Carbon Sequestration Status of Sunaulo Ghaympe Danda Community Forest, Mid Kathmandu Valley, Nepal

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Developing countries like Nepal has the potentiality to earn money from the carbon sequestration if the forest are managed properly either by government or through participation approach. Community forestry in Nepal was beginning through handover of degraded forest area. Researches on carbon sequestration capacity of community forest in Nepal indicate towards high capacity. Globally, climate change and mitigation issues have been receiving an increasing attention, and Nepal is no exception. Deforestation is the second single Greenhouse Gas (GHG) source, behind energy production, responsible for about a quarter of anthropogenic GHG emissions. Forests in Nepal cover nearly 40% of the total land areas and significantly contribute to mitigating the adverse impact of climate change. This paper strongly revealed the data of carbon sequestration of Mid-Nepal's community fores, i.e. Sunaulo Ghyampe Danda Community Forest. Present study was carried out to estimate carbon sequestration rate for eight years (2004-2014) by using standard methods. The study result revealed biomass organic carbon as 23.5ton /ha, 25.95ton /ha, 27.24ton /ha, 28 ton /ha and 24 ton/ha for the respective years 2004, 2007, 2009, 2011 and 2104. Similarly, the average yearly carbon sequestration rates starting from 2004 to 2015 was 0.05 ton /ha/yr.

Key words: *Carbon Stock, Carbon Sequestration, Climate Change and Community Forest*

INTRODUCTION

Globally, deforestation, forest degradation, forest fires and burning of fossil fuel are playing a significant role in producing the Green House Gases (GHGs) (IPCC, 2000). Hence, deforestation and forest degradation, caused by increasing population and land degradation, are major problems in developing countries; whereas burning of fossil fuel from industries is major problem mainly in developed countries. The conversion of forest area into non-forest area, which leads to the additional GHGs in the atmosphere, was recorded as 12.3 million ha between 1990 and 2000 in the tropical countries (FAO, 2004). The increasing amounts of GHGs adversely affect the global environment. These effects are climate change, global warming, rising of mean sea level, alteration of weather and they threaten the life of living beings. Hence, the relationship between the increasing amount of GHGs in the atmosphere and climate change was taken seriously in 1990 and many efforts were made to create awareness globally. A Recent Reports (IPCC, 2013) revealed that concentrations of CO2, CH4, and N2O have now substantially exceeded the highest concentrations recorded during the past 800,000 years.

All development is now taking place in a world shaped by climate. Climate change is happening now and impacting countries and people, with the poor the hardest hit. Potsdam Institute for Climate Impact Research shows, globally warming of close to 1.5°C above pre-industrial times – up from 0.8°C warming today – is already locked into Earth's atmospheric system by past and predicted greenhouse gas emissions. Immediate global action is needed to slow the growth in greenhouse gas emissions this decade and to help countries prepare for a warmer world and adapt to changes that are already locked in. Getting there will require economic transformations and a path to net zero emissions before the end of the century. (World Bank, 2015).

The contribution to emission of GHGs by Nepal can be neglected, but due to variation in climate system has serious implications for our ecology, physical, economic, health, and agriculture system and to the population. ICIMOD (2011) stated that the temperature in Nepal is rising at a rate higher than the global average, with a 1.8°C increase between 1975 and 2006. Climate warming has already started threatening food security, habitants, water imbalances etc. As Nepal's altitude varies abruptly from 70 metres from sea level to 8848 metres within a very short span, the impact of climate events such as rainfall, flood and other climate related incidents could be catastrophic.

CONCEPT OF CARBON SEQUESTRATION

Carbon dioxide has a vital role in environmental system. Proportional increase in CO2 results in steadily rising amount of GHGs. So, to check the GHGs is global grave concern and one of the significant measures is to sequester the carbon which is possible by either expanding forest resource or conserving them (Houghton, 1996).

