Oxygen production potential of trees in India

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This study deals with the oxygen production potential of India taking baseline data from ISFR 2019. The Indian forests have an oxygen production potential of 7896.14 million tonnes (mt) and the annual potential was 28.04 mt yr^{-1} for 2019. Considering oxygen production potential of the top 10 tree species from forests and those outside forests, *Shorea robusta* (Sal) and *Mangifera indica* (Mango) ranked first, i.e. 657.87 and 214.39 mt respectively. The fast-growing agroforestry tree species exhibit a net oxygen production rate in the range of 1.03–34.15 tonnes ha^{-1} yr^{-1}. Bamboo being a fast-growing and higher biomass-producing species showed oxygen production of 27.38 mt yr^{-1}. Overall this provides huge scope for establishing oxyparks in India.

Keywords: Agroforestry, bamboos, oxygen production potential, oxyparks.

OXYGEN is one of the important elements necessary for the survival of every species in this planet. Forests and trees are the major source of oxygen and an important reservoir of carbon dioxide. They meet half of the oxygen demand, producing 26 billion tonnes per year and are thus referred to as 'oxygen factories'[1]. Among the different types of forest, tropical forests, and savannas account for 34% and 26% of global photosynthesis and amazon rainforests hold one-half of the world's tropical rainforests[2]. Since 1990, the area of naturally regenerating forests has been decreasing due to deforestation, but the area of planted forests has increased by 123 million ha[3]. However, the Indian scenario shows an increasing trend in terms of forest and tree cover (80.73 million hectares), which is 24.56% of the total geographical area of the country[4]. The decrease in the number of trees/plants can result in a decrease in oxygen production[5]. Therefore, in this study we estimate the oxygen production potential of India under the following sub-headings: (a) Annual production potential of oxygen based on forest carbon, (b) Oxygen production potential of Indian forests (state-wise), (c) Top ten tree species of Indian forests and trees outside forests (TOF), (d) Agroforestry tree species, (e) Bamboo species. The baseline data were collected from the Indian State of Forest Report (ISFR) by Forest Survey of India (FSI), Dehradun[4,5] and net oxygen release was calculated based on organic carbon produced by trees or local plants[6–8].

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$$\text{Net } O_2 \text{ release (tonnes ha}^{-1}\text{ yr}^{-1}) = \text{Net carbon sequestration (tonnes ha}^{-1}\text{ yr}^{-1}) \times 32/12. \quad (1)$$

(Note: 32 is the molecular weight of oxygen and 12 is the molecular weight of carbon.)

Based on the wood density of different species according to FAO estimates (http://www.fao.org/3/w4095e/w4095e0c.htm), the mass of the species was calculated. In simple terms

Wood density = Biomass/volume.

Biomass = Volume × wood density.

The obtained biomass of trees from volume provides the aboveground biomass. Therefore, to calculate belowground biomass, the aboveground biomass is multiplied with the IPCC-driven universal conversion factor of 0.26. Then, the total dry biomass is multiplied by carbon content (50% of wood is carbon) to obtain the carbon sequestration of woody species.

The results indicate that the net oxygen production potential was 28.04 million tonnes per year, of which aboveground oxygen production (25.37 mt yr^{-1}) was more than belowground oxygen production (2.67 mt yr^{-1}) (Figure 1).

The total oxygen production potential of Indian forests is 7896.14 million tonnes (mt). Arunachal Pradesh (1151.40 mt) ranks first, followed by Madhya Pradesh (613.29 mt) and Jammu and Kashmir (582.13 mt), whereas the least oxygen production potential is from the Union Territories of Daman and Diu (0.12 mt), Chandigarh (0.22 mt) and Puducherry (0.20 mt). The production potential of oxygen is linked to greenery, growing season, stems per unit area, age, geographical area and forest cover of a state. Moreover, the area of very dense forest (21,095 km^2) and medium dense forest (30,557 km^2) in Arunachal Pradesh is more in comparison with the other states[4]. Therefore, if forest canopy is increased and sustained over a period, net carbon dioxide will be removed and more oxygen will be produced[9]. Figure 2 shows the state-wise oxygen production potential in India.

