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Forest carbon stock assessment of the Musk Deer National Park, Azad Jammu andKashmir (AJK)

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Abstract

In order to tackle with the increasing challenges of climate change, forests are considered as a viable option. Schemes such as Reduced Emissions from Deforestation and Forest Degradation Plus (REDD+) are regarded as financial ventures for not only tackling climate change but also conserving forestry resources and for alleviating poverty. Such schemes however require the exercise of forest carbon stock assessments. It is therefore essential to understand the dynamics of carbon stocks in various forest ecosystems. The study therefore was conducted to assess the carbon stocks of the forests of Musk Deer National Park, AJK. Standard methods were used to calculate the carbon stocks of the Musk Deer National Park. The results revealed that the sampled area of the park contained mean carbon stocks per hectare (ha) of 44.64±12.44 Mg ha^{-1}. The *Piceasmithiana*with 25.40±14.53 Mg ha^{-1} had the highest of the mean carbon stocks per ha followed by *Abiespindrow*which had the mean carbon stocks per ha of 17.77±11.80 Mg ha^{-1}. The study was the first attempt, to the extent of my knowledge, for forest carbon stock assessment of the Musk Deer National Park. The results can be helpful in developing REDD+ projects in future, which can assist in forest resource conservation and poverty alleviation.

1. Introduction

The adverse impacts of climate change are becoming quite evident, which can also be observed if we observe the global events(Houghton et al., 2009). The brunt of which is mainly being faced by the developing countries. The developing countries do not have the resources and technology to cope with the hazards of climate change. Forests however are considered to be the cheapest option for tackling climate change(Tobin and Nieuwenhuis, 2007). Most of the global population, but, residing in the developing countries is highly relying on the forests. Forests thereby deliver various tangible and intangible benefits to the wider societies(Paquette and Messier, 2010). Unfortunately despite manifold benefits associated with forests, they are still not accounted for in policies of many developing countries, further augmenting the problems of deforestation and forest degradation.

Reduced Emissions fromDeforestation and Forest Degradation Plus (REDD+), regarded as a financial mechanism, is focused upon reducing carbon emissions from deforestation and forest degradation, aimedtowards the conservation and enhancement of forest carbon stocks, and sustainable forestmanagement which includes ecological and social targets (Bluffstone et al., 2013).

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It has been considered as one of the viable options for not just tackling climate change but also conserving unique forestry resources along with alleviating poverty(Ngo et al., 2013). Due to the above mentioned, it has also been identified as one of the most economically feasible mitigation options (Stern, 2007). For REDD+ initiatives, however, forest carbon stock assessments and monitoring is essential. It is thus important that carbon stock assessments of various forest types should be conducted.

In view of the above, a study was conducted in Musk Deer National Park. The main objective of the study was the carbon stock assessment of the forests of the Musk Deer National Park. Thereby for this purpose, the carbon stocksin aboveground biomass of the trees of the Musk Deer National Parkwere estimated.

2. Materials and Methods

2.1 Study area

The Musk Deer National Park, Gurez, is located in District Neelum of Azad Jammu andKashmir (AJK). The park is spread over an area of 52,817 hectares. The altitudinal range is between 2,107 m to 4,345 m. It was established by the Government of AJK in 2007, mainly for the conservation of Himalayan Musk Deer (*Moschuschrysogaster*; Qureshi et al., 2013). The park is mostly comprised of moist temperate forests, except for the sub-alpine forests which lies between 3352 m to 3657 m (Qureshi et al., 2013). The park is comprised of 19 villages, relying heavily on the natural resources of the park(Jalil et al., 2016).

