



## Eucalyptus inventory in India

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**ABSTRACT:** *Eucalyptus* is the most common tree in agroforestry models, with a small percentage also planted on forest lands in India to produce wood for commercial utilisation. The tree has come a long way since the 1980s when it was first planted in farmers' fields. Currently, it is the mainstay of wood production in the country. *Eucalyptus* is an extremely important industrial and commercial tree that needs a detailed assessment of its inventories. The only existing system capturing forest and TOFs (Trees Outside forests) inventories on a regular basis is the FSI biennial reports. *Eucalyptus*-based agroforestry plantations are often very small in size and fragmented. *Eucalyptus* is among the prominent trees in many states, for which its inventories related to tree count, growing stock, occurrence in mixed and pure forests, and in agroforestry and non-agroforestry areas are given. This paper reviews *Eucalyptus* inventories from past FSI biennial reports released to date, and supplements FSI data with additional information reported by various states and other reputed institutes, for which some suggestions are made.

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## 1. INTRODUCTION

*Eucalyptus* is the top-planted, top-wood producer, and the backbone of at least the paper and panel industry in India. The tree was first introduced in India in the year 1790 (Shyam Sunder, 1984) to produce firewood; it subsequently found its way into a wide variety of uses, such as raw material for paper pulp and panel industry, furniture making, scaffoldings, and many more. *Eucalyptus* is now primarily grown by the farmers in agroforestry (AF) though a small share has also been planted on forest lands by some state forest departments for meeting needs of the wood-based industry (WBI). So much so that *Eucalyptus* now lies at the base of a complex value chain comprising nurseries, plantations, harvesting services, marketing networks, inter-state trade, and finally its processing for manufacturing final products as already referred to above. Trade of *Eucalyptus* wood in India alone has been valued at INR 480 Billion. (Dhiman *et al.*, 2023).

As a major share of *Eucalyptus* and other TOFs (Trees Outside Forests) existing outside recorded forest areas (RFAs) are scattered over large areas, their proper and accurate monitoring and documentation pose serious challenges. Currently, there is no management information system in the country that credibly

captures a reasonably accurate picture of the growing stock of *Eucalyptus* and other major trees' inventories. This leads to a situation where a large chunk of production, harvesting and conversion of farm-grown wood remains largely unaccounted. This creates challenges not only for forward planning but also adds to volatility in wood prices from time to time.

As of now the only source of information about tree count and growing stock (GS) inventories, both within RF and TOF areas, are biennial reports (named as the India State of Forest Reports (ISFRs) brought out by Forst Survey of India (FSI). ISFRs provide data on *Eucalyptus* inventories for states where it is among the predominant trees within RF and TOF areas.

This paper reviews the *Eucalyptus* inventories given in ISFRs released to date, while also supplementing FSI data sets with other related published information. This consolidation of information on *Eucalyptus* form can help in developing a better understanding of the geographical spread, tree count and growing stock pertinent to *Eucalyptus* at a national level, which is extremely important for the users of *Eucalyptus* wood for raw material planning and related investment decisions.

## 2. EUCALYPTUS EMERGENCE AS TOP PLANTED TREE AND WOOD RESOURCE

Though introduced over two centuries ago, *Eucalyptus* largely remained restricted to selected locations during the pre-independence era. The fact that *Eucalyptus* roots, especially at the seedling stage, are highly sensitive to exposure adversely impacted

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their expansion in the initial phase. Introduction of polybags in Indian nurseries during the mid-1950s (Dhiman *et al.*, 1996) helped address the root exposure in Eucalyptus seedlings, thereby improving the survival of field-planted Eucalyptus in a significant manner and propelled Eucalyptus to be a preferred species in forest nurseries and plantations (both within and outside RFA) in many states.

The Indian Forest Policy 1952 placed a greater significance on the production aspect of forestry. As a result, industrially important trees like Eucalyptus were promoted in many states on a large scale. High survival and fast growth of Eucalyptus had made it one of the favored trees in plantation programmes by the 1960's. There was a special project to plant industrially important trees for producing raw material for Wood Based Industries (WBIs) during the 3<sup>rd</sup> five-year plan (1963 to 1968). In this period large scale Eucalyptus plantations were created including in areas bearing high value natural forests like Sal forests (Raj, 2023) and the inner Himalayan semi-cold arid region (Rizvi *et al.*, 2025). For example, 2163 ha. patchy Sal growth and miscellaneous forests in Paonta Forest Division, H.P. were felled and planted with *Eucalyptus tereticornis* (Mysore hybrid) between 1963 and 1968 (Raj, 2023). Eucalyptus began to account for ever larger share in plantation programmes and working plans (WPs) in many states.

Mid 1970's was another significant phase in Eucalyptus expansion in the country. While there were sporadic efforts by Haryana and Gujarat and a few other states to promote Eucalyptus on farmlands for firewood production, externally funded projects supporting social- and farm-forestry during 1980's and 90's promoted its large-scale proliferation as an AF species in many states. Around same time the private sector also started showing a keen interest in Eucalyptus as a source of industrial raw material. This was manifested in development of wide variety clones that enabled a shift towards large-scale clonal plantations. Introduction of root trainer technology in 1984 (Rawat and Dhiman, 2002) further transformed the clonal planting stock production and adoption. Starting with first rooting of cuttings in 1984 (Chandra and Yadav, 1986), Eucalyptus soon became the top planted tree using clonal planting stock in the country (Dhiman and Gandhi, 2014). Eucalyptus plantation and economic footprint gradually expanded with improvement in the utility of its under-valued produce. Eucalyptus is now considered a zero-wastage tree as its harvestable components, including excavated roots and foliage are also chipped and extensively used by industries and locals.

Some studies have reported the total area under Eucalyptus as 5 Mha in the country (ENVIS, 2014). Another estimate of 3.94 Mha ([www.git.forestry.com](http://www.git.forestry.com)) was reported for Year 2009. However, as there has been a steady increase in area under Eucalyptus plantations in different parts of the country over the last two decades, an area of at least 5 Mha appears more realistic.

