

# Application of Google earth in carbon assessment and monitoring in agroforestry: a study from Ratanpur, Nepal

## Abstract

The carbon assessment and monitoring in small scale forests like agroforests are difficult tasks but it creates enormous opportunity as carbon credit. This study aims to assess carbon sequestration potential in agroforestry including soil carbon using google earth imageries. Agroforestry of Ratanpur village in Tanahun district Nepal was selected as the study site. Total agroforests of 19 farmers were selected as the experimental and no agroforests area of 4 farmers were selected as the control site. The high resolution imageries of 2020 and 2015 were acquired from Google earth pro. The digitization was done to classify the image into agriculture, agroforestry, natural trees, settlement areas and others. Total enumeration was done to measure the diameter and height of the plants (tree species) planted in the agro-forest. Moreover, total 69 soil samples were collected from 0-10, 10-20 and 20-30 cm depth. The biomass was calculated using Chave *et al.* equation while soil carbon was analyzed using Walkley Black method. The biomass was converted into carbon which was used to calculate mean annual carbon increment. The result showed the highest carbon stock was 17.6 kg/ stand of *Paulownia tomentosa*. Total carbon sequestration potential was 2057.689 kg and its monetary value was US\$ 30.863. The mean soil carbon stock of agro-forest was higher 52.92 ton/ha than this of 50.3 ton/ha in agriculture site. The map showed it was 7.63 ha agroforest in map of 2020. The overall accuracy of map of 2015 was 90.91% with Kappa coefficient 0.86 but these values were 80.65% and 0.74 respectively of map of 2020. One-way ANOVA and Post hoc test showed that there was significant difference in species wise carbon stock per stand at 95% confidence level. The research will be useful to understand the carbon stock in agroforestry practices.

**Keywords:** agroforestry, plantation, carbon sequestration, land use land cover

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## Introduction

### Background

According to definition given by Ellis et al.,<sup>1</sup> Lal,<sup>2</sup> agroforestry is the system of mixture of two or more land use and land cover practice where the forestry activities are the prime one. The statistics showed that approximately 630 million ha land is potential for agroforestry activities which may be able to sequester around 586 Mt C by 2040.<sup>3</sup> It is estimated that 0.29MgC/ha/yr. in West Africa, 15.29MgC/ha/yr. in Puerto Rica, 161.52MgC/ha in Philippines 287.9C/t/ha in Indonesia, 3.8- 4.82t/ha/yr carbon has been stocked in agroforestry in India.<sup>4</sup>

Carbon sequestration is the process of removal of carbon from the atmosphere.<sup>5</sup> One of the important examples of carbon sequestration is reducing deforestation and forest degradation, sustainable forest management as well as plantation. Globally, around 1 - 4 billion t CO<sub>2</sub> can be reduced through minimizing and stopping deforestation and forest degradation.<sup>6,7</sup> Agroforestry is one of the important practices which can contribute to sequester the carbon, meet the demand of basic forest products as well as reduce the deforestation and forest degradation.<sup>8-10</sup>

The monitoring reporting and verification is one of the important components of carbon credit<sup>11,12</sup> under the Reducing Emission from Deforestation and Degradation (REDD+) mechanism. This needs the reliable method of assessment and monitor carbon in order to determine the carbon credit. Importantly, REDD+ mechanism emphasizes on the application of remote sensing and GIS in monitoring the carbon credit in the forest.<sup>13</sup> The spatial and temporal change detection considered as

the appropriate way to monitor the forest carbon;<sup>14</sup> Rawat & Kumar.<sup>15</sup> If the high resolution imageries are available on Google Earth platform which is freely available the change detection in land use and land cover will be more easier.<sup>16</sup> Countries like India, Bangladesh, and Pakistan including Nepal are practicing the small scale plantation as agroforestry system where the carbon assessment and monitoring is difficult. Nepal also has been practicing several model of carbon sequestration and agroforestry practices. In this context, there is big challenge to monitor and assess the carbon sequestration in small scale forestry like agroforest. However, comparison of features in two periods of imageries is becoming popular method of carbon assessment and monitoring.<sup>17</sup> This change detection will be useful techniques to quantify and monitor the carbon stock change in agroforests.<sup>18</sup> However, there is limited study regarding this. Thus, this research was objectively conducted to assess carbon sequestration potential in agroforests applying google earth high resolution imageries.

### Rational and justification

The agroforest is the best example of carbon sequestration in small scale forestry. This can meet the criteria to trade the carbon but monitoring is accreditation and monitoring is difficult because it is costly. The owner of such small scale agro-forest cannot afford the accreditation and monetary cost. In this context, application of google earth imageries is cheap, easy and convenient method to monitor the carbon. The high resolution imageries also available on google earth platform. The forest and other non-forest areas can be delineated easily on digitized of imageries of different time period which can be used as the change in forest areas in the farm. This types of change

can be used as carbon additionality which is one of the important criteria of REDD+ activities. However such methods are not explored to research purpose widely. Thus, this research is essential to show the application of google earth imageries to monitor the carbon. This method can be useful for carbon credit buyer to monitor the small scale agroforest.

