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Assessment of total Soil organic carbon in Teak Ecosystem in Humid tropics using CENTURY model

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Abstract

A study on assessment of total soil organic carbon in teak ecosystem in humid tropics was done using a soil carbon model, CENTURY. The objectives of the study included the evaluation of suitability of this model in teak ecosystems and to analyse the of total soil organic carbon simulated by this model. The study was conducted based on secondary data sets collected from the experiments done in teak plantations of Thrissur district. The other data sets related to soil parameters were collected from various resources of Kerala Agricultural University and Kerala Forest Research Institute. Soils in natural forest were used as a baseline to compare the soil in teak plantations. Hence any variation in soil conditions can be considered as a result of various management operations carried out on these natural forests and based on 1965 to 2050 year time sequence, it was reconstructed. The net primary productivity prediction by the model was taken as an accuracy index for other model outputs represented at those sites. The simulated carbon values were compared with the carbon baseline data obtained from different aged teak plantations. For CENTURY model, site data, site specific parameters, Event.100 file and schedule files were used. Hence it was concluded that for simulation of soil organic carbon, CENTURY model was efficient and it predicted a declining trend of total soil organic carbon. The model efficiency of CENTURY models for teak ecosystem was 0.88.

Keywords: Soil organic carbon, Soil carbon models, CENTURY, Simulation and Model efficiency.

Introduction

Carbon is a vital component of soil organic matter (SOM), created by cycling of organic compounds in plants, animals and microbes into the soil. Globally, soils contain approximately 1500 pg of carbon, making it the largest terrestrial carbon pool[1-2]. Hence soil plays a major role in global carbon sequestration. The global soil carbon pool is 2300 Pg which is three times the size of atmospheric carbon (770Pg) and 3.8 times the size of biotic pools (610 Pg)[3]. The soil carbon stock was determined by taking the balance of flow of carbon present in the soil as dead organic matter and carbon output as heterotrophic respiration[4]. Soil carbon provides as the energy source for microbial processes such as respiration, nutrient storage and turnover are soil quality minimum data set indicators that mainly dependent on soil organic carbon[5]. The trees have its own potential for producing larger quantities of above ground and below ground biomass compared to shrubs and herbs. More biomass content results in increased production of above ground litter and belowground root activity. So according to this reason the trees are considered has an important factor for soil organic carbon sequestration[6]. Due to the enhanced decomposition rate under high moisture and temperature, soils in tropics show a faster turnover rates than temperate soils. In Kerala, soils show low organic carbon content in lower elevation and high in mid and higher elevations. Tropical forests especially Teak (*Tectona grandis*) has an important role in global carbon cycle. Kerala Forest Department has about 57885 ha under teak, out of which, approximately 64 per cent is in the first rotation and the remaining 36 per cent is in the second and third rotation ages[7]. Planting teak is one of the major incentives which were taken up nowadays, in order to meet the demand in terms of carbon sequestration along with high economical returns[8]. Young plantations can sequester relatively larger quantities of carbon while a mature plantation can act as a reservoir[9]. Long rotation species such as teak has long carbon locking period compared to short duration species and has an advantage that most of the teak wood is used indoors extending the locking period further. The soil in teak plantations continue to accumulate carbon and thus act as a sink always. Generally the soil carbon in soils was highest in the surface and decreased with the depth in both teak plantations as well as natural forest. But natural forest had higher soil organic carbon when compared to teak plantations[10]. Models were evaluated in terms of their ability to simulate observed soil carbon changes. Numerous studies and evaluation of simulation models have been reported. The CENTURY model, developed for the grassland[11], subsequent model modifications has expanded its applicability to forest systems [12] and agricultural systems[13]. In CENTURY model based on the input climate data such as monthly minimum temperature, monthly maximum temperature, and monthly precipitation for each year, the SOC is simulated[14].

