Promising Agroforestry Models for Maharashtra

ICAR-Central Agroforestry Research Institute

Jhansi-284003, Uttar Pradesh, India

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Project Implementation Team

Dr. A. Arunachalam

Mr. Suresh Ramanan S.

Dr. A.K. Handa

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Maharashtra state in India is known as the "Gateway to India". It is a highly urbanized and industrialized state located along the Arabian Sea between latitudes 15°48' North and 22°06' North and longitudes 72°36' East and 80°54' East. In the north-west are the Union Territories of Daman, Dadra, and Nagar Haveli; in the north is Madhya Pradesh; in the east is Chhattisgarh; in the south-east is Andhra Pradesh; and to the south of Maharashtra are Karnataka and Goa. Comprising a total size of 307,713 km², or 9.36% of the total area of the country's land, the state is physically divided into three main areas: the Maharashtra Plateau, the Sahyadri Range, and the Konkan Coastal Strip (Chaudhari., 2016).

Physiography

The mountain range of Western Ghats (also known as Sahyadri) is the mountainous, faulted and eroded edge of the Deccan Plateau. Its range runs parallel to the Arabian sea coast. Many of fshoots are branching eastwards in Sahyadri ranges such as Satmala, Ajanta, Harish chandra, Balaghat and Mahadeo hills. Most of the rivers originate from the Sahyadri which forms the water divide to produce eastward and westward flowing rivers. These ranges are also characterized by several ghats (passes) and the important ones being Thal, Bor, Kumbharli, Amba, Phonda. The Plateau region of Deccan: In the north, the plateau is flanked by Satpura ranges, which run in the East-West direction in Maharashtra. Maharashtra state is a highland of the Deccan plateau formed by volcanic activity and the subsequent cooling down of the lava. The rocks are of igneous type mainly basalt and granite. The altitude of the plateau varies from 450 to 750 meters. Important cities in this region are Pune, Nagpur and Solapur. The Coastal Plain of Konkan coastal region is a narrow plain that stretches from the states of Gujarat to Kerala lying to the west between the Arabian Sea and the western ghats. This coastal strip is Barely 50 km in width which is wider in the north and narrows down to the south. Tapi, Godavari, Bhima and Krishna are the main rivers of the state. About 75% area of Maharashtra is drained by eastward gently flowing rivers of the Godavari and Krishna into the Bay of Bengal. The other 25% area is drained by westward flowing rivers of Narmada and Tapi; and short-swift flowing Konkan Rivers rising from cliffs of Sahyadri viz: Ulhas, Savitri, Vashishthi and Shastri flowing into the Arabian Sea(IDOL, 2022).

Climate

Maharashtra has a typical monsoon climate, which includes hot, rainy, and cold seasons. Tropical conditions Prevail over the state, and even the hill stations are not very cold. Dew, frost, and hail can also occur depending on the season, and this climate is classified into three major seasons: (i) summer (March to April), (ii) rainy (June to September), and winter (November to February). Rainfall in Maharashtra varies by region and the rainfall in Thane, Raigad, Ratnagiri, and Sindhudurg districts averages 200 cm year (Maharashtra Tourism, 2024). However, the districts of Nasik, Pune, Ahmednagar, Dhule, Jalgaon, Satara, Sangli, Solapur, and parts of Kolhapur receive less than 50 cm of rainfall. The mean maximum average temperature is approximately 33 °C in summer and 30 °C in winter (Nath *et al.*, 2023).

Land use pattern

Land use statistics play a crucial role in understanding agricultural dynamics. In Maharashtra, out of the total geographical area of 307,713 km², only a small portion is covered by forest, accounting for 16.98%. Precisely, in 2021-22, the net sown area in Maharashtra was 1,69,430 km², representing 55.11% of the total geographical area. This net sown area experienced a decrease of 1.28% compared to the previous year.

Forest and resources

Out of the 16 major forest types in India, Maharashtra hosts 5 forest types: Southern Tropical Semi-Evergreen Forests, Southern Tropical Moist Deciduous Forests, Southern Tropical Dry Deciduous Forests, Southern Tropical Thorn Forests, and Littoral and Swamp Forests (Chaudhari, 2016). The state's total recorded forest area is 52.2 thousand km², which accounts for 16.51% of its total geographical area. The distribution of forest cover in Maharashtra includes very dense forest (8,733.75 km²), moderately dense forest (20,589.00 km²), and open forest (21,475.01 km²). Gadchiroli district has the highest forest cover at 68.71% of its geographical area(ISFR, 2021).
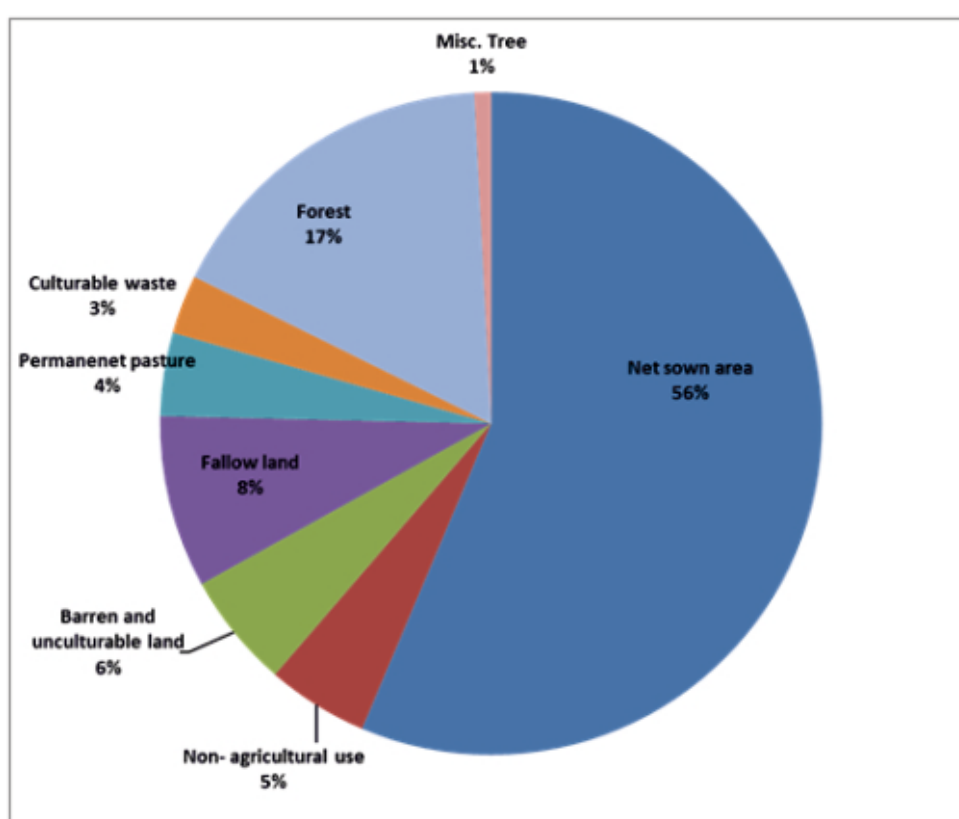
Source: Gorain *et al.* (2020)