## Materials and methods

### Study site

The plantation in Ratanpur village was selected as the study site. This village is situated in Bhanu Municipality of Tanahun District,

Nepal. Geographically, the study site is at 28.03°N and 84.44°E and elevation ranges from 300 to 3300m (Figure 1). The average temperature from 11°C to 24°C and total annual rainfall is around 1377mm. Hence, the vegetation types are generally subtropical to lower temperate. There are 39 farmers in Ratanour village. Out of this agroforests of 19 farmers were selected as the study site since they have been applying the agroforestry practice. *Paulownia tomentosa*, *Golden michelia*, *Cinnamomum tamala*, *Melia azedarach*, *Mangifera indica*, *Schima wallichii*, *Quercus leucotrichophora*, *Leucaena leucocephala*, *Choerospondias axillaris*, *Azadirachta indica* plant species are afforested in the farm.

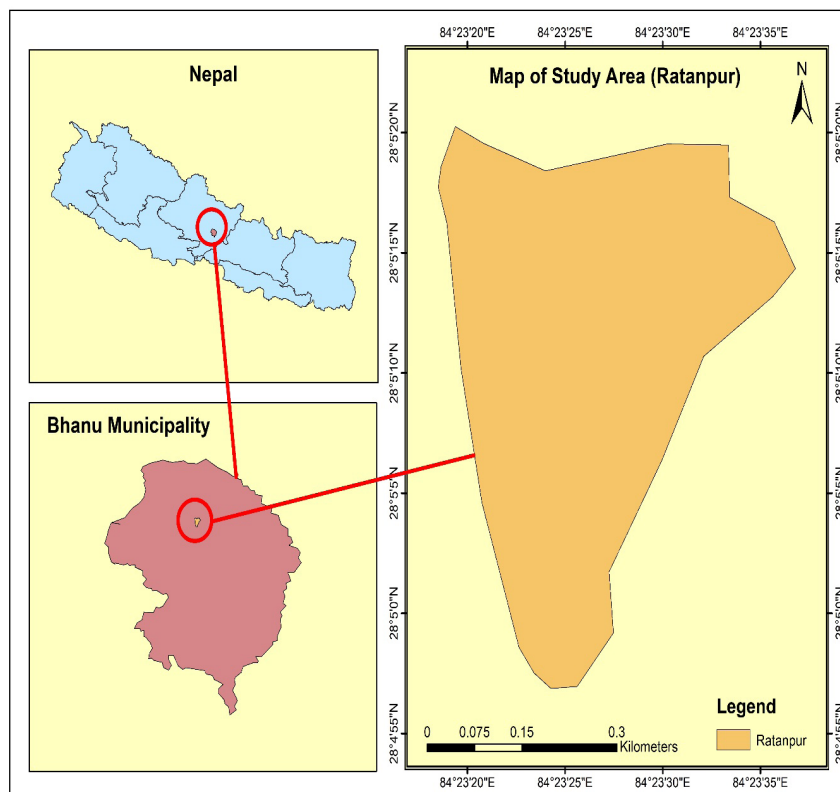


Figure 1 Map of study area.

### Selection of study site and parameter

The plantation of Ratanpur village is situated in remote area of Lamjung district. The farmers are generally practicing the agriculture in their land but them also practicing agroforestry in the farm particularly in degraded land. They have been planting tree and growing grasses under it so that they can feed the livestock. These agroforestry practices here in rural area are one of motivation site for the people. Moreover, the farmers are interested to work with REDD+ mechanism but they are unknown about accreditation and monitoring process which is prerequisite for this mechanism. Thus this site was selected. The agroforest practices are clearly visible to digitize and delineate agroforest area.

In fact, four parameters are very important to assess the carbon. These parameters are change is forest land, diameter at breast height, height of the tree and species wise wood density. The field level carbon assessment used to know the carbon sequestration which can be claimed as carbon credit. The above ground, below ground and soil carbon is the estimation parameter which is used to assess the total carbon and its monetary value.

### Data collection

Primary and secondary data were collected to meet the objectives of the research. Primary data were collected from field observation, direct measurement and laboratory analysis while the secondary data and information were collected from internet surfing, reports, published and unpublished papers. The site was categorized into two main groups namely control site and experimental site. The record of assessment of carbon stock was used as a baseline for experimental site. The plantation area in agroforestry system was considered as the experimental site whereas, Control site (agriculture land) was established near the experimental site in order to compare the carbon increment. For this purpose, total 19 experimental sites and 4 control sites were established to collect the data.

