarcane, coconut, wheat, small millets, bajra, arhar, groundnut, castor, linseed, cashew and turmeric are of great significance (OBB, 2023). Fruits like banana, guava, mango, jackfruit, and watermelon are commonly grown in Odisha. Major vegetables grown in state include potato, sweet potato, onion, brinjal, cabbage, cauliflower, spices like ginger and turmeric.

In 2021-22, the net sown area in the State was 54.1 lakh ha accounting for 35% of the total geographical area (OES, 2023). Cereals are the leading crops in the State, accounting for about 52% of the gross cropped area in 2021-22. Production of major crops in Odisha during 2021-22 is presented in the Table.

Major crops in Odisha (in '000 MT)

Crop	Production
Rice	9291
Maize	869
Other cereals	185
Total cereals	10345
Green gram	417
Black gram	189
Tur	131
Other pulses	299
Total pulses	1035
Groundnut	339
Other oilseeds	168
Total oilseeds	508
Cotton	626
Other fibers	119
Total fibers	745
Sugar cane	1541
Vegetables	9830
Spices & Condiments	1127
Total	25131

Government of Odisha has implemented several schemes and plans such as National Food Security Mission, Integrated Farming System, Integrated Action Plan, Mission for integrated development of Horticulture, Odisha Millet Mission, Technology Mission on Sugarcane and crop-oriented programme for pulses and oilseeds, to foster crop diversification in the State (OES, 2023). According to the 19th livestock census, livestock population Odisha is 20.73 million (ISFR, 2021).

Odisha Mushroom Mission

This mission aims to make the state self-sufficient in production of button mushroom and a net exporter of paddy straw and oyster mushroom by involving women SHGs/ FPOs through area expansion and promotion of value added products between 2022 23 and

Odisha Spices Mission

The mission will double the area under spices and promote primary processing of spices by establishing market linkages through buy back arrangement involving women from SHGs/ FPOs in selected clusters.

Odisha Jackfruit Mission

During 2022-23 and 2023 24, the mission will cover 50 potential blocks across 9 identified districts. The key objectives of the Mission are (i) to expand the area under jackfruit cultivation by 1500 Ha in 5 years, (ii) Production of Quality Planting Material including 5 lakh local elite varieties and grafts.

Odisha Floriculture Mission

The mission will make the state self-sufficient in production of Loose flowers in first three years of the mission period through area expansion in 30 districts. In addition, this also aims make the state a net exporter of cut flowers in five years involving women SHGs.

Odisha Millet Mission

Odisha Millet Mission (OMM) is a uniquely designed government-facilitated multi-stakeholder intervention with a "fork to farm" approach .It focuses on developing a sustainable food system of millets and ensuring nutritional security for vulnerable rainfed areas of Odisha Odisha was recognized as the best-performing millet promotion state award at the National Convention on Nutri-Cereals in 2021 and 2022 by the Ministry of Agriculture & Farmers' Welfare, Government of India and Indian Institute of Millets Research . TheMinistry of Agriculture & Farmers' Welfare, Government of India, and NITI Aayog identified OMM as one of the best models and asked different state governments to adopt the OMM approach for the promotion of millets. World Food Program identified OMM as one of the best practices that can be replicated in other states and other countries in Africa as part of the South-South Collaboration.

New Policy initiatives for crop sector in Odisha (*Source:* Odisha Economic Survey 2022-23)

Biodiversity

Biodiversity refers to variability among living organisms which includes floral, faunal and microbial diversity. Odisha's unique location in Peninsular India has blessed it with an interesting assemblage of floral and faunal diversity. To protect and conserve biodiversity, wildlife and natural resources the state government has created 19 wildlife sanctuaries, two national parks (Bhitarkanika and Simlipal), one biosphere reserve (Simlipal), and two Tiger Reserves in the state. Number of different groups of organisms in the following Table.