### 3. INVENTORYING THE FORESTS AND TREES IN INDIA

The history of undertaking the forest and tree inventories dates to 1961 when the Pre-investment Survey of Forest Resources (PISFR) was set up for documentation and monitoring inventories of selected species and in specific locations from the commercial perspective. PISFR was later upgraded to the Forest Survey of India (FSI) in 1981. FSI undertakes inventories as per its committed mandate for monitoring and reporting forest and tree resources at regular intervals and on the special request of states. Agencies, other than FSI, involved in assessing TOF inventories at various levels include state forest departments, State Remote Sensing Centers (SRSC), ICAR-Central Agroforestry Research Institute (CAFRI), CIFOR (Centre for International Forestry Research)- World Agroforestry (ICRAF), Natural Remote Sensing Centre Hyderabad, Indian Space Research Organization (ISRO), Indian Institute of Photo-interpretation, state horticulture departments (for fruit trees), and the private sector. The purpose of conducting these inventories may vary for each organization. The purpose of conducting TOF inventories by FSI often overlaps with that of other agencies, which invariably conduct them as research projects to test new methodologies and techniques. Gujarat regularly makes inventory of tree wealth in the non-forest areas at 5-year intervals. It reported 397.55 M trees (>10 cm dbh) in its 5<sup>th</sup> Tree Counting Report-2021 (GFD 2021). Haryana conducted its first Tree Census in the state on land other than RFA and reported 41.20 M trees (>10 cm dbh) during 2023 (HFD 2023).

TOF inventories are compiled and presented for tree numbers, GS, area, tree configurations, geographical locations, crop compositions, land-use production systems, biomass, basal area, *etc.* Some studies, especially those conducted by academic institutions based on interpretation of high-resolution imageries (Arunachalam *et al.*, 2022), present tree and forest inventories in terms of their area coverage, tree size, geographical formations and some other traits. For example, Archana and Kumar (2013) reported over two dozen trees and their associated land formations in their TOF mapping study in Haryana. Many mappings

studies document TOF inventories without mentioning tree species, though some casually referred names of the predominant trees recorded during their ground truthing exercise. For example, studies carried out by Kumar *et al.* (2021) mentioned Eucalyptus as a dominant tree in linear and farm forest formations in Haryana, and Babu *et al.* (2022) reported trends in Eucalyptus-based AF land-use between 2000 and 2019 in Ambala District of Haryana. Rizvi *et al.* (2020) developed spectral reflectance-based specific signatures for Poplar and reported the area under this tree in some districts and states in the country.

FSI, for the first time, tested the methodology for TOF inventories in some states (FSI, 1991). The results of the initial surveys/inventories were reported in a series of publications between 1995 and 1998 by the Shimla Centre of the FSI, and the final report was published as “Inventory Survey of TOF” in 1998 (FSI 1998), which for Haryana were analysed by Sapra (2000). FSI has reported the detailed methodology adopted in the TOF inventory (FSI N.M.). The process of conducting TOF inventory was accelerated, and some of their fragmented information was reported from 2001 onward and on a regular basis in ISFRs 2013 onward. A special publication of TOFs was published by FSI during 2020 (FSI 2020). Some state-specific TOF inventories were also conducted by FSI at the request of states.

FSI biennial reports were named as the State of Forest Reports (SFRs) before 2005 and India State of Forest Reports (ISFRs) thereafter. Tree-inventories are prepared for both RFA and TOF over 10 cm dbh till ISFR 2021, with an additional class of 5-10 cm dbh was introduced for TOF inventory in ISFR 2023, with a justification that some species grown as TOFs are now being harvested at a very young age, which earlier were not getting captured in TOF inventories. ISFRs provide forest and TOF inventories at the country and state levels. The predominant trees, including Eucalyptus contributing to numbers and GS at the country and state levels are given as Annexure. Forest cover is reported for Dense Forests (>70% crown density), Moderately Dense Forests (40-70% crown density), Open Forests (10-40% crown cover) and Scrubs in these reports. TOF cover on land >1 ha and >10% crown density is picked up as forest cover, and those of scattered trees occurring in <1 ha land patches are classified as tree cover, calibrated to 70% crown cover.

ISFR 2023 reported the total forest and tree cover to be 84.36 Mha (25.17% of the geographical area), out of which forest cover was 21.76%, and tree cover was 3.41%. The extent of TOF (forest cover outside the RFA & GW and tree cover) was 30.70 Mha in the

country. Out of a total forest cover of 71.5 Mha, 52.0 Mha was reported within the recorded forest area (RFA) and 19.5 Mha outside RFA. The total GS of wood was 6,429.6 Mm<sup>3</sup> which included 4,478.9 Mm<sup>3</sup> inside RFA and 1,950.7 Mm<sup>3</sup> in TOFs. ISFR 2023 recorded an increase in total forest and tree cover by 1445.81 Km<sup>2</sup> and total GS of 262.32 Mm<sup>3</sup> (4.25%), which included 90.92 Mm<sup>3</sup> (2.07%) in RFA and 171.40 Mm<sup>3</sup> (9.63%) in TOFs in comparison to ISFR 2021. The total tree cover and GS under AF were 12.7690 Mha and 1291.7 Mm<sup>3</sup>, respectively, which increased by 20.02% and 28.56% respectively, in a decade period from 2013. The potential wood production from TOFs was estimated to be 91.51 Mm<sup>3</sup> in ISFR 2023.

#### 4. INVENTORIES OF RFAs AND TOFs

Working Plans (WPs) at the level of Forest Divisions and Annual Administrative Reports (AARs) at the state level are important government documents that cover relevant aspects of forests, including some inventory-related information of predominant forests and trees planted within RFAs. The concept of WP was introduced for the first time in 1891 in the country (D’arcy, 1891) and over the years has undergone some changes. The current regulations on WPs are provided in the National Working Plan Code-2014, with the provision of statistics of growth and yield of the main trees in Chapter 12 (Part-I). Eucalyptus started finding regular mention in the WPs and management of local forests around the 1960s, when the tree was aggressively promoted as an industrially and commercially important tree in many states.

There is a fairly good body of documented information on Eucalyptus tree inventories in WPs of forests where it is one of the predominant trees. Detailed information exists regarding to number, Growing Stock (GS), local volume tables, management prescriptions, yields, productivity, *etc.* There are specific Eucalyptus-based Working Circles (WC) in many WPs which are titled after their or some other names. For example, Eucalyptus tree is a leading contributor with 41.7% by tree number and 59.6% by GS in the Ludhiana Forest Division, Punjab, where it is covered under Road WC, Railway WC, Canal WC, Drain WC and Block WC (Singh N.M.); and Pulpwood WC in Bijnor Social Forestry Division (Gupta, 2019). In some areas, WCs are constituted exclusively for Eucalyptus. For example, In Paonta Forest Division in H.P., Eucalyptus (overlapping) WC was constituted to grow it as a commercial and industrially important tree during the 1960s. The old Eucalyptus forests of this division are still working under the Eucalyptus Plantation Restoration & Rehabilitation Plan (WC) (Raj, 2023).

