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# Assessment of Soil organic carbon stocks in *Dendrocalamus stocksii* and *Dendrocalamus strictus* plantations in three different agroclimatic zones

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**Abstract**: The study was undertaken to understand the carbon sequestration potential of two popularly grown bamboo species, *D. stocksii* and *D. strictus* in different agroclimatic zones. The study sites were from the districts of Bengaluru Rural, Belgaum and Chikmagalur in Karnataka representing semi-arid, sub-humid and per-humid regions respectively. The Soil Organic Carbon (SOC) stock recorded in six plantations from four locations falling in three agro-ecological zones were classified into 0-30 cm and 30-100 cm depth and 0-100 cm depth. The 0-30 cm was considered the dynamic SOC part, 30-100 as the potential SOC part and a combination of these two depths (0-100 cm) indicated the SOC stocks, a land quality indicator. The difference in SOC stock in various depths across agro-climatic zones can be attributed to climate, biomass production, root spread, canopy cover,ground cover, rate of mineralization and fixation in soil solum. Highest SOC content in *D. stocksii* plantation was found in per-humid region for all the three layers ,while highest SOC content in *D. strictus* plantation was found in sub-humid region for all the layers. Accordingly, *D. stocksii* can be considered the most economically viable option for per-humid regions, and *D. strictus* appears to be more effective for managing land degradation and for carbon sequestration particularly in the semi –arid and sub-humid zones.

*Keywords*: Agroclimatic zone, *D. stocksii*, *D. strictus*, land quality, soil carbon stock

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## Introduction

Soil carbon is a powerful solution to the climate change crisis. By harnessing the immense power of photosynthesis, we can convert atmospheric carbon, a problem, into soil carbon, a solution. Healthy soil can be a major sink for carbon. An integral role in reducing $CO_2$ emissions can be played by soil owing to their carbon sink potential if we practice proper proactive mitigation strategies (Lal, 2004). Soils constitute the largest terrestrial organic C pool (~1,500 Pg C to a depth of 1 m and 2,400 Pg C to 2 m depth) (Batjes, 1996). Bamboo is one of the most productive and fastest-growing plants, it potentially acts as a valuable sink for carbon storage (Seethalakshmi *et al*., 2009 and Song *et al*., 2011). *Dendrocalamus stocksii* and *Dendrocalamus strictus* are two nationally prioritized bamboo species by National Bamboo Mission (NBM) for large scale cultivation in Peninsular India.

*Dendrocalamus stocksii* (Munro) M. Kumar, Remesh and Unnikrishnan (Kumar *et al*., 2000) (Synonyms-*Pseudoxytenanthera stocksii* (Munro) Naithani, *Oxytenanthera stocksii* (Munro) is endemic to the Western Ghats. It is a potential multiuse bamboo suited fo commercial cultivation in semi-arid conditions and is a graceful mid-sized non-thorny bamboo species with loosely spaced largely solid erect culms ranging from 30-55 mm diameter, which provides flexibility in harvesting, easy management and steady income to farmers. *D. strictus* is the most common bamboo across India,while *D. stocksii* is restricted to Central Western Ghats. However, both these species are similar in habit and culm characteristics and also it is very difficult to distinguish between the two in early stages of establishment (Banik, 2000). Moreover only these two species have shown the growth potential to attract attention for cultivation outside forest areas in the realm of farmlands (Bystriakova, 2003; Bystriakova *et al*., 2004 and Rane *et al*., 2016). The dry matter accumulation of different bamboo species in different locations of the world is well documented (Seethalakshmi *et al*., 2009). But there exists a data gap in soil carbon stocks of these species. Soil organic carbon stocks in the plantations of *D. strictus*, *Bambusa vulgaris*, *B. balcooa* and *B. nutans* were 106.56 t $ha^{-1}$, 85.06 t $ha^{-1}$, 65.40 t $ha^{-1}$, and 57.28 t $ha^{-1}$ respectively. With this, the highest carbon sequestration potential was observed in plantation of *D. strictus*(Tariyal *et al*., 2013 and Gu *et al*., 2019).