The forest cover inside the Recorded Forest Area (RFA) is 36,040 km², while outside the RFA is 14,758 km². The tree cover in Maharashtra has increased from 10,806 km² in the 2019 assessment to 12,108 km² in the 2021 assessment. Trees outside Forests (TOF) in Maharashtra cover an area of 26,866 km², which is the sum of forest cover outside RFA and tree cover. The top five tree species in TOF for rural areas in Maharashtra are *Azadirachta indica* (15.37%), *Mangifera indica* (9.69%), *Acacia arabica* (6.53%), *Tectona grandis* (6.47%), and *Terminalia crenulata* (5.44%). In urban TOF areas, the top five tree species include *Cocos nucifera* (11.80%), *Mangifera indica* (10.48%), *Azadirachta indica* (8.47%), *Moringa spp* (3.53%), and *Areca triandra* (3.31%). The total carbon stock of forests in Maharashtra, including TOF patches larger than 1 hectare, amounts to 451.61 million tonnes, representing 6.27% of the country's total carbon stock. Major Non-Timber Forest Produce (NTFP) species in Maharashtra include *Ocimum spp.*, *Butea monosperma*, *Helicteres isora*, *Acacia catechu*, and *Syzigium cumini* (ISFR, 2021).

Types of Forest

| S. No	Type of Forest	Area (in sq. km)	% of the total mapped area
1.	West coast semi-evergreen forest	6659.15	12.10
2.	Moist teak forest	5715.15	10.38
3.	Southern moist mixed deciduous forest	11353.06	20.63
4.	Littoral forest	1.11	0.00
5.	Mangrove scrub	28.33	0.05
6.	Mangrove forest	291.94	0.53
7.	Riparian fringing forest	1.18	00
8.	Dry teak forest	9536.93	17.34
9.	Southern dry mixed deciduous forest	14390.79	26.15
10.	Dry deciduous scrub	4354.34	7.91
11.	*Boswellia* forest	45.02	0.08
12.	*Babul* forest	9.30	0.02
13.	*Hardwickia* forest	61.28	0.11
14.	*Butea* forest	10.01	0.02
15.	Dry bamboo brakes	254.70	0.46
16.	Southern thorn forest	219.22	0.40
17.	Western subtropical hill forest	661.19	1.20
18.	TOF plantation	1441.35	2.62
	Total (Forest Cover & Scrub)	55034.05	100.00

Source: ISFR, (2021)

Soil

The soils in Maharashtra are residual and originate from basalts. In the semi-dry plateau, the Regur, known as black-cotton soil, is clayey, rich in iron, but lacks nitrogen and organic matter; it retains moisture well. When redeposited in river valleys, the kali soils become deeper and heavier, suitable for Rabi crops. Moving farther, the Morang soils, with a better lime mixture, are ideal for Kharif crops. The higher plateau areas feature pather soils with more gravel. In the rainy Konkan and Sahyadri range, the same basalts give rise to brick-red laterites, productive under forest cover but become sterile Varkas when vegetation is removed (Envis Maharashtra, 2024).

Soil groups	District covered	Area cover (in lakh ha)	pH	Feature
Laterite	Ratnagiri and Sidhudurg	13.20	5.5-6.5	Acidic, poor in phosphorus rich in nitrogen and potassium
Coarse & Shallow	Thane & Raigad	16.59	5.5-6.5	Acidic rich in nitrogen, poor in phosphorus & potash
'Warkas' light laterite & reddish brown	Kolhapur, Satara, Pune, Ahmednagar and Nashik	0.033 + 25% forest area of the state	5.5-6.5	Distictly poor fertility low phosphorous & potash content
Reddish brown to black	Nashik, Pune, Satara, Sangli and Kolhapur	10.20	6-7	Well supplied in nitrogen but low in phosphorus and potash

