The Pharma Innovation Journal 2021; SP-10(5): 801-806

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The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2021; SP-10(5): 801-806

www.thepharmajournal.com
Received: 09-03-2021
Accepted: 18-04-2021

**Prabhugowda I Biradar**
Department of Silviculture and Agroforestry, College of Forestry, University of Agricultural Sciences, Sirsi, Dharwad, Karnataka, India

**Channabasappa KS**
Faculty, Department of Silviculture and Agroforestry, College of Forestry, University of Agricultural Sciences, Sirsi, Dharwad, Karnataka, India

**Corresponding Author:**
**Prabhugowda I Biradar**
Department of Silviculture and Agroforestry, College of Forestry, University of Agricultural Sciences, Sirsi, Dharwad, Karnataka, India

# Assessment of biomass and carbon sequestration potential of sacred Kaans in Soraba taluk of central Western Ghats, Karnataka

**Prabhugowda I Biradar and Channabasappa KS**

**Abstract**
Sacred groves are the natural forest patches and are still conserved due to various traditional beliefs and religious practices. The present study was carried out in the Kaan forests of Soraba taluk in Central Western Ghats of Karnataka. The aims to estimate the above ground biomass and carbon sequestration potential across different Kaans. Non-destructive method was followed to estimate the aboveground Biomass and carbon stock of sacred groves. Measuring the tree growth parameters such as girth and height were used to calculate both biomass and carbon stock of the Kaan forest using standard equations, which was expressed in Mega grams (Mg). The results revealed that, maximum biomass and carbon stock was found in Kaans presented in high rainfall area (170.78 Mg and 80.26 Mg, respectively) compared to low rainfall zone (163.55 Mg and 76.87 Mg, respectively). In the two rainfall zones, the total biomass and carbon stock was significantly higher in less disturbed Kaans (227.99 Mg and 226.38 Mg and 107.16 and 106.40 Mg respectively) compared to highly disturbed Kaans (113.56 Mg and 100.73 Mg and 53.37 and 47.34 Mg, respectively). The total biomass and carbon stock showed direct relation with extent of Kaan size. These results suggest that informal management systems such as sacred groves have not only conserved useful species, but people have tended to 'discover' medicinal values more often among plants unique to sacred groves, than those found in other landscapes. Affording more attention to these relic fragments would be more effective in conserving local biodiversity. The present study reveals that the sacred groves of Soraba taluk in Central Western Ghats are species rich, have higher carbon sequestration potential and calls for an immediate attention for conservation.

**Keywords:** Kaan, diversity, carbon stock, biomass

## Introduction

Habitat fragmentation is the major causes of biodiversity loss; tropical trees increasingly survive only in remnant fragments. Habitat fragmentation by definition is the "breaking apart" of continuous habitat such as tropical forest into distinct patches. The process of land clearing and habitat fragmentation is continuing rapidly all around the globe, but especially in areas of tropical rainforest. Western Ghats is one of the global biodiversity hotspot and well known biodiversity hub of India, however, this rich biodiversity is threatened by the variety of human pressure and only one third of the total area of Western Ghats remains under natural vegetation (Anon., 2017) [1]. Various studies have reported that this area has witnessed loss of habitat and consequently many plant and animal populations have gone extinct due to habitat loss and fragmentation (Umapathy *et al*., 2013, Vasudeva *et al*., 2001) [22, 24]. The forested districts of Central Western Ghats are also home to mosaic patches of fragmented forests known as "Kaans" also called as 'Devar Kaans' literally meaning evergreen sacred forests. These relic patches are protected on the grounds of religious and cultural beliefs (Gunaga *et al*., 2015) [7]. Sacred Kaans are patches of forests abode of unique species which evolved from centuries due to conservation effort of ethnics in this region.

