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Analysis of growing stock and species distribution of Sal dominated Kushmi forest Gorakhpur, Uttar Pradesh, India

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Abstract
The growing stock analysis of a forest helps in estimation of biomass and total assets of any forest areas. Present study was carried out during 2017-18 in Kushmi Sal Forest near Gorakhpur, Uttar Pradesh. The whole forest is a best example of plantation forest mainly dominated by *Shorea robusta and Tectona grandis* with other associate species like *Syzygium cumini, Terminalia arjuna, Albizia lebbeck, Dalbergia sissoo, Eucalyptus sp., Madhuca indica, Azadirachta indica, and Bombax ceiba* in certain part in patches or in scattered form. Present research is an attempt in this direction to quantify the height class wise and diameter class wise growing stock of Kushmi forest. The total area of Kushmi forest is 3207.10 ha (Tilkonia forest range) comprises total number of forest tree 580480. The maximum number of tree was found of species *Shorea robusta* (402560) followed by *Tectona grandis* (80640) whereas the least trees species was found to be *Bombax ceiba* (5052). The height of different species is ranged between 8-45 meters while diameter of the different species ranged between 0.10-2.10 m. Majority of the stock have diameter in the range of 60 to 180 cm. Maximum numbers (173329) of tree belongs to diameter range 90-120 cm followed bydiameter range 60-90 cm while minimum numbers (4480) of stock have diameter range less than 30 cm. Comparatively high diameter trees belong to *Madhuca indica, Tectona grandis, Shorea robusta, Syzygium cumini* and *Bombax cieba* while short height recorded in, *Azadirachta indica, Albizia lebbeck, Eucalyptus sp., Dalbergia sissoo* and *Terminalia arjuna.*

Keywords: Tree species, growing stocks, height class, diameter class, and Kushmi forest etc.

Introduction
Forest play important role in mitigation and adaptation of climate change. Forest is one of the potential energy sources which actively caters to the mitigation and adaptation of climate change (Pathak *et al*. 2016) [22]. Forest sequesters and acts as largest reservoir of carbon than any other terrestrial ecosystem, has attracted much interest as a mitigation approach (ISFR, 2017). Ecologists are more interested in potential function of forest and carbon sequestration and storage (Chapin *et al*. 2000, Tilman *et al*. 2001, Srivastava & Vellend 2005, Kirby & Potvin 2007) [6, 29, 16]. Carbon in the system moves between the four major reservoirs: fossil and geological formations, the atmosphere, the oceans and terrestrial ecosystem including forest (Melillo *et al.*, 1993) [20] and (Siegenthalar and Sarmiento 1993). The forest biomasses represent the largest terrestrial carbon sink and account for approximately 90% of all leaving terrestrial biomass.

The precise information on growing stock which is the measure of the tree wealth includes distribution of stem in different diameter class, volume, biomass, and carbon stock within forest areas is required for strategic planning of forestry sector at various levels. Growing stock is considered as an important indicator of forest wealth and productivity and can be estimated through forest inventory. Estimates of carbon stock are generally carried out by external measurements such as stem diameter and sometimes height, to total tree biomass. Vegetation analysis is a key factor in determining the structure of any ecosystem and one of the important factors in determining the species content of the area (Khesoh and Kumar, 2017) [14]. The Quantification of above ground biomass (AGB) is an essential aspect of studies of carbon stocks and effects of deforestations and carbon sequestration on global carbon balance (Ketterings *et al*. 2001) [13]. The calculation of growing stock has assumed greater importance as it provides a key input for deriving the amount of carbon sequestered in the forests. Keeping in mind, present study was carried out to estimate the total growing stock under different height class and diameter class in different forest tree species in Sal dominated Kushmi forest of Gorakhpur. The composition of tree species found in study are *Shorea robusta, Tectona grandis, Syzygium cumini, Terminalia arjuna, Dalbergia sissoo, Albizia lebbeck, Eucalyptus, Madhuca indica, Azadirachta indica, and Bombax ceiba etc.*