Greyish black	Ahmednagar, Sangli, Nashik, Satara, Pune and Kolhapur	17.91	7.4-8.4	Moderately alkaline lowest is layer is 'Murum' strata. Fair in NPK content. Well drained & good for irrigation
Black and Red	Aurangabad, Jalna, Beed & Osmanabad. Major parts of Parbhani, Nanded, Latur, Buldhana, Akola, Amravati, Yavatmal, Jalgaon, Dhule and Sholapur	75.00	7-7.5	Type- 1 Vertisol, 2 entisols and 3 inceptisols
Black soil derived from basalt rock	Wardha, Nagpur, Yavatmal, Aurangabad, Jalna, Parbhani and Nanded	49.88		Medium to heavy in texture alkaline in reaction. Low-laying areas are rich and fertile
Brown and Red colour	Bhandara, Gachiroli, Chandrapur and Nagpur	32.70	6-7	Soils derive from parent rock granite, gneisses and schists
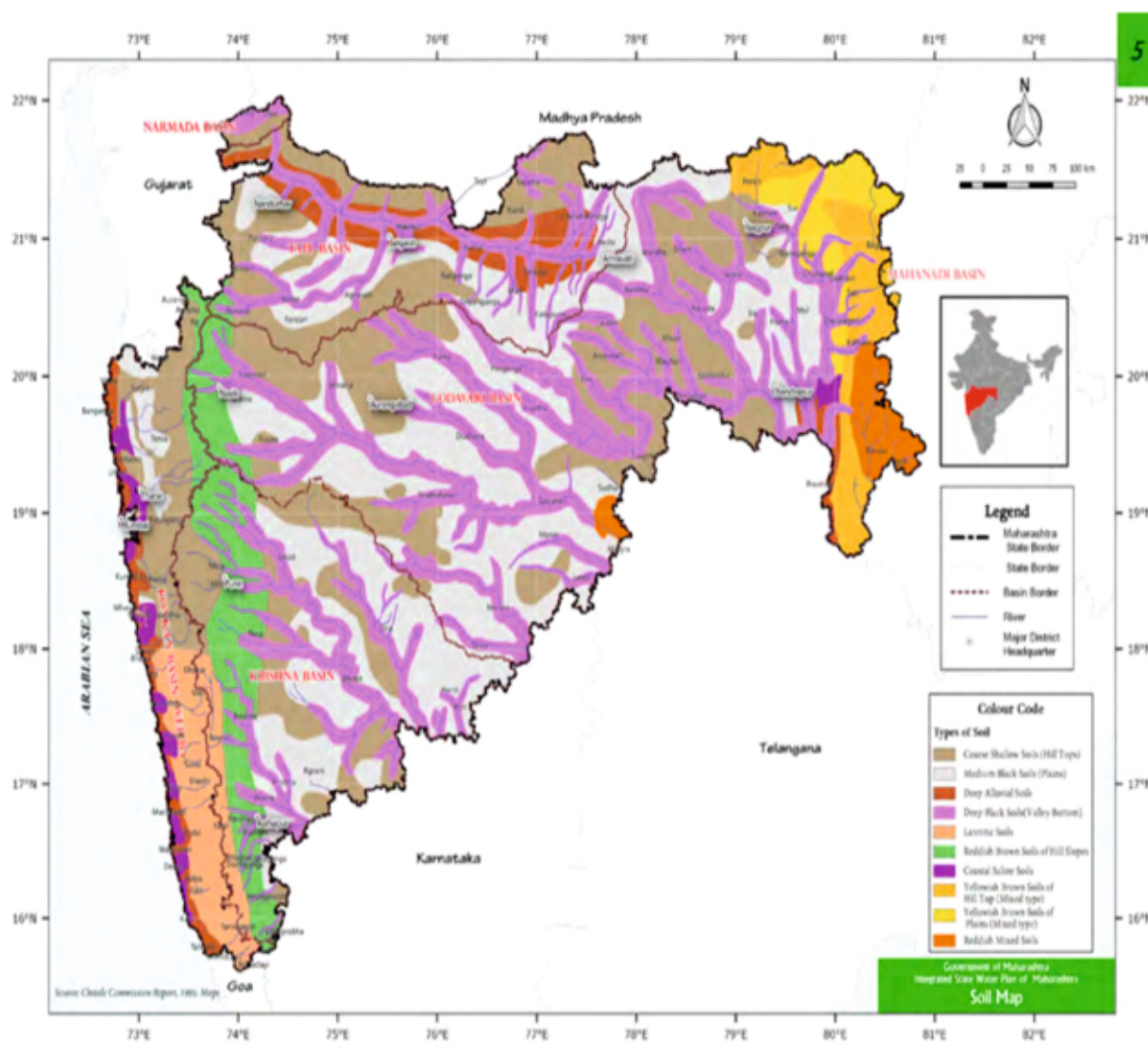
Source : ISWP, (2018)

Water Resources

Maharashtra state receives 0.7% of its annual rainfall in the winter season (Jan-Feb), 2.3% during the Pre-monsoon season (Mar-May), 88.4% during the southwest monsoon season (Jun-Sept), and 8.6% during the Post-Monsoon season (Oct-Dec) (IMD, 2022).

The state has five river basins: Godavari, Krishna, Tapi, Narmada, and west-flowing rivers. The total water available in Maharashtra state is 195968 mcum, with 163820 mcum being surface water and 32148 mcum being groundwater. These four main river basins cover 92% of the cultivable land and over 60% of the rural population. Additionally, 45% of the state's water resources come from west-flowing rivers, which are primarily monsoon-specific rivers originating from the ghats and flowing into the Arabian Sea.

S.No.	Basin & Sub-basin Percentage of State	Geographical Area/ Area (%)	Culturable Availability	Annual Average Water (mcum)
1	Godavari Basin (Godavari, Purna, Dudhna, Manjra, Penganga, Wardha, Waitarna)	15.43 (49.5 %)	11.25	50880 (31.05 %)
2	Krishna Basin Krishna, Koyana, Panch-ganga, Bhima, Neera, Man, Sina,	7.01 (22.6 %)	5.63	34032 (20.77 %)
3	Tapi Basin Purna (Tapi), Girna, Panzara,	5.12 (16.7 %)	3.73	9118 (5.56 %)
4	Narmada Basin	0.16 (0.5%)	0.03	580 (0.35 %)
5	Kokan River Damanganga, Vaitrana, Shastri, Kudalika, Vashishthi, Savitri, Amba, Terekhol, Patalganga, Ulhas etc.	3.16 (10.7 %)	1.86	69210 (42.24 %)
6	Maharashtra State	30.80 / 100.0%	22.53	163820

Source: Maharashtra Water Resources Regulatory Authority, Government of Maharashtra (2024)

Agriculture

Agriculture is the backbone of Maharashtra's economy, with approximately 56% of its total geographical area dedicated to cultivation. The state's economy is largely agrarian, and agriculture serves as the primary occupation for its people. Maharashtra cultivates a variety of crops, including both food crops and cash crops. The major principal crops grown in the state are rice, bajra, jowar, onions, wheat, cotton, pulses, sugarcane, turmeric, and various oil seeds like sunflower, groundnut, and soybean. This agricultural diversity contributes significantly to the state's economy and sustains the livelihoods of a large portion of its population (Gorain et al., 2020).