In fact, carbon is held in the terrestrial ecosystems as vegetation and in soils. In addition oceans hold a large volume of carbon so does atmosphere. Carbon sequestration is the process of removing additional carbon from the atmosphere and depositing it in other reservoir principally through changes in land use. The terrestrial carbon sequestration is the net removal of CO_2 from the atmosphere and storing it in terrestrial ecosystem (Sedjo and Marland, 2003). Forestry is only the major option for carbon sequestration in the terrestrial ecosystem among agricultural systems and agroforestry systems (Kalpan, 2003 cited from Singh, 2005) and has concluded that the total carbon was found highest in the naturally grown forest. . In practical terms carbon sequestration occurs mostly through the expansion of the forests (Houghton, 1996). Forest has a prime role in sequestering carbon from the atmosphere. In reality, the forest is a reservoir, a component or components of the climate system where a green house gas is stored, as well as sink, any process which removes a green house gas from the atmosphere (Pearce *et al*., 2003). Thus the forest is the complement of carbon sequestration. So, the forest expansions and sustainable forests, as mitigation measure, have a significant contribution to the environmental benefit but any shrinkage of forests, as emission, has a long term influence and impact. Therefore, the sustainable forest , as a carbon sinks, is the key factor to balance the GHGs emission (Levy *et al*., 2004).

The carbon sequestration process involved in individual tree is an important concern in environmental system. The process of carbon sequestration is the most rapid during the early stage of the life of tree while, as tree reaches maturity the above two processes become increasingly similar. Additionally, the rate of carbon sequestration is less particularly in over mature stage of the tree. Hence, the tree or forest expands the capacity of carbon sequestration also increases and vice-versa (Sedjo *et al*., 2003).

Conclusively, sustainable forests are reliable sinks of GHGs (Levy *et al*., 2004). Hence, the sustainable forest and the management system is key concern as sinks. Generally, there are three broad categories of interventions such as management of the existing forest and trees source for instance community forest management in developing countries, expanding the forest area and tree cover for example afforestation and reforestation as well as using the renewable energy sources as a substitute for fossil fuel (Baral *et al.*, 2004). Among these, the community forest management which is a successful example of sustainable forest management, is the preferable option of carbon sequestration, primarily in developing countries (Klooster *et al*., 2000). Carbon is store in the terrestrial ecosystem in vegetation as biomass and in soil as soil organic carbon (SOC). The long term conversion of grass land and forest land to cropland and grazing lands has resulted in the historic losses of biomass carbon and SOC world wide but there is a major potential for increasing forest carbon by adopting soil conservation practices and by restoring forested areas.

THE ROLE OF COMMUNITY FORESTRY OF NEPAL IN CARBON SEQUESTRATION

Nepal emits only 0.1 metric tons of CO2 per capita relative to a global average of 4.7 (World Bank, 2013). However, its forest carbon density is comparable to large carbon rich countries such as Indonesia and Brazil (FAO, 2011). Forty percent of Nepal's land area is classified as 'national' forests (29 percent forests and 11 percent shrub land) (DOF, 2015). Nepal is also home to seven climatic zones ranging from the tropical to the arctic, 112 forest ecosystems (DOF, 2015) and more than 125 ethnic communities (CBS, 2012). In forestry circles, Nepal is best known for implementing a community forestry program in its middle-hill areas (Shyamsundar and Ghate, 2014).

Community forestry program in Nepal officially started in late 1970s. For more than two decades, local communities have been involved in the management and utilization of forests in Nepal. The main impacts of Community forest are restored degraded forest land, resumed greenery and carbon Sequestration, increased Bio-diversity, Increased supply of forest products, Empowered women, poor and the disadvantaged group, Promoted income generation and community development activities and Improved Livelihood.

Table 1. Community forestry national profile

Total area of the Community Forests handed over	1,652,654 ha.
Average size of the community forest	79.43 ha.
Total number of CFUGs	17,685
Total number of households involved	1.45 million
Percent of total population benefited	35%
Total number of household benefited	2,177,858

Source: (DOF, 2015)

From land-use data, 1978/79 to 1994, the total forest area decreased from 38% of the national land area to 29% [5616.8 thousand hector (ha) to 4268.8 thousand ha], while shrub land increased from 4.7% to 10.6% (1559.2 thousand ha from 689.9 thousand ha).

Table 2. Comparison of carbon sequestration in Nepal's standing forest (except shrub land)

Year	Forest ('000 ha)	Above ground biomass (M T)	Total biomass (MT)	Total Carbon (MT)
1978/79	5616.8	238.7	302.0	151.0
1994	4268.8	279.6	353.7	176.9
Change (78-94)	- 1348	+ 40.9	+51.7	+ 25.9

Source:(MFSC,1999)

Between 1978 to 1994, the carbon in forests (standing stock) increased from 151 megaton (MT) to 176.9MT with the net increase of 25.9 MT. Moreover, the carbon sequestered in under-storey trees of less than 10 cm diameter and shrubland, whose area increased by 869.3 thousand ha during the same period, the actual amount, would be higher than this. Furthermore, if the amount of carbon retention in varieties of harvested products[i] and pools from 1978-94 was counted the net sequestration would be higher again (MFSC, 1999).