The primary data collection was conducted applying three major steps. They were bio-physical data collection, soil data collection and spatial and temporal data collection.

**Bio-physical data collection:** The diameter at breast height (DBH: at 1.3m height) and height of individual trees (DBH>30cm), pole (DBH

=10-29.9cm) and sapling (DBH> 5cm) were measured in the field. Moreover, all the saplings (1cm <DBH< 5cm), seedlings, herbs and shrubs were counted in the field and their fresh weights were recorded making the sub-sample to find the moisture content. The age of the plants will be recorded from plantation records as well as the asking with the owners.

**Soil data collection:** Soil carbon is significantly contributing to total carbon. Total 69 soil samples were collected using known volume soil corer from control site and experimental site maintaining the soil depths of 0-10, 10-20 and 20-30 cm. These samples were placed in the labeled sample bag in order to analyze the carbon in the lab.<sup>19</sup>

### Spatial and temporal data collection

The spatial temporal land use change detection using the Google earth data is of very importance and very useful as spatial temporal of land use detection for land use mapping.<sup>20</sup> The integration approach between remote sensing and GIS was applied to find the change detection so, the Google earth was as the source of data. The survey was performed throughout the study area using global positioning system (GPS) receiver to prepare the map of the study area. The map of afforested area transformed into kmz file in order to overlaid on Google earth image. The afforested areas of farmers were digitized in the Google earth platform. The historical imagery was used to show the change detection.<sup>18</sup> Google earth image (high resolution imagery) of 2015 and 2020 was acquired from Google earth professionals (Table 1) in order to digitize on the GIS.<sup>21</sup>

**Table 1** Description of remote sensing data

Platform	Bands	Date of acquisition	Eye altitude (M)
Google earth professionals	RGB	5/8/2020	200
Google earth professionals	RGB	3/5/2015	200

### Data analysis

**Biophysical data and soil sample analysis:** Collected data were analyzed to estimate the carbon stock, mean annual carbon increment and carbon sequestration potential from the agroforestry area of all the farmers and also for all the species planted in the site.

#### a. Above ground biomass and carbon calculation

- Above ground tree and pole biomass calculation: Above Ground Tree Dry Biomass (AGTB) was calculated by using allometric equation<sup>22</sup> for tree, poles and sapling (DBH >5cm).

$$AGTB = 0.0509 \times \rho D^2 H$$

Whereas AGTB = above ground tree biomass (kg)

$\rho$  = dry wood density (gm/cm<sup>3</sup>), D = tree diameter at breast height (cm) & H = tree height (m)

- Above ground sapling biomass calculation (DBH< 5 cm): The biomass was calculated using the equation compiled by Tamrakar et al.,<sup>23</sup> and its samples were taken to get dry biomass as this allometric equation provides only the fresh weight.

Moreover, the samples of sapling (DBH< 5cm), seedling, leaf litter, herbs and grass (LHG) together were carried out in the laboratory to dry. The biomass of sapling, seedling and LHG of sampled area was estimated which was further used to calculate biomass per ha.

#### b. Below ground biomass and carbon calculation

- Root Biomass calculation: Default value i.e. root shoot ratio 0.125 was used<sup>24</sup> to calculate the root biomass.
- Conversion factor: Similarly, the universal conversion factor i.e. 0.47 was used to convert dry biomass to carbon content.<sup>25</sup>
- Soil Organic Carbon (SOC): The collected soil samples were brought to the laboratory to determine the carbon content. The soil samples were oven dried at 105°C in the laboratory until they reached a constant weight to estimate soil bulk density.<sup>26</sup>

Bulk Density (gm/cm<sup>3</sup>) = (oven dry weight of soil)/ (volume of soil in the core).

The soil samples were analyzed by Walkley & Black Method<sup>27</sup> by digestion using Sulphuric acid and oxidized by the Potassium dichromate in laboratory. The soil samples were oven dried at 105°C to obtain constant weight.

For calculation of soil organic carbon (SOC), the following formula was used.<sup>28</sup>

$$OM\% = (B-S) \times N \times 3 \times 100 \times 100 / \text{wt. of soil} \times 1000 \times 77 \times 58$$

$$OM\% = (B-S) \times N / \text{wt. of soil} \times 0.67$$

Where, B= Volume of FAS used up for blank titration

S= Volume of FAS used up for sample

N= Normality of FAS from blank titration

Wt. = Weight of sample.

Note: Organic matter contains 58% carbon. Recovery factor for this method is 77 percent. Equivalent weight of carbon is 3.

SOC= Organic Carbon Content % \* Soil Bulk Density (gm/cm<sup>3</sup>) \* thickness of horizon

Whereas SOC = soil organic carbon stock, C = carbon concentration

$\rho$  = soil bulk density (gm/cm<sup>3</sup>) & d= total depth at which the sample was taken (cm).