Biodiversity of Odisha at a glance

Group of organisms	Number of taxa in Odisha
Higher plants	2800
Grasses	300
Orchids	153
Pteridophytes	178
Gymnosperms	22
Mangroves and their associates	63
Sseaweeds	24
Sseagrasses	7
Carnivorous plants	17
Bryophytes	300
Lichens	275
Fresh, marine, and brackish water algae	1000
Wild edible mushrooms	30
Macro-fungi	450
Wild relatives of crop plants	300
Mammals	114
Birds	537
Reptiles	131
Amphibians	29
Pisces	800
Crustaceans	584
Molluscs	366
Coleoptera	259
Diptera	98
Hymenoptera	265
Spider	112
Lepidoptera	300
Odonata	102
Isopteran	31

*Source:*https://www.odishabiodiversityboard.in/cms/biodiversity-treasure-odisha

Agro-climatic-zones

Odisha state can be divided into 10 distinct agro-climatic zones based on soil types, topography, rainfall, and cropping pattern (Nayak et al., 2020). The state has 10 Agroclimatic Zones (i) North Western Plateau, (ii) North Central Plateau, (iii) North Eastern Coastal Plain, (iv) East and South Eastern Coastal Plain, (v) North Eastern Ghat, (vi) Eastern Ghat High Land, (vii) South Eastern Ghat, (viii) Western Undulating Zone, (ix) Western Central Table Land and (x) Mid Central Table Land. Rice-based production system is the major cropping system of Odisha

Agro-Climatic Zones of Odisha

ACZs	Districts	Climate	Mean annual rainfall (mm)	Mean maximum summer temp (^{o}C)	Mean minimum winter temp (^{o}C)	Soil types
North Western Plateau	Sundargarh, parts of Deogarh, Sambalpur & Jharsuguda	Hot & moist sub-humid	1600	38.0	15.0	Red, Brown forest, Red & Yellow, Mixed Red & Black
North Central Plateau	Mayurbhanj, major parts of Keonjhar, (except Anandapur & Ghasipura block)	Hot & moist sub-humid	1534	36.6	11.1	Lateritic, Red & Yellow, Mixed Red & Black
North Eastern Coastal Plain	Balasore, Bhadrak, parts of Jajpur & hatdihi block of Keonjhar	Moist sub-humid	1568	36.0	14.8	Red, Lateritic, Deltalc alluvial, Coastal alluvial & Saline
East & South Eastern Coastal Plain	Kendrapara, Khurda, Jagatsinghpur, part of Cuttack, Puri, Nayagarh & part of Ganjam	Hot & Humid	1577	39.0	11.5	Saline, Lateritic, Alluvial, Red & Mixed red & Black
North Eastern Ghat	Phulbani, Rayagada, Gajapati, part of Ganjam & small patches of Koraput	Hot & moist, sub-humid	1597	37.0	10.4	Brown forest, Lateritic Alluvial, Red, Mixed Red & Black
Eastern Ghat High Land	Major parts of Koraput, Nabarangpur	Warm & humid	1522	34.1	7.5	Red, Mixed Red & Black, Mixed Red & Yellow
South Eastern Ghat	Malkangiri & part of Keonjhar	Warm & humid	1710	34.1	13.2	Red, Lateritic, Black
Western Undulating Zone	Kalahandi &Nuapada	Hot & moist sub-humid	1352	37.8	11.9	Red, Mixed Red & Black and Black
Western Central Table Land	Bargarh, Bolangir, Boudh, Sonepur, parts of Sambalpur & Jharsuguda	Hot & moist sub-humid	1614	40.0	12.4	Red & Yellow, Red & Black, Black, Brown forest, Lateritic
Mid Central Table Land	Angul, Dhenkanal, parts of Cuttack &Jajpur	Hot & moist sub-humid	1421	38.7	14.0	Alluvial, Red, Lateritic, Mixed Red & Black

