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# Biomass and Carbon Allocation in Legume based Silvipastoral System in Degraded Wastelands of Tamil Nadu, India

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## ABSTRACT

**Background:** In India, grazing based livestock husbandry continues to play an important role in rural economy of the country as around 50 per cent animals depend on grazing in forests and other grazing areas. In Tamil Nadu, grasslands/ rangelands are a major source of feed and fodder for the livestock. Silvipastoral systems give farmers access to fuel, fodder and timber, they can help decrease the strain on existing natural forests and play a significant part in carbon mitigation programs through carbon sequestration. Therefore, this study was carried out to estimate biomass and carbon allocation in different components of legume based Silvipastoral System in Degraded Wastelands of Tamil Nadu, India

**Methods:** The present study was carried out in the existing fourteen year old silvipastoral system consisting of legume tree fodder *Gliricidia sepium* with an understorey of *Stylosanthes scabra*. All qualitative and quantitative traits of plants and soils were recorded at regular intervals using standard analytical procedures and methods. To assess biomass and carbon allocation in the existing silvipastoral system, a sample plot of 0.25 ha was allocated and within this sample plot, diameter of all trees at breast height was measured and recorded. The total system carbon sequestration potential (Mg C $ha^{-1}$) was computed using tree carbon, crop carbon and soil carbon.

**Result:** Studies on the allocation of biomass and carbon in *Gliricidia sepium* based silvipastoral system in Degraded wastelands of Tamil Nadu, India have revealed that the total carbon in fourteen year old *Gliricidia sepium* was calculated as 46.74 t C $ha^{-1}$. From the study, it was visible that average annual increase in carbon sequestration potential of silvipasture in degraded lands was 3.94 t $ha^{-1}$. *Gliricidia sepium* with an understorey of *Stylosanthes scabra* based silvipastoral system exhibited significant carbon accumulation, which serves as an extra carbon sink in the area.

**Key words:** Agroforestry, Biomass, Carbon accumulation, Degraded wastelands, G*liricidia sepium,* Silvipasture.

## INTRODUCTION

The worldwide issue to reduce the rising concentration of green house gases in the atmosphere is carbon management in forests (Wani, 2019). Restoring forest cover and locating inexpensive ways to trap carbon is becoming a key international policy objective (Shively *et al*., 2004). The effectiveness of agroforestry systems in storing carbon depends on both environmental and socio-economic factors; in humid tropics, agroforestry systems have the potential to sequester over 70 Mg/ha in the top 20 cm of the soil. The carbon storage capacity in agroforestry varies across species and geography (Meragiaw Misganaw, 2017). Further, the amount of carbon in any agroforestry system depends on the structure and function of different components within the systems put into practice. There is also clear evidence to suggest that the type of agroforestry system greatly influences the source or sink role of the trees. Agroforestry provides the best example of promoting mitigation and adaptation synergy in addressing climate change.

India has a long tradition of agroforestry, several indigenous agroforestry systems, based on people's needs and site-specific characteristics have been developed over the years. Agroforestry research was initiated in the country about three decades ago and several agroforestry technologies have been developed and tried on farmer's lands (Chinnamani, 1993).

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Tree based intercropping system is one of the best options to sink carbon and nourish the people who depends

on land for livelihood, by way of integrating food production with environmental services (Soto-Pinto *et al.,* 2010). Trees included in dry land ecosystems not only conserve the ecology but also adds to farmers economic returns in terms of its tangible benefits. With increasing awareness of carbon trading, it is attracting the researchers, planners and farmers as an important economic source to the farmers in the days to come (Devaranavadgi *et al.,* 2012). Carbon sequestration in different agroforestry systems occurs both belowground, in the form of enhancement of soil carbon plus root biomass and aboveground as carbon stored in standing biomass. High carbon sequestration potential becomes more important in the context of utilization of degraded land. The present study was carried out to estimate biomass and carbon allocation in different components of fourteen year old *Gliricidia sepium* in silvipasture system under degraded waste land.