In 2022-23, Maharashtra had a net sown area of 167.22 lakh hectares, representing approximately 54.4% of the total geographical area (MES, 2022). Cereals are the predominant crops in the state. The production of major crops in Maharashtra during 2022-23 is presented in the below table.

Major crops in Maharashtra (in 000 MT)

Crop	Production
Rice	3,496.4
Wheat	2,301.0
Jowar	140.6
Bajra	536.3
Ragi	109.5
Maize	2,613.8
Other Cereals	20.9
Coarse Cereals	3,421.1
Tur	859.1
Mung	178.5
Urd	233.4
Gram	2,974.1
Other pulses	148.2
Groundnut	205.2
Sesamum	1.6
Nigerseed	2.1
Sunflower	4.9
Soyabean	6,679.9
Linseed	1.9
Safflower	24.0
Other Oilseed	10.5
Sugarcane (Harvested)	1,35,754.3
Cotton (Lint)	8,590.9
Jute & Mesta	10.09
Tobacco	2.2
Total	1,68,310.4

Source: Department of Agriculture, Government of Maharashtra

Scheme of Maharashtra

The government of Maharashtra has implemented several schemes and plans such as the National Food Security Mission (NFSM), the National Horticulture Mission, the Integrated Farming System, the Turmeric Research and Processing Policy, and Micro Food Processing Enterprises Scheme (MES, 2023).

S.No.	Scheme	Objective
1.	Horticulture Plant Protection Scheme (State-sponsored)	The scheme implemented in 2017-18 aims to provide plant protection chemicals like insecticides, pesticides, and fungicides to farmers at a 50% subsidy to manage pests and diseases.
2.	Plantation of Fruit Crops and Vegetables in Kitchen Garden (Backyards) of Tribal Framers	In all 14 districts of the state with a significant tribal population facing malnutrition, a scheme has been initiated to address this issue by promoting the cultivation of fruit crops and vegetables in the backyard of tribal families. This scheme provides a subsidy of Rs. 252 per beneficiary, which includes mini-kits of vegetable seeds and grafts/seedlings of fruit crops.
3.	National Mission for Sustainable Agriculture (NMSA), Sub Mission on Agroforestry (SMAF)	The initiative aims to promote and enhance tree plantation in a coordinated way, ensuring the availability of high-quality plant materials such as seeds, seedlings, clones, and improved varieties. It seeks to promote diverse agroforestry practices suitable for various agroecological regions and land use patterns while offering extension services and capacity-building support to the agroforestry sector. The funding structure involves a 60% central share and a 40% state share.
4.	*Bhausaheb Phundkar Falbaug Lagwad Yojna*	Enhancing farmers' earnings and fostering job creation via horticultural plantations. Beneficiaries will get a subsidy in the ratio of 50:30:20 for three years.
5.	National AYUSH Mission – Medicinal Plants Component	In 2015-16, the national government implemented the National AYUSH Mission through the Department of AYUSH (Ayurved, Yoga, Naturopathy, Unani, Siddha, and Homoeopathy). To promote medical practices and develop the educational system. The main objectives of this mission are to ensure quality control and continuous supply of plant material. Under Monitoring of Maharashtra State Horticulture and Medicinal Plant Board.
6.	*Punyashlok Ahilyadevi Holkar Nursery Scheme*	Since 2020-21, this initiative has been rolled out in the state under RKVY to incentivize farmers to cultivate chemical-free, high-quality vegetables for export purposes. Eligibility criteria include farmers with a minimum of 0.40 hectares of land and access to a permanent water source for nursery establishment. Female agricultural graduates, their groups, small and marginal vegetable farmers, and their groups are prioritized for participation in the scheme.
7.	National Horticulture Mission	The National Horticulture Mission (NHM) was started by the Government of India in 2005-06 to boost horticulture yield and increase post-harvest management.

8.	Orchard Plantation Scheme under Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA)	The initiative has been implemented in all districts of the state since 2011-12. The initiative aims to increase MGNREGA job card holder farmers' income and create jobs by planting orchards on their own productive or fallow land of up to two hectares. Gramsabha selects beneficiaries under the plan. Beneficiaries must recruit MGNREGA job card holders as labourers for this work. Farmers receive subsidies immediately in their bank accounts based on plant survival percentage.
9.	Maharashtra Millet Mission	The initiative in the state aims to increase millet production and promote millet processing to enhance consumption. Innovative strategies like 'Millet of the month' and 'Shet tithe poushtik trundhanya' are being introduced to popularize millets.
10.	*Atal Bamboo Samruddhi Yojna*	To initiate the people to grow the bamboo. The National Bamboo Mission aims to enhance post-harvest management by establishing innovative primary processing units near production sources, primary treatment facilities, and preservation technologies to improve market infrastructure. It also focuses on promoting product development by supporting research and development, entrepreneurship, and business models at different levels to meet market demands. Additionally, the mission emphasizes skill development, capacity building, and awareness generation to facilitate the growth of the bamboo sector from production to fulfilling market requirements.

Source: Government of Maharashtra (2021)

Biodiversity

Maharashtra, located in western India, covers an area of 3,07,713 km². Its geography is conducive to ecotourism development due to its diverse features. The Western Ghats run parallel to the coast with an average elevation of 1,200 meters. Kalsubai near Nasik is the highest peak in the Sahyadri range. To the west of these hills lies the Konkan coast plain, 50-80 km wide, while to the east is the flat Deccan plateau. The Western Ghats are one of India's three watersheds, giving rise to rivers like Godavari and Krishna that flow eastward into the Bay of Bengal, forming significant river basins. Maharashtra has established 6 National Parks, 35 Wildlife Sanctuaries, and 4 Tiger Reserves to protect its rich biodiversity and promote ecotourism (Shinde and Pardeshi, 2015).