2.2 Data collection and analysis

Overall 24 circular plots were sampled. The circular plots were with 20 m radius. The random sampling approach was adopted with laying of plots(Qasim et al., 2016b). In each plot, diameters at breast height (DBH) of trees with DBH above then 5 cm were measured. The DBH were measured with the help of a diameter tape at 1.3 m above the ground level (Qasim^{a} et al., 2016). The height of the trees was measured with the BlumeLeiss Hypsometer(Qasim^{a} et al., 2016). The observed slopes were adjusted following (Sharma et al., 2011). The tree volume for each was measured with the help of following Formula1adopted from (Philip, 1994);

$$Volume\ (m3)\ =\ (\pi/4)\ DBH2\ x\ h\ x\ f \qquad (1)$$

Where:

h= tree height

f= form factor

The form factors were sourced from available literature(Masota et al., 2014). The stem biomass was further calculated using following Formula 2.

$$Stem\ Biomass\ (kg)\ =\ Volume\ x\ WD \qquad (2)$$

Where:

WD = Basic Wood Density

The WD (kg m^3) for the trees species were sourced from available literature (Sharma et al., 2016). The total biomass was calculated using Biomass Expansion Factor (BEF). The BEF were taken from the available literature(Alam and Nizami, 2014;Haripriya, 2000). The total biomass was converted into carbon stocks by using a conversion factor of 0.5 (Tan et al., 2010). The density was taken as the total number of trees per hectare (ha). The Basal Area was calculated following (Qasim et al., 2016).

2.3 Statistical analysis

The normal distributions of different variables were tested using the Shapiro-Wilk test. The means±Standard Deviations (SD) for averages of different variables were calculated. The Kruskal Wallis Rank Sum Test was used for exploring differences between more thantwo variables. The post-hoc analysis for significant differences between means of different variables was done using Tukey's test.A significance level of 0.05 was used for all the statistical tests. The version 3.1.0 of Rwas used for statistical analysis and for producing graphs.

3. Results

The highest mean carbon per hawas recorded for *Piceasmithiana* which was 25.40±14.53 Mg ha^{-1}. The *Abiespindrow* recorded the second highest mean carbon per ha, which was 17.77±11.80Mg ha^{-1}. The *Betulautilis* and *Acer ceasium* recorded mean carbon per ha of 1.00±0.84Mg ha^{-1} and 0.45±0.06Mg ha^{-1}respectively (Table 1). The highest mean biomass was recorded for the *Piceasmitheana* which was 5.23±2.99 Mg. It was followed by *Abiespindrow*, which showed mean biomass of 3.66±2.43 Mg (Table 1). Similarly, the highest mean volume was recorded for *Piceasmithiana* with 7.53±4.30 m^3.The lowest mean volume on the other hand was recorded for *Acer ceasium*, which was 0.08±0.01 m^3 (Table 1). The highest mean basal area per ha was recorded for *Piceasmithiana*, with 7.17±3.98m^{2}ha^{-1} and it was followed by *Abiespindrow*with5.58±3.20m^{2}ha^{-1} (Table 1). The highest mean DBH was also recorded for *Piceasmithiana*, with 97.01±4.95 cm and the lowest DBH was recorded for *Acer ceasium* with 19.01±1 cm (Table 1). The highest mean density per ha was recorded for *Betulautilis*as92.98±57.02 trees ha^{-1}, which was followed by *Abiespindrow*, with 72.45±41.11 trees ha^{-1} (Table 1).

Table 1: Structural characteristics of the Forests of Musk Deer National Park.

No.	Tree species	Mean Density (trees ha^{-1})	Mean DBH (cm)	Mean Height (ft)	Mean Basal Area (m^2 ha^{-1})	Mean Volume (m^3)	Mean Biomass (Mg)	Mean Carbon (Mg ha^{-1})
1	*Abiespindrow*	72.45 ± 41.11	85.57 ± 30.57	52.91 ± 13.01	5.58 ± 3.20	5.04 ± 3.35	3.66 ± 2.43	17.77 ± 11.80a
2	*Piceasmithiana*	32.38 ± 21.17	97.01 ± 4.95	61.66 ± 15.41	7.17 ± 3.98	7.53 ± 4.30	5.23 ± 2.99	25.40 ± 14.53a
3	*Betulautilis*	92.98 ± 57.02	24.46 ± 9.7	25.02 ± 5.63	0.45 ± 0.31	0.19 ± 0.16	0.20 ± 0.17	1.00 ± 0.84b
4	*Acer ceasium*	48.57 ±1.58	19.01 ± 1	20 ±0.70	0.27 ±0.02	0.08 ±0.01	0.09 ±0.01	0.45±0.06b
				Overall				44.64± 12.44