STUDY AREA

The study area Sunaulo Ghyampe Danda Community Forest lies on Seti Devi VDC located at Katmandu valley, on the way of Pharping. It is situated in between the latitude 27º37′22" to 27º38′48" and longitude 85º16′35" to 85º17′10" and elevation ranges from 1100m to 1600m above the sea level. The climate of this area is temperate i.e. neither so cold nor so hot. The average annual rain fall recorded at the study area was 1490.79mm and maximum and minimum rainfall recorded at the month of June and November respectively. The average annual temperature and relative humidity recorded at the study area ranges from 25.61°C to 11.97°C and 1027.40 to 803.15 respectively.

The study area was surrounded by Hattiban Community Forest in the West, Hattiban Forest in East and North and in the south dashinkali highway passes. This Sunaulo Ghaympe Danda community forest was declared as community forest on 1999 with occupying an area of 51.4 ha of which 31.4 ha area was occupied by Mixed Broad forest and 20 ha was occupied by Pine forest. Pine and Mixed Broad Leaf Forest were two forests with in this community forest. Pine forest lies on southeastern part where as northeastern part was covered by Mixed Broad Leaf forest. The major dominant tree species of Mixed Board Leaf forest are *Schima wallichina, Rhododendron arboreum, Castanopsis tribuloides, C. indica, Myricia esculanta, Engelhardia spicata, Lyonia ovalifolia, Quercus glauca, Acer oblongum* followed by *Myrsine capillellata, M. semiserrata, Albezzia lebbek, Celtis australis, Fraxinus floribundus, Alnus nepalnensis, Zizyplus incurva, Semicarpus anacardium* and Pinus roxburgii was dominant tree species of Pine Forest.

Total population of Seti Devi VDC was 3989 with male and female population of 1989 and 2000 respectively with total 766 household. The major economic activity in the study site was agriculture followed by poultry, business and government job. 80.2% of the people depend on the agroforestry for the fuel wood, timber and fodder (CBS, 2011).

The study aim was to estimate the carbon sequestration status of sunaulo ghaympe danda community forest, Katmandu, Nepal. The study addresses the following issues.

- To know the carbon stock of sampled year.
- To find the carbon sequestration rate of community forest.
- To estimate the carbon sequestration trend of sampled year.

METHODOLOGY

Field sampling

The sampling was done during January to March, for each collected Data i.e 2007, 2009, 2011 and 2014. By the use of Geographical Positioning System (GPS) and Geographic Information System (GIS), total 29 sampling plots were identified. The sampling plot was designed based on the tree density and slope of the area. Furthermore, on southeast part of the Mixed Broad leaf forest, most of the land is opened so no sampling was conducted. The sampling plot was designed such that the difference on the length between the sampling plots is 100m.

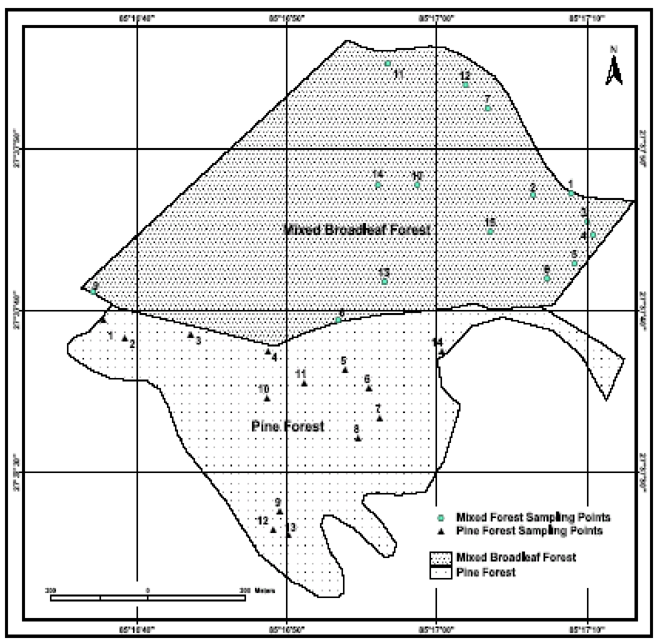

Figure 1. Location Map of Study Area with Sampling Point

Only 15 sampling plot were taken for sampling in Mixed Broad Leaf Forest which was shown on the above figure. Once the plot centre was identified, the radius of 8.92m was measured to make circular quadrat with an area of 250m.sq.