Group of organisms	Number of species in Maharashtra
Mammals	129
Aves	556
Reptiles	117
Amphibians	53
Freshwater Fishes	215
Marine and estuarine fishes	653
Vertebrata	3971

Agro-climatic Zone

The Maharashtra state is divided into nine distinct agro-climatic zones based on soil type, topography, and rainfall (Kalyankar *et al.*, 2008). These zones are: South Konkan Coastal Zone (SKCZ), North Konkan Coastal Zone (NKCZ), Western Ghat Zone (WGZ), Sub Mountain Zone (SMZ), Western Maharashtra Plane Zone (WMPZ), Western Maharashtra Scarcity Zone (WMSZ), Central Maharashtra Plane Zone (CMPZ), Central Vidarbha Zone (CVZ), and Eastern Vidarbha Zone (EVZ).

Name of the Zone	Annual Rainfall (mm)	Temperature		Soil type	Principle Crops
		Min	Max		
North Konkan Coastal Zone (NKCZ)	Above 2500	18.0	33.9	Laterites	Paddy, Nagli, Mango, Cashew
South Konkan Coastal Zone (SKC)	Above 2000	16.9	39.8	Coarse to shallow	Paddy, Minor millet
Western Ghat Zone (WGZ)	Above 2500	8.7	41.9	Light laterite and reddish	Paddy, Wheat, Bajra, Sugarcane Sorghum, Gram and Groundnut
Sub Mountain Zone (SMZ)	1750-2500	10.0	37.0	Reddish brown and reddish	Paddy, Wheat, Bajra, Sugarcane Sorghum
Western Maharashtra Plane Zone (WMPZ)	700-1750	10.0	37.0	Grayish black	Groundnut, Bajra, Wheat, Sorghum, Gram, Sugarcane
Western Maharashtra Scarcity Zone (WMSZ)	Below 700	10.2	43.1	Vertisols	Sorghum, Bajra, Paddy, Wheat, Tur, Gram, Sunflower, Safflower, Sugarcane
Central Maharashtra Plane Zone (CMPZ)	700-900	12.6	41.4	Vertisols	Cotton, Sorghum, Sugarcane, Tur, Wheat, Gram, Bajra, Soyabean
Central Vidarbha Zone (CVZ)	900- 1250	12.6	41.4	Brown to dark brown Calcareous	Cotton, Sorghum, Tur, Wheat, Paddy, Safflower, Sugarcane
Eastern Vidarbha Zone (EVZ)	More than 1250	7.6	45.1	Yellowish brown to red	Paddy, Cotton, Bajra, Sorghum, Tur, Gram, Sugarcane

Source: ICAR-CAFRI

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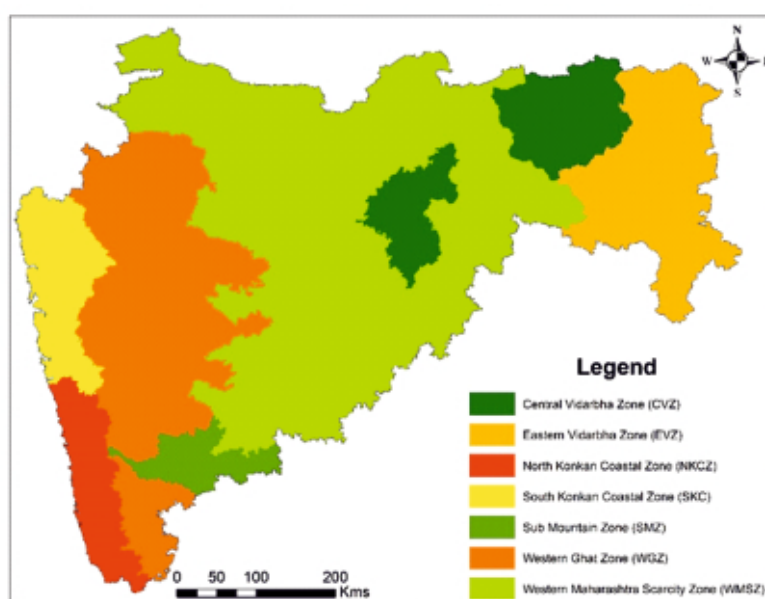
Demography

As of the Census of India 2011, Maharashtra's total population was 1,12,374 million, with 58,243 million males and 54,131 million females (Census, 2011). This accounts for 9.3% of the country's total population of 1,210.855 million. The population density in Maharashtra is 365 individuals km², slightly lower than the national average of 382 km². The state has a literacy rate of 82.3% and a sex ratio of 929 females per 1,000 males, below the national average of 943. The tribal population in Maharashtra is reported to be 10,510 million (Maharashtra at a Glance, 2023).

Administrative profile

Mumbai (also known as known as Bombay until 1995) is the capital city of the Indian state of Maharashtra. The state divided 36 districts into six revenue divisions: Konkan, Pune, Nashik, Aurangabad, Amravati, and Nagpur. The state has a long history with important planning organizations at the district and local levels. Rural self-government entities include 33 Zilla Parishads, 355 Panchayat Samitis, and 27,993 Gram Panchayats. The state has 23 Municipal Corporations, 222 Municipal Councils, 4 Nagar Panchayats, and 7 Cantonment Boards that regulate its urban areas. The name of 36 districtsis as follows: Ahmednagar, Akola, Amravati, Aurangabad, Beed, Bhandara, Buldhana, Chandrapur, Dhule, Gadchiroli, Gondiya, Hingoli, Jalgaon, Jalna, Kolhapur, Latur, Mumbai, Mumbai Suburban, Nagpur, Nanded, Nandurbar, Nashik, Osmanabad, Palghar, Parbhani, Pune, Raigad, Ratnagiri, Sangli, Satara, Sindhudurg, Solapur, Thane, Wardha, Washim and Yavatmal (ESM, 2023).