The mean carbon (Mg ha^{-1}) for the species not sharing common lower case differ significantly not sharing a common ($p<0.05$) based on Tukey's test.

The total mean carbon stocks per ha for the sampled area of the forests of Musk Deer National Park was recorded as 44.64±12.44Mg ha^{-1}. The highest mean carbon stock was measured for Plot 8, which was 7.46 Mg ha^{-1}. The lowest was recorded for Plot 11, which was 0.11 Mg ha^{-1} (Figure 1). The maximum mean DBH of 95.28 cm was recorded for Plot 8 and the minimum mean DBH of 19.35 cm was recorded for Plot 11. The highest mean height of 55 feet (ft) was recorded for Plot 13 and the lowest mean height of 25 ft was recorded for Plot 11. Significant differences were recorded between the mean carbon stock of the four trees species, *Abiespindrow*, *Piceasmithiana*, *Betulautilis* and *Acer ceasium*($P<0.05$; Wilcoxon Test). The significant differences between the mean carbonswere recorded between

*Betulautilis-Abiespindrow, Betulautilis-Piceasmithiana, Acerceasium-Abiespindrow*and*Acer ceasium-Piceasmithiana*($P<0.05$; Tukey's Test; Table 1).

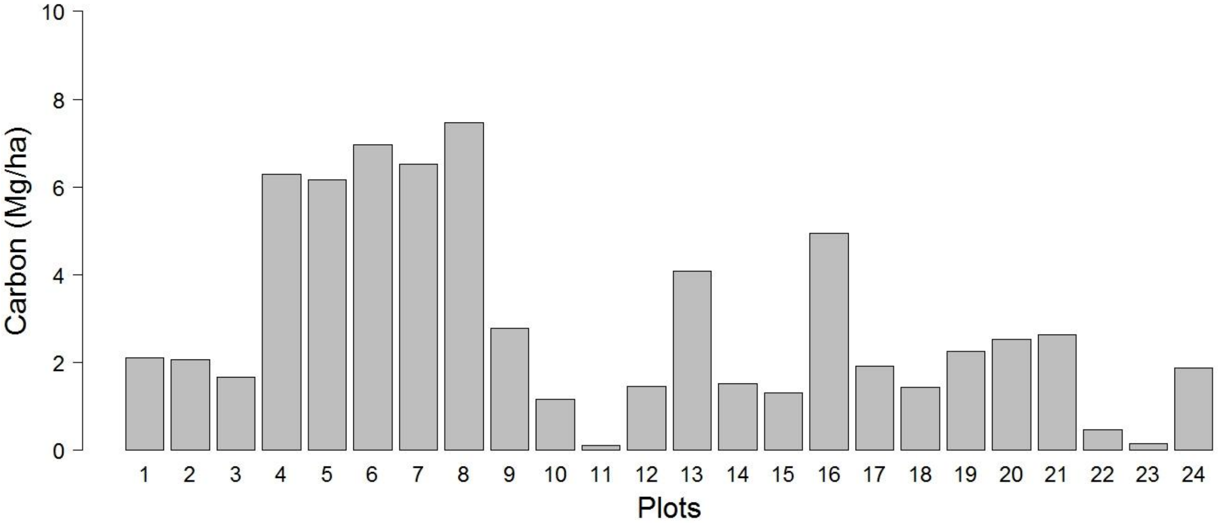

Figure 1**:** Carbon stocks at Musk Deer National Park.

