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Research Article

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Carbon Sequestration by Mandarin Tree in Nepal: An Empirical Study

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Abstracts

Nepal has immense potential of fruit tree cultivation. These fruit trees are a good source of carbon reserve. But these fruit orchards do not account for carbon trade in Nepal. This could be due to limited information on carbon sequestered by these commodities. An empirical study on the amount of carbon sequestered by mandarin trees at Dhankuta was conducted using both seedling and grafted 70 mandarin trees of 8-50 years of age. The amount of carbon sequestered was 0.24-1.22 ton/ha by native mandarin variety cv. Khoku local in Dhankuta district Nepal. The rate of carbon accumulation is around 0.02 t/ha/yr. This kind of study needs to be carried out in different parts of the country to make robust estimation using different types of citrus species and their varieties. Further, government of Nepal should consider fruit orchard while doing carbon trading business.

Keywords : Carbon, mandarin, Nepal, sequestered

Introduction:

Tree fruit crop is of immense importance in mid hills and Terai region of Nepal whether it be citrus or mango (Acharya et al., 2021). They have ecological, economic, and environmental importance (Sharma et al., 2021). Citrus fruit trees can be grown from 100 to 1600 meters above sea level. Nepal has been involved in initiatives related to Reducing Emissions from Deforestation and Forest Degradation (REDD+) and forest carbon trading. REDD+ aims to incentivize developing countries to reduce emissions from deforestation and forest degradation, as well as promote conservation, sustainable management of forests, and enhancement of forest carbon stocks. Through REDD+ mechanisms, countries like Nepal could potentially receive financial incentives for preserving their forests, which act as carbon sinks (MoFE, 2018). Trees outside forests including fruit orchards have still not accounted as carbon sinks. Hence the citrus trees which are planted around 50253 ha area in Nepal (MoALD, 2022) have been left out as it is not considered the forest. In addition to citrus, there are many fruit trees such as mango, litchi, apple, and pears which need to be accounted for this carbon trade as all these fruit orchards cover more than 177568 ha areas in Nepal (MoALD, 2022). In Australia, the government are using their Macadamia plantation for carbon business (Murhpy et al., 2012) and Nepal must include fruit trees for the carbon trade in near future. Hence an empirical study on carbon sequestration was carried out considering mandarin trees as a representative crop.

Materials and methods:

Study area:

The National Citrus Research Program (NCRP), Paripatle lies in Dhankuta Municipality, Dhankuta District, Nepal (Fig. 1). It lies at 26°59'54.3" N latitude to 87°18'44.6" E longitude and 1250 to 1390 meter above sea level (NCRP, 2003). The average annual maximum and minimum temperature were 29.36 and 4.33oC, respectively. The station received 1024 mm annual rainfall in the year 2019 (NCRP, 2020). The soil texture is sandy to sandy loam with gravel in some terraces. The soil pH was 4.5 to 6.2 with low (0.04%) to medium (3.33%) organic matter.

Sampling of mandarin trees:

The sampled mandarin trees were 8 -50 years old both grafted and seedling trees planted at 4 m x 4 m distance

All the authors declares that there is no any conflict of interest.