State symbols

The Indian Giant Squirrel (*Ratufa indica*) and yellow-footed green pigeon (*Treron phoenicopterus*) serve as the state animal and state bird of Maharashtra. The Jarul or Pride of India (*Lagerstroemia speciosa*) is the state flower, known as the pride of India, while the state trees include the Mangrove tree, White chippi (*Sonneratia alba*), and Mango Tree (*Mangifera indica*) is the State tree. The Blue Mormon (*Papilio polymnestor*) and Rohu (*Labeo rohita*) are designated as the state butterflies and fish. Marathi is the official language of Maharashtra, and it also holds the status of an additional official language in the state of Goa.

Promising Agroforestry Models/Systems of Maharashtra
Agri-silviculture system

S.No.	Agroforestry models	Tree component	Crop component	Economic returns/ Benefits Cost Ratio (BCR)
1.	Agri-silviculture system	Teak, Mango, Neem, Ber, Custard apple	Jowar, Cotton, Groundnut	SRS-8 Jowar (35.20) produced higher yield flowed by PVK-400 (25.73)
2.	Agri-silviculture system	Teak	Jowar, Cotton, Tur, Mung	In the *Kharif* season, Tur (Pigeon pea) (9.75 kg per plot) gave more yield followed by Jowar and Mung.
3.	Agri-silviculture system	Teak	Jowar, Gram, Safflower, Linseed	Jowar (7.55 kg per plot) yield is higher than the gram safflower and Linseed
4.	Agri-silviculture system	Ber	Tur, Mung, Urd, Soyabean	Tur (Pigeon pea) (51.99 kg per plot) gives the higher yield followed by Soybean.

5.	Agri-silviculture system	Teak and Bamboo		The 39.20 q/ha and 26.50 q/ha leaf litter fall was observed in the system.
6.	Agri-silviculture system	*Ailanthus excesla, Azadirachta indica, Acacia mangium, Acacia albida* and *Tectona grandis*	Kharif-Blackgram and Green gram. Rabi- Wheat and Mustard.	The *Ailanthus excesla* grows well but intercrops were affected due to biotic factors.
7.	Agri-silviculture system	*Ailanthus excesla, Tectona grandis* and *Faberdia albida*	Sesame(AKT64) Sesame (G4)	Maximum B: C ratio was observed in Ailanthus + sesamum (3.77) followed by Teak + sesamum (1.88) and (1.27).
8.	Agri-silviculture system	Teak and Bamboo	Hybrid Napier	Maximum B:C ratio 2.8 was estimated for Teak+ Hybrid napier followed by Bamboo+Hybrid napier (2.20) system.
9.	Agri-silviculture system	Bamboo *var Bamboosa balcooa* (Bhima), *Dendrocalamus stocksii* (Manga) and *Dendrocalamus strictus* (Manvel)	Cowpea	*Bamboosa balcooa* + Cowpea + RDF 125% B:C ratio (3.50) is higher followed by *Dendrocalamus stocksii*+ Cowpea + RDF 125% (3.39).
10.	Agri-silviculture system	*Tectona grandis*	Horsegram	Trail Failed
11.	Agri-silviculture system	*Terminalia paniculata* (Kinjal), *Terminalia tomentosa* (Ain), *Hevea brasiliensis* (Rubber), *Casuarina equisetifolia* (Suru), *Leuceana leucocephala* (Subabul), *Acacia auriculiformis* (A. Babul), *Eucalyptus citriodora* (Nilgiri) and *Gliricidia sepium* (Gliricidia)	Rice (*Oryza sativa*)	The yield of Solo rice (*Oryza sativa*) was more (49.61 q/ha) than the yield in between the two rows of *Hevea brasiliensis* (41.21 q/ha)

12.	Agri-silviculture system	*Casuarina equisetifolia* (Suru) and *Acacia auriculiformis* (A. Babul)	Rice (*Oryza sativa*)	The Net return was higher in *Acacia auriculiformis* than in Casuarina. The maximum grain yield obtained in *Acacia auriculiformis* (A. Babul) hedge row 15x2 m spacing (1997 to 2002).
13.	Agri-silviculture system	*Anacardium occidentale* (Cashewnut),	In Kharif season- Finger millet, Proso millet, Niger, Groundnut and Sesamum. In Rabi season- Cowpea, Mustard and Groundnut	The maximum crop grain yield is recorded in Cashewnut + Finer millet (14.75 q/ha) followed by Cashewnut + Proso millet (14.11 q/ha). The gross income was a maximum of Rs. 10175/- for the groundnut crops.
14.	Teak-based agroforestry system	Teak	Cowpea, Fodder sorghum, Fodder maize, Blackgram	In the Kharif season intercrop pulse treatment (Teak +Black gram – Fodder Maize) B: C ratio (1.63). Whereas in the Rabi season the intercrop fodder treatment (Teak + Cowpea – Fodder Sorghum) B: C ratio (1.64). The Pulse fodder system economics B: C ratio is higher (1.62) in Sole crops Cowpea + Fodder Sorghum followed by Teak+ Cowpea- Fodder Sorghum (1.58).
15.	Agri-Horti-silviculture system	Mango and Teak	Soyabean, Blackgram and Greengram	Trail failed
16.	Agri-Horti-silviculture system	Mango, Teak and Gmelina	Soyabean, Blackgram and Greengram	Mango + Gmelina + Blackgram-based system give the higher grain yield (7.67 q/ha).
17.	Agri-Horticulture system	Mango, Guava and Jackfruit	Blackgram, Greengram and Soyabean	-
18.	Agri-Horticulture system	Citrus (Orange)	Gram, Wheat, Cotton, Cauliflower and Brinjal	Highest B: C ratio (2.74) was estimated for the orange+ cauliflower system (5 yrs). The lowest B:C ratio was estimated for orange+ gram(2.0).
19.	Agri-Horticulture system	Mango	Wheat, Gram and Pigeon pea	Highest B:C ratio (3.25) was estimated for the Mango+ pigeon pea system followed by Mango + Gram (2.00) and Mango + Wheat (1.47).
20.	Citrus-based agroforestry system	Sole Nagpur mandarin, Teak, *Eucalyptus* and *Ailanthus*	Wheat, Gram and Pigeon pea	-
21.	Citrus-based agroforestry system	Sole Nagpur mandarin, Teak, *Eucalyptus* and *Ailanthus*	Cowpea and Mustard	Maximum B:C ratio was recorded under Mandarin + *Eucalyptus teritocornis*+ Intercrop (Cowpea + Mustard) (5.06) and minimum B: C ratio was recorded under sole Mandarin + Intercrop (Cowpea + Mustard) (1.10).