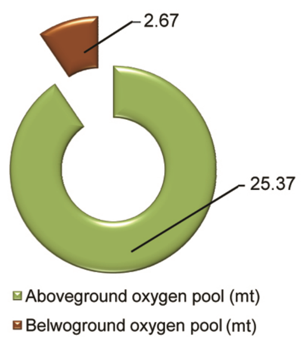

Figure 1. Annual oxygen production (million tonnes yr^{-1}) from forests and trees outside forests in India.

Table 1. Oxygen production potential of top 10 species from Indian forests and trees outside forests (TOF)

Species	Growing stock (million cubic metre)	Carbon sequestration (million tonnes)	Oxygen production potential (million tonnes)
Forests			
Shorea robusta	543.81	246.67	657.87
Tectona grandis	194.54	67.41	179.78
Terminalia tomentosa	165.71	80.39	214.39
Pinus roxbhurghii	156.52	64.09	170.94
Abies pindrow	129.20	32.56	86.83
Anogeissus latifolia	124.12	61.77	164.75
Pinus wallichiana	119.27	36.07	96.19
Cedrus deodara	118.71	43.38	115.69
Lannea coromandelica	101.41	34.50	92.01
Picea smithiana	94.45	23.80	63.48
TOF			
Mangifera indica	207.24	77.03	205.44
Azadirachta indica	133.23	57.92	154.46
Madhuca latifolia	81.46	37.98	101.28
Cocos nucifera	63.93	20.14	53.71
Borassus flabelliformis	62.42	38.14	101.73
Acacia arabica	52.34	23.08	61.56
Butea monosperma	45.65	13.80	36.82
Tamarindus indica	42.50	20.08	53.56
Pinus wallichiana	42.45	12.84	34.24
Ficus religiosa	40.07	16.91	45.11

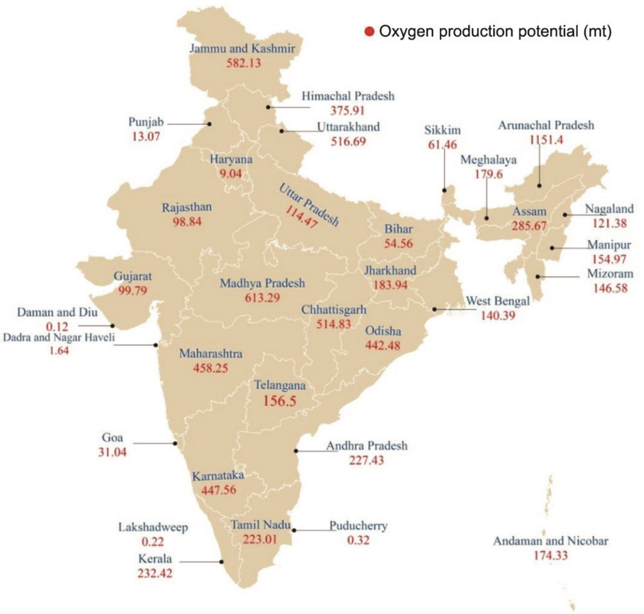

Figure 2. Oxygen production potential (mt) in different states of India.

The oxygen production potential of the top ten tree species from forests ranged from 63.48 mt (*Picea smithiana*) to 657.87 mt (*Shorea robusta*). For trees outside forest (TOF), *Mangifera indica* (214.39 mt) had the highest oxygen potential, followed by *Azadirachta indica* (154.46 mt), *Borassus flabellifer* and *Madhuca latifolia* (Table 1). *M. indica* (mango) is considered as the 'King of fruits' and is commercially cultivated in the tropical regions of the world. However, *A. indica* (neem) is considered a versatile tree species, which is distributed throughout India. It is both a naturally grown and cultivated species on roadsides, field boundaries and associated with rituals.