For the measurement of carbon pool, the methodology given by MacDickhen,1997 was followed.

Biomass calculation. Estimation of above and below (root) ground biomass.

Following regression model was used to calculate above ground biomass of trees (NARMSAP, 2000).

Regression model was: Ln W = a+ b X Ln (DBH)

Where: W = Green weight of tree component (biomass) in kg.

a=intercept, b=slope and DBH = diameter of the tree at breast height.

The root biomass was assumed to be 15% of total aboveground biomass as suggested by (MacDickhen, 1997).

Total above ground biomass and root biomass were multiplied by carbon expansion factor, i.e. 0.5 (Brown, 1997; Montagnini and Porras, 1998) to get the biomass carbon stock of tree.

Total above ground biomass organic carbon =Total above ground biomass of tree X 50%.

Total below ground organic carbon = Total root biomass of tree X 50% + total SOC

TOTAL BIOMASS ORGANIC CARBON OF THE TREE IS= Total above ground biomass organic carbon + Total below ground organic carbon

Carbon sequestration rate as biomass = (carbon stock of this year-carbon stock of previous year)

RESULT AND DISCUSSION

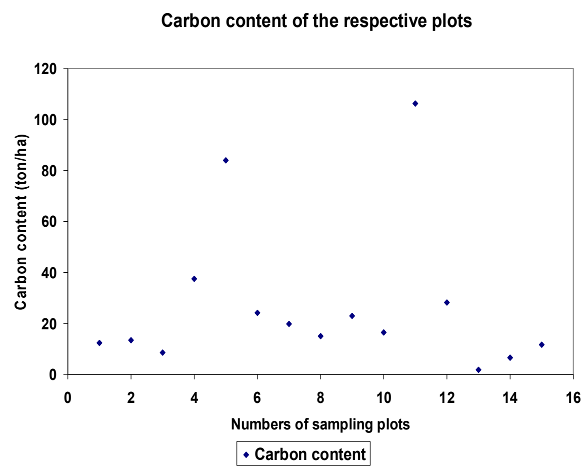

Figure-2: Carbon Content for the year 2007

From the above figure-2, for the year 2007, the total carbon content of the mixed broad leaf forest was found to be 389.44 ton from total sampling plot. The average carbon stock of this forest was found to be 25.95 ton/ha. The analysis of the carbon content in each plot, shows that the distribution pattern of the biomass carbon content was somehow similar expect few 6 and 11 plots. The maximum carbon content was found to be 100.37 ton C and 79.56 ton C on sampling plot no. 11 and 5 respectivily. In plot number 11 and 5, their was mature tree with the average DBH of 25cm. Along with this in some sampling plots, their was tree with DBH more than 25 cm but the other tree's DBH value is very low, so on those sampling plots the carbon content was found in average amount. But in sampling plot number 13, there were no big trees with high DBH value, so the minimum carbon content was found to 1.78 ton C on it.

From figure number 3, the result for the year 2009 also matches with 2004 and 2007. The total carbon content for this year was found to be 408.61 ton in total sampling plot. Again

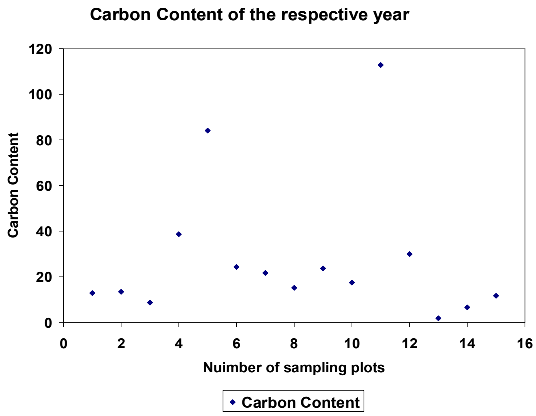

Figure-3. Carbon Content for the year 2009

average carbon stock of this forest was found to be 27.24 ton/ha. The carbon content in each plot seems to be similar as that of year 2007, but in some cases it was fluctuated. The range of carbon content starts from 106.29 ton to 1.77 ton. i.e. the maximum carbon content was found to be 106.29 ton C and 83.99 ton C on sampling plot no.11 and 5 respectively. Again, the minimum carbon was content found to be 1.77 ton in samplig plot number 13. Due to the difference in DBH value of tree in each plots, such inconsistency of carbon content was observed.