Gadgil and Vartak, (1976) [5] believed that shifting cultivation could be also one of the reasons for creation of sacred groves. Kaan forests might have also originated as result of its utilitarian nature. A social institution or as a part of the taboo that evolved historically over several generation to provide a site for culturally crucial social interactions. Ramanujam *et al*., (2002) [16] mentioned that, the formation of sacred patches was due to transition of human cultures to modern lifestyle and agriculture from hunter gatherers. The intelligent society sanctified the forests and trees as an index of reverence, as due to the society was unable to balance clear felling and restoration activity. The biotic interferences such as lopping, firewood collection and grazing were prohibited.

Subsequently the religions adopted the concept and hence these forest patches survived through ages as scared groves.
Increased human population with the advent of modern lifestyle and high living standards had greater impact on traditional management and sustainable utilization of resources. Additionally intensive agriculture declined fertility of agricultural land which leads to increased dependence on the Kaan forests as a source of income and hence resulted in non-sustainable harvesting of the resources. With high rate of land value and also for timber, the encroachment and illegal felling of the valuable timber trees, have increased and thereby eroded plant diversity wealth and carbon stock potentiality. Apart from these effects, Kaans are also exposed to different kinds of exploitation such as conversion of these landscapes into monoculture plantations, allotting them for rehabilitation purposes, etc. (Gokhale *et al*., 2011) [6]. Thus there is a fear of losing rich treasures of traditional conservation culture as well as protected biodiversity in these landscapes. Since Kaan forests are located in areas of high to moderate rainfall, it is likely that species composition is influenced by both rainfall and by the level of disturbance; forest disturbance would affect local diversity and in turn the dependent fauna (Parthasarathy, 2001) [15].
Terrestrial carbon sequestration is the net removal of $CO_2$ from the atmosphere, carbon dioxide emissions from terrestrial ecosystems into the atmosphere. The process of removal includes $CO_2$ uptake from the atmosphere by chlorophyllous plants through photosynthesis. The carbon is stored in the form of plant biomass and as soil organic carbon (SOC) in the soil (IPCC, 2000) [9]. Carbon sequestration is an important aspect from the environmental point of view because all living and non-living organic matter contains approximately 50 per cent carbon. Carbon exists in various forms and is cycled between several biotic and abiotic pools including oceans, terrestrial biota and atmosphere (Skole *et al*., 1995) [20]. Plants are important sinks for atmospheric carbon since 50 per cent of their standing biomass is carbon itself (Ravindranath *et al*., 1997) [17]. Forest ecosystems are the major biological filters of atmospheric $CO_2$, and the most extensively forested areas with traditional associations have the highest carbon sink potential (He *et al*., 2015) [10]. Therefore, such sacred forests should be conserved for better management of carbon stock. This could help in better understanding the feasibility of their use in a carbon credit mechanism and will be a good basis to the incentive provisioned for Reducing Emission from Deforestation and Forest Degradation (REDD) mechanism.
Deforestation and forest degradation have been considered to be the second most anthropogenic source of $CO_2$ to the atmosphere (Montagnini and Nair, 2004; Van der Werf *et al*., 2009) [14, 21]. In international efforts, biodiversity and its relationship with the carbon cycle has become an important consideration for mitigating climate change through reducing the conversion of natural ecosystems (Midgley *et al*., 2010) [13]. Since the sacred groves have been maintained traditionally for such a long time, it is essential to document the biomass carbon stock of such land uses. Unfortunately, these effects have not been documented. In this context we have studied the above ground biomass and carbon stock potentiality of the Kaan forests as influenced by the level of disturbance as well as by the rainfall regime. Many studies have been done in the Kaan forests of surrounding districts of the study area. However, no such studies have been attempted in the Soraba taluk of Shimoga district of Karnataka state in the central Western Ghats. Given this background, we choose to inventory the carbon stock of these kaan forests across different size gradient, which formed the prime objective of this study.