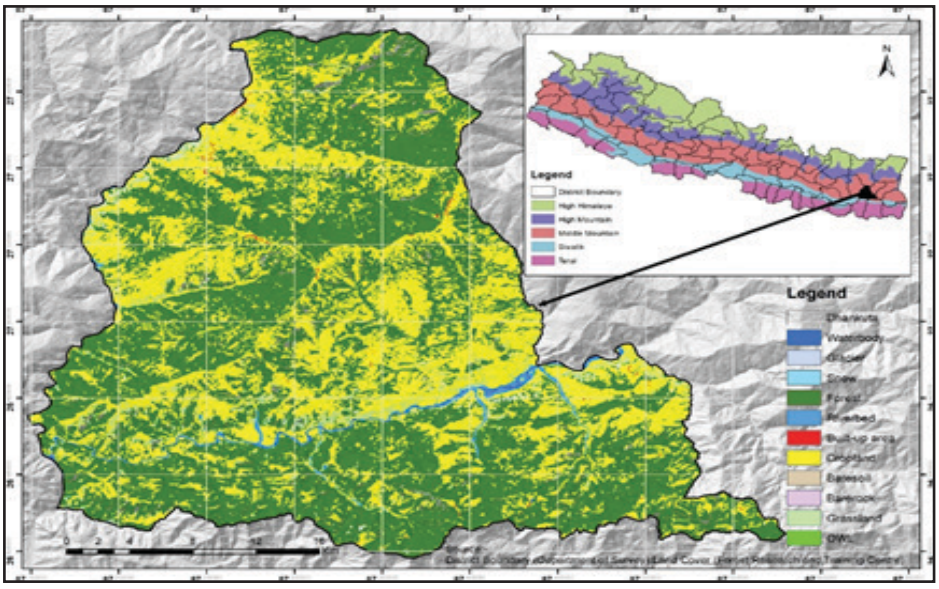

Fig 1: Location map of study area of National Citrus Research Program, Dhankuta

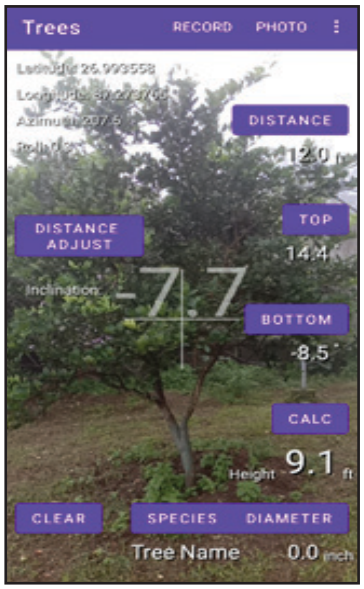

Fig 2: Features of mobile application Trees used for measuring tree height

in terraced land as shown in Table 1. For each age group trees were selected randomly from mandarin orchard of NCRP Dhankuta. The samples were collected on 26th July 2023. The sample numbers were 10 for 8- and 17-year-old trees; 15 for 20-, 30- and 35-year-old trees; and 5 for 50-year-old trees.

Calculation of Physical parameters:

Two important physical parameters for tree biomass calculations are tree height and weight which are needed for calculation of tree biomass (Timsina et al., 2019). The use of allometric method needs destruction of tree sample and which is not possible, and an empirical (algometric) approach has been employed in this study. The tree height was measured using a mobile application (Trees Ver 4.1.8 2023/5/10 @ 2019 Forest Monitoring Tools; Fig. 2) from android platform. The trunk diameter at breast height (1.3 m) was measured using a measuring tape (Timsina et al., 2019). Considering the trees are tapering on its top, the tree volume is calculated using the following formula:

Tree volume (cm3) = 1/3 (π dbh2/4 × h)---------- Equation 1

Where, π= 3.14, dbh= Tree diameter at breast height, and h= Tree height

Allometric calculation of tree carbon content:

The above-ground biomass (AGB) and the below-ground biomass (BGB) constitute the total biomass of a tree. The AGB accounts for all the visible plant parts like bark, leaves, branches, stem, fruit, seeds, etc. above the soil while the BGB accounts for all the live roots at least 2 mm in diameter below the soil surface. Both these biomasses constitute the total biomass of a tree and are generally expressed as tons per hectare (Ravindranath and Ostwald 2008).

The above-ground biomass was calculated using the following equation as used by Timsina et al. (2019)

Dry weight of the tree as AGB (kg)= [V × WD (g/cm3)] / 1000-------- Equation 2

Where, V= Tree volume (cm3), WD= Wood density (g/cm3)

The volume of the tree was calculated as equation 1 stated above. The wood density values differ with plant type and species. The value for citrus species is considered 0.59 (Cairns et al., 1997).

The BGB measurement is very costly and time-consuming. Hence it is estimated based on the AGB measurement using an algometric equation as follows:

The dry weight of the root biomass as BGB (kg) = R x dry weight of the tree or AGB (kg)---- Equation 3.

Where R= root to shoot ratio. The R-value is derived from the literature as 0.26 as reported by Cairns et al (1997).

Carbon sequestration estimation:

The total biomass of a tree is sum of the AGB and BGB. The total biomass is used for calculation of carbon sequestered by a tree (Murhpy et al., 2013) and expressed as ton per hectare using the following formula:

CO_2 sequestered (t/ha) = Total biomass × 0.5---------- Equation 4

When the value obtained from the equations number 4 is divided by the age of the tree it provides the value of CO_2 sequestered by a particular tree species in ton per year.

Results:

A description of sampled mandarin trees and their clas-

sification based on the age of the trees and the method of their regeneration (grafted/ seedlings) are shown in Table 1. The classification was done to get a better picture of various aspects of the study. The algometric estimation was done for each sampled tree and converted to a hectare basis using the total plant population per hectare as shown below. The data were recorded on MS Excel and analyzed using R-based open-source software Jamovi stat V 2.2.

erage of 2747 cm3 (Table 1). Relatively lower volume was from 8-year-old trees and relatively higher volume was from 50-year-old trees. The tree volume has shown a highly significant positive correlation with the tree age and tree height (Fig. 3 and 4).