Source: https://odishaahvs.nic.in/upload/files/Agro-climatic-zones.pdf
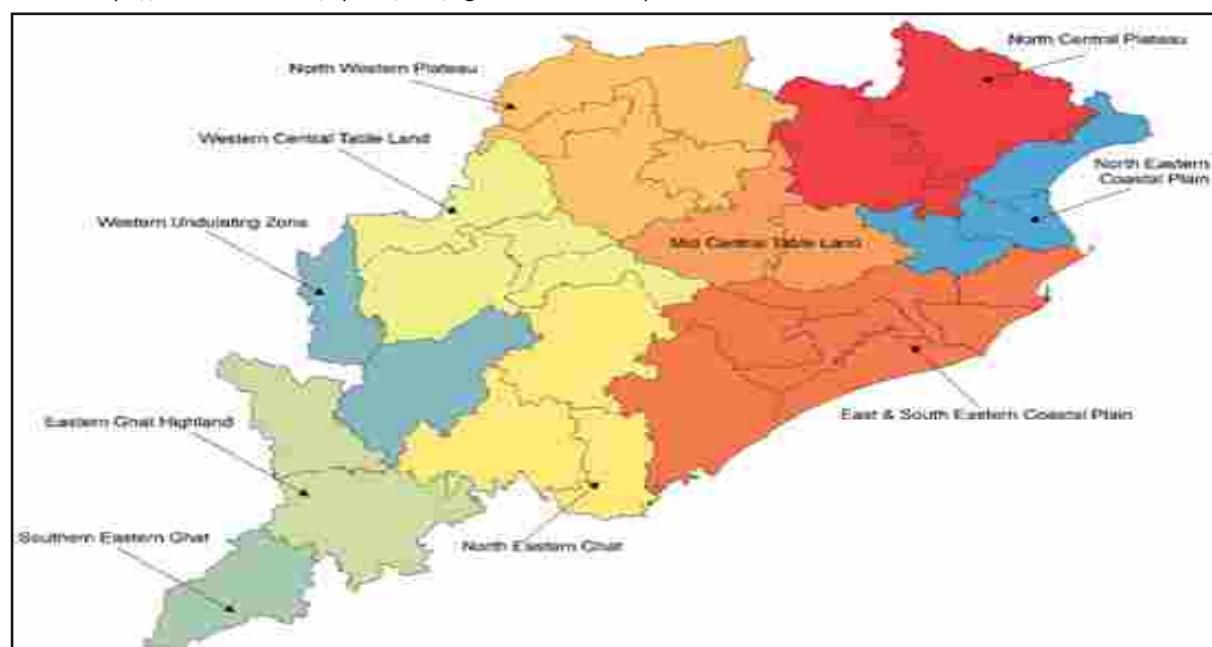
Agro-Climatic Zones of Odisha (*Source: ICAR-CAFRI*)

Demography

As per the Census of India 2011, the total population of Odisha is 41974218 in which males are 21,212,136 while females are 20,762,082 (Census, 2011).Odisha accounts for 3.47% of the total population of the country (1,210,854,977). Population density in Odisha is 270/km^2 as compared to the national average of 382/km^2. The literacy rate of Odisha is 72.87. The sex ratio of the state encouragingly stands at 979 against the national ratio of 940. The tribal population in the state is 9.59 million (ISFR, 2021).

Administrative profile

Bhubaneswar is the capital city of Odisha. The state is divided into 30 administrative geographical units called districts. These 30 districts have been placed under three different revenue divisions to streamline their governance. Overall, Odisha has 03 Divisions, 30 Districts, 58 Sub-Divisions, 317 Tahasils and 314 Blocks. The name 30 districts are as follows: Angul, Boudh, Balangir, Bargarh, Balasore (Baleswar), Bhadrak, Cuttack, Deogarh (Debagarh), Dhenkanal, Ganjam, Gajapati, Jharsuguda, Jajpur, Jagatsinghapur, Khordha, Keonjhar (Kendujhar), Kalahandi, Kandhamal, Koraput, Kendrapara, Malkangiri, Mayurbhanj, Nabarangpur, Nuapada, Nayagarh, Puri, Rayagada, Sambalpur, Subarnapur (Sonepur), and Sundargarh.