## MATERIALS AND METHODS

**The experiment was conducted on a legume tree fodder *Gliricidia sepium* based Silvipastoral System maintained in degraded wasteland established under AICRP on Agroforestry scheme**

### Location

A field experiment was conducted at the Institute of Animal Nutrition, Tamil Nadu Veterinary and Animal Sciences University, Kattupakkam, Chennai, Tamil Nadu during 2020-22 to study the biomass and carbon allocation in fourteen year old legume tree fodder *Gliricidia sepium* based silvipastoral system in degraded wastelands. The farm is situated at 13.03′N latitude and 80.12′E longitude with an altitude of 28 m above mean sea level. The soil of the experimental site was calcareous in nature and having a pH of 7.0, organic carbon content was 0.45% and having a cation exchange capacity of 11.9 cmol/kg. The mechanical composition of the soil was 32% Sand, 38.5% Silt and 29.5% Clay.

### Silvipasture system

The site was fourteen-year-old legume tree fodder *Gliricidia sepium* based silvipastoral system with an understorey of perennial legume fodder *Stylosanthes scabra.* The legume tree fodder *Gliricidia sepium* was planted at a spacing of 2 × 2 m. Excluding the 2 m area immediately around the base of *Gliricidia sepium*, the remaining space was sown with perennial legume fodder *Stylosanthes scabra*, a popular and nutritious, high yielding, palatable legume fodder crop. The system was maintained under rainfed conditions. A total of 36 *Gliricidia sepium* trees were selected to perform this experiment. All qualitative and quantitative traits of plants and soils were recorded at regular intervals using standard analytical procedures and methods. To assess biomass and carbon allocation in the existing silvipastoral system, a sample plot of 0.10 ha was allocated. Data was recorded for three consecutive years 2020, 2021 and 2022.

### Tree growth and fodder yield

Above-ground growth parameters *viz.,* tree height, diameter at breast height (DBH) and canopy spread of trees, were measured. Green biomass yield of fodder crops was measured by harvesting 1 × 1 m area at six random places in each plot (60 × 60 m) and then it was calculated per hectare basis and expressed as Mg $ha^{-1}$. For tree species, canopies were imposed to 30% pruning and shrubs were pollarded at 1 m height during the winter season and green pruned fodder biomass (leaves and soft twigs) per tree/ shrub was recorded. Thereafter, the fresh biomass was calculated per hectare basis based on the number of stems per hectare and was expressed as Mg $ha^{-1}$.

### Carbon stock/carbon density estimation

The total (green) weight of the standing trees was measured using the following protocol. The weight of a tree is measured as W = Above-ground weight of the tree in kgs; D = Diameter of the trunk in diameter; H = Height of the tree in Meter. For trees with D<11; W = $0.25D^2H$; For trees with D >= 11; W = 0.15D-H. To determine the dry weight of the tree, multiply the weight of the tree by 72.5%. Growth parameters *viz.*, Biomass estimation, diameter at breast height (DBH; cm) and tree height (H; m) were measured. The crop biomass of fodder crops was determined by quadrate method. For recording the green fodder yield, the crops were harvested from three quadrates of 1 $m^2$ each from the centre of the tree rows of various spacing geometries and averaged to get crop biomass per ha basis as per the procedure given by (Magnussen and Reed, 2004). The amount of soil organic carbon that was stored in a soil was calculated using the equation given by Broos and Baldock, (2008). Walkley and Black wet oxidation method was employed to assess the organic carbon content (%) of the soil (Walkley and Black, 1934). Bulk density was measured by cylinder method. Finally total system carbon sequestration potential (Mg $ha^{-1}$) was calculated by adding tree carbon, crop carbon and soil carbon.

### Statistical analysis

The data were subjected to analysis of variance as a factorial randomized block design using the General Linear Model procedure of SPSS and means were compared for statistical significance by Duncan's multiple range tests (Snedecor and Cochran, 1994).