Agroforestry is gaining importance for expanding greenery and increasing tree cover outside the forests. It is considered as 'low hanging fruit'[10] due to its various outputs of both tangible and intangible benefits. Therefore, based on net carbon sequestration rate reported by various researchers, the most prominent agroforestry tree species were chosen to calculate the oxygen production potential (Table 2)[11–21]. In India, *Populus deltoides* and *Eucalyptus tereticornis* are widely cultivated due to their importance in pulp and paper production and sustainable wood supply. Both these fast-growing trees have high oxygen production potential around 33 tonnes ha^{-1} yr^{-1}. The net oxygen production rate ranges from 1.04 to 34.15 tonnes ha^{-1} yr^{-1}. Again this depends on location, number of trees, diameter distribution, annual timber increment, tree health, age and management techniques.

Bamboo is one of the fast-growing multipurpose species widely adapted to different climatic conditions, comprising 125 indigenous species and 11 exotic species[21]. It also releases 35% more oxygen than an equivalent volume of other trees[22]. Nath *et al.*[23] compiled numerous published information and reported average biomass of bamboo as 124 tonnes ha^{-1} (with a range 60–242 tonnes ha^{-1}). They also found that mean carbon storage and sequestration rate ranged from 30 to 121 Mg ha^{-1} and 6 to 16 Mg ha^{-1} yr^{-1} respectively. This highlights that bamboo has a huge potential to capture CO_2 and produce more oxygen than other tree species. It is considered as a major oxygen

Table 2. Net oxygen production rate (tonnes ha^{-1} yr^{-1}) of important agroforestry tree species in India

Species	Age (yr)	Tree density (trees ha^{-1})	Net carbon sequestration rate (tonnes ha^{-1} yr^{-1})	Net oxygen production rate (tonnes ha^{-1} yr^{-1})	Reference
Populus deltoides	8	500	12.61	33.67	11
Eucalyptus tereticornis	8	1111	12.79	34.15	11
Dalbergia sissoo	14	312	2.15	5.74	12
T. grandis	15	2500	5.42	14.47	13
Melia spp.	10	640	3.94	10.52	14
Terminalia arjuna	10	690	9.54	25.47	
Pongamia pinnata	8	258	2.75	7.34	15
Alnus nepalensis	21	458	4.68	12.50	16
Dendrocalmus strictus	20	100	5.46	14.59	17
M. indica	10	400	0.38	1.03	18
Prosopis cineraria	19	45	0.46	1.24	19
Casuarina equisetifolia	20	1600	9.30	24.83	20
Emblica officinalis	12	100	0.47	1.25	21

Net carbon sequestration rate alone has been taken from the above-mentioned references.

Table 3. Baseline oxygen production (mt) and annual oxygen production (mt yr^{-1}) from bamboo resources in India

Bamboo	Green weight of bamboo* (A)	Dry biomass** ($B = A \times 0.45$)	Carbon storage ($C = B \times 0.50$)	Oxygen production potential ($D = C \times 2.67$)
Baseline oxygen production potential from bamboo				
Reserve Forest	277.59	124.91	62.46	166.76
TOF	19.73	8.88	4.44	11.85
Total	297.32	133.79	66.90	178.61
Annual oxygen production potential from bamboo				
Reserve Forest	88.83	39.97	19.99	53.36
TOF	2.32	1.04	0.52	1.39
Total (difference of 2017 and 2019)	91.15	41.02	20.51	54.76
Per year	45.57	20.51	10.25	27.38

*Bamboo resources of India, ISFR[4]. **Factor of dry matter content in bamboo[25]. mt, million tonnes.

source and an 'Oxygen Park' of bamboo has been established at Tamil Nadu Agricultural University (TNAU), Coimbatore. A fully grown bamboo species generates 300 kg of oxygen every year per person[24]. The calculated oxygen production potential of bamboo was 178.61 mt, both from Reserve Forest and TOF in India, whereas oxygen production potential per year was 53.36 mt from Reserve Forests and 1.39 mt from TOF respectively. However, annual production of oxygen from bamboo was 27.38 mt yr^{-1} (Table 3).

Holistically, the emerging oxygen crisis and increasing CO_2 concentration is a common phenomenon all over the world. In order to mitigate this, the focus must be shifted to encourage the proportion of urban vegetation coverage. Moreover, after the initiation of the Millenium Development Goals, several efforts are also made to quantify the services provided by tree species.

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