From the figure number 4, for the year 2011, the result was also similar to that of year 2007 and 2009. In same sapling plot maximum and minimum carbon content value was observed. The total carbon content value was continuously increasing. In this

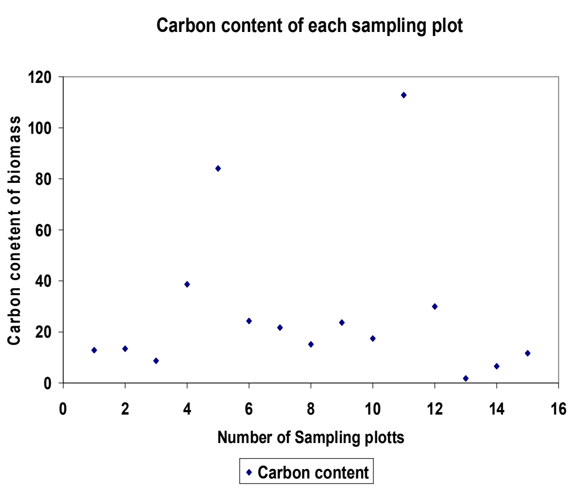

Figure 4: Carbon Content for the year 2011

sampling year was found to be 422.69 total sampling plots. Again, the average carbon stock was found to be 28.1 ton/ha which was continuously increasing since the year 2007. The distribution of the carbon content in each sampling plots was found to be fluctuated i.e. the maximum carbon content was found to be 112.83 ton C and 84.06 ton C on sampling plot no.11 and 5 respectively, similar to the sampling plots than that of the year 2007 and 2009. Again, similar results also resembles with the minimum carbon content which was found to be 1.78 ton in sampling plot number 13.

From figure 5,for the year 2014, the result was found different from the others sampled years 2007, 2009 and 2011. The carbon

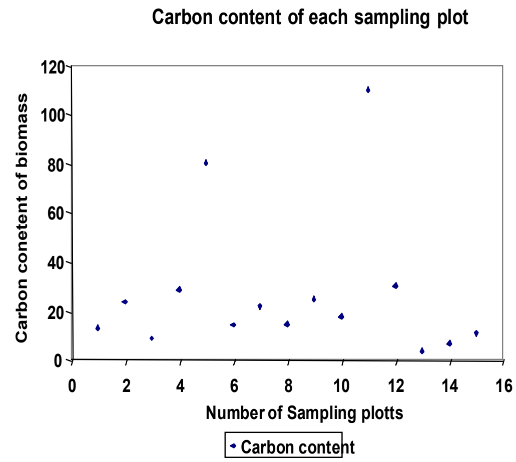

Figure 5. Carbon Content for the year 2014

stock was found to be 24ton/ha which higher than the sampled year 2004 but lower than others sampled years. On plot number 4, 5, 6 and 10, community forest users group fell down total 8 mature trees for the developments works. But on others plots the results were found to be similar of others years. The range of carbon content starts from 106ton/ha to 2.97ton/ha. The maximum carbon content 106ton/ha was found to be on plot number 11 and minimum was found to be on plot no 13 i.e. 2.97.

From Figure 6, The average carbon content of the respective year was calculated and found to be 23.5ton/ha, 25.95 ton/ha, 27.24ton/ha, 28.1ton /ha and 24 ton/ha of the sampled year 2004, 2007, 2009,2011 and 2014.

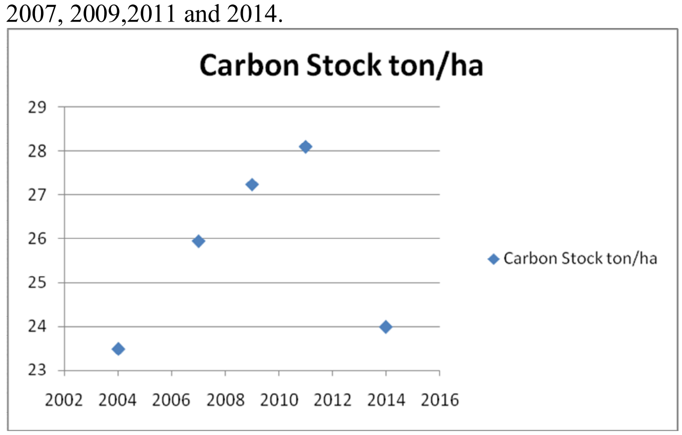

Figure 6: Average Carbon content of the sampled year.