Haryana is among a few states where the share of Eucalyptus in total TOF inventory is very high (HFD 2023). Out of a total number of 41.97 M trees (>10 cm dbh) in the state, Eucalyptus had 10.22 M trees (24.8% of the total trees). Ambala District leads with one-fourth of its inventory in the state, followed by Yamuna Nagar and Jind, which had double-digit percentages of 11.82% 10.61% respectively. Eucalyptus tree number inventory in Haryana changed from 21% in 1998 (FSI 1998), to 26.5% in 2006 (Ahmad, 2008), 19.8% in 2017 (Anon. 2021) and 24% in 2023 (HFD 2023), while its GS to saw changes from 22.4% in 1998 to 20.02% in 2006, 18% in 2017 and 37% in 2023.

Gujarat is another state that has been conducting tree counting outside recorded forest areas at a five-year interval. The state has conducted 5 tree counting exercises between 2003 to 2021. Total tree inventory in the state changed from 251.0 Million trees in 2003 to 288.69 M in 2008, 301.44 M in 2013, 343.53 M in 2017 and 397.55 M in 2021 (GFD 2021). The share of Eucalyptus has witnessed quantum jump over the years. For example, Eucalyptus (>10 cm dbh) was the top tree with 78.883 M number (19.84%) out of a total of 397.5 M trees in the state during 2021. There was an increase of 29.64 M Eucalyptus trees (61.18%) in 2021 from 2017 when its number was 50.24 M (14.6%) whereas this increase was 21.94 M trees (60%) in 2017 from 2013 inventory. Eucalyptus is among the top 10 prominent trees in the majority of the districts amongst which Dahod and Panchmahals districts top the list with their substantial number in Anand, Surat, Bharuch, Sabarkantha and Kheda districts.

The private sector is also an important player in the promotion of Eucalyptus in its operational catchment areas. Some private sector players regularly monitor Eucalyptus and other planted trees over varying time horizons for scoping wood availability for their industrial units. These companies are now using these datasets for offsetting their carbon footprints, getting these plantations registered under certification programmes and/or carbon finance schemes. Some are also maintaining a huge tree inventory dataset of their promoted tree resources. The private sector plays a significant role in developing selected commercially important trees, namely Eucalyptus, Poplar, Leucaena, Casuarina and some others, by supplying their quality planting material to growers.

## 5. EUCALYPTUS INVENTORIES IN ISFRs

In ISFRs Eucalyptus trees are predominantly reported in two variables, namely tree number and GS. Till 2021, Eucalyptus and other TOF inventories were conducted and reported in 3 dbh classes, namely 10-30 cm, 30-50 cm and +50cm. 5-10 cm dbh class was added in ISFR 2023.

Initially, Eucalyptus was treated as one category under Eucalyptus species; however, *E. globulus* started finding additional mention in ISFR 2019. In AF inventories, another category *i.e.*, Eucalyptus hybrid was also mentioned in ISFR 2023. SFR 2003 first started additional and separate reporting of TOF cover, whereas SFR 2005 started reporting GS of forest trees and TOFs separately for the first time. For estimating GS of Eucalyptus and other prominent tree species, local volume tables were developed using regression equations for different physiographic zones. The first regression equation reported for Eucalyptus species was for Northern Plains as  $V = 0.02894 - 0.89284D + 8.72416D^2$  in SFR 2003, and it continued to find mention in all the ISFRs till 2023. This regression equation is also reported for estimating Eucalyptus GS in Haryana, Punjab, Karnataka, Tamil Nadu, and West Bengal and Chandigarh Union Territory in ISFR 2023. Two other regression equations, one each for Eucalyptus species in West Bengal ( $V = (0.031 - 0.64087 * D + 8.72416 * D^2)$ ) and another for *E. globulus* in T.N. (under root  $V = (0.115412 + 3.12191 * D)$ ) were reported in ISFR 2019 and ISFR 2023. In these regression equations, V stands for volume of Eucalyptus wood in m<sup>3</sup>, and D for diameter at breast height (dbh).

These regression equations were developed from tree datasets collected from different states and physiological regions in the past. SFR 2001 presented tabular statements for various diameter classes of dominant trees in different physiographic zones for constituting one ha stand with 70% crown cover (Table 1). Eucalyptus was reported to be a prominent tree in at least 9 out of 14 zones. In another 5 zones it was in somewhat lesser proportions. On average basis in all the physiographic zones together, Eucalyptus trees constituting one Ha. stand varied from 496 trees/ha in 10-20 cm, 275 trees/ha in 20-30 cm, 180/ha in 30-40 cm, 128 trees/ha in 40-50 cm and 97 trees/ha in +50 cm dbh classes.

### Eucalyptus inventory in ISFR 2023

Eucalyptus inventory in ISFR 2023 has been reported as pure and mixed forest, and in three land formations, namely recorded forest areas (RFA), TOFs, and AF at the country level and also in states where it is the predominant species. Eucalyptus tree number and GS datasets are given in Table 2 and their percentages in Figure 1. There were 319.12 Million Eucalyptus trees in the country, out of which 149 M were in the lowest diameter class of 5-10 cm; 153.4 M in 10-30 cm dbh class; 15.7 M in 30-60 cm; and 1.02 M in >60 cm dbh class. Percent-wise, the tree distribution was 46.69%, 48.09%, 4.91% and 0.32% in the 5-10, 10-30, 30-60 and >60 cm diameter classes, respectively. Maximum

GS of 14.18 Mm<sup>3</sup> Eucalyptus wood was in the 10-30 cm dbh class, followed by 11.64 Mm<sup>3</sup> in the 30-60 cm, 3.02 Mm<sup>3</sup> in the >60 cm, and 1.42 Mm<sup>3</sup> in the 5-10 cm dbh class. Percentage-wise maximum GS of 46.86% was in the 10-30 cm dbh class, followed by 38.47% in the 30-60 cm, 4.69% in the 5-10 cm, and 9.98% in the >60 cm.