Methodology

The study was based on secondary data sets collected from experiments done in teak plantations of Thrissur areas which belong to humid areas. Soils in natural forest were used as a baseline to compare the soil in teak plantations of different age groups. As these ecosystems were established by clear felling of the natural forest, it can be assumed that the initial soil conditions were similar. Hence any variation in soil conditions in teak plantations of different age classes can be considered as a result of various management operations. The weather file was created for the model. The parameters were prepared to be compatible with the models using site. 100 file. The site specific parameters which include latitude and longitude of site, soil texture, bulk density, field capacity, wilting point, p^H etc were created (Table-1). Site specific event options such as site.100, tree.100 and fire.100 were used. The next step was the creation of schedule files which determined the order and types of events that were included in the simulation and, the model was run.

The model outputs were examined for accuracy with net primary productivity (NPP). The NPP prediction by the model was taken as an accuracy index for other model outputs represented at that site. Thus, the simulated carbon values were compared with the carbon baseline data obtained from teak plantation ecosystems. Estimated the soil organic carbon values of teak plantations from different places in Thrissur district [10] (Table-2). The soil organic carbon showed a decreasing trend with an increasing age class. Based on his study, the teak plantations were divided into 5 age classes. The age classes were 0-5, 6-10, 11-20, 21-30 and above 30 years. The reason for selecting these five age groups was that the first and second mechanical as well as the silvicultural thinning would be over during the period of 5-25 years after the establishment, while third and fourth silvicultural thinning would be over during the period of 25-45 years, after which there will not be further operations in the plantation. The measured (observed) and modelled datasets were compared qualitatively through graphs and quantitavely by statistical tests which were used to evaluate the model performances.

The Model Efficiency (ME) was calculated based on the equation as ME= 1- ∑ (Observed –Simulated) ^{2}/∑ (Observed-Mean)^2. To find out mean ∑Error^2 = (Observed-Simulated)^2
Mean= ∑Error^2/ Number of observations. If the ME is less than 0, the performance of the model is not satisfactory. If it is between 0 to 0.5, then it is satisfactory and greater than 0.5, very good to use.

Results and Discussion

Simulated results of total soil organic carbon by CENTURY model: It was assumed that the teak plantations were raised after clear felling of natural forest, by adopting cultural practices that take place at each growth stage. In the beginning of the plantation year, the simulated data shows that the total soil organic carbon declined from 6656.87 to 3346.82 g C m^{-2} at 30 years of establishment. Further soil organic carbon got stabilized during the following 26 years. During the 56th year, it showed a gradual decline reached a value of 3142.79 g C m^{-2} then it decreased to 2683.73 g C m^{-2} by the next five years after which it became stabilized. From this result was clear that the conversion of natural forest to teak plantation resulted the significant loss of soil organic carbon (table-3 and figure-1).

Table-1
Site and control parameters

Site and soil variables		Value
SITLAT	Site latitude (degrees) latitude of model site (deg)	10.31
SITLNG	Longitude of model site (deg)	76.13
SAND	Sand in soil (%)	0.70
SILT	Silt in soil (%)	0.18
CLAY	Clay in soil (%)	0.12
BULKD	Bulk density of soil (g/Cm^3)	1.42
NLAYER	Total soil layers in column (No.)	3.0
AWILT	The wilting point of soil layer (Fraction)	0.08
AFIEL	The field capacity of soil layer (Fraction)	0.20
pH	Soil pH	7.0

Table-2
Observed soil organic carbon content of teak plantations

Locations	Age	Soil organic carbon (%)
Machad	0-5 years	2.36
Pattikkad	6-10 years	1.68
Vadakanchery	11-20 years	1.52
Vazhachal	21-30 years	1.38
Athirapilly	>30 years	1.20

Table-3
Decennial changes in total soil organic carbon (g C m^{-2}) in teak ecosystem simulated by CENTURY model (1965-2050)

Age	Year	Soil organic carbon
1	1965	6656.87
10	1975	4144.46
20	1985	3491.22
30	1995	3346.82
40	2005	3351.43
50	2015	3396.81
60	2025	2683.73
70	2035	2752.25
80	2045	2854.31

The loss of soil organic carbon can be attributed to many reasons. Teak being an early fastest grower canopy generally closes in about one to four years. Hence weeding and thinning is recommended in order to prevent crowding. The loss of SOC can be attributed to many reasons. Subsequently, thinning is done in order to prevent crowding. Hence the disturbance to the soil during the above processes and decrease of soil cover leads to loss of soil organic carbon. Litter production at this stage appears to be inadequate to balance for the loss of organic carbon. The net result is progressive loss of soil organic carbon. The mechanical and silvicultural thinning ends by 25 years. Thereafter the soil starts to recuperate. It is probable that at this stage, the rate of nutrient return to the soil through the fall and break down of litter is greater than its loss from soil. Thus an increase in soil organic carbon occurs[15].