The maximum carbon stock was found to be on the year 2011 i.e. 28.1ton/ha and minimum carbon stock was found to be on the year 2004 i.e.23.5ton/ha. The carbon stock present in mature tree was found to be higher than that of sapling or seeding and of regenerative forest (Banskota and Karky, 2006). This study also reveals with this findings, i.e. the average carbon content of plot no 11 and 5 was fond to be higher than that of others plot, since in this two plots mature trees were found and on others plots growing trees were found. Since from the consecutive year i.e. 2011 to 2014, mature and others trees were cut down by the community forest users group on plot numbers 4, 5, 6 and 10, so the carbon stock was found decreased on the sampled year 2014.

Further more, the regenerative community forest in temperate zone, their is impressive growth of biomass carbon stock which was about 10% of its total weight in a year; which is largely due to regeneration and protective measures (Dahal, 2006). The present study compared with these findings, the increment in the biomass carbon stock per year was found lower. The increment in the biomass carbon for the year 2004 to 2007 was 23.5 ton/ha to 25.95ton/ha, i.e. 3.5% per year. Similarly 5.96% of the biomass carbon was increased for the year 2007 to 2009. Finally, 3.14% of the biomass carbon was increased for the year 2009 to 2011.

The carbon sequestration rate of the respective conjugative year i.e. 2004 to 2007, 2007 to 2009 and 2009 to 2011 was calculated and found to be 0.81 ton/ha/year, 0.64 ton/ha/year and 0.43 ton/ha/year respectively which was shown in the Figure number 6. But from the year 2011 to 2014, the carbon stock was found to be decreased by 4ton/ha. The total carbon sequestration status of this forest from the year 2004 to 2014 was found to be 0.5ton/ha.

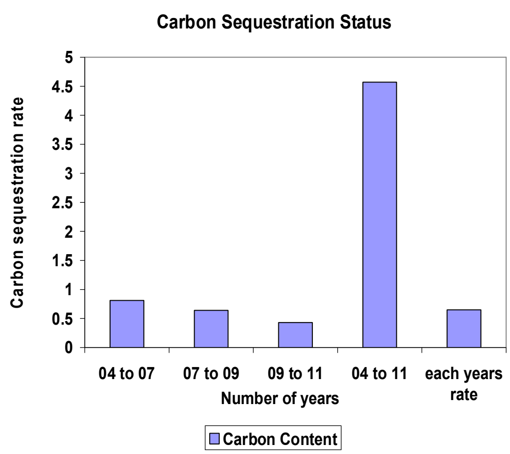

Figure 6: Carbon Sequestration status of each year

From the year 2004 to 2011, the carbon Sequestration rate for each individual year was found to be 0.65 ton/ha/ year since the carbon stock was gradually increased. But for the year 2014, since carbon stock was decreased, the average carbon sequestration rate from 2004 to 2014 was decreased from 0.65 to 0.05ton/ha/year. From the figure no-6 , the carbon sequestration rate for the year 04 to 07 was higher than that of year 2007 to 2009 and 2009 to 2011. The carbon sequestration status for the respective year was found to be slowly decreasing stating from the year 2004 to 2014, even though the carbon stock was found to be increasing from the year 2004 to 2011. Accordingly, the carbon sequestration rate of the regenerative forest was higher as compared with mature forest and the carbon sequestration rate of the mature forest is constant (Banskota and Karky, 2006). This study also shows such trend i.e. the total carbon stock of the forest was increasing each year but the rate of carbon sequestration is gradually decreasing with the time period. The average carbon sequestration of the Mixed Broad leaf forest was 0.65 ton/ha/year, but Maraseni et.al. (2005) estimated that the carbon sequestration by the Nepal's forest was found 1.62 MT/yr, which is lower than this study.

CONCLUSION:

- The carbon stock of mixed broad leaf forest was found to be increased from the year 2004 to 2011 i.e. 23.4t/ha to 28.1 t/ha.
- The carbon stock for the year 2014 was found decreased compared with others years i.e.24t/ha.
- In all sampling years in plot number 11, the carbon stock was found highest where as on plot no 13 the carbon stock was found lowest.
- The carbon sequestration trends for the year 2004 to 2007, 2007 to 2009 and 2009 to 2011 was found to be 0.81 t/ha/year, 0.64 t/ha/year and 0.43 t/ha/year respectively.
- The carbon stock was found to be decreased by 4t/ha from 2011 to 2014.
- The total carbon sequestration status of this forest from the year 2004 to 2014 was found to be 0.5ton/ha.

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