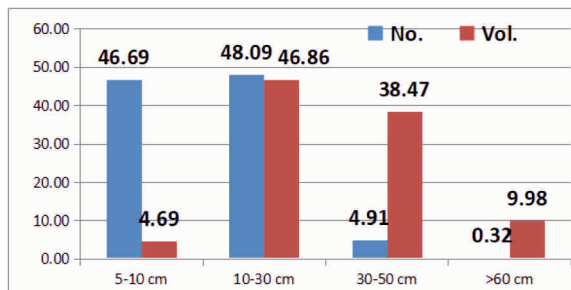


Figure 1. Percent of Eucalyptus tree number and GS in different diameter classes.

Another dataset in Eucalyptus inventories is given for their number and GS in Recorded Forest Areas (RFAs) and rural as well as urban areas (Table 3). Eucalyptus has been reported from 1<sup>st</sup> to 5<sup>th</sup> top position in these three categories in many states. Eucalyptus ranked No. 1 in Haryana in the three configurations of RFA, urban areas and rural areas. In rural areas, it was ranked No. 1 in Punjab, Uttar Pradesh and Chandigarh; No. 3 in West Bengal and No. 5 in Puducherry. In urban areas, the tree was ranked No. 1 in Punjab and Haryana and No. 3 in West Bengal. In RFAs, the Eucalyptus was ranked 1<sup>st</sup> in Punjab and Haryana, 3<sup>rd</sup> in West Bengal, 4<sup>th</sup> in Punjab & Tamil Nadu, and 5<sup>th</sup> in Karnataka. In RFA, Karnataka it tops the list with 35 M trees and 4.4 Mm<sup>3</sup> GS, followed by Tamil Nadu (17.7 M trees and 2.38 Mm<sup>3</sup> GS), and West Bengal (11.91 M trees and 1.44 Mm<sup>3</sup> GS). From the perspective of wood-based industry, its inventory in rural areas was very significant. It was maximum in UP

Table 1. Eucalyptus tree number constituting one ha stand

Physiographic Zone	Diameter Class				
	10 -20	20-30	30-40	40-50	50+
Western Region	518	304	188	125	88
Eastern Region	388	240	148	97	67
Northern plains	595	344	242	187	152
Eastern Plains	467	280	200	156	127
Western plains	513	359	259	190	145
North Deccan	494	272	160	102	70
South Deccan	480	219	124	80	56
East Ghats	563	186	112	80	62
East Coast	448	268	185	138	108
Average	496	275	180	128	97

Table 2. Diameter-class wise tree number and GS in the ISFR2023 inventory

Particulars	Eucalyptus inventory in 2023 (Thousands)					% of total 2023
	5-10	10-30	30-60	60+	Total	
Tree No. (1000)	148987	153480	15663	1022	319121	2.95
Vol. (Mm <sup>3</sup> )	1.42	14.18	11.64	3.02	30.26	1.55

Table 3. ISFR 2023: Eucalyptus Tree No. (1000), GS (Mm<sup>3</sup>) and their ranks in RFA, rural and urban areas

State	RFA			Rural areas			Urban areas		
	No.	Vol.	Rank	No.	Vol.	Rank	No.	Vol.	Rank
Haryana	3750	1.25	1	23968	4.9	1	1333	0.215	1
Karnataka	35001	4.4	5	-	-	-	-	-	-
Punjab	2787	1.91	4	22686	4.828	1	2246	0.396	1
T.N.	17701	2.38	4	-	-	-	-	-	-
U.P.	-	-	-	142126	6.971	1	2866	0.331	3
West Bengal	11905	1.44	3	14534	1.044	3	-	-	-
Chandigarh	-	-	-	13	0.005	1	-	-	-
Pondicherry	-	-	-	102	0.007	5	-	-	-

(142.13 M trees and 6.971 Mm<sup>3</sup> GS), followed by Haryana (23.97 M trees and 4.9 Mm<sup>3</sup> GS), Punjab (22.69 M trees and 4.828 Mm<sup>3</sup> GS), and West Bengal (14.53 M trees and 1.044 Mm<sup>3</sup> GS).

ISFR 2023 first presented the status of forests by crop composition in the RFA. It includes 2 types, namely pure forest and mixed forest categories, based on the predominance of a particular tree species. The report identified 33 crop compositions, wherein mixed composition is represented by a particular tree with miscellaneous forests.

Eucalyptus-based pure forests and mixed forests are reported for different states (Table 4), which shows that Eucalyptus-based pure forests were a maximum of 7.47% in Tamil Nadu followed by 5.59% in Haryana, 4.98 % in Karnataka, and 2.49% in Telangana. The states with a lower percentage of Eucalyptus pure forests were Jharkhand (0.11%), Bihar (0.23%), Uttar Pradesh (0.37%), and Himachal Pradesh (0.41%). Percentage-wise Eucalyptus-based mixed forests were 6.02% in Punjab, 3.5% in Haryana, 2.89% in Karnataka, and 2.4% in West Bengal compared to 0.08% in Odisha, 0.12% in U.P., and 0.15% in Uttarakhand.

Many states where Eucalyptus occurs in appreciable quantity as pure forests are largely those where this tree is grown for commercial wood production on forest lands. In category 1 it is grown by state forest development corporations (Andhra Pradesh, Tamil Nadu, Telangana, etc.) and in category 2 by the state forest departments in some other states (Punjab, Haryana, Uttarakhand, Uttar Pradesh, etc.) In Category 2 areas state forest corporations are engaged in only harvesting of mature trees, and not in raising plantations. Many states like Karnataka, H.P. and some others, now do not plant Eucalyptus in RFAs,

and as such, the tree inventories appearing in the ISFR reports are from old plantations that still exist.

At the country level, in terms of number of trees in Agro-forestry, Eucalyptus is at the 5<sup>th</sup> rank (after mango, neem, *Prosopis juliflora*, and *Areca catechu*). Tree inventory in AF is given in two categories, namely Eucalyptus species and Eucalyptus hybrid. The total number of Eucalyptus trees was 310.79 M trees, out of which 274.13 M were of Eucalyptus species and 36.36 M were of Eucalyptus hybrid. Maximum Eucalyptus trees were in the 5-10 cm dbh class (numbering 152.67 M, including Eucalyptus species and Eucalyptus hybrid) followed by 10-30 cm (14.721 M); 30-60 cm (10.182 M); and >60 cm dbh (1.225 M). The percentage share of tree number was 49.12%, 47.21%, 3.28% and 0.39% in dbh class 5-10 cm, 10-30 cm, 30-60 cm and >60 cm respectively. Eucalyptus GS was a maximum of 9.97 Mm<sup>3</sup> in the 10-30 cm dbh class, followed by 30-60 cm dbh class (4.55 Mm<sup>3</sup>), then >60 cm dbh class (2.16 Mm<sup>3</sup> in, and lastly 5-10 cm dbh class (1.15 Mm<sup>3</sup>). The share of GS in different dbh Classes was 6.45%, 55.92%, 25.52%, 12.11% in 5-10 cm, 10-30 cm, 30-60 cm and >60 cm dbh class, respectively (Table 5).