Materials and methods

Site Description

The present investigation entitled "Estimation of Growing stocks, Biomass and Carbon stock of Kushmi Sal Forest of Gorakhpur U.P." was conducted in Kusmi Forest Division of Gorakhpur district Uttar Pradesh, during the 2017-18. The area situated at between 26 ^{0} 35 to 27^0 17 N latitude and 83^0 13 to 83^0 35 E longitude and 78 m above asl. Kushmi Forest is nestled amidst a scenic landscape full of lofty Sal trees. The forest of Gorakhpur division mainly comprises of dense *Sal* tress. The forest area of division remains unchanged 15276.60 ha notified under section 5 division. Gorakhpur 152.40 ha, Tilkonia 3207.10 ha, Banki 3679.60 ha, Campeargang 3161.10 ha, Farenda 5076.40 ha land have per section. In 1932 government has taken under these areas and started re-plantation in the whole forest areas. The re-plantation method complete in the whole Forest areas in 1934.

Climate

Kushmi Forest is located near Gorakhpur in the eastern part of state Uttar Pradesh and has tropical to sub-tropical climate with extremes of summer and winter. The climate is humid to sub humid influenced some extent by the north and the existence of Tarai swamps. During winter months especially December to January temperature drops down to as low as 2 to 5^0 c while in summer temperature above 40 to 48^0 c. hot scorching winds commonly known as "Loo" is regular feather during the summer whereas there may be and occasionally spell of frost during the winter. The annual rainfall is 1380 mm mostly during the south west monsoon i.e. mid June to September with of few occasional showers during winter months.

Biophysical Measurements of the tree species

The height and diameter at breast height (DBH) are the two main biophysical measurements which were measured for each tree sample. Biophysical measurement of different species was recorded by selecting tree by transect line laid in the study area. The data pertaining to height and diameter were recorded in class wise with the help of Ravi altimeter. Diameters at breast height (1.37m) above the ground level of sampled tree were measured during the study using measuring tape.

Result and discussion

Growing stock

Kushmi forest is a kind of sal dominated plantation forest. The data pertaining to numbers of the trees in each species presented in table1 and figure1 shows that maximum number (402560) of trees are of *Shorea robusta*, followed by *Tectona grandis* (80640) and *Syzygium cumini* (45440) *and* the minimum (5052) was of *Bambax ceiba*.

Tree height

Perusal of data in table 1 and figure 1 shows that the height of the trees varies greatly in different species and ranged between 10 to 50 meters. Majority of the stock have height in the range of 20 to 45 meters. Maximum numbers (237374) of tree belongs to height range 40-45 meter followed by height range 35-40 meter while minimum numbers (770) of stock have height range 10-27 meters. Comparatively taller trees belong to *Tectona grandis, Shorea robusta and Terminalia arjuna* while short height recorded in *Madhuca indica, Azadirachta indica* and *Syzygium cumini.* Height variation in many species is their hereditary character assisted with crown shape and competition of light for photosynthesis brings about tallness or short posture. Generally height of the tree has positive correlation with diameter of the tree.

Table 1: Growing stock in different height class and species of Kushmi forest.

Species	Height class wise growing stock										
	5-10 (m)	10-15 (m)	15-20 (m)	20-25 (m)	25-30 (m)	30-35 (m)	35-40 (m)	40-45 (m)	>45m	Total	Cont. (%)
Shorea robusta	0	0	315	1790	2760	15780	94710	205465	81740	402560	69.6
Tectona grandis	0	0	0	670	1520	12014	35070	21512	9854	80640	13.9
Syzygium cumini	0	0	560	1528	7025	16260	18090	1977	0	45440	7.8
Terminalia arjuna	0	0	0	960	1720	2180	2910	3550	1480	12800	2.2
Albizia lebbeck	0	0	0	380	960	2790	1890	1020	0	7040	1.2
Dalbergia sissoo	0	210	560	1120	1330	2530	1985	1060	165	8960	1.5
Eucalyptus sp.	0	0	0	0	0	680	1060	2790	620	5120	0.8
Madhuca indica	0	0	980	1920	2875	1250	0	0	0	7025	1.2
Azadirachta indica	0	560	1520	2550	1213	0	0	0	0	5843	1
Bambax ceiba	0	0	670	1120	1480	1402	380	0	0	5052	0.8
Total	0	770	4605	12038	20853	54886	156095	237374	93859	580480	100