This study tried to assess the amount of soil organic carbon stocks present in soil under bamboo plantations of *D. stocksii* and *D. strictus* in three different agroclimatic zones, which will help to assess potential of bamboo in carbon sequestration, a strategy for climate change mitigation.

## Materials and Methods

To compare soil carbon stocks for both *D. stocksii* and *D. strictus* plantations, soil profile samples were collected from bamboo plantations of various age groups grown in different places like Hoskote (Bangalore Rural), Hattar Gunji, Ramgurwadi (Belgaum) and Koppa (Chickmaglur) which belong to the semi-arid, sub-humid and per-humid agroclimatic regions respectively (Thornthwaite and Mather, 1955; Seghal *et al*., 1992). Per-humid are region those have moisture index of 100 per-cent and above, Sub-humid region have moisture index of minus 33.3 per-cent to plus 20 per-cent and semi-arid have moisture index of minus 66.7 per cent to minus 33.3 per-cent (Hlm-crous *et al*., 2011).

The sites selected were representative of the area. A profile dimension of 1.5m x 1.5m x 1.5m was

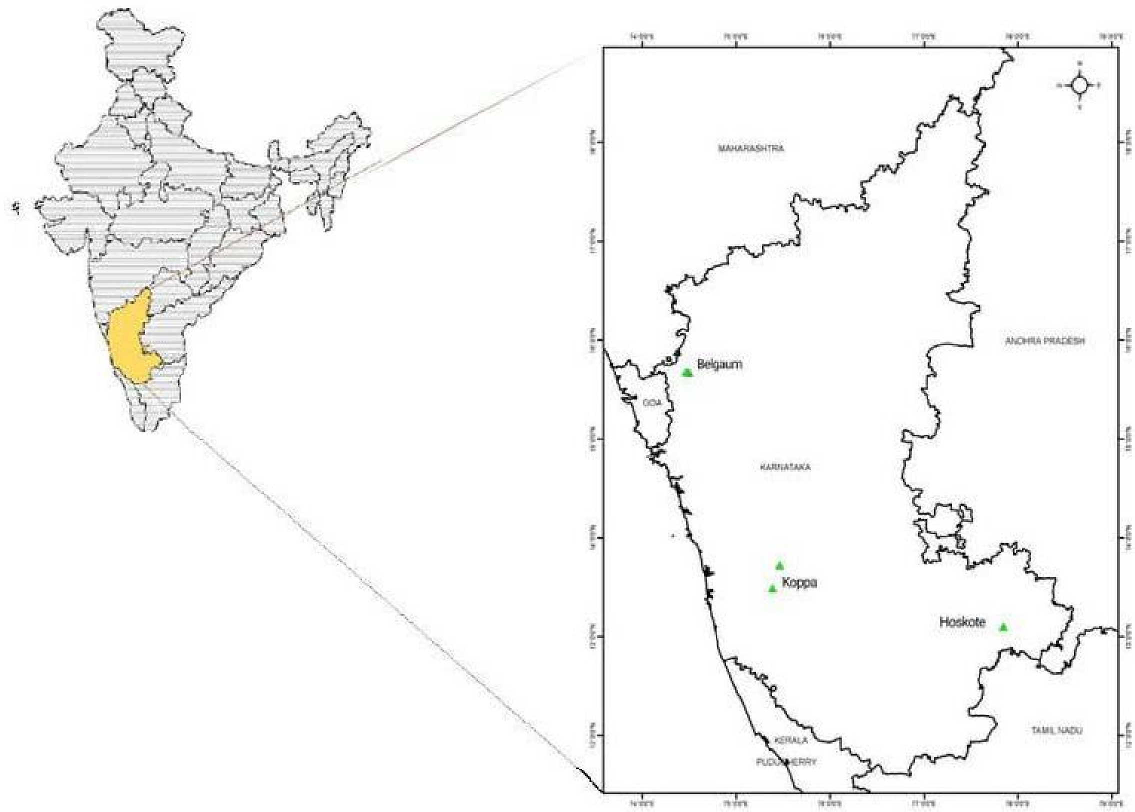


**Fig 1.** Location map showing sampling region from three agroclimatic zones in Karnataka

dug. The profile was oriented in such a manner that a face was well lighted. Side to be examined was made even and different horizons were demarcated based on variability in colour, texture and structure. The details like depth, color, texture, rock fragments, structure and consistency were studied and recorded in the standard proforma for soil profile description.

Soil samples were collected separately in polythene bags from one meter profile depth wise (0 -30 cm, 30-60 cm and 60-100 cm), labelled properly and transported to laboratory for processing and analysis. Samples for determination of bulk density were collected using a metallic core of known volume, which was driven into each horizon. The cutting edge of the core was pressed into the soil and driven in using a wooden hammer and then carefully removed to gather a known volume of soil sample.