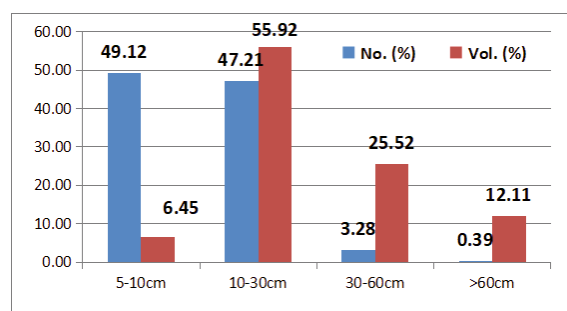


Figure 2. Per cent of Eucalyptus tree number and GS(m<sup>3</sup>) in different dbh classes in agroforestry.

Table 4. Eucalyptus based pure and mixed forests (%) in states

Sr. No.	State	Share of Eucalyptus-based Pure forests (%)	Share of Eucalyptus Miscellaneous forests (%)
1	Andhra Pradesh	2.35	0.69
2	Bihar	0.23	0.37
3	Haryana	5.59	3.5
4	H.P.	0.41	0.28
5	Jharkhand	0.11	0.22
6	Karnataka	4.98	2.89
7	Odisha	-	0.08
8	Punjab	2.41	6.02
9	Tamil Nadu	7.47	1.89
10	Telangana	2.49	1.46
11	U.P.	0.37	0.12
12	Uttarakhand	0.76	0.15
13	West Bengal	1.54	2.4

### Trends of Eucalyptus inventories in SFRs & ISFRs till date

SFR 2005 first reported GS of trees separately for RFAs and TOFs at the country level and gave the ranking of the top 10 trees based on GS in each of RFAs and TOFs. Thereafter, ISFRs started reporting GS in three dbh classes, namely 10-30 cm, 30-50 cm and >50 cm in inventories published till 2021. In ISFR 2023, the dbh classes have been re-categorized for some TOFs into four dbh classes as 5-10 cm, 10-30 cm, 30-50 cm and >50 cm. 10-30 cm dbh is the only common class in all the inventories reporting GS till date. The datasets given in Table 6 are in three dbh classes for all inventories till ISFR 2021 and for only 10-30 cm dbh class for ISFR 2023 inventory. Total Eucalyptus number in ISFR 2023 was 319.12 M out of which 148.99 M; 15.66 M; and 1.02 M were in 5-10 cm, 30-50 cm, and >50 cm dbh class respectively. No. of Eucalyptus trees reported in ISFR 2023 are not fully reflected in Table 6 due to difference in dbh classes used in earlier inventories.

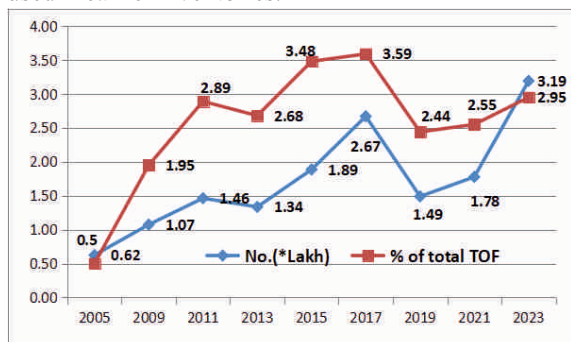


Figure 3. Trends in Eucalyptus tree No. and per cent to the total tree inventory.

Table 5. Eucalyptus tree inventory in Agroforestry

Particulars	Eucalyptus type	Tree inventory in AF (Thousands)					Rank among AF trees
		5-10	10-30	30-60	60+	Total	
Trees No. (1000)	E. species	136524	129290	7599	1018	274431	46
	E. hybrid	16143	17431	2583	207	36364	5
	Total	152667	146721	10182	1225	310795	
Vol. (Mm <sup>3</sup> )		1.15	9.97	4.55	2.16	17.83	16

Table 6. Diameter-wise Eucalyptus tree numbers (1000) from 2005-2023

Year	10-30	30-50	>50	Total	Eucalyptus (%) of total
2005	58849	3380	268	62497	0.5
2009	93564	11902	1969	107435	1.95
2011	130038	13135	3125	146296	2.89
2013	119312	12542	1683	133537	2.68
2015	176929	10159	1450	188538	3.48
2017	253679	11611	1705	266995	3.59
2019	133175	14955	815	148945	2.44
2021	161778	14994	864	177736	2.55
2023	153480	-	-	319121	2.95

The datasets given for Eucalyptus GS in Table 7 also follow the same pattern as mentioned for tree numbers in Table 6. Eucalyptus GS in different dbh classes was 1.41Mm<sup>3</sup> in 5-10 cm, 14.18 Mm<sup>3</sup> in 10-30 cm, 11.64 Mm<sup>3</sup> in 30-50 m and 3.02 Mm<sup>3</sup> in >50cm class in ISFR 2023. Eucalyptus tree number (266.99 M) and GS (50.104 Mm<sup>3</sup>) were maximum in ISFR 2017 compared to their lower number (133.53 M) and GS (31.07 Mm<sup>3</sup>) in ISFR 2013. GS in other reports was 30.26 Mm<sup>3</sup> in 2023, 29.08 Mm<sup>3</sup> in 2021, 26.89 Mm<sup>3</sup>, and 26.07 Mm<sup>3</sup> in 2019 inventories.

The datasets on tree number were divided by 100,000 to normalize graph scale for number and GS (Figure 4). It shows a similar pattern and overall trends for the total number of trees and total GS in all the inventories. The 10-30 cm class was represented in all inventories and had upper end values for both diameter as well as GS, a trend common to all inventories.