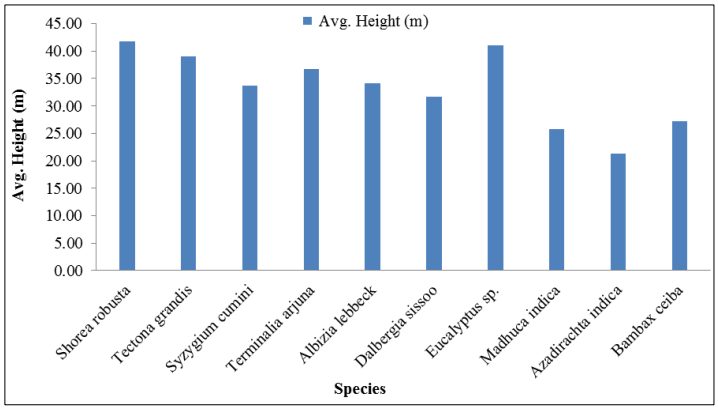

Fig 1: The average height of tree of each species.

Tree diameter

Perusal of data in table 2 and figure 2 shows that the diameter of the trees varies greatly in different species and ranged between 20 to210 cm. Majority of the stock have diameter in the range of 60 to 180 cm. Maximum numbers (173329) of tree belongs to diameter range 90-120 cm followed bydiameter range 60-90 cm while minimum numbers (4480) of stock have diameter range less than 30 cm. Comparatively high diameter trees belong to *Madhuca indica*, *Tectona grandis*, *Shorea robusta*, *Syzygium cumini* and *Bombax cieba* while short height recorded in, *Azadirachta indica*, *Albizia lebbeck*, *Eucalyptus sp.*, *Dalbergia sissoo* and *Terminalia arjuna*. Higher diameter in many species is a kind of adaptation to overcome load burden of branch as well main stem on base portion while lesser diameter is due to lower load of braches as well as leafy crown in many species.

Table 2: Growing stock in different diameter class and species of Kushmi forest.

Species	Diameter class wise (cm) growing stock								Total
	<30	30-60	60-90	90-120	120-150	150-180	180-210	>210 cm	
Shorea robusta	1920	27520	113920	126720	67200	44800	14720	5760	402560
Tectona grandis	1280	9600	25600	23040	11520	6400	1920	1280	80640
Syzygium cumini	0	4480	12160	13440	5120	5760	3200	1280	45440
Terminalia arjuna	0	640	4480	1920	2560	3200	0	0	12800
Albizia lebbeck	0	0	1920	2560	1280	1280	0	0	7040
Dalbergia sissoo	1280	4480	3200	0	0	0	0	0	8960
Eucalyptus sp.	0	0	0	1920	1920	1280	0	0	5120
Madhuca indica	0	0	360	1060	2145	1502	1305	653	7025
Azadirachta indica	0	45	540	1160	1975	1280	843	0	5843
Bambax ceiba	0	70	450	1509	1760	865	290	108	5052
Total	4480	46835	162630	173329	95480	66367	22278	9081	580480