**Material and Methods**
The study sites is located in Soraba taluk it is one among the seven taluks of Shimoga district of Karnataka state and has historical background with very diverse cultural as well as biological heritage. Soraba is located at 14.38ºN and 75.1ºE with an average elevation of 580 meters. In order to develop spatial maps, the details of Kaan list along with the survey numbers and extent of Kaan area was collected from Range Forest Office in Soraba. Further, extensive field survey was conducted to locate the Kaans in Soraba taluk using global positioning system and co-ordinates were collected. Using geographic co-ordinates of sites of each of the Kaans, the distribution map was developed using Q-GIS platform. As per the Working Plan information, the total Kaans in Soraba taluk were 67 with an area of 2921.15 ha. However, only 54 Kaans were present during the field survey and the remaining 13 Kaans were found to be absent. Among the absent Kaans, the area used for cultivation of agriculture crops was noticed during the survey in some of the Kaans (Fig. 1).
The developed spatial distribution map was used to demarcate the boundary based on the information of rainfall regimes namely high rainfall (>2000mm) and low rainfall (<2000mm). Based on the information of extent of Kaan area, maps were also developed according to the Kaan sizes into large (>50 ha), medium (15-50 ha) and small Kaan (0-15 ha). Depending on the level of disturbance, each size class of Kaan forests were categorized into two broad categories such as less disturbed (less than 40 per cent disturbance level) and highly disturbed (more than 40 per cent disturbance level).
In order to assess the above ground biomass and carbon stock, three Kaan forests from each size class was randomly selected under each gradient of disturbance and rainfall range in Soraba taluk. Since the sampling localities were very variable in size as the Kaans are fragmented patchy ecosystem. In order to overcome the problem of variable size, emphasis was given on sampling random. For sampling the vegetation of Kaan forests, belt transect method was employed. Transect length of 1000 x 5 m breadth (0.5 ha) were laid in each category classes. All the wood species including climbers above 30 cm gbh (girth at breast height) at 1.30 m height was enumerated and were identified by referring to standard floras and floristic field keys of the study area. The GBHs of trees having diameter greater than 30 cm were measured directly by measuring tape and expressed in meters. After GBH, the tree height was measured and tree height is also one of the important parameter for estimation of volume of tree. The dominant trees with greater height with overlapping canopies were measured using Ravi Multimeter and expressed in meters.

**Statistical analysis**
The above ground biomass (AGB) was estimated by using DBH and total height of trees. It is calculated using the following formula.

AGB (kg) = Volume of tree ($m^3$) x Wood density ($Kg/m^3$)
$V = \pi r^2 H$
V: volume of the cylindrical shaped tree in $m^3$
r: radius of the tree in meter

H: height of the tree in meter

The belowground biomass (BGB) includes all biomass of live roots excluding fine roots having < 2 mm diameter. The belowground biomass was calculated by multiplying the above ground biomass (AGB) by 0.26 factors as the root: shoot ratio.

Below ground biomass (BGB) kg/tree or ton/tree = Above ground biomass (AGB) x 0.26.

The carbon stock of tree is the sum of both above and below ground biomass. It was calculated using the following formula. The carbon stock of tree was expressed in Mg (Mega grams or tons per sampling unit).

Carbon stock (CS) = Total biomass (AGB + BGB) x C – organic (47%).