#### c. Total carbon calculation

Following formula was used to calculate the total carbon.

$$C (LU) = C (AGTB) + C (AGSB) + C (BB) + C (LHG) + SOC$$

Where, C (LU) = Carbon stock for a land use category

C (ABTG) = Carbon in above ground tree biomass

C (AGSB) = Carbon in above ground sapling biomass

C (BB) = Carbon in below ground biomass

C (LHG) = Carbon in litter, herb and grass

SOC = Soil Organic Carbon.

Carbon sequestration potential: The species wise carbon sequestration was estimated using the following formulas:

$$\text{Carbon increment} = \text{total carbon} / \text{Age}$$

$$\text{Carbon sequestration potential} = \text{Carbon increment} \times 44 / 12$$

Total Carbon sequestration potential= Carbon Sequestration potential per stand \* Total no. of stand<sup>29</sup>

Monetary value of carbon sequestration= Total carbon sequestration \*US\$15(per ton) (The True Cost of Carbon Pollution, 2020).

## Spatial data analysis

The Google earth imagery was geo-referenced and required land use features shape file of Agriculture, Agroforestry, Settlement area, Road and Natural trees was created in the Arc GIS. Next, the map of the study area was overlaid on the geo-referenced image and on-screen digitization was made to map land use land cover based on their geometric boundaries.<sup>30</sup> Finally, change detection in different land use classes was compared.

**Accuracy assessment:** Accuracy assessment is an important part of a classification which was evaluated using confusion matrix. The ground truth points of different land use and land cover classes were collected from field and these were overlaid on the digitized map. This was done for classified map of 2020. For the accuracy assessment of map 2015 ground truth points were collected from historical imagery provided by the Google earth and overlaid on the digitized image.

**Error of omission (OE) and commission (EC):** Error of omission refers to the reference sites that were left out from the correct class in the classified map. The real land cover type was left out or omitted from the classified map. The errors of omissions were calculated by reviewing the reference sites for incorrect classifications. Similarly,

the error of commission was calculated by reviewing the classified sites for incorrect classifications.

**Overall accuracy and Kappa coefficient:** The overall accuracy shows where all referenced sites were classified correctly. Similarly, the Kappa Coefficient is generated from a statistical test to evaluate the accuracy of a classification.

$\text{Kappa Coefficient} = (\text{total accuracy} - \text{random accuracy}) / (1 - \text{random accuracy})$ .

**Statistical analysis:** The One-way ANOVA test Post hoc test was performed to compare the species wise carbon stock in the agroforests.

## Result

### Carbon status of agroforestry at ratanpur

**Carbon status in agroforest:** The Table 2 shows that descriptive statistics of above ground total carbon, below ground total carbon and total carbon in kg. The estimated highest and lowest total carbon was 3482.41 and 127.39 kg respectively. The maximum total carbon was 3482.41kg/ha while the minimum was 127.39 kg/ha. The average and standard error of total carbon was 1555.01±281.42kg. The above ground carbon was 1335.22±249.57kg, below ground carbon was 219.79±31.98kg while the soil carbon was 53.27±3.19. However, the Standard deviation of these parameter.

**Table 2** Statistics of carbon stock of agro-forest in farm land

	Mean±SE	Standard deviation	Sample variance	Range	Minimum	Maximum
Above ground carbon (kg)	1335.22±249.57	1087.87	1183470	65.51	45.63	3025.8
Below ground carbon (kg)	219.79±31.98	139.4	19434.41	396.12	60.5	456.2
Total carbon (kg)	1555.01±281.42	1226.69	1504780	3355.02	127.39	3482.41

(Source: Field Survey, 2020)

### Species wise number of stand and carbon status

The highest number of planted tree species was *Cinnamomum tamala* with 973 which was followed by *Michelia champaca* with 652 stands, *Leucaena leucocephala* with 54 stands, *Bauhinia*

*purpurea* with 50 stands, *Paulownia tomentosa* with 41 stands, *Melia azadirach* with 38 stands, *Morus indica* and *Schima wallichii* with 27 stands, *Ficus cunia* with 22 stands, *Artocarpus lakoocha* with 14 stands, *Mangifera indica* and *Choerospondias axillaris* with 1 stand (Table 3).