State symbols

Sambar Deer and Indian roller are state animal and state bird of Odisha, respectively. Sacred Fig (*Ficus religiosa)* is the state tree of Odisha. Odia, one of the oldest languages in the country, is the predominant language spoken in the State. It is the official language of the State.

Promising Agroforestry Models for Odisha

Agroforestry is a sustainable land use system that integrates trees or shrubs with crops and/or livestock. In simple words, agroforestry is the association of trees with farming practices (Torquebiau, 2000). Agroforestry is agriculture with trees. Thus, it describes practices developed and employed by farmers over many centuries to cultivate trees on farmland in different combinations with crops and livestock.

From a purely agricultural perspective, agroforestry recognizes and promotes trees on a farm. From a strict forestry perspective, it is about recognition and rights for tree-based systems and livelihoods that farmers have created and can expand with appropriate support from relevant forest management techniques. Nevertheless, agroforestry is a fusion of agriculture and forestry, rather than treating these as separate land uses, institutions, policy domains and fields of science (FAO and ICAR-CAFRI, 2022a).

This sustainable farming system provides several products like timber, fiber, fruit, food, fodder, fuelwood, fertilizers, medicine that underpin the subsistence needs of farmers. These goods of agroforestry improve income of farmers and supports the food production through climate resilient agriculture (Handa et al., 2020). Agroforestry is pivotal for food security, biodiversity conservation, and sustainable development (Mahata et al., 2019).In Odisha, agroforestry has received increasing attention in recent decades. According to ICAR-CAFRI estimates, the agroforestry area in Odisha is nearly 1.34 million ha. The following table shows the list of potential agroforestry models for the state of Odisha.

Potential agroforestry models for Odisha

Agroforestry models	Tree component	Crop component	Economic returns/Benefit Cost Ratio (BCR)
Casuarina-based Agroforestry Model (Handa et al., 2020)	*Casuarina equisetifolia*	**Kharif:** Groundnut, pulses, sesame **Rabi:** Vegetables; Perennial-banana	Net returns of Rs. 88,827 ha^{-1}yr^{-1} with groundnut within a short rotation period of 3-4 years. The average net income from plantations is Rs. 2,27,000 ha^{-1} under 6-7 years rotation period.