Above ground biomass (AGB):

Above ground biomass ranged from 0.60 to 3.10 kg with an average of 1.62 kg (Table 1). Relatively lower bio-

Table 1 : Tree physical parameter and estimated carbon pool of mandarin trees of various age groups.

Tree Age (yr)	Plant Type	Tree Height (cm)	Diameter at Breast height (cm)	Tree Volume (cm3)	AGB (Kg)	BGB (Kg)	Total Biomass (Kg)	CO2 Sequestered (t/ha)*	CO2 Sequestered (t/ha/yr)+
8	Grafted	409.00	11.72	1023.00	0.60	0.16	0.76	0.238	0.0297
17	Grafted	375.00	14.88	1064.00	0.63	0.16	0.79	0.247	0.0145
20	Grafted	557.00	25.00	2030.00	1.20	0.31	1.51	0.472	0.0236
30	Seedling	549.00	62.60	3179.00	1.88	0.49	2.36	0.739	0.0246
35	Seedling	645.00	68.00	3929.00	2.32	0.60	2.92	0.913	0.0261
50	Seedling	676.00	111.80	5257.00	3.10	0.81	3.91	1.220	0.0244
	Grand mean	535.17	49.00	2747.00	1.62	0.42	2.04	0.64	0.02
	Standard deviation	66.83	6.40	519.17	0.31	0.08	0.39	0.12	0.004

Note:* t/ha- ton per hectare; + t/ha/yr- ton per hectare per year

Tree height:

The tree height ranged from 375 cm to 676 cm with an average of 535 cm (Table 1). The 17-year-old tree had relatively lower plant height due to severe pruning practice as these were from high-density planted blocks whereas relatively taller trees were 50-year-old. Hence there was increasing plant height with increasing tree age except for 17-year-old grafted trees.

Tree volume:

Tree volume ranged from 1023 to 5257 cm3 with an av-

mass was from 8-year-old grafted trees and the relatively higher was from 50-year-old trees. The AGB has shown a very positive and significant correlation with trunk diameter at breast height (DBH) and tree volume (Table 2).

Below Ground Biomass (BGB):

The tree biomass below ground ranged from 0.16 to 0.81 kg with an average of 0.42 kg (Table 1). The relatively lower biomass was from 8-year-old and the higher was from 50-year-old trees. The relationship of BGB was significantly positive with DBH and tree volume (Table 2).

Table 2 : Correlation matrix of tree physical parameters and sequestered carbon content.

Parameter	Trunk Diameter(cm)	Tree Volume (cm3)	AGB (Kg)	BGB (Kg)	Total Biomass (Kg)	CO2 Sequestered (t/ha)	CO2 Sequestered (t/ha/yr)
Trunk Diameter (cm)	1						
Tree Volume (cm3)	0.948 (<.001)	1					
AGB (Kg)	0.948 (<.001)	1 (<.001)	1				
BGB (Kg)	0.948 (<.001)	1 (<.001)	1 (<.001)	1			
Total Biomass (Kg)	0.948 (<.001)	1 (<.001)	1 (<.001)	1 (<.001)	1		
CO2 Sequestered (t/ha)	0.948 (<.001)	1 (<.001)	1 (<.001)	1 (<.001)	1 (<.001)	1	
CO2 Sequestered (t/ha/yr)	0.336 (<.002)	0.41 (<.001)	0.41 (<.001)	0.41 (<.001)	0.41 (<.001)	0.41 (<.001)	1

Note: value in parenthesis are the p values and outside the parenthesis are Pearson's correlation coefficient (r) values; ABH- above ground biomass, BGB- below ground biomass, t/ha- ton per hectare; +t/ha/yr- ton per hectare per year

Total Biomass:

Total tree biomass is the sum of AGB and BGB and it ranged from 0.76 to 3.91 kg with an average of 2.04 kg (Table 1). The relatively lower biomass was from 8-year-old grafted trees and the highest was from 50-year-old trees (Fig. 3). Total biomass was highly significant with tree age and types of trees (grafted/seedling origin) (Table 1 and Fig. 3).