It was reported that teak plantations showed an increase in soil hydraulic conductivity and macro porosity compared to grazed lands. So they generally showed a high erosion rate, in which most of the top soil is lost and the subsurface layer is exposed, leading to the loss of soil organic carbon during the initial years when the soil disturbance is high[16].

Forest fires are common in teak plantations. Fire burns organic matter, heats up the top soil and changes the physiochemical properties of soils and cause erosion. Hence the organic matter decreases with a marked decrease in C: N ratio and initial organic matter level is reached only 55 years after fire incidence[17].

Efficiency of CENTURY model: The total SOC was measured in different aged classes of teak plantations. The age classes of 1-5, 6 -10, 11- 20, 21-30 and more than 30 years showed average SOC values of 5664, 4032, 3648, 3312 and 2880 g C m^{-2} respectively whereas the CENTURY model simulated average values were found to be 5859, 4564, 3776, 3403 and 3341 g C m^{-2} respectively.

It was found a linear relationship (r^2=0.865) between measured and simulated total soil organic carbon values. A t test was done to find out the difference between measured and simulated total soil organic carbon was significant or not. The model efficiency of CENTURY model in teak ecosystem was found to be 0.88 and it was revealed that the CENTURY model is reliable in simulating the carbon dynamics in teak plantations (table-4 and figure-2).

Table-4
Comparison of model efficiency of CENTURY models in teak ecosystem

Year	Observed values of soil organic carbon (g C m^{-2})	Simulated values of soil organic carbon (g C m^{-2})
0-5	5664	5860
6-10	4032	4564
11-20	3648	3776
21-30	3312	3403
>30	2880	3341
Model efficiency		**0.88**

Simulation of nitrogen and crop yields using CENTURY and APSIM found that the CENTURY model simulate better in predicting relative yields of nitrogen treatment than the other[18]. Study using CENTURY model in different ecosystems found that the model performed better in grass, forest and crop systems[19]. Dynamics of above ground soil organic carbon at the soil depth of 0-20 cm can successfully simulated using CENTURY model and also the results which was simulated by the model will agreed with the estimates[20]. Study conducted in teak ecosystem using CENTURY and STELLA model also found that the performance of CENTURY model was much better than the other[10].