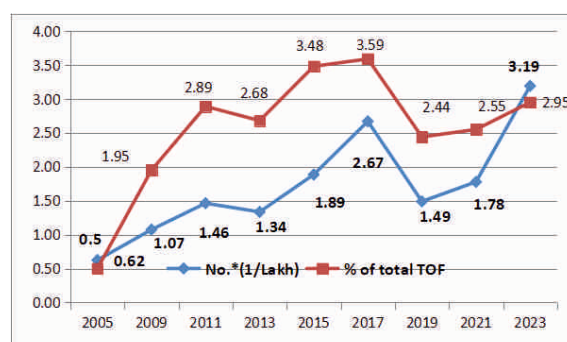


Figure 4. Trend in Eucalyptus GS (m<sup>3</sup>/15) and per cent between 2009 to 2023.

### Decadal change in Eucalyptus inventory

The ISFR 2023 report also compared Eucalyptus inventories with that of the decade-old inventory of ISFR 2013 (Table 8). Eucalyptus trees recorded a significant increase in the number of 15.51 M, which was 130.77%, whereas GS decreased by 17.01% during a one-decade period. This increase was largely due to including additional trees of 5-10 cm dbh class. Eucalyptus GS was 1.91% in 2013, which was reduced to 1.38% in 2023.

## 5. DISCUSSION

Some specific features and issues that emerged from above need further discussion to make Eucalyptus inventories more relevant. These are discussed below:

### 5.1 Higher Eucalyptus inventory in North India

Eucalyptus datasets provided in the latest ISFR 2023 indicate that three north Indian states, namely Uttar Pradesh, Haryana and Punjab, together have 59.12% of the total Eucalyptus trees (188.79 M) and 55.18% GS (16.70 Mm<sup>3</sup> of total). These states had aggressively promoted Eucalyptus under social-forestry programmes during 1970's and 80's, which could be one of the reasons that helped this tree to establish better in this region compared to other regions. North India is also the food-bowl of the country, and growing more Eucalyptus in AF on highly productive farmland indicates its better integration and synergy with agriculture production systems, which also includes generating higher returns to the growers. In South India, the tree was aggressively promoted initially by ITC for pulpwood production during the 1990s and thereafter by some other paper mills. The tree also became a higher revenue generator for many state forest corporations, especially those of Uttar Pradesh,

Haryana, Punjab, Tamil Nadu, Andhra Pradesh, Telangana, and Maharashtra, which have been growing and/or harvesting their commercial plantations for a few decades now.

### 5.2 Comparison of Eucalyptus inventory in Agroforestry versus non- Agroforestry landscape

FSI adopted the working definition of AF given in the National Agroforestry Policy (2014) as "A land use system which integrates trees and shrubs on farmlands and rural landscapes to enhance productivity, profitability, diversity, and ecosystem sustainability (ISFR 2023). According to this definition and ISFR 2023, the Eucalyptus TOF inventory was 97.4% (310.79 M trees) in AF and only 2.6% in non-AF, whereas its GS was 58.9% in AF and 39.1% in non-AF. Eucalyptus GS of 0.057m<sup>3</sup>/tree was in AF compared to 1.493 m<sup>3</sup>/tree in non-AF and 0.948 m<sup>3</sup>/tree in total tree inventory at the country level (Table 9). Eucalyptus GS/tree was 2502% higher in non-AF and 1474% higher in total inventory compared to that in AF. It indicates that the Eucalyptus trees grown in non-AF land are larger in size and older in age, and they are retained for a longer period compared to those in AF, where they are harvested at shorter production cycles.

### 5.3 Some abrasions and inconsistencies in reported Eucalyptus inventories

Despite a small increase in Eucalyptus- based forest and tree inventory datasets over the years, it recorded some decrease in ISFR 2023 (based on their number in the same dbh classes) which, though reported the highest ever number of 319.12 M trees due to the first-time inclusion of 5-10 cm dbh class (148.99 M) in this report. It had around 95% of trees between 5-30 cm

**Table 7. Diameter-wise Eucalyptus GS (Mm<sup>3</sup>) from 2013-2023**

Year	10-30	30-50	>50	Total	% of total
2009	11.767	10.260	4.422	26.449	1.65
2011	17.935	11.395	6.645	35.975	2.32
2013	16.187	10.992	17.96	31.076	2.09
2015	15.408	8.113	3.37	26.897	1.71
2017	29.348	15.383	5.372	50.104	2.12
2019	12.88	11.05	2.14	26.07	1.59
2021	15.17	11.19	2.72	29.08	1.63
2023	14.18	-	-	30.26	1.55

**Table 8. Decadal change in Eucalyptus inventory between 2023 and 2013 reports**

	2023	2013	Change	
Rank	7	-	No.	%
Tree No. (000)	274432	118918	155514	130.77
Vol. (000)	17.84	21.5	-3.66	-17.01
% vol of 2023	1.38	1.91	-	-

dbh range, whereas around 90% GS was in dbh range between 10-60 cm. Around 50% trees and GS were between 10-30 cm dbh and recorded a significant decline, thereafter, indicating that maximum of them is now being harvested <30 cm dbh. This trend appears realistic in view of the dynamic change happening in the adoption of shorter Eucalyptus production cycles for chip wood and pole production, as its plantations are now opportunistically harvested earlier based on growers' hard-pressed needs for money (Dhiman, 2021). During the periods of low wood availability, high demand, and high market prices, Eucalyptus trees are harvested even at around 2-year age to supply their wood to the chip wood industry.

ISFR 2017 reported Eucalyptus inventory of 267 M trees (excluding 5-10 cm dbh class that did not exist then), which appears unusually high compared to other reports. One possible reason for this variation could be related to the gradual buildup of its inventories due to less harvesting when its wood prices were extremely low during this period in North India. There could be other probable reasons related to methodological and technological issues of a very small sampling size used in highly diverse TOFs, including Eucalyptus distribution in different land configurations in such a large geographical area of the country. The sampling methodology is stratified in such a way that each set of surveyed land frames was earlier revisited after 20 years, and after 10-year interval from 2017 onward. For the TOF survey, country land is now divided into 10 frames, *i.e.*, 1 to 10 and during each survey, a specific set of frames are picked up, which are thereafter revisited after 10 years, after completing the other 9 frame land patches. TOFs in linear formations have many subsets like, roadside, railway side, canal side, bund side *etc.*, with unique tree distribution patterns in each of them. The comparison of TOFs, including Eucalyptus captured in a specific frame, land patches and land configurations with that of the immediate past and future reports could be different and may also be a potential reason for such variation in inventories.