The dry soil sample was powdered using agate pestle and mortar to pass through 0.2 mm sieve for organic carbon estimation. A known weight of powdered sample was treated with known volume of standard $K_2Cr_2O_7$ and concentrated $H_2SO_4$. The unused $K_2Cr_2O_7$ was quantified by back titration with standard ferrous ammonium sulphate using ferroin indicator (Walkley and Black, 1934).

The total soil organic carbon stock for each pedon was estimated in kg m$^{-3}$ using the general equation (Grossman *et al*., 2001) presented below;

$$SOC = (L_1 \times SOC\ P_1 \times \rho 33_1\ (1 - V > 2_1)/100) + L_2 \times SOC\ P_2 \times \rho 33_2\ (1 - V>2_2)/100 + ..))/10$$

Where, SOC = soil organic carbon in kg m$^{-3}$ soil

SOC $P_1$, SOC $P_2$ = Soil organic carbon percent of horizons

$L_1$, $L_2$ = Thickness of the horizons in cm

$\rho 33_1$, $\rho 33_2$ = Moist bulk density of the soil horizons in mg m$^{-3}$ at field capacity

$V>2_1$, $V>2_2$ = Volume per-cent of >2 mm portion of soil horizons

Moist bulk density was found out from oven dry bulk density by using the equations by (Kern, 1995) which is,

Moist bulk density = (oven dry bulk density x 0.88) + 0.046

**Table 1**. Average Rainfall, Maximum and Minimum of Temperature and Relative Humidity of study location

| Sl No. | Location | Average Rainfall (mm) | Maximum temperature ($^0$C) | Minimum temperature ($^0$C) | Maximum Relative Humidity % | Minimum Relative Humidity % |
|---|---|---|---|---|---|---|
| 1 | Hosakote (Bengaluru Rural) | 808 | 32 | 18 | 75 | 54 |
| 2 | Hattar Gunji (Belgaum) and Ramgurwadi (Belgaum) | 1932 | 34 | 18 | 81 | 75 |
| 3 | Koppa (Chikmagalur) | 2915 | 31 | 19 | 89 | 73 |

**Table 2.** Land use and Location co-ordinates of sampling area

| Agroclimatic zone | Bamboo species | Age of Plantation (years) | Location Name | Location coordinates |
|---|---|---|---|---|
| Semi- Arid | *D. stocksii* | 13 | Hoskote | 13° 06' 04.25" N 77° 50' 46.11" E |
| | *D. strictus* | 13 | Hoskote | 13° 06' 03.76" N 77° 50' 46.86"E |
| Sub Humid | *D. stocksii* | 19 | Hattar gunji (Belagavi) | 15° 40' 23.02"N, 74° 30' 04.10" E |
| | *D. strictus* | 21 | Ramgurwadi (Belagavi) | 15° 40' 49.84" N 74° 28' 14.27"E |
| Per humid | *D. stocksii* | 12 | Kappa | 13° 29' 33.51" N 75° 23' 30.11" E |
| | *D. strictus* | 6 | Koppa | 13° 43' 19.56" N 75° 28' 00.84" E |