Teak-based Agroforestry Model (Handa et al., 2020)	*Tectona grandis*	**Kharif:** Black gram, soybean, cotton, red gram and sesame **Rabi:** Sorghum, cowpea and linseed	Rs. 60,000 ha^{-1} at first 50% thinning upon 7 years; Rs. 2,28,900 ha^{-1} at second (25%) thinning upon 12 years and Rs. 19,44,000 ha^{-1} at final harvesting upon 20-25 years.
Gamhar-based Agroforestry Model (Handa et al., 2020)	*Gmelina arborea*	Legumes, maize, rice, vegetable crops and mustard in central India; pineapple, ginger, turmeric in North-Eastern India	Net income Rs. 30,000 to 50,000 ha^{-1}yr^{-1} with crops after 12-15 years of rotation
Mangium-based Agroforestry Model (Handa et al., 2020)	*Acacia mangium*	Pineapple, mango, ginger, turmeric and arrowroot	Net return of a 12-year old *Acacia mangium* agroforestry with sesame, arrowroot and pineapple is Rs. 1, 93,104 ha^{-1}yr^{-1}.
Bamboo-based Agroforestry Model (Handa et al., 2020)	*Bambusa balcooa, B. bambos, B.tulda, B. nutan, Dendrocala mushamiltonii, D. strictus* and *D. stocksii*		Net income of Rs. 95,000 to 2,00,000 ha^{-1}yr^{-1} after 4 years under irrigated condition
Leucaena+Gliricidia-based Agroforestry Model (Handa et al., 2020)	*Leucaena leucocephala* & *Gliricidia sepium* Stylo (*Stylo santhesscabra*)		A net income of Rs. 67,680 ha^{-1}yr^{-} obtained on degraded lands.
Ailanthus based Agrisilvicultural System (Handa et al., 2019)	*Ailanthus excelsa*	Green gram, cluster bean and cowpea	Ardu tree sole (BCR: 8.53) Ardu + cluster bean (BCR: 2.40) Ardu + cowpea (BCR: 2.77) Ardu + green gram (BCR: 3.10) Ardu+ til (BCR: 2.83) Cluster bean sole (BCR:-0.59) Cowpea sole (BCR: 0.03) Green gram sole (BCR: 0.55) Til Sole (BCR: -0.31)
Mango based Agri-horticultural System (Handa et al., 2019)	*Mangifera indica*	Pineapple (*Ananas comosus*), mango ginger (*Curcuma amada*), turmeric (*Curcuma longa*) and arrowroot (*Maranta arundinacea*)	After 5 years of plantation with a BCR of 2.85 or more
Dalbergia sissoo based Agri-silvicultural System (Handa et al., 2019)	*Dalbergia sissoo*	Pineapple (*Ananas comosus*), mango ginger (*Curcuma amada*), turmeric (*Curcuma longa*) and arrowroot (*Maranta arundinacea*)	At the end of 20 years, the system yields a BCR of 2.35

Dalbergia sissoo based Agri-silvicultural System

Scientific Name: *Dalbergia sissoo* Roxb. ex DC.

Rotation: On a good site, marketable timber can be produced on a 20- to 25-year rotation. To produce large-diameter logs with a high percentage of valuable heartwood, a rotation age of 60 years is not uncommon.

Suitable Intercrops: Pineapple (*Ananas comosus*), mango ginger (*Curcuma amada*), turmeric (*Curcuma longa*) and arrowroot (*Maranta arundinacea*) by following standard package of practices and improved varieties.

Tree Productivity: *Dalbergia sissoo* trees are generally 10 to 20 m tall with clear boles of 3 to 6 m. Final harvests at 20 years averaged 90 to 100 m³/ha. The mean annual increment (MAI) for 20-year-old, non-irrigated plantations averaged 11.2 m³/ha on good sites, 8.4 m³/ha on fair sites, and 5.9 m³/ ha on poor sites.

Economic Returns: At the end of 20 years the system yields a B:C ratio of 2.35.

Casuarina-based Agroforestry Model

Scientific Name: *Casuarina equisetifolia* L.

Suitable Spacing: 1.5m×1.5m; 2m×2m for block plantation; 4m×2m; 6m×2m for agroforestry; paired row (2m×1m) for windbreak

Rotation: Poles: 2 years; Pulpwood-4 to 5 years; Timber: 8-12 years

Suitable Intercrops

Kharif crops- Groundnut, pulses, and sesame

Rabi crops- Vegetables

Perennial- Banana

Tree Productivity: Biomass-120-150 t ha^{-1} under irrigated & 70-100 t ha^{-1} in rainfed; Timber yield-15-25 m^3 ha^{-1} from windbreak, Charcoal yield-10-15 t $ha^{-1}yr^{-1}$.

Economic Returns: Net returns of ₹ 88,827 $ha^{-1}yr^{-1}$ with groundnut within a short rotation period of 3-4 years. Average net income from plantations is ₹ 2,27,000 ha^{-1} under 6-7 years rotation period (Handa et al., 2020).