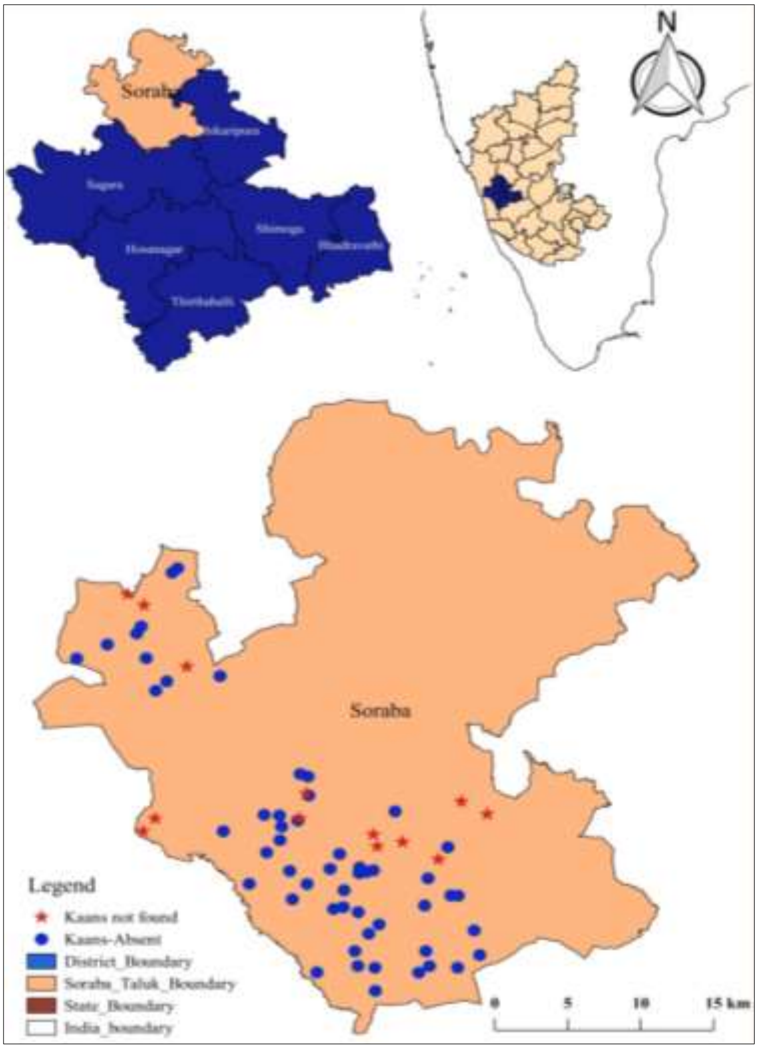


**Fig 1:** Distribution map (Present and absent) of Kaans in Soraba taluk

**Results and Discussion**

The results on effect of rainfall, disturbance gradient and different size class on total biomass and carbon stock in Kaan forests exhibited statistically significant difference between disturbance regimes and also for size class of Kaan, except for rainfall gradient (Table 1 and 2). The results revealed that, maximum biomass and carbon stock was found in Kaans presented in high rainfall area compared to low rainfall zone. In the two rainfall zones, the total biomass and carbon stock was significantly higher in less disturbed Kaans compared to highly disturbed Kaans. The total biomass and carbon stock showed direct relation with Kaan size. Where, the biomass was significantly higher in large Kaans compared to medium and small Kaans at both the rainfall regimes.

The total biomass was highest in Kaans which were presented in high rainfall area (170.78 Mg) and Kaans present in low rainfall zone recorded least value of biomass (163.55 Mg). In both the rainfall zones, the total biomass was significantly higher in less disturbed Kaans (227.99 Mg and 226.38 Mg) compared to highly disturbed Kaans (113.56 Mg and 100.73 Mg). The total biomass was found to be directly proportional to increase in Kaan size at both high and low rainfall. Where, the biomass was significantly higher in large Kaans (285.73 Mg and 223.22 Mg) and least biomass was found in small Kaans (103.14 Mg and 84.52 Mg) at both rainfall gradients (Fig. 2).