**Table 3** Species wise number of stands and carbon stock

	No of stands	Carbon (Kg/stand)	Remarks
<i>Melia azadirach</i>	38	14.42	
<i>Leucaena leucocephala</i>	54	1.16	
<i>Michelia champaca</i>	652	16.55	
<i>Ficus cunia</i>	22	4.71	
<i>Cinnamomum tamala</i>	973	1.32	
<i>Paulownia tomentosa</i>	41	17.61	
<i>Bauhinia purpurea</i>	50	1.47	
<i>Morus indica</i>	27	2.88	
<i>Schima wallichii</i>	27	1.99	
<i>Mangifera indica</i>	1	1.57	
<i>Choerospondias axillaris</i>	1	9.32	

(Source: Field Survey, 2020)



The highest carbon stock was found around 17.6 kg/ stand of *Paulownia tomentosa* plantation. This was followed by *Michelia champaca* with 16.5 kg /stand. The lowest value of this was found in *Leucaena leucocephala* with 1.1 kg /stand (Table 3). Statistically, One-way ANOVA showed that there were significant differences in carbon per stand among the species since the p value was less than 0.05. Post hoc test showed that carbon stock per stand of *Leucaena leucocephala*, *Bauhinia purpurea*, *Cinnamomum tamala* and *Litsea polyantha* was different from carbon stock of other species at 95% confidence level since the mean carbon values of these species falls under same subset.

### Species wise carbon sequestration potential

#### Carbon sequestration and monetary value of sapling staged plant:

The carbon sequestration in plantation was varying according to species. The monetary value of carbon sequestration was also differed accordingly. Total carbon sequestration was 2057.689 kg and its monetary value was US\$ 30.863. The results showed that the highest annual carbon sequestration potential was of *Ficus cunia* with 4.327

kg /stand. Since, the number of stands of *Michelia champaca* was the highest at saplings stage therefore the monetary value of carbon sequestration was found to be highest with US\$22.68/ton.

#### Carbon sequestration and monetary value of pole staged plant:

The result revealed that the highest annual carbon sequestration potential of *Paulownia tomentosa* at pole stage with 18.63kg/stand. Since, *Paulownia tomentosa* is the only species with large number of poles the monetary of carbon sequestration was found to be highest with US\$3.91. Total carbon sequestration was 475.013 kg and its monetary value was US\$ 7.122.

#### Carbon sequestration and monetary value of Sapling DBH<5 cm staged plant:

The species wise carbon sequestration was differed of sapling DBH<5 cm and the monetary value of this were also varied. The results showed that, total carbon sequestration was 213.38 kg and its monetary value was US\$ 3.201. The highest annual record of carbon sequestration was 0.38 kg/stand of *Morus indica* while the number of stands was the highest of *Cinnamomum tamala* so the carbon sequestration was the highest 141.15 kg and its monetary value was US\$ 2.12 (Table 4).

**Table 4** The highest annual record of carbon sequestration

Species	Carbon sequestration potential (kg/stand)	Total Carbon sequestration potential (kg)	Monetary value of carbon sequestration (US\$)	Carbon sequestration potential (kg/stand)	Total Carbon sequestration potential (kg)	Monetary value of carbon sequestration (US\$)	Carbon sequestration potential (kg/stand)	Total Carbon sequestration potential (kg)	Monetary value of carbon sequestration (US\$)
	Tree stage			Pole Stage			Sapling stage		
Melia azadirach	3.263	97.9	1.468	10.267	82.13	1.232			
Leucaena leucocephala	0.99	51.48	0.772				0.069	0.139	0.002
Michelia champaca	3.19	1512.06	22.68	13.457	121.11	1.82	0.348	58.87	0.88
Ficus cunia	4.327	95.187	1.428						
Bauhinia purpurea	1.008	19.158	0.287				0.29	9.093	0.14
Cinnamomum tamala	1.052	33.675	0.505				0.15	141.15	2.12
Paulownia tomentosa	2.677	69.593	1.044	18.63	260.77	3.91			
Morus indica	2.578	59.286	0.889				0.38	1.525	0.02
Artocarpus lakoocha	2.567	35.933	0.539						
Schima wallichii	3.703	74.067	1.111				0.183	1.283	0.02
Litsea polyantha	2.64	7.92	0.119				0.33	1.32	0.019
Mangifera indica	1.43	1.43	0.021						
Choerospondias axillaris				11.003	11.003	0.16			
Total		2057.69	30.863		475.013	7.122		213.38	3.201

### Soil carbon stock at study site

From 19 farmers of the experimental site whose soil carbon stock was analyzed, the average soil carbon stock  $\pm$ SE was found to be 52.9 $\pm$ 3.21 ton per ha which was greater than that of average  $\pm$ SE of 4 control site i.e. 50.34 $\pm$ 3.82 ton per ha. The SOC of forest depend upon various biotic and abiotic factors such as micro-climate, faunal diversity, land use, land management and crops.<sup>31</sup> It shows that the mean of the soil organic carbon was decreased along with the depth of the soil.

The clear trend was seen in soil carbon according to the soil depth. It was the highest in 0-10cm while the lowest value was in 20-30cm depth in all the control site and experimental site. The soil organic carbon (SOC) was decreased with the increase in soil depth in all the control site (Agriculture land) and experimental site (Agroforestry land). All the agroforestry land and the agriculture land contained greater SOC in the upper layer 0-10cm followed by 10-20cm and 20-30cm depth respectively (Table 5).