Teak-based Agroforestry Model

Scientific Name: *Tectona grandis*

Suitable Spacing: 8m×2m, 12m×2m for agroforestry, 2m×2m for block and 2-5m for boundary plantation

Rotation: 20-25 years; intermediate yield from thinning at 7th and 12th year

Suitable Intercrops

*Kharif crops-*Black gram, soybean, cotton, red gram and sesame

Rabi crops- Sorghum, cowpea and linseed

Tree Productivity: First thinning (50%) at 7th year (300 poles/ha), second thinning (25%) at 12th year (small timber 7.65 $m^3 ha^{-1}$) and final harvesting (timber 77$m^3 ha^{-1}$) at 20-25 years.

Economic Returns: ₹ 60,000 ha^{-1} at first 50% thinning upon 7 years; ₹ 2,28,900 ha^{-1} at second (25%) thinning upon 12 years and ₹ 19,44,000 ha^{-1} at final harvesting upon 20-25 years (Handa et al., 2020).

Gamhar-based Agroforestry Model

Scientific Name: *Gmelina arborea* Roxb.

Suitable Spacing: 8m×2.5m, 6m×3m, 4m×3m for timber; 1.2m×1.2m, 1.8m×1.8m for pulp and small poles

Rotation: 4-5 years for small size timber and 12-15 years for sawn timber

Suitable Intercrops

Central India- Legumes, maize, rice, vegetable crops and mustard

North-Eastern India- Pineapple, ginger and turmeric

Tree Productivity: 20-22 m3 ha^{-1} of timber and 200 t ha^{-1} of total biomass after 12-15 years

Economic Returns: Net income ₹ 30,000 to 50,000 ha^{-1}yr^{-1} with crops after 12-15 years of rotation (Handa et al., 2020).

Mangium-based Agroforestry Model

Scientific Name: *Acacia mangium* Willd.

Suitable Spacing: 3m×3m for block plantation and 2-3m between trees on field bund

Rotation: 4-years for poles and 10-12 years for sawn timber

Suitable Intercrops: Pineapple, mango, ginger, turmeric and arrowroot

Tree Productivity

Timber- 20-25 $m^3 ha^{-1}yr^{-1}$ (even higher in humid regions up to 30-35 $m^3 ha^{-1}yr^{-1}$)

Firewood- 100 t ha^{-1} after 10 years

Economic Returns: Net return of a 12-year old *Acacia mangium* agroforestry with sesame, arrowroot and pineapple is ₹ 1, 93,104 $ha^{-1}yr^{-1}$ (Handa et al., 2020).

Bamboo-based Agroforestry Model

Scientific Name: *Bambusabalcooa, 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

Rotation: Yield starts after 4th year up to 30-35 years

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

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

Economic Returns: Net income of ₹ 95,000 to 2,00,000 ha^{-1}yr^{-1} after 4 years under irrigated condition.

Ailanthus based Agrisilvicultural System

Scientific Name: *Ailanthus excelsa* Roxb.

Suitable Spacing: 5 x 5 m under rainfed conditions and as a block and boundary plantation the spacing should be 3 x 3 m

Suitable Intercrops: Green gram, cluster bean and cowpea

Tree Productivity: Timber volume: 944.2 cubic feet/ha; Fuelwood: kg/ha

Economic Returns: The net return from Ardu intercropping with green gram is highest (₹ 76,024/ha) over sole and other agri-silvi system. The B: C ratio from sole Ardu is higher (8.53) than Ardu intercropping (Handa et al., 2019).

Mango-based Agri-horticultural System

Scientific Name: *Mangifera indica* L*.*

Rotation: Mango trees may remain in production for 40 years or more.

Suitable Intercrops: Pineapple (*Ananas comosus*), mango ginger (*Curcuma amada*), turmeric (Curcuma longa) and arrowroot (*Maranta arundinacea*) by following standard package of practices and improved varieties.

Tree/Fruit Productivity: Fruit productivity is 8 t/ha per annum after 5 years of plantation.

Economic Returns: At the end of five years, the system yields a B: C ratio of 2.85 or more.