The DBH distribution of the forests of Musk Deer National Park has displayed an inverted J (Figure 2). Most of the trees have been recorded in the lower DBH classes comparing to the highest DBH classes (Figure 2). For the height distribution, most of the trees were recorded for lower DBH classes (Figure 3).

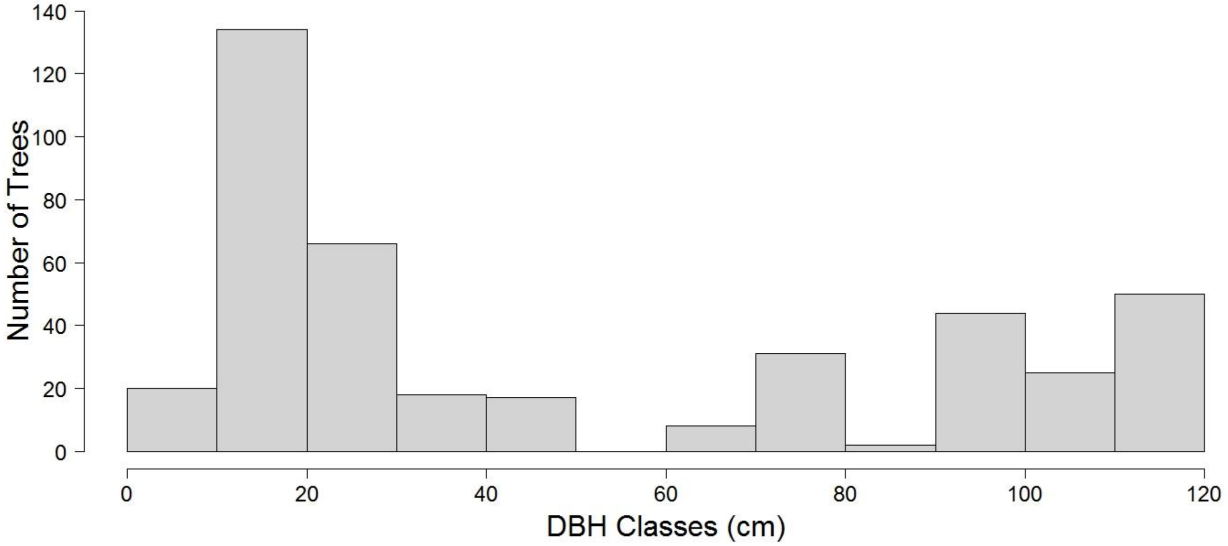

Figure 2**:** DBH distribution of the forests of the Musk Deer National Park.