22.	Mango-based agroforestry	Mango, Ber, Custard apple, Drumstick, Aonla, Mango var (Vanraj), *Casuarina* and *Eucalyptus*	Cowpea and Mustard	The higher grain yield of Sole horsegram is (8.75 q/ha) followed by Mango + Ber system (8.01 q/ha).
23.	Agri-horticultural system	Tamarind, Ber and Aonla	Urdbean (Irrigated/ Rainfed) and Wheat	The fruit yield is higher of sole trees Ber followed by Aonla and Tamarind (22.80, 8.21 and 4.85 q/ha) in irrigated conditions. Tamarind fruit tree species gave more fruit yield (3.15 q/ha) in combination with T+B+A treatment. The yield of Urdbean in Irrigated and Rainfed conditions was higher in Control (11.37 and 7.21 q/ha). The Irrigated Wheat gave higher yield in the control(23.46 q/ha).
24.	Agri-horticultural system	Tamarind, Mango, Aonla and Custard apple	Chickpea and Soyabean	The highest B: C ratio of Sole Chickpea (2.79) followed by Sole Chickpea (1.99).
25.	Horti-Agricultural system	Mango	Finger millet, Proso millet, Niger, Sesamum and Groundnut	Groundnut intercropped in Mango higher grain yield is (13.03 q/ha) followed by Finger millet (12.46 q/ha) and Proso millet (12.40 q/ha).
26.	Horti-silvicultural system	*Mangifera indica*, *Bridelia retusa*, *Acacia mangium*, *Terminalia arjuna*, *Pongamia pinnata*, *Terminalia chebula*, *Tectona grandis* and *Gmelina arborea*		The Mangium grown as intercrop in mango recorded highest East-West and North-South canopy is 246.06 and 230.25 cm.
27.	Asana-based horticultural system	*Bridelia retusa* (Asana)	*Dioscorea bulbifera* (Arial yam*), Ananas comosus* (Pineapple), *Amorphophallus paeonifolins* (Elephant foot yam), *Morus alba* (Mulberry), *Carissa carandas* (Karonda), *Syzygium samarangense* (Jam) and *Citrus latifolia* (Seedless lemon)	The height and DBH of Asana were higher in Asana + Elephant foot yam and Sole Asana (6.95 and 6.20 m) and (15.03 and 13.23 cm) and the Asana + Mulberry recorded the highest yield (211.333 t/ha) followed by Arial yam (2900 kg/ha)

| 28. | Sandal-based horticultural system | *Santalum album* (Sandal), *Artocarpus heterophyllus* (Jackfruit), *Psidium guajava* (Guava), *Syzygium cumini* (Jambhul), *Carissa carandas* (Karonda), *Syzygium samarangense* (Jam), *Emblica officinalis* (Amla) and *Garcinia indica* (Kokum) | | The height of the sandal is higher in the sole Sandal (2.60 m) followed by intercropped with Jam (2.47 m). The Mean annual increment (MAI) with respect to height was higher in Sandal intercropped with Jackfruit (1.43 m) followed by Sandal intercropped with Guava (1.21 m). In the intercropped species, Guava (1.81 m) attained the more height followed by Jackfruit and Jambhul (1.75 m). Jambhul grown as intercrop recorded maximum DBH (3.96 cm) followed by Guava (3.64 cm). |

Silvipastoral systems

S.No.	Agroforestry models	Tree component	Crop component	Economic returns/Benefits Cost Ratio (BCR)
1.	Silvi-Pasture system	Ber, Custard apple, Teak, Sisso	Stylo grasses	-
2.	Silivi-Pasture system	Casuarina	Jowar *var* (M.P Chari),(MKV-Chari),(PVK-400) and (Nilwa)	-
2.	Silivi-Pasture system	Casuarina	Jowar *var* (M.P Chari), (MKV-Chari), (PVK-400) and (Nilwa)	-
3.	Horti-Pasture system	Aonla	*Dicantheum annulatum*, *Themeda triandra* and *Cynadon dactylon*	Maximum B:C ratio was calculated for Aonla pasture (1.5)
4.	Horti-Pasture system	Mango, Orange and Cauliflower	Gram, Wheat, Cotton and Cauliflower	Highest B:C ratio was found for Mango + Gram (3.84)
5.	Silvi-pasture system	*Acacia tortilis, Zyziphus mauritiana, Azadirachta indica* and *Albizia lebbeck*	*Chrysopogon fulvus, Cenchrus ciliaris Stylosanthes hamata* and *Sehima nervosum*	The average productivity of grasses and range legumes was higher (20.10 q/ha) during the 2nd, 3rd, and 4th year after planting compared to the later three years 1991-92 to 1993-94 (10.07 q/ha).