Some overlaps in TOF versus forest inventories are often reported. Trees in strip forests, especially on

roadside, canal side, railways sides are considered as TOFs in FSI inventories, whereas some states have declared them as protected forests. For example, Haryana has approximately 3 M ha under strip/linear and block forests, out of which 58% are linear forests. It is significant acreage that has an overlap between the forest and TOF inventories. Dhyan (2014) was of the opinion that FSI assessments are overestimated compared to tree cover.

The trend of making fresh Eucalyptus plantations is on the rise, and that of old trees on farmland is on the decline. A large number of Eucalyptus trees, which were earlier planted on public land including roadside avenues, have been harvested in recent years due to the widening and up-gradation of many such roads to national and state-level highways. During 2024-25, around 500 M clonal Eucalyptus plants were field planted in the country (Dhiman, 2025), especially in those locations where its intensive culture has been taking place for a couple of decades now. There was a gradual shift from seed origin plantations to clonal plantations in this region after farmers had recorded better growth and economic returns from high-yielding clones grown by them. In many other locations, where Eucalyptus culture is not so intensive and its growers have not yet tested and tasted the growth of good clones, they are still planting it with seed-origin planting material. It is estimated that around 50 M seed origin plants are still being planted in different parts of the country, making a total of approximately 550 M Eucalyptus planted in the country now. The exiting Eucalyptus inventory of the short production model also includes two additional coppice production cycles after the main harvest of originally planted trees. Chip wood and pole production model is now the most dominant Eucalyptus wood production in the country. This model provides better and higher economic returns to growers in a quick succession of 3-4 year cycles, wood trade happens locally, survival rates of plants are very high, and productivity is also high (Raina *et al.* 2011).

The recent years' fast expansion of Eucalyptus culture has been closely associated with its increased demand from an ever-expanding utilisation base in panel,

**Table 9. Eucalyptus inventory in AF versus non-agroforestry areas (Values in parentheses are percent)**

Particulars	Eucalyptus inventory in AF and non-AF landscape		
	Total	AF	Non-AF
Tree No. (M)	319.121 (97.4%)	310.795 (2.6%)	8.326
GS (Mm <sup>3</sup> )	-	30.26	17.8312.43
Vol (m <sup>3</sup> /tree)	0.094823	0.057369	1.492914
Change in m <sup>3</sup> /tree from non-AF (%)	1.398 (1474%)	1.435 (2502%)	0
Change in m <sup>3</sup> /tree from AF (%)	0.0374 (65%)	0	0

paper and construction (Poles) industries. According to an estimate, there was consumption of 15000 Mt/day Eucalyptus wood collectively in Uttar Pradesh, Uttarakhand, Punjab and Haryana during 2012 (Dhiman and Gandhi, 2012), which has now reportedly increased 3 times to around 45000 Mt/day in these states during 2023-24. Almost stagnated Eucalyptus inventories in FSI biennial reports fail to capture this dynamic change gradually happening in its plantations and wood volume production over the years. There is also some inconsistency in Eucalyptus tree numbers reported in ISFRs and those in state-made inventories discussed above. Harvesting many Eucalyptus plantations now at very short production cycles of 2-3 years in many locations may be one reason for not getting captured in biannual reports.

#### **5.4 Revision of tables for No. of trees constituting a one-hectare stand**

SFR 2001 reported tabular statements for the number of predominant TOFs, including Eucalyptus, in different dbh classes in different physiographic zones for constituting one ha stand (Table 1). A lot has changed in Eucalyptus production and utilisation in the country over the last 2 decades. The chip-wood production model evolved during the last 2 decades, where smaller thick wood sections are now finding increased demand from the paper, panel and pole industry. The tree is now planted at high density with an average of 2500 plants/ha and at times over 3000 plants/ha in some locations. Even for peeling logs, the tree is now grown at much higher density of over 1500 plants/ha compared to normal planting of 1100 plants which was the norm on forest land around 2 decades back. The current Eucalyptus production models for chip wood production on farmer's fields are based on an average 3-4 years age, veneer logs of around 5-6 years age and sawn log production model above 6 years age. The tabular statements for Eucalyptus constituting one ha stand reported in SFR 2001 have now lost relevance and its new norms need to be re-developed keeping in view the different production models including high density blocks and widely apart grown trees on boundaries, those grown in agroforestry versus non-agroforestry, clonal versus seedling-origin trees, different physiographic zones, etc. These tables are invariably used by many states to convert their conducted inventories into an area which at times gets inflated due to multiple variables in the current Eucalyptus culture.

#### **5.5 Local volume regression equations**

FSI started using regression equations for estimating GS of different TOF species and reporting it w.e.f. ISFR 2005. Before that, FSI and state forest departments had been estimating GS of predominant

trees while preparing WPs for each forest division and using it along with annual increment for estimating wood yield. FSI estimated the national level wood yield of forests from GS by using Von Mental Formula and reported it in its 1995 biennial report (SFR-1995). The earlier regression equations used for estimating Eucalyptus GS were developed using larger dbh datasets from large and old trees. Latest, ISFR 2023 has included an additional diameter class of 5-10 cm; thus, GS estimation for lower dbh datasets also needs inclusion in the regression equation for reliable prediction of GS. Chaturvedi (1995) had developed regression equations for estimating Eucalyptus wood production from seed origin planted Eucalyptus. This was based on dbh and height of trees for estimating over bark and under bark volume table as  $VoB = 0.00352 + 0.0341 \text{ Girth}^2 * \text{Height}$ ,  $Vub = 0.00258 + 0.0281 \text{ Girth}^2 * \text{Height}$ . This regression equation was also used for GBH range 18-42 cm and 9.4 to 19.5 m height Eucalyptus hybrid trees (NewGen Eucalyptus, 2019). Eucalyptus GS in Uttar Pradesh WPs is estimated using a regression equation:  $V = 0.0014 + 0.2401 D^2 H$  (Gupta, 2019)

The bulk of Eucalyptus production system is now based on high-yielding clonal Eucalyptus, for which applying regression equations developed for seed origin Eucalyptus could lead to high variance in estimates. According to Rajan (1987) the regression equations developed for seedling origin Eucalyptus are not suitable for its clonal plantations. Keeping in view the importance of large wood production in the country, there is a need for developing Eucalyptus-based local volume equations for different physiographic zones; production models based on production cycles, spacing, seed versus clonal plantations; and those grown in AF and non-AF land-uses for better and precise estimation of its GS at the state and country level.