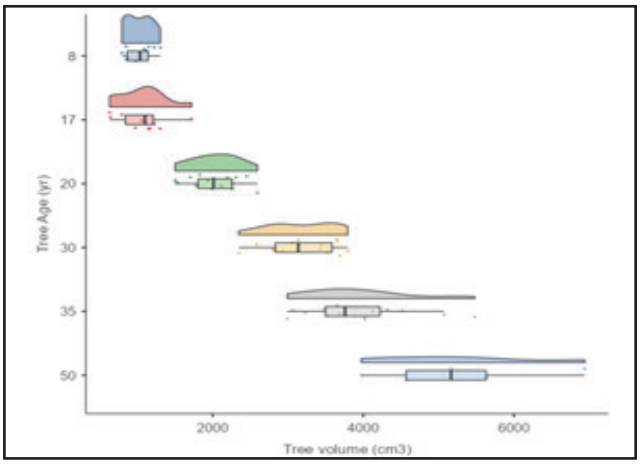

Fig 3: Mandarin tree volume based on age group

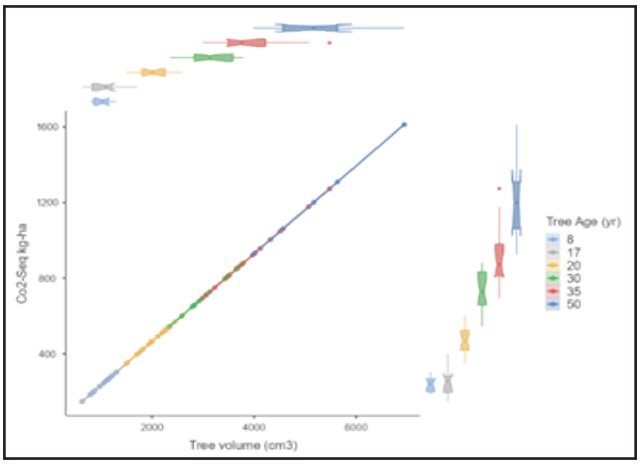

Fig 4: Relationship of tree volume with amount of carbon sequestered by mandarin tree (Kg/ha)