**Table 5** Statistics of soil organic carbon of experimental and control site

Soil carbon ton/ha					
Land use		0-10 cm	10-20 cm	20-30 cm	Total carbon (ton/ha)
Agroforestry (experimental site)	Mean±SE	25.5±1.58	16.59±1.08	10.79±0.88	52.9±3.21
	SD	6.91	4.74	3.84	14.01
	Minimum	9.464	8.83	4.76	30.6
	Maximum	37.63	26.78	18.05	79.2
	Mean±SE	23.44±2.03	17.24±1.37	9.65±1.08	50.34±3.82
Agriculture land (control site)	SD	4.06	2.75	2.16	7.64
	Minimum	17.85	13.65	6.65	41.15
	Maximum	27.6	19.98	11.78	59.36

(Source: Field Survey, 2020)

#### Land use land cover dynamics of agroforestry between 2015 and 2020 at ratanpur:

The digitization of the google earth image 2020 showed five thematic classes namely agriculture, agroforestry, natural trees, settlement areas and others. Specifically, Agriculture land was 3.6 ha (18.01%), Agroforestry was 6.2 ha (31.03%), Natural trees area was 4.67 ha (23.37%), Settlement was 0.03 ha (0.15%) and other area was 5.48 ha (27.42%) of the total study area but agriculture was

10.12 (50.65), agroforestry was 0 ha, natural trees was 4.45 (22.27%), settlement areas was 0.024 ha (0.12%) and others was 5.38 (26.9%).

Comparison of land use land cover classes between 2015 and 2020 showed that there was negative change in Agriculture class but this was positive change in other land use and land cover thematic classes. Mainly agriculture land use class was reduced by 6.52 (32.64%) which was converted into mainly agroforest (6.2 ha, 31.03%) and Natural trees (0.22 ha, 1.1%) and so on (Table 6).

**Table 6** Change area of Ratanpur between 2015 and 2020

Land use land cover class	Classification of 2015		Classification of 2020		Changes between 2015 & 2020	
	Area (ha)	Percentage	Area (ha)	Percentage	Area (ha)	Percentage
Agriculture	10.12	50.65	3.6	18.01	-6.52	-32.64
Agroforestry	0	0	6.2	31.03	6.2	31.03
Natural trees	4.45	22.27	4.67	23.37	0.22	1.1
Settlement area	0.024	0.12	0.03	0.15	0.006	0.03
Others	5.38	26.9	5.48	27.42	0.1	0.52

(Source: Field Survey, 2020)

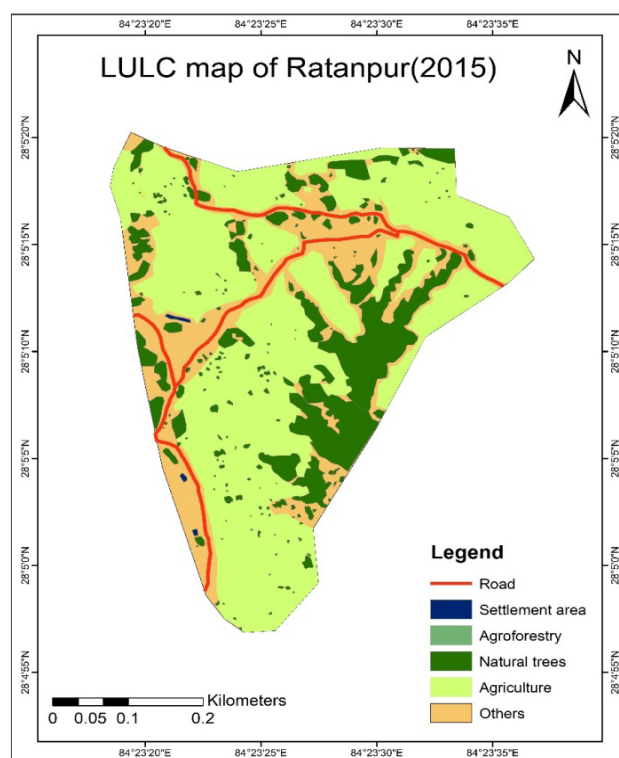
Carbon increment: The conversion of agriculture land to agroforest land resulted in the remarkable increase in carbon densities. It was only 509.442 ton carbon in 2015 which was reached to 606.916

in 2020. Thus the total increase in carbon stock in agroforest was 97.475ton (Table 7) (Figure 2) (Figure 3).