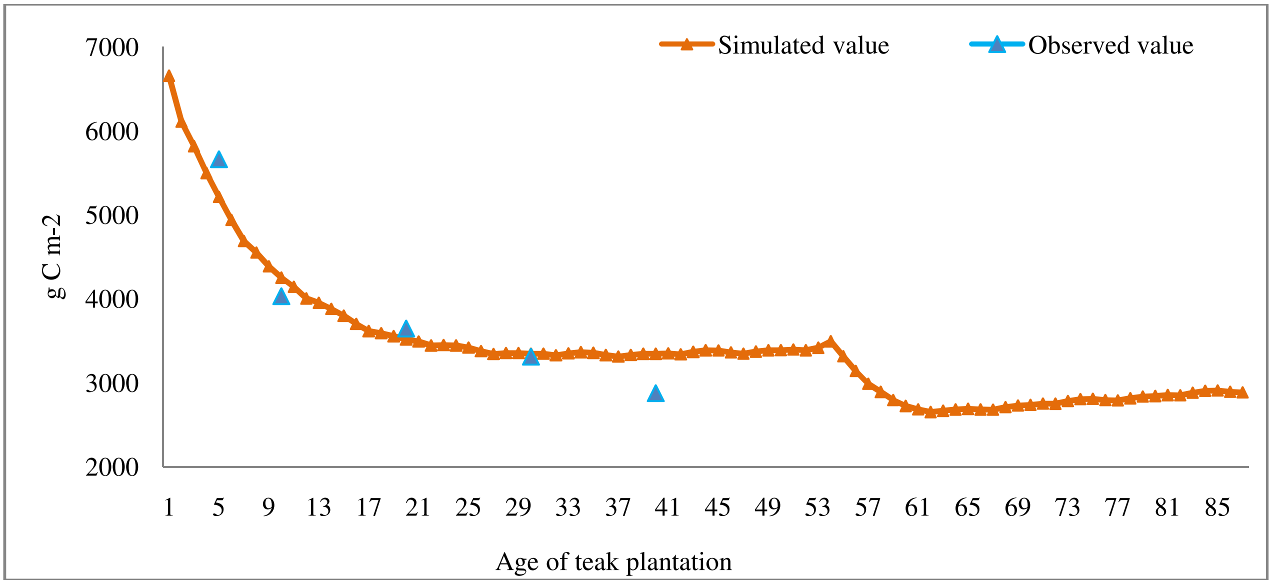

Figure-1
Observed and CENTURY model simulated total soil organic carbon

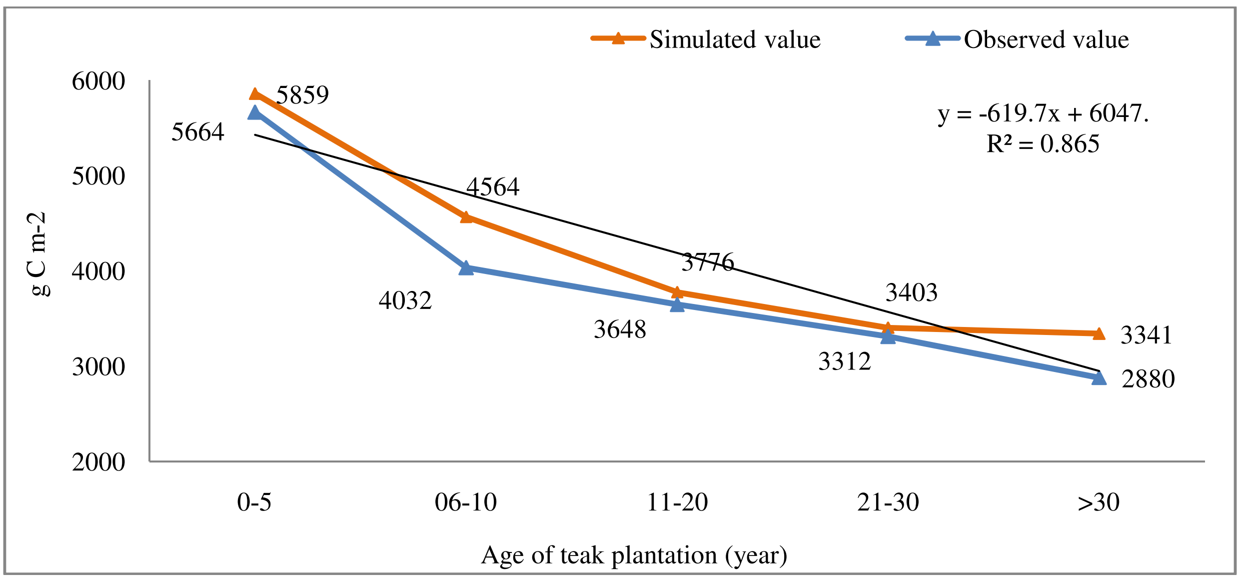

Figure-2
Relationship between observed and CENTURY simulated total soil organic carbon

Conclusion

It was assumed that when natural forest was cleared for teak plantation and adopting CENTURY model for simulation of soil organic carbon. It was observed a declining trend of soil organic carbon and the model effency of CENTURY reached 0.88. It shows that the model was more efficient in computing soil organic carbon. Hence we concluded that for simulation of soil organic carbon in teak ecosystem CENTURY was more efficient than other soil carbon models.

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References

1. Lal R. (2004). Soil carbon sequestration impacts on global climate change and food security, *Science,* 30(4), 1623–1627.
2. Lal R. (2001). Soil Carbon Sequestration and the Greenhouse Effect. Soil Science Society American special publication, Madison, WI, 236.
3. Berg B., Mc Claughty C. and Johanson M.B. (1992),

Litter Mass loss rates in late stages of decomposition at some climatically and nutritionally different pine sites: A study on the effects of climate change, Dept. of forest ecology and forest soils, Swedish University of Agricultural Sciences, Swedon, Report 67.