References:

Behera, S., Mahapatra, A., Mishra, P., Behera, B., Pattanayak, S., 2016. Soil Moisture and Nutrient Dynamics of Bamboo (*Bambusa vulgaris*) Based Agrisilvicultural Systems in North Odisha. Advances in Life Sciences 5(9) 3701-3705.

Bhuiya, J., Behera, S., Mohapatra, S.C., 2019. Performance of medicinal plants under fast growing timber trees in coastal ecosystem of Odisha. *Journal of Pharmacognosy and Phytochemistry*, *8*(5), 613-615.

Census, 2011. Odisha Population Census 2011 | Odisha Religion, Caste Data-Census 2011. https://www.censusindia.co.in/states/odisha. Accessed on November 21, 2023.

DOWR (Department of Water Resources), 2023. State's Water Resources: An Overview. Department of Water Resources, Government of Odisha. https://dowr.odisha.gov.in/sites/default/files/2021-11/Source-Water.pdf. Accessed on November 24, 2023.

Handa, A.K., Chavan, S.B., Kumar, V., Vishnu, R., Suresh Ramanan, S., Tewari, R.K., ... & Mohapatra, T., 2020. Agroforestry for income enhancement, climate resilience and ecosystem services. Indian Council of Agricultural Research, New Delhi.

Handa, A.K., Dev, I., Rizvi, R.H., Kumar, N., Ram, A., Kumar, D., ... & Rizvi, J., 2019. Successful Agroforestry Models for Different Agro-Ecological Regions in India. Central Agroforestry Research Institute (CAFRI) and South Asia Regional Programme of World Agroforestry (ICRAF). file:///F:/Desktop/TOFI/Agroforestry%20models/Handa%20et%20al.,%202019.pdf. Accessed on 10 February 2023.

ISFR (India State of Forest Report), 2021. Forest Survey of India, Ministry of Environment, Forest and Climate Change. https://fsi.nic.in/forest-report-2021-details. Accessed on November 24, 2023.

Mahata, A., Samal, K.T., Palita, S.K., 2019. Butterfly diversity in agroforestry plantations of Eastern Ghats of southern Odisha, India. Agroforestry Systems, 93(4), 1423-1438.

OBB (Odisha Biodiversity Board), 2023. Biodiversity of Odisha. https://www.odishabiodiversityboard.in/cms/biodiversity-treasure-odisha. Accessed on November 23, 2023.

OES (Odisha Economic Survey), 2023. Odisha Economic Survey 2022-23. Planning and Convergence Department, Directorate of Economics and Statistics. Bhubaneswar: Government of Odisha. https://finance.odisha.gov.in/sites/default/files/2023-02/Odisha%20Economic%20Survey-2022-23%20%28Digital%20Version%29%20Final.pdf. Accessed on November 23, 2023.

Odisha Profile, 2018. Government of Odisha. http://www.desorissa.nic.in/pdf/odisha-profile- 2018.pdf. Accessed on November 21, 2023.

OSDMA (Odisha State Disaster Management Authority), 2023. State Profile. https://www.osdma.org/state- profile/#gsc.tab=0. Accessed on November 21, 2023.

Pati, B.K., 2010. *Water Resources of Odisha: Issues and Challenges*. Regional Centre for Development Cooperation.

Sahu, G.C., Mishra, A., 2005. Soil of Orissa and its management. *Orissa Rev*, *16*, 56-60.

Singh, R., Kundu, D.K., Verma, H.N., 2002. Hydro-physical characteristics of Orissa soils and their water management implications. Research Bulletin No. 12. Water Technology Centre for Eastern Region (Indian Council of Agricultural Research), Bhubaneswar, Orissa 751023, India.

Agroforestry Business Incubation Centre

AB*i*C

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.

Promoting Agroforestry based Business Opportunities and Creating an Ecosystem for Entrepreneurship

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