## Results and discussion

The SOC content recorded in six plantations falling into three agro-ecological zones were classified into 0-30 cm depth and 30-100 cm depth and 0-100 cm. 0-30 cm gave dynamic part, 30-100 cm gives potential part and 0-100 cm gave SOC stock as land quality.

The SOC in bamboo plantations of both the species grown in different agroclimatic conditions are given in table 4. Highest SOC content in *D. stocksii* plantation was found in per-humid region for all the three layers. The highest soil organic carbon content (0-100 cm) layer was 17.07 kg $m^{-3}$ in per-humid region, which is very good quality soil. In the semi-arid region, the SOC stock in 0-30 cm layer was 3.27 kg $m^{-3}$,which is higher than 30-100 cm layer. The total SOC content (0-100 cm) in semi-arid region is 6.48 kg $m^{-3}$, which comes in medium land quality class. In the semi-humid region, the SOC stock in 0-30 cm layer was 4.49 kg $m^{-3}$, which is higher than 30-100 cm layer. The total SOC content (0-100 cm) in sub-humid region was 7.12 kg $m^{-3}$, which comes in a moderate land quality class. The SOC content in per-humid region for 0-30 cm and 30-100 cm were 7.64 and 9.44 kg $m^{-3}$ respectively. The total SOC content, 17.07 kg $m^{-3}$, in per-humid region comes in a high land quality class.

Highest SOC content in *Dendrocalamus strictus* plantation was found in Sub-humid Region at 0-30 cm and 0-100 cm layers and in semi-arid region at 30-100 cm layer. The highest SOC content (18.08 kg $m^{-3}$) in 0-100 cm layer in sub-humid region,comes under a very high land quality category. In the semi-arid region, the SOC stock in 0-30 cm layer was 4.67 kg $m^{-3}$, which is lower than 10.38 kg $m^{-3}$ in the 30-100 cm layer. The total SOC content (0-100 cm) in semi-arid region is 15.05 kg m-3 ,which comes in a very high land quality class (Kumar *et al.*, 2015). The SOC content in the sub-humid region for 0-30 cm and 30-100 cm were 9.40 and 8.68 kg $m^{-3}$ respectively. There is almost similar distribution in both layers. The total SOC content (0 cm -100 cm) in the Sub-humid region was 18.08 kg $m^{-3}$, which comes in a very good land quality class. The SOC content in per-humid region for 0 cm -30 cm and 30 cm -100 cm were 6.19 and 6.56 kg $m^{-3}$ respectively. The total SOC content in Per-humid region was 12.75 kg/$m^3$, which comes in a high land quality class.