4. Reeves D.W. (1997). The role of soil organic matter in maintating soil quality in continuous cropping systems. *Soil and tillage Research*, 4(3), 131-167

5. Lemma B., Kleja D., Olsson B. and Nilsson M. (2007). Factors controlling soil organic carbon sequestration under exotic tree plantations: A case3 study using the Co2 Fix model in southwestern Ethipia, *Forest Ecology and Mangement*. 252(13), 124-131.

6. Nagesh and Prabhu. (2003). Teak in Kerala state, India: Past, Present and Future. In: Quality Timber Products of Teak from sustainable Forest Management. Proceedings of the international conference on quality timber products of teak from sustainable forest management. Bhat K.M., Nair K.V., Bhat E.M., Muralidharan E.M. and Sharma J. K.(eds.).Kerala Forest Research Institute, Peechi. 1-18.

7. Jayaraman K., Bhat K.V., Rugmini P. and Anitha V. (2010). Kerala Forest Research Institute, Teak net Bulletin, Peechi, Thrissur, Kerala. India, 3, 2.

8. Thomas P.T., Rugmini P. and Balagopalan M. (2013). Carbon storage potential of different age teak plantations of Kerala. KFRI, 20-28.

9. Manjunatha M. (2015). Modeling carbon dynamics in teak plantations of Kerala, Ph D (Forestry) thesis, Kerala Agricultural University, 137.

10. Parton W.J., Schimel D.S., Cole C.V. and Ojima D.S. (1987). Analysis of factors controlling soil organic matter levels in Great Plains grasslands. *Soil Science Society Americal Journal* 51(3) 1173-1179.

11. Sanford R.L. Jr., W.J. Parton, D.S. Ojima and D.J. Lodge (1991). Hurricane effects on soil organic matter dynamics and forest production in the Luquillo Experimental Forest, Puerto Rico: Results of Simulation Modeling. *Biotropica*. 2(3), 364-372.

12. Paustian K., Elliot E.T., Peterson G.A. and Killion K. (1996). Modeling climate, CO_2 and management impacts on soil carbon in semi arid agroecosystem, *Plant and soil*, 18(7), 351-365.

13. Carvalho Leite L.F., Sa mendonça E., Ameida machado P.L.O., Fernandes Filho E.I. and Lima Neves J.C. (2004). Simulating trends in soil organic carbon of an Acrisol under no-tillage and disc-plow systems using the CENTURY model. *Geoderma*, 21(2), 283-295.

14. Kadambi K. (1992). Silviculture and management of Teak. Austin state University, Bulletin 24, Wacogdoches, Texas. 137.

15. Mapa R.B. (1995). Effect of reforestation using *Tectona grandis* on in filtration and soil water retention. *Forest, Ecology and Management*, 7(7), 119-125.

16. Vukicevic E. and Milosevic R. (1960). Dynamics of the vegetation and microbe population on some forest fir area, S*umarstvo*, 13 295-306.

17. Probert M.E., Keating B.A., Thompson J.P. and Parton W.J. (1995), Modeling water, nitrogen and crop yield for a long term fallow management experiment. *Aust. J. Exp. Agric*, 35 941-950.

18. Smith P., Smith J.U., Pawlson D.S., McGill W.B., Arah J.R.M., Chertov O.G., Coleman K., Frmko U., Frolking S., Jekinsan L.S., Kelly R.H., Klein-Gunneweik H., Komam A.S., Li C., Molina J.A.E., Mueller T., Parton W.J., Thornley J.H.M. and Whitmore A.P. (1997), A comparison of the performance of nine soil organic matter models using datasets from seven long term experiments. *Geoderma*. 14(5) 113-222.

19. Yongqiang Z., Tang Y., Jie J. and Yang Y. (2007). Characterizing the dynamics of soil organic crabon in grasslands on the Qinghai-Tibetan Plateau.Science ibn china Series D., *Earth Science*, 50, 113-20.