The total carbon stock of the Kaans was calculated by computing both above and below ground biomass values using standard equations. It is apparent from the results that, the pattern of significance was similar as like biomass component. Highest carbon stock was observed in high rainfall (80.26 Mg) than low rainfall (76.87 Mg). The carbon stock was found to be significantly highest in less disturbed Kaans (107.16 and 106.40 Mg) than highly disturbed Kaans (53.37 and 47.34 Mg) at both the rainfall gradients. The carbon stock calculated across different size class exhibited significant difference. The results on carbon stock for low rainfall area were maximum in large Kaans (104.91 Mg) and found to be on par with medium Kaans (85.97 Mg). Latter two Kaans were significantly different from small Kaans and the value of carbon stock was lowest (39.73 Mg). Similarly, in case of high rainfall area the pooled carbon stock was significantly higher in large Kaans (134.29 Mg) and was statistically different from medium and small Kaans. Latter two size class was found to be on par with each other and the lowest carbon stock was found in small Kaans (48.47 Mg) (Fig. 3).

Conservation of Sacred forests managed by local communities especially in developing countries is an important component of a comprehensive climate mitigation strategy (Brown and Adger, 1994) [3]. Either primary forests or climax forests lose its carbon pool both from soil as well as from standing growing stock due to biotic pressure. However, an undisturbed forest always maintains its overall carbon balance on a sustainable way (Apps *et al.*, 2000) [2]. In the present study the values of above ground biomass and carbon stock in the Kaan forests are much lower than the earlier reported values from India and other parts of Asia (Brown and Lugo, 1984; IPCC, 1996) [4, 8]. In a study by Singh *et al.*, (1994) [19] reported the biomass ranging from (92-640 Mgha$^{-1}$) in central Himalayan mixed deciduous forests of India. The less tree biomass and carbon storage capacity of Kaans might be due to severe anthropogenic disturbances to sacred Kaans with less conservation efforts put by communities. However in the past decades, the fear of deity was used as a weapon to reduce the disturbances. But, in the recent years such fear was not maintained by the local communities living around, which might be the reason for absence of much older grown trees in this sacred Kaans and hence their ability to fix and store less carbon compared to undisturbed natural forests.

Furthermore, the biomass and carbon stock was found to be maximum in high rainfall compared to low rainfall areas. Though the stand density in terms of number of tree individuals were significantly higher in low rainfall area, but the maximum number of old matured individuals were lesser in low rainfall areas. This is due to increased anthropogenic disturbances, as the value of combined disturbance index (CDI) was found to be higher in lower rainfall area compared to high rainfall zone. On the other hand less disturbed Kaans had higher total biomass and sequester significantly more carbon compared to highly disturbed Kaan ecosystems. The total biomass and rate of carbon sequestration depends upon age, site quality, species composition, total basal area and the style of forest management. The vegetation composed of mature and over-mature trees in many forest types elsewhere actually serves as a net carbon sink (Schulze *et al.*, 1999) [18]. The amount of carbon stock present in the sacred Kaans also indicates the reduced emissions from deforestation. This sequestration capacity and traditional conservation faith of these types of Sacred Kaans need to be conserved and could be viable scientific approach for carbon offset project.

A study on assessment of carbon stock of scared groves in Garhwal Himalaya, Uttarakhand by Vikrant and Nazir, (2019) [23]. The results depicted tree density of 688 trees ha$^{-1}$, whereas total carbon stock and biomass were 587.19 Mgha$^{-1}$ and 1159.90 Mgha$^{-1}$. Highest biomass and carbon density was observed for *Cedrus deodara*. Waikhom *et al.*, (2018) [25] depicted similar result of above ground biomass and carbon stock of scared groves in Manipur, Northeast India. The results showed that the aboveground biomass and carbon stock ranged from 962.94 to 1130.79 Mg ha$^{-1}$, 481.47 to 565.40 Mg ha$^{-1}$ respectively. Trees in largest groves with diameter class of 80-100 cm contributed the highest proportion of aboveground biomass and carbon stock. The total biomass and carbon stock in sacred groves of Central India, Madhya Pradesh as revealed by Javid *et al.*, (2019) [11] was ranged from 34.9-409.8 Mg ha$^{-1}$ with a mean value of 194.01 Mg ha$^{-1}$, while, tree carbon stock ranged between 17.5 to 204.9 Mg C ha$^{-1}$ with a mean value of 97.0 Mg C ha$^{-1}$. The contribution from larger groves with a tree density of 500 to 675 no. of stems ha$^{-1}$ was found to be maximum. In another similar study by Konkane *et al.,* (2018) [12], the carbon sequestration potential of sacred groves was conducted in Ambegaon taluka of Pune district. The study revealed that the carbon sequestration potential is directly proportional to number of individual trees present in the grove.