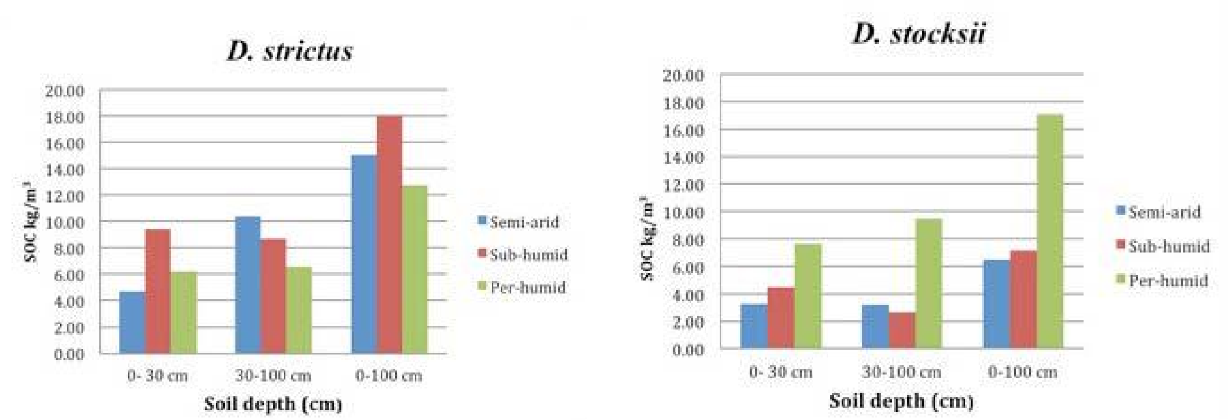


**Fig 2.** Schematic representation of Soil Organic stock in different agroclimatic zones for *D. strictus* and *D. stocksii*

Difference in SOC stock in various depths across agroclimatic zones can be attributed to climate, biomass production, root spread, canopy cover,ground cover, rate of mineralization and fixation in soil solum. Biomass production, root spread and canopy cover depends on stand management practices like planting density regulation and other cultural operations. This can modify the resource acquisition patterns of bamboo that can increase the growth and productivity considerably. (Kittur *et al*., 2017 and Pathak *et al*., 2011; Xu *et al*., 2011)

Heavy rainfall of around 3000 mm at a hot per-humid location, Koppa taluk makes high biomass production and rapid rate of mineralization assisted by high temperature and increased and active microflora and fauna. High rate of decomposition during long dry spell favour high sheet erosion of

**Table 3.** Depth wise pH, EC, O.C, B.D and SOC variation in bamboo plantation in different agroclimatic zones

| | ***D.strictus*** | | | | | | ***D.stocksii*** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Agroclimatic zone** | **Depth of soil layer (cm)** | **pH** | **EC (ds/cm)** | **O.C%** | **B.D (moist)** | **SOC/ cm² depth of soil-stock** | **pH** | **EC (ds/cm)** | **O.C%** | **B.D (moist)** | **SOC / cm² depth of soil stock** |
| Semi arid | 0-15 | 5.71 | 0.121 | 1.82 | 1.19 | 3.09 | 5.3 | 0.11 | 1.13 | 1.30 | 2.07 |
| | 15-30 | 5.59 | 0.059 | 0.90 | 1.30 | 1.58 | 5.22 | 0.06 | 0.82 | 1.13 | 1.20 |
| | 30-60 | 5.51 | 0.099 | 3.27 | 1.26 | 7.69 | 5.28 | 0.037 | 0.59 | 1.10 | 1.82 |
| | 60-100 | 5.78 | 0.053 | 0.70 | 1.07 | 2.69 | 5.61 | 0.036 | 0.36 | 1.09 | 1.38 |
| Sub humid | 0-15 | 5.65 | 0.156 | 4.85 | 1.10 | 6.14 | 5.66 | 0.05 | 1.82 | 0.99 | 1.91 |
| | 15-30 | 6.13 | 0.048 | 1.76 | 1.32 | 3.26 | 5.82 | 0.042 | 1.55 | 1.64 | 2.58 |
| | 30-60 | 6.12 | 0.039 | 1.46 | 1.68 | 5.74 | 6.14 | 0.03 | 0.94 | 1.36 | 1.33 |
| | 60-100 | 5.74 | 0.02 | 0.84 | 1.27 | 2.94 | 6.1 | 0.042 | 0.30 | 1.43 | 0.94 |
| Per humid | 0-15 | 5.97 | 0.098 | 3.71 | 1.03 | 4.52 | 5.82 | 0.107 | 2.89 | 1.03 | 4.47 |
| | 15-30 | 5.76 | 0.046 | 1.62 | 0.89 | 1.67 | 5.76 | 0.075 | 2.35 | 1.07 | 3.17 |
| | 30-60 | 5.78 | 0.049 | 1.54 | 1.08 | 4.26 | 5.65 | 0.066 | 1.90 | 1.24 | 5.48 |
| | 60-100 | 5.91 | 0.04 | 0.82 | 0.90 | 2.51 | 5.76 | 0.06 | 1.05 | 1.12 | 3.96 |