6.	Silvi-pasture system	*Gmelina arborea* (Shivan), *Terminalia tomentosa* (Ain), *Tectona grandis* (Teak), Ceiba pentandra (Shevar), *Gliricidia sepium* (Gliricidia), *Acacia catechu* (Khair), *Pongamia pinnata* (Karanj), *Acacia auriculiformis* (A. Babul), *Leuceana leucocephala* (Subabul), and *Eucalyptus* (Nilgiri)	Gram, Wheat, Cotton and Cauliflower	The maximum grass production was observed in the control (37.7 q/ha) followed by the Teak (33.0 q/ha)
7.	Horti-pastoral system	*Themeda quadrivalvis* (Natural grass), *Panicum maxicum* (Guinea grass), *Chlorisgayana* (Rhodus*)*, *Setaria anceps* (Setaria grass) and *Themeda mooneeyi* (Grass selection-1)	Gram, Wheat, Cotton and Cauliflower	The height of the mango tree is higher in the Mango+Rhodus grass(1.89m) followed by Mango + Natural grass (1.81m).
8.	Horti-silvi-pastoral system	*Anacardium occidentale*, *Bixa orellena* (Anato), *Garcina indica* (Kokum), *Embelia ribes* (Wavading), *Tectona grandis*, *Gmelina arborea*, *Bridelia retusa* and *Emblica officinalis*	Gram, Wheat, Cotton and Cauliflower	The treatment Cashewnut sole (3.60 t/ha) is higher grass yield followed by Cashewnut + Anato (3.46 t/ha) and Cashewnut + Kokum (3.46 t/ha).

Other systems

S.No.	Agroforestry models	Tree component	Crop component	Economic returns/Benefits Cost Ratio (BCR)
1.	Bamboo-based agroforestry system	Bamboo	Arhar (Pigeon pea)	B:C ratio is 1:2.94 when the first crop of Bamboo was harvested. During 6th year indicated is progressive year would be wider than then present year
2.	Silvi-medicinal system	Neem, Anjan, Bakan, Teak, Eucalyptus, Ber and Babul	*Aloe vera* and *Asparagus racemosus*	The yield of *Aloe vera* is found in the Ber, Bakan and Neem treatment (2.733, 2.513 and 2.533 kg/plant)
3.	*Melia dubia*-based medicinal agroforestry system	*Aegle marmelos* (Bael), *Oroxylum indicum* (Tetu), *Gmelina arborea*	*Solanum khasianum* (Ran Wangi), *Clerodendrum phlomidis* (Agni month), *Embelia basal* (Wavding), *Justicia adhatoda* (Adulsa) and *Plumba gozeylanica* (Chitrak)	The average height of *Melia dubia* was observed (11.82 m) and CAI height was (2.00 m) whereas DBH or CAI DBH of Melia is (17.55 cm and 3.02 cm). Among the medicinal plant Shivan tree Root weight, Root length, Stem weight and Total Biomass (232.0 g/per plant; 69.8 cm/ per plant; 880.0 g/per plant and 1184.4 g/per plant)

Agroforestry Systems
for
Maharashtra

Ailanthus based Agri-silvicultural 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; Fuel wood : 10834 kg/ha

Economic Returns: The highest net return from Ardu intercropping with green gram was Rs 76,024/ha, surpassing both sole cropping and other agri-silvi systems. However, the benefit-cost ratio (B:C ratio) from sole Ardu was greater at 8.53 compared to the Ardu + green gram system (Handa et al., 2019).

Melia (*Melia azedarach*) based Agroforestry System

Scientific name: *Melia azedarach*

Suitable Spacing: 5 x 1 m, 5 x 2 m, 5 x 3 m and 5 x 4 m**.**

Suitable Intercrops: Soybean (JS-335)

Tree productivity : Productivity significantly increased in the 5 x 4 m spacing configuration after the 10th year, primarily utilized for small timber and pole purposes.

Economic Returns: At the 10th year, the net returns and benefit-cost ratio (BCR) were superior in *Melia* planted at 5 x 4 m with field crops, amounting to Rs 10,502/ha/yr and Rs 1.86:1, respectively. This was followed by sole field crop cultivation, yielding Rs 6,410/ha/yr with a BCR of Rs 1.73:1 (Handa et al., 2020).

Tamarind based Silvi-horticultural System

Scientific name: *Tamarindus indica*

Suitable Spacing: 12 x 12 m apart on degraded sloping and for the boundary and block plantation land of hilly zone.

Suitable Intercrops: Natural grass

Tree productivity : Eucalyptus: 10–15 t/ha

Economic Returns: The combined net income from tamarind and Eucalyptus cultivation amounted to Rs 6,180 per hectare per year, with a Benefit-Cost Ratio of 1.79:1 in this agricultural practice (Handa et al., 2020).

Tamarind + Curry leaf based Agroforestry System

Scientific name: *Tamarindus indica* and *Murrayya koenigii*

Suitable Spacing: Tamarind is planted at 6 x 6 m spacing and the Curry leaf is planted at 2 x 2 m spacing in between two tamarind trees in Boundary and block plantation.

Economic Returns: The tamarind + curry leaf based agroforestry system net returns obtained amounted to Rs 6125/ha/yr with the Benefit Cost ratio of 1.68:1 (Handa et al., 2020).

Bamboo based Agri-silvicultural System

Scientific name: *Bambusa vulgaris*

Suitable Spacing: 10 m x 10 m or 10 m x 12 m (as block plantation) and 4 m x 4m (as bund plantation).

Suitable Intercrops: Green gram, black gram and sesame during Kharif season and mustard, chickpea and barley during Rabi season.

Economic Returns: The time span of seven years, farmers generated an annual net profit exceeding Rs 26,000.00 from their bamboo cultivation (Handa et al., 2020).

Teak based Agri-silvicultural System

Scientific name: *Tectona grandis*

Suitable Spacing: 8mx2m, 12mx2m for agroforestry, 2mx2m for block and 2-5m for boundary plantation.

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

Suitable Intercrops: Kharif crops- Black gram, soybean, cotton, redgram and sesame. Rabi crops- Sorghum, cowpea and linseed.

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

Economic Returns: Rs 60,000 ha at first 50% thining upon 7 years; Rs 2,28,900 ha at second (25%) thining upon 12 years and Rs 19,44,000 ha at final harvesting upon 20-25 years (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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+91-510-2730214   **director.cafri@icar.gov.in**   **https://cafri.icar.gov.in**

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