## RESULTS AND DISCUSSION

The biomass and carbon allocation in different components of *Gliricidia sepium* in the existing fourteen year old silvipasture in degraded wastelands is presented in Table 1. Tree density of fourteen year old *Gliricidia sepium* was 1600 trees $ha^{-1}$ and the total tree basal area was 29.5 $m^2$ $ha^{-1}$. The fourteen year old *Gliricidia sepium* had a mean DBH (diameter at breast height) of 46.8 cm. The total biomass of fourteen year old *Gliricidia sepium* was calculated

98.4 t ha$^{-1}$ and a single tree accounts about 0.062 t biomass. The above ground components were contributed 90.65% and below ground components were contributed 9.35% biomass to the total biomass. A total of 46.74 t C ha$^{-1}$ was stored in the fourteen year old *Gliricidia sepium.* A total of 90.53% carbon was allocated in the above ground components whereas only 9.35% carbon was allocated in the below ground components of the trees.

The assessment of carbon storage potential has been difficult due to the lack of information on biomass compartmentation and carbon allocation in different species. For most of the species used for afforestation/ reforestation, only the above ground biomass potentials are known but to have a picture of carbon storage potential of species, the below ground biomass pattern are equally important. This study was aimed to measure the biomass partitioning and the actual carbon allocation in different components of agroforestry tree species. The overall differences in carbon and biomass allocation had much influence on total carbon storage compared to the relative amount of mass contained in each tree component. On an average, the stem is the largest carbon store but combining the litter including branches and the roots, the carbon proportion becomes more than 50 per cent. As the above litter part is added to the soil, thus depicting huge potential of plantation in soil organic carbon build up. It is important to mention that the short rotation plantations have high carbon sequestration potential but short term capacity for carbon storage. The biomass accumulation through stem was highest in *Gliricidia sepium* (46.35 t/ha). The mean carbon storage in stem was 22 t ha$^{1}$, while the mean branch carbon storage was 10.70 t ha$^{-1}$. It was observed that the carbon content of biomass components had relatively little influence on total carbon storage compared to the relative biomass in each tree components. Stem alone though was the largest store house of carbon but litter and roots in the short rotation tree species play a major role in carbon sequestration in the soil reservoir. The fate of stem carbon depends upon its end use and needs locking up in post harvest products for longer period. Singh and Lodhiyal (2009) reported similar findings. Nabuurs and Mohren (1995) also underlined the short term nature of the short rotation plantation carbon sink. The mean carbon storage values for plantations are valid till the plantations exist and replaced after each harvest. Therefore, the average tree carbon storage over many rotations is suitable for long term storage. The young and short rotation plantation store most of the carbon as soil organic carbon. The forest and agro-forestry ecosystem contribute significantly to carbon cycling and helps to mitigate climate change because it is dominated by perennial vegetation, which has a larger capacity to store carbon (Nthebere *et al.,* 2022 and Jayara *et al.,* 2023).

**Table 1:** Biomass and carbon allocation in different components of *Gliricidia sepium* in the existing fourteen year old silvipasture in degraded wastelands.

| Components | Biomass (t/ha) | Carbon (t/ha) | Per cent contribution |
|---|---|---|---|
| Branch | 22.6 | 10.7 | 22.97 |
| Twig | 9.75 | 4.6 | 9.91 |
| Stem | 46.35 | 22.0 | 47.10 |
| Leaves | 10.5 | 5.0 | 10.67 |
| Roots | 9.2 | 4.4 | 9.35 |
| Total | 98.4 | 46.74 | 100.00 |

The estimated total (green) weight of the standing trees of fourteen year old *Gliricidia sepium* would be 0.46 kgs. Dry weight of the tree is 33.35 kgs. Dry fodder biomass of *Gliricidia sepium* is 2.46 t ha$^{-1}$, 3.48 t ha$^{-1}$ and 4.1t ha$^{-1}$ during the year 2020, 2021 and 2022, respectively. Dry fodder biomass of perennial legume fodder *Stylosanthes scabra* was 0.87 t ha$^{-1}$, 0.84 t ha$^{-1}$ and 1.1 t ha$^{-1}$ during the year 2020, 2021 and 2022, respectively. The carbon sequestration of existing twelve, thirteen and fourteen year old silvipasture in degraded wastelands is presented in Fig 1. The amount of soil organic carbon stored in the soil was 19.87 t ha$^{-1}$, 21.84 t ha$^{-1}$ and 25.87 t ha$^{-1}$ during the year 2020, 2021 and 2022, respectively. Finally total system carbon sequestration potential (Mg ha$^{-1}$) was calculated as 23.2 t ha$^{-1}$, 26.16 t ha$^{-1}$