## Conclusion

The reduction in total areas of forests, isolation of small mosaic patches, loss of habitat with increased disturbance are all due to forest fragmentation. All these were responsible for decrease in total biomass and carbon stock in the smaller Kaans. Large Kaans which were less disturbed than small Kaans, which harbored such dominant species which were not present in small Kaans. However, the species composition, density and basal area as well as special categories of species such as threatened, endemic and evergreen species also increase with area. Thus, both small and large Kaans together enhanced the plant diversity, total biomass and carbon stock potentiality of the Kaan forests. Therefore, to safeguard the relic scared Kaan forests a strategic conservation measures is required to protect the diverse habitat specialist species from anthropogenic pressure. In this context, study on impact of forest fragmentation especially in Kaan forests on above ground biomass and carbon stock will provide significant support to develop effective conservation strategies in protecting these pristine habitats.

**Table 1:** Effect of rainfall, disturbance gradient and different size class on total biomass (Mg) in Kaans forests

| Location | Kaan size | Highly disturbed | Less disturbed | Mean of Kaan size |
|---|---|---|---|---|
| High rainfall | Large | 183.86 | 387.60 | 285.73 |
| | Medium | 68.14 | 178.78 | 123.46 |
| | Small | 88.68 | 117.60 | 103.14 |
| | Disturbance mean | 113.56 | 227.99 | |
| Mean of rainfall condition | | 170.78 | | |
| Low rainfall | Large | 125.12 | 321.32 | 223.22 |
| | Medium | 107.24 | 258.60 | 182.92 |
| | Small | 69.84 | 99.21 | 84.52 |
| | Disturbance mean | 100.73 | 226.38 | |
| Mean of rainfall condition | | 163.55 | | |
| | | SE(m) + | | CD @ 5% |
| Rainfall (R) | | 15.141 | | NS |

| | | |
|---|---|---|
| Disturbance gradient (D) | 15.141 | 44.42 |
| Kaan size (S) | 18.543 | 54.40 |
| RxD | 21.412 | NS |
| RxS | 26.224 | NS |
| DxS | 26.224 | 76.93 |
| RxDxS | 37.087 | NS |

**Table 2:** Effect of rainfall, disturbance gradient and different size class on total carbon stock (Mg) in Kaans forests

| Location | Kaan size | Highly disturbed | Less disturbed | Mean of Kaan size |
|---|---|---|---|---|
| High rainfall | Large | 86.41 | 182.17 | 134.29 |
| | Medium | 32.03 | 84.03 | 58.03 |
| | Small | 41.68 | 55.27 | 48.47 |
| | Disturbance mean | 53.37 | 107.16 | |
| Mean of rainfall condition | | 80.26 | | |
| | | | | |
| Low rainfall | Large | 58.81 | 151.02 | 104.91 |
| | Medium | 50.40 | 121.54 | 85.97 |
| | Small | 32.82 | 46.63 | 39.73 |
| | Disturbance mean | 47.34 | 106.40 | |
| Mean of rainfall condition | | 76.87 | | |
| | | SE(m) + | CD @ 5% | |
| Rainfall (R) | | 7.116 | NS | |
| Disturbance gradient (D) | | 7.116 | 20.88 | |
| Kaan size (S) | | 8.716 | 25.57 | |
| RxD | | 10.064 | NS | |
| RxS | | 12.326 | NS | |
| DxS | | 12.326 | 36.16 | |
| RxDxS | | 17.432 | NS | |