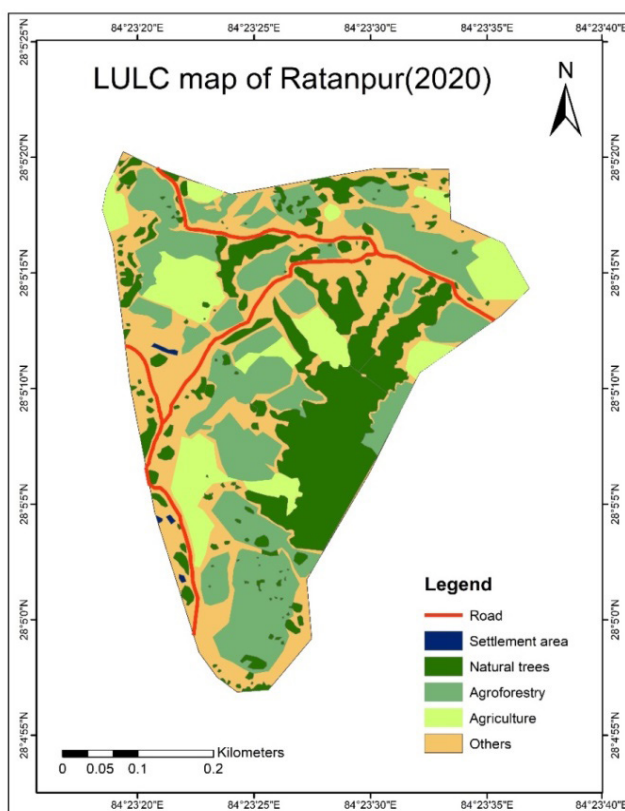
**Table 7** Increment in carbon

Detail	2015		2020	
	Agriculture	Agroforest	Agriculture	Agroforest
Area ha	10.12	0	3.6	6.2
C ton/ha	50.34	0	50.34	68.66
Total C ton	509.441	0	181.224	425.692
Total C: 606.916 ton in 2020. Increase in C between 2015 & 2020=97.475 tom				

(Source: Field Survey, 2020)



**Figure 2** Land-use land-cover map of Ratanpur (2015).



**Figure 3** Land-use land-cover map of Ratanpur (2020).

**Accuracy assessment for map of 2015 and 2020:** The overall accuracy for 2015 was 90.91% with Kappa coefficient 0.86. So, Kappa of 0.86 means there is 86% better agreement than by

chance alone in 2015. The summary of classification accuracy with producer's accuracy (PA), User's accuracy (UA), Commission error (CE) and omission errors (OE) is presented below in Table 8. The

overall accuracy for 2020 was 80.65% with Kappa coefficient 0.74. So, Kappa of 0.74 means there is 74% better agreement than by chance alone in 2020. The summary of classification accuracy with

producer's accuracy (PA), User's accuracy (UA), Commission error (CE) and omission errors (OE) is presented below in Table 8.

**Table 8** Summary of classification accuracy (%) for 2015

Accuracy Assessment of map of 2015				
Thematic Class	Producer's accuracy	User accuracy	Commission error	Omission error
Natural trees	100	100	0	0
Agriculture	87.5	100	0	12.5
Agro forestry	0	0	0	0
Road	100	50	50	0
Settlement	100	50	50	0
Others	80	100	0	20
Accuracy Assessment of map of 2020				
Natural trees	90	90	20	10
Agriculture	83.33	100	20	16.67
Agro forestry	66.67	85.71	28.57	50
Road	100	33.33	66.67	50
Settlement	0	50	100	0
Others	75	75	100	60

(Source: Field Survey, 2020)

## Discussion

This research describes about the carbon sequestration potential of agroforestry practices and comparing the soil organic carbon of agroforestry land with agriculture land, addresses land use land cover dynamics of study area Ratanpur, Tanahun during the period 2015 and 2020. The carbon stock in the experimental site denoted was found to be higher with 68 ton/ha than other because the site contained large number of trees with greater diameter and height and with greater number of planted plants. The carbon stock was generally higher in plantation site.<sup>32,33</sup> The influential role was found in carbon sequestration in agroforest area<sup>34</sup> in the study site.

The carbon status of *Paulownia tomentosa* was the highest carbon stock which was found to be 17.6kg stand because among all the planted species *Paulownia tomentosa* was the fast-growing species which had reached the pole size having the highest diameter and height.

Carbon sequestration potential of pole is greater than that of saplings because they sequester more carbon than others. Since, the planted species have not been grown to trees and few species has been to pole more carbon will be sequestered in the future from the saplings. Sized trees have better carbon sequestration potential than young plants and saplings.<sup>35</sup>

Soil carbon stock of the agroforestry land which was denoted by the experimental site was found to have higher potential to sequester carbon than that of agriculture, pasture or field crops which was denoted by the control site. This conjecture is based on the notion that tree incorporation in cropland pasture land would result in greater net above ground as well as below ground C sequestration.<sup>36</sup> The above result also reveals that the carbon is increased when converting agriculture land to agroforestry land as the number of trees and soil carbon is increased.<sup>37,38</sup> Carbon increment of pole, sapling, differ

for varying species. Carbon increment of pole is seen maximum in *Pauwlonia tomentosa* with 13.45kg/plant. Likewise, carbon increment of sapling is seen maximum in *Schima wallichii* with 2.72kg/plant.