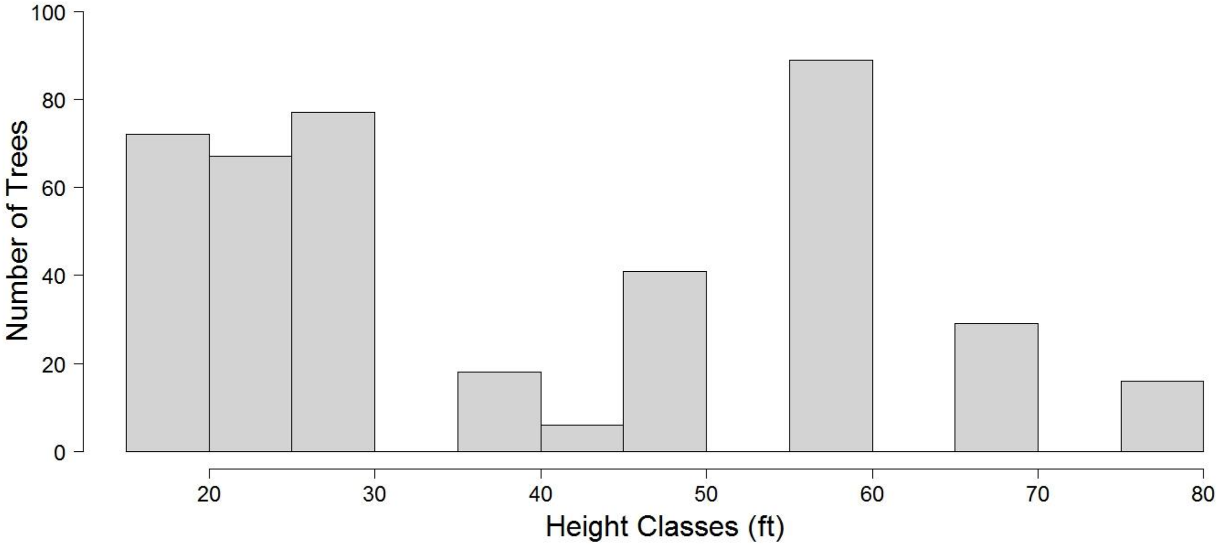

Figure 3**:** Height distribution of forest of Musk Deer National Park.

3. Discussion

Results from this study for the mean carbon stocks of *Spruce smithiana* and *Abiespindrow* are close to the results of A. Ahmad et al.(2014). The mean densities of *Spruce smithiana* and *Abiespindrow*from our study are also close to the results of A. Ahmad et al.(2014). The result from this study for mean carbon stocks of moist temperate forests is in correspondence with Kumar and Sharma(2015). The results from this study for mean carbon stocks of temperate forests is also close to Sharma et al. (2011). The mean volume of *Piceasmithiana*. from this study, was close to the mean volume of the same species reported by Ahmad et al. (2014). The volume of *Betulautilis*from this study is close to the volume reported by Alam and Nizami(2014). The result for carbon stocks for *Betulautilis*for this study is not in correspondence with Alam and Nizami(2014). This could be attributed to the quality of the site(Cummings et al., 2002).

The DBH distributions provide the spatial relationship between the trees and their environment. These are widely adopted for extrapolating forest structures(Burgess et al., 2005). The DBH distributions can help forest managers in relating of various parameters such as age and density (Schreuder and Swank, 1974). Growth and yield predictions are often widely based on DBH distributions(Zeide, 1989). The DBH distribution of the forests of Musk Deer National Park followed aninverted J shape. The trees were found to be mostly in the lower DBH classes, which infers good recruitment and reproduction(Gebrehiwot and Hundera, 2014). Such DBH distribution pattern was also reported by Siddiqui et al.(2013)in other mountainous areas of Pakistan. Tree height is also considered as one of the most important variables in forest management (Gómez-García et al., 2014). Tree height is essential because it helps in characterizing the forest stand structures, for estimation of single tree volume and forest stand volumes, and for determining dominant heights and site index of forests (Peng et al., 2001). The lowest mean height was recorded for *Betulautilis*, 15 ft, in the Musk Deer National Park and the highest mean heights were recorded for *Piceasmithiana* and *Abiespindrow*, which were 80 ft each.

4. Conclusions

The mean carbon stocks per ha for the sampled area of the forests of the Musk Deer National Park was recorded as 44.64±12.44 Mg ha^{-1}. Significant differences were recorded between the mean carbon stocks per ha of all four trees species *Abiespindrow, Piceasmithiana, Betulautilis* and *Acer ceasium*. The DBH Distribution of the sampled plots have shown an inverted J, where most of the trees have been recorded in the lower DBH classes. The height distribution has also displayed higher occurrence of trees in lower DBH classes. The study was the first attempt, to the extent of my knowledge, for quantifying the carbon stocks of the forests of the Musk Deer National Park. Studies such as this can be helpful in developing forest carbon stock tables which can be included in the forest management plans of the national park. Moreover, the data can also be helpful for developing REDD+ projects in the future, which can support the cause of conservation of the forest resources but as well as the poverty alleviation in the area.

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