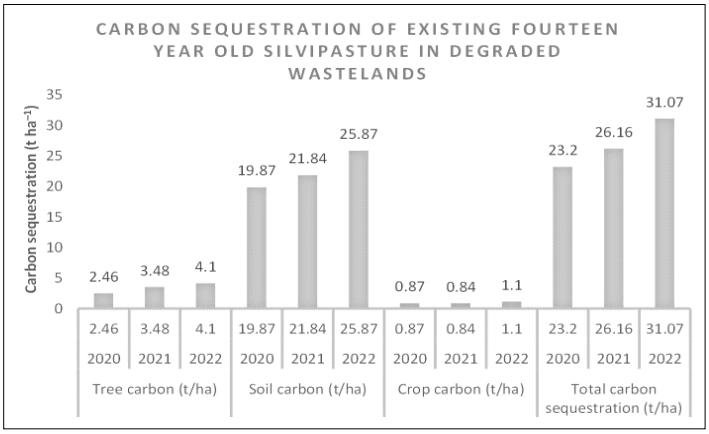



**Fig 1:** Carbon sequestration (t ha$^{-1}$) of existing twelve, thirteen and fourteen year old silvipasture in degraded wastelands.

and 31.07 t $ha^{-1}$ during the year 2020, 2021 and 2022, respectively. The increasing carbon storage in agroforestry systems are expected to increase carbon accumulation in the biomass of planted trees and provide inputs of lignin rich litter that decomposes slowly to stabilize soil organic carbon (Montagnini and Nair, 2004). The dynamics of nutrients in the terrestrial ecosystem were altered by increasing urbanization and human activities due to loss of biodiversity, altered land use, degradation of forests and deforestation (Kaur *et al.,* 2025).

All of the systems have the same capacity to produce biomass since their carbon storage and carbon capture capabilities are directly related to the biomass output of the different plant components. In a complex agroforestry system, plant biomass can vary greatly in terms of carbon concentration, which impacts output. The biomass in an agroforestry system depends on a number of factors including the growth habit of the species, site quality, age, management practices and the interaction between trees and understorey crops (Kanime *et al.,* 2013). Accordingly, we found that the carbon stock and carbon sequestration potential values in our study followed a similar pattern to the total biomass estimates in agroforestry systems discussed above (Kouchi *et al.,* 2017). From the above table, it is visible that average annual increase in carbon sequestration potential of silvipasture in degraded lands was 3.94 t $ha^{-1}$. Results of this study showed that *Gliricidia sepium* with the understorey of *Stylosanthes scabra* based silvipastoral system show significant carbon accumulation in living biomass, as well as soil carbon, demonstrating the potential to offer the environmental service of carbon sequestration.

Carbon sequestration in different agroforestry systems occurs both belowground, in the form of enhancement of soil carbon plus root biomass and aboveground as carbon stored in standing biomass. Besides the potential of agroforestry system to accumulate and sequester carbon, these systems could evolve into a technological option for reducing the vulnerability of farming system to climate variability and climate change impacts.

## CONCLUSION

From the three years study it can be concluded that there is great potential for carbon sequestration potential of silvipasture in degraded lands. Studies on the allocation of biomass and carbon in *Gliricidia sepium* based silvipastoral system in Degraded wastelands of Tamil Nadu, India have revealed that the total carbon in fourteen year old *Gliricidia sepium* was calculated as 46.74 t C $ha^{-1}$. From the study, it is visible that average annual increase in carbon sequestration potential of silvipasture in degraded lands was 3.94 t $ha^{-1}$ *Gliricidia sepium* with an understorey of *Stylosanthes scabra* based silvipastoral system exhibited significant carbon accumulation, which serves as an extra carbon sink in the area.

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### Conflict of interest

All authors declared that there is no conflict of interest.

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