The soil carbon was decreased with respect to soil depth in all selected control site and experimental site. All the sites contained greater SOC in the upper layer 0-10cm followed by 10-20 and 20-30cm depth. This may be attributed by the fact that higher amount of humus was present in the top layer of the soil profile and decreasing the organic matter with the increase in soil depth. Likewise, the study shows that the both the agriculture land and agroforestry land in soil carbon with the increase in soil depth was supported different authors.<sup>39-43</sup> They found the maximum amount of SOC in the upper layer 0-10cm as compared to the lower layer 80-100 cm.

Monetary value of carbon is different for all the poles and saplings of different species. The monetary value of carbon for sapling is US\$22.68 for *Michelia champaca*. Monetary value for pole was US\$3.92 for *Paulownia tomentosa*. Likewise, monetary value for sapling DBH< 5 cm was less with US\$2.12 per ton for *Cinnamomum tamala*. The annual increment can be used to determine the monetary multiplying with market rate of carbon.<sup>44</sup> The value of carbon in agroforestry depends up on total carbon sequestration and price of carbon credit as well. Thus, the value of carbon sequestration in the agroforest was varying.

Land use land cover map of Ratanpur showed that agriculture area was reduced by 46.86%, Agroforestry was increased to 48.4% since there was no any agroforestry practices adopted in 2015. Natural trees in the study area is increased by 4.63% whereas, settlement area is increased by 0.069% because local people have established the goat farm in Ratanpur. The land cover change between 2015 and 2020 had an impact on the total carbon stock in the study area. As land use change has been detected as one of the major sources for anthropogenic carbon emissions, studies quantifying these changes



should also have a link to reasons behind such change.<sup>45</sup> Land uses with woody perennials have high carbon stock than those without. Hence, conservation based production systems with inclusion of woody perennials helps to enhance the carbon sequestration.<sup>38</sup>

Accuracy assessment of the land use and land cover map showed that the land use land cover map of 2015 is 90.91% accurate with Kappa coefficient 0.86 because almost all the lands were agriculture land and was easy to identify in the image. Whereas, the land use land cover map of 2020 was 80.65% with Kappa coefficient of 0.74. The accuracy of 2020 was less than 2015, this might be because the planted agroforestry plants in 2020 were maximum of age 4 yrs. and in this age most of the plants were not fully grown and had not attained the maximum height that can be visible aerially.

The study shows that carbon stock in agriculture land varies with the carbon stock in agroforestry land. Soil carbon was found to be slightly higher in agroforestry land than in the agriculture land. The higher soil organic carbon stock recorded in the agroforestry land was mainly because of the biomass inputs and organic fertilizer used during plantation. Increment in the tree component and on agricultural land is an achievable and relatively fast route for increment in carbon sequestration.<sup>46</sup>

## Conclusion and recommendations

The agroforest practice was done since 2016 at Ratanpur, Nepal. These agroforests sequester more carbon than the agriculture practice. The application of carbon increment in agroforests showed the area, location and carbon dynamics at Ratanpur, Nepal. The highest carbon stock/stand was of *Paulownia tomentosa* but it was the lowest of *Leucaena leucocephala*. The highest number of stands planted was *Cinnamomum tamala* so total carbon sequestration was highest and its monetary value was also the highest. The highest annual carbon sequestration potential per stand was of *Ficus cunia* but the total highest carbon sequestration potential was of *Michelia champaca* at saplings stage therefore the estimated monetary value was also the highest. The highest carbon sequestration potential was of *Paulownia tomentosa* at pole stage and so as the monetary value. The highest carbon sequestration of DBH<5cm was of *Cinnamomum tamala* and the monetary value was also the highest. Agroforestry practice was not adopted in 2015 so there was no agroforest thematic class in the map which was remarkably observed in thematic map of 2020. The mean carbon stock per stand of *Leucaena leucocephala*, *Bauhinia purpurea*, *Cinnamomum tamala* and *Litsea polyantha* were significantly different from carbon stock of other species.

The agroforestry in small scale farmers is potential for carbon sequestration and it will be applied to claim the carbon credit under REDD+ mechanism. Use of high resolution imagery from google earth platform and digitation will be reliable tool to assess the carbon which will be able to use for carbon monitoring. Intensive research on assessing the carbon stock on different agroforestry model will further scope of study.

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## Conflicts of interest

All author listed here declare no conflict of interest exists.

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