**Table 4.** SOC content (kg/m$^3$) in different depth in bamboo plantation in different agroclimatic zones

| **Agroclimatic zone** | ***D.stocksii*- SOC content ( Kg/m$^3$)** | | | ***D.strictus*- SOC content ( Kg/m$^3$)** | | |
|---|---|---|---|---|---|---|
| | 0-30 cm | 30-100 cm | 0-100 cm | 0-30 cm | 30-100 cm | 0-100 cm |
| Semi arid | 3.27 | 3.20 | 6.48 | 4.67 | 10.38 | 15.05 |
| Sub humid | 4.49 | 2.63 | 7.12 | 9.40 | 8.68 | 18.08 |
| Perhumid | 7.64 | 9.44 | 17.07 | 6.19 | 6.56 | 12.75 |

finer materials from top horizon and sometimes the entire surface horizon itself if the surface is disturbed or not having a thick vegetative cover (Ravi Kumar, 2006). Heavy downpour also makes high percolation of water containing dissolved organic matter deep beyond solum or towards down slope. That is why here heavy production and mineralization may not favour very high SOC stocks as thickness of layer having very high organic carbon per cent will decide high SOC stock (Sarika *et al*., 2014).

In case ofsub-humid (Belgaum), near 1000 mm rainfall also makes comparable biomass production, high temperature and very high mineralization and decomposition rate helped by long dry spell. The low removal or storing mineralized organic matter within solum itself as the medium rainfall is not sufficient enough to remove the accumulated organic carbon beyond solum and down slopes. High thickness of layer having very high organic carbon per cent here will decide high SOC stock makes better SOC stock depending on the surface exposure and canopy cover (Shalima Devi and Anil Kumar, 2009).

Under hot moist semi-arid climate very low biomass production occurs owing to low rainfall, but very high mineralization and decomposition favoured by increased microbial population but compete for available nitrogen for further decomposition and population may reduce and slower the decomposition rate, which make a better storage of mineralized and decomposed organic matter at upper layers of soil itself (Subbiah and Asijia *et al*., 1956). Here also thickness of layer containing high organic carbon per cent will be lesser than that of soils under sub-humid climate (Bashour *et al*., 2007 and Batjes, 1996). Low storage in lower horizons as rainfall of 500-800 mm is not sufficient enough to remove SOC from upper horizons to sub-soil horizons depending on exposure and canopy cover (Jobbagy *et al*., 2000).

Organic matter is the most important constituent of soil and its composition depends upon the nature of vegetation. Replacement of native vegetation by agriculture, Eucalyptus or any other plantations may change the quality and quantity of organic matter (Hombegowda *et al*., 2016 and Sharma *et al*., 2014). Thus, a comparison of soil organic carbon stock will enhance our understanding of these ecosystems. Based on SOC content in 0-100 cm depth we can classify profile into different land quality classes, SOC content 0-3 kg m$^{-3}$ very low 3-6 kg m$^{-3}$ low 6-9 kg m$^{-3}$ medium 9-12 kg m$^{-3}$ moderate 12-15 kg m$^{-3}$ >15 kg m$^{-3}$ very high (Shalima Devi and Anil Kumar, 2009).

## Conclusion

This information can be used to study the feasibility of these bamboo species as an alternate land use in these agro climatic conditions concerning soil carbon stock assimilation. Considering multifarious utility of *D. stocksii*, it is most economically viable option for per-humid region. *D. strictus* appears to be more effective for managing land degradation and for carbon sequestration particularly in the semi-arid and sub-humid zones.

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