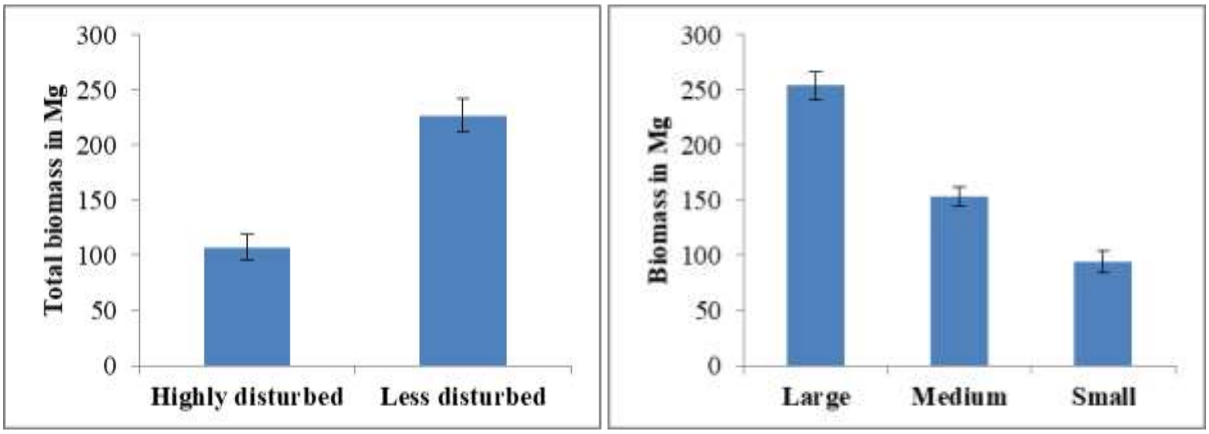


**Fig 2:** Total biomass (Mg) as influenced by disturbance gradient (A) and different size class of Kaans forests

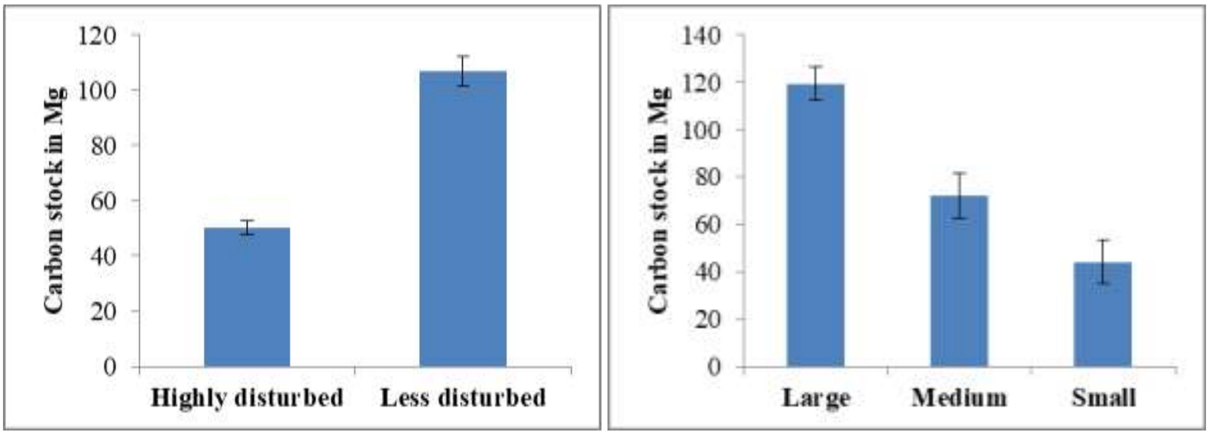


**Fig 3:** Total carbon stock (Mg) as influenced by disturbance gradient (A) and different size class of Kaans forests

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