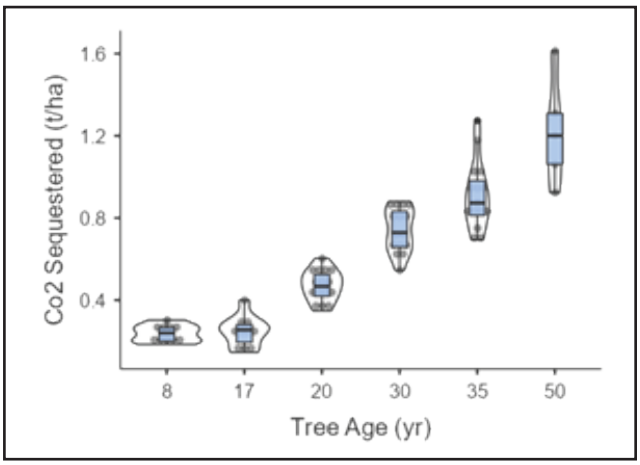

Fig 5: Amount of carbon sequestered (t/ha) by mandarin tree based on tree age

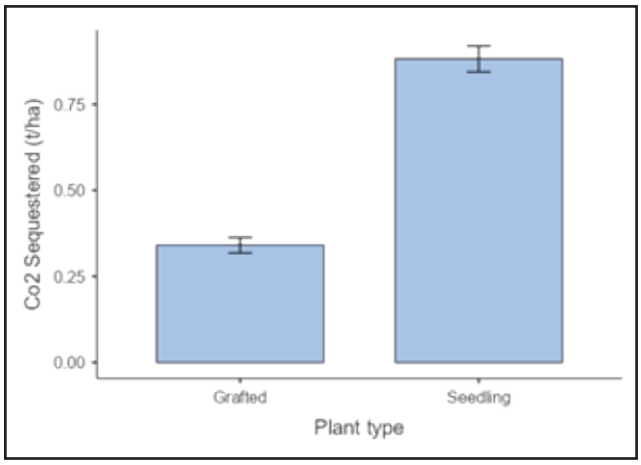

Fig 6: Amount of carbon sequestered (t/ha) by mandarin tree based on plant type

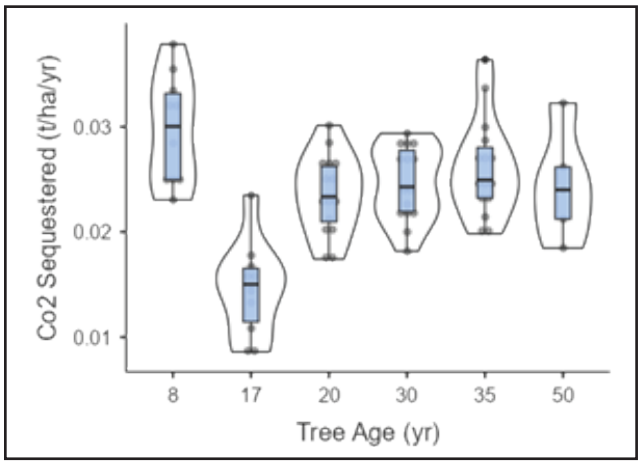

Fig 7: Amount of carbon sequestered by mandarin tree based on tree age (t/ha/yr)

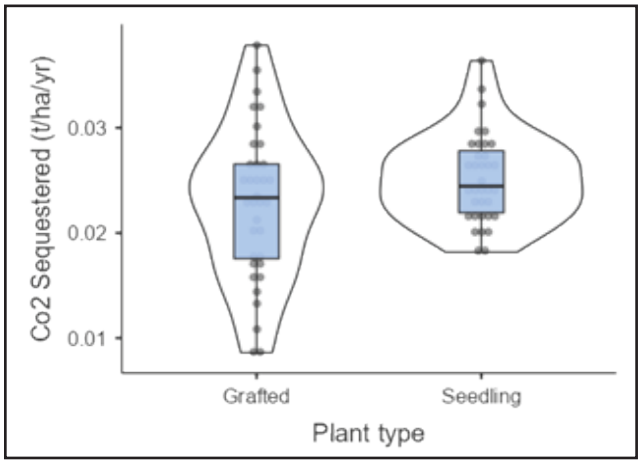

Fig 8: Amount of carbon sequestered by mandarin tree based on plant type (t/ha/yr)

Carbon sequestered:

The carbon sequestered per hectare by mandarin tree ranged from 0.238 to 1.220 (t/ha with an average of 0.64 (t/ha) (Table 1). The lower amount of carbon was sequestered by 8-year-old trees and the higher was from 50-year-old trees (Fig. 5). Further, the carbon sequestered by mandarin orchards per year was in a range of 0.0145 to 0.0297 with an average of 0.0239 t/ha/year (Table 1).

There was no definite relation between the yearly sequestered carbon and the age of the tree (Fig.7). The carbon sequestered (ton/ha and ton/ha/year) was found to be highly significant in relation to tree age and types of trees (grafted/seedling origin, Table 2 and Fig. 8).

Discussion:

Forest trees are considered a good source for balancing the ecosystem with the deposit of excess carbon produced by our modernized society. Hence Nepal government has obtained a good appraisal of carbon balance from the global arena (MoFE, 2018). However, the fruit trees covering 177,569-ha area are still unaccounted for carbon credit (MoALD, 2022). Among these fruit crops, mandarin alone accounts for 26591 ha in Nepal. There is limited information available on carbon sequestration by fruit crops in Nepal and this study could serve as a model for future investigation. A study from India on Nagpure mandarin found that the carbon sequestration was 1.65 ton/ha (Mehta et al., 2016) whereas in this study it was 0.34 t/ha and 0.88 t/ha for grafted and seedling origin trees, respectively (Fig. 6). The difference in tropical Nagpur climate and sub-tropical Dhankuta climate, as well as different management practice, could be the reason for this difference (Wembede et al., 2022). The carbon sequestered by the mandarin (C. reticulata) orchard/year in this study is quite low as compared to the orange (C sinensis) orchard 0.5-1.8 ton/ha/yr. as reported by Liguori et al (2009). This could be due to differences in species, climatic and spatial variations of two locations (Sharma et al., 2021).

Conclusion:

This empirical study is an example of streamlining the fruit orchard into carbon trade which could benefit Nepal as there is nearly two hundred thousand orchards have gone unrecorded into the business. The present study is a preliminary work on carbon sink estimation of citrus trees and several other studies need to be conducted including more citrus species, and their varieties across multiple environmental sites to make robust carbon estimation. Further, the government of Nepal should consider fruit orchards also for future carbon trade.

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Declaration of conflict of interest and ethical approval:

UK Acharya was involved in designing the experiment. A Katuwal was involved in collecting the field data. UK and AK Acharya were involved in writing the manuscript. All the authors have read the manuscript before submitting it to the Journal Nepalese Horticulture and declares that there is no competing interest regarding the current manuscript.

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