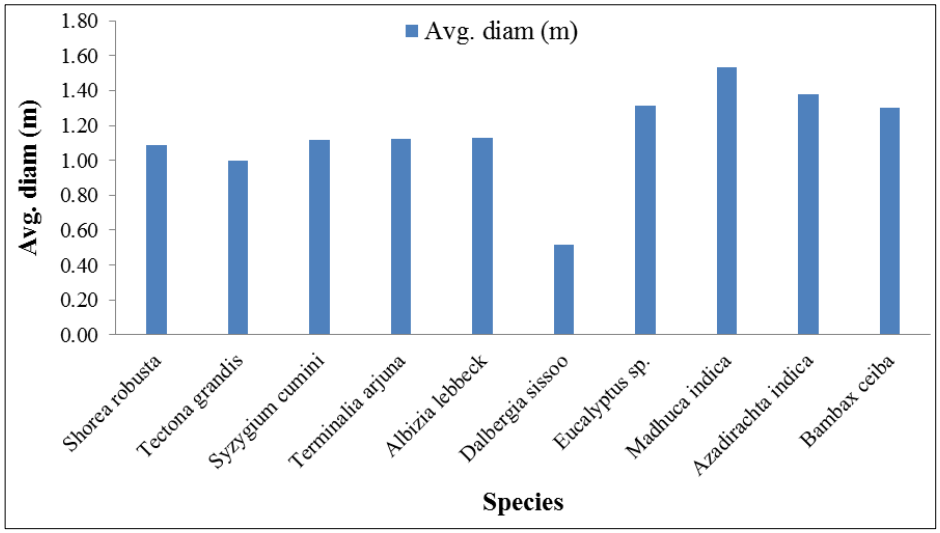

Fig 2: The average diameter (m) of each tree species

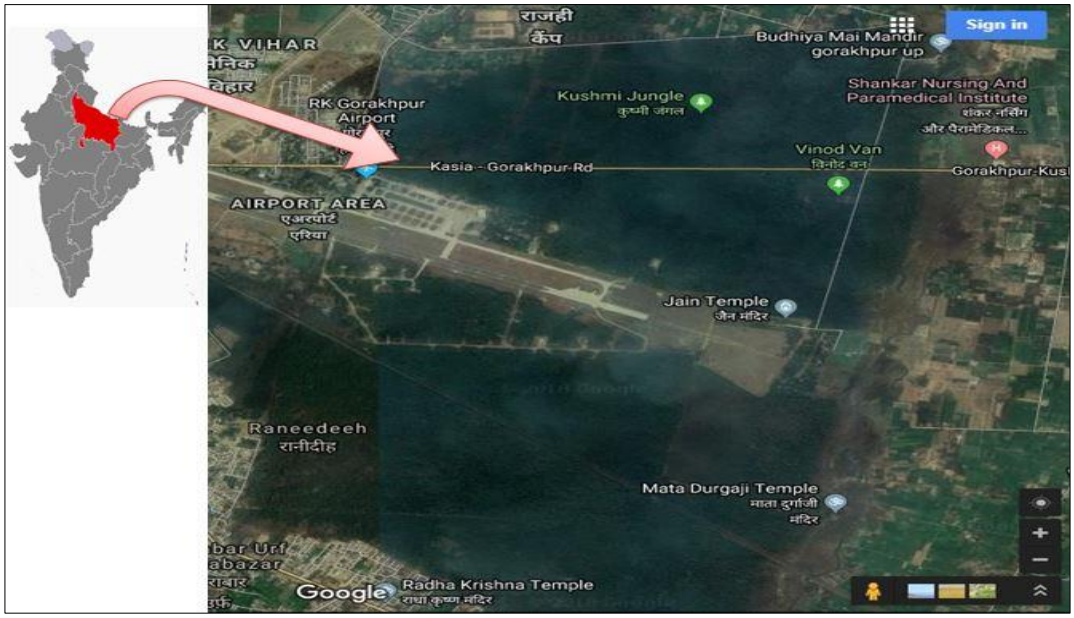

Fig 3: Map of the study area (Kushmi Forest Division, Gorakhpur)

Conclusion

Analysis of present study conclude that Kushmi forest division is dominated by Sal tree and the growing stock are of older age group having height variation ranged between 20-45 meters and diameter ranged between 30 -210 cm. The study reflects that there high growing stock concern with higher diameter and height coupled with shortage of new regeneration in the forest area.

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