#### **5.6 Revisiting the methodology for TOF, including Eucalyptus inventories**

Wood availability is a key issue in licensing WBI in the country. The current regulations *in-vogue* for licensing WBI are called as "Wood Based Industries (Establishment and Regulation) Guidelines, 2016 of MoEF&CC". The credibility of the estimates of timber availability from TOFs made by the FSI and states has often been questioned at NGT, CEC and the Supreme Court in the past. These regulations specifically advised the states to commission wood availability studies once every five years, which are currently being ignored by most states, as this involves heavy expenditure and technical manpower. The Hon'ble Supreme Court, while deciding the case related to the establishment of WBI in Uttar Pradesh

vide its order dated 21.10.2022, settled the matter related to the estimation of wood availability surveys. This order had approved the methodology adopted by FSI in estimating potential wood availability, with advice to the lower courts to honour such estimates prepared by professional bodies like FSI. Wood supply chain, at the country level, has now effectively shifted to non-forest plantation resources, which are currently supplying around 92% of raw material to the wood-based industry, and Eucalyptus is the main wood producer in the country (Dhiman, 2025).

There is now a need to give much higher focus on TOF inventories as the major RFA is under conservation that produces very low wood quantity. The revisiting cycle for the same grids/sample in TOF inventories needs to be reduced to 5 years, at par with that of RFAs. ISFR biennial surveys can be integrated in such a way that each targeted state gets their detailed TOF inventories conducted in cycles of five years. This will be a big relief for all the states and country in taking forward developing their wood resources and utilization base. Each state during the TOF survey may pool its respective human and financial resources with those of FSI for meeting the requirement to estimate wood availability once every five years, as outlined in the central guidelines of 2016.

#### **5.7 Geo-tagging Eucalyptus inventories emerging need**

Geo-tagging trees and plantations are now increasingly required under forest certification, carbon credit, tractability of wood and some other programmes. Most existing Forest management certified and carbon credit schemes, especially those initiated by the private sector in the country have Eucalyptus as predominant tree. Many state forest departments are currently using different versions of WhatsApp for capturing geo-coordinates of planted trees and areas under other plantation schemes. Uttar Pradesh and Punjab have been doing it for the last few years to capture farm-grown Eucalyptus and Poplar plantations to estimate carbon credits and make payments to the farmers. The possibility of generating, capturing, estimating and making payments for the carbon credits is gradually increasing, and the importance of geo-coordinates of TOFs is now being used for multiple purposes, which may further help in developing AF/TOF management Information system (MIS), wood balance studies, *etc.*

MOEF&CC, in June 2025, issued an advisory framework on Model Rules for Felling Trees in Agricultural Land to the states for issuing state-specific notifications on these rules. These rules suggest entering details of plantations with land records, date of planting, species and number planted,

height of the planted seedlings, geo-tagging planted seedlings and area with photographs, growth data of trees at regular intervals, including that just before felling. The felled wood thereafter could be connected with One Nation-One Pass under the National Timber Management System (NTMS) to facilitate the wood movement for traceability.

#### **5.8 Adding new traits in Eucalyptus inventories.**

A new dimension in tree inventories is now being added, where tree-specific signatures have been developed, which are accordingly used for mapping trees and forests in the targeted areas. Signature-based mapping of Eucalyptus plantations and forests is now used in some countries (Oliveira *et al.* 2021, Higgs and van Niekerk 2024, Zhou *et al.* 2024, Ferra and Vicens 2025 and others). Some studies on signature-based monitoring of tree mapping were applied for poplars (Rizvi *et al.*, 2020) and some horticulture trees (Rizvi *et al.* 2016, 2017) in India. There is a need to extend signature-based mappings of Eucalyptus in view of it being a top-planted tree in the country. Some other dimensions added in the tree inventory include biomass and carbon-related parameters. Area-specific Eucalyptus biomass and carbon-related studies have been reported by Singh and Gill (2014) and Kanime *et al.* (2013).

#### **5.9 Removing Eucalyptus from ecologically sensitive forest areas**

Eucalyptus invariably attracted controversies for a few of its proclaimed negative roles, one of which is often cited as its role in damaging the local biodiversity, especially in ecologically sensitive native forests. Table 4 lists states in which Eucalyptus-based pure and mixed forests exist in appreciable percentages in the country. Eucalyptus produces viable seed but has failed to get naturally regenerated and expanded beyond planted locations to any forest areas and ecologically sensitive ecosystems. Its coppicing has also been restricted to a few coppicing cycles and therefore cannot spread beyond planted spots. India also does not have any sister species with which the introduced Eucalyptus could outcross to affect our biodiversity. The tree, on the other hand, is effectively and efficiently helping in conserving and protecting the diversity & ecology of native forests by shifting a huge wood production pressure to non-forest areas where it is grown.

Eucalyptus is now increasingly grown by farmers in their fields, and many states have stopped its planting in RFAs. It is now desirable that some states, which still have their old trees in ecologically sensitive forests, need to remove them to avoid some controversy surrounding these trees. The Karnataka Forest department has already initiated a process to

uproot Eucalyptus trees from RFAs. RFAs that are currently growing Eucalyptus could easily be replaced with high-value tree plantations, like that of teak and some other species. Growing more Eucalyptus in AF will have dual benefits of better conservation of native forests and increased production of Eucalyptus wood from outside forests, which integrates well with the overall goal of the Indian Forest Policy 1998 and National Agroforestry Policy 2014.

## 6. CONCLUSION

Eucalyptus inventories reported in SFRs and ISFRs provide valuable information and are relevant for policy and planning, especially for establishing WBI, as its wood is the lifeline for the major industrial units around its culture. Except for some contrasting datasets on its inventories in some reports, its inventories are, by and large, showing reasonable trends. There are parallel studies by scientific communities based on signature-based mapping of Eucalyptus and other TOFs. There is a strong need to integrate these two different dimensions of Eucalyptus inventories and use them for capturing the real trends in its culture. Eucalyptus is now increasingly discussed and debated for its ecological, social, economic and industrial applications in the country. The tree is now well-suited for wood production in AF, and its presence inside RFAs needs to be critically curtailed.

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