Suitability of fodder trees under silvopastoral practices: An on-farm study from Adimali Panchayath, Kerala

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ABSTRACT: *Silvopastoral systems offer a sustainable approach to improving fodder availability while enhancing land-use efficiency in hilly agroecosystems. The present study evaluated the biomass productivity of selected fodder tree species under silvopastoral practices through on-farm trials conducted in Adimali Panchayath, Idukki district, Kerala, during 2020–2022. The experiment aimed to assess the suitability and yield performance of fodder trees under farmers' field conditions. Four fodder tree species, Calliandra calothyrsus, Neolamarckia cadamba (Kadamba), Gliricidia sepium, and Morus indica (Mulberry) were established at a spacing of 45 cm × 45 cm and harvested at 12-week intervals. The trials were laid out in a randomized block design with five replications. The results revealed significant variation in fresh fodder yield among the species. Calliandra and Kadamba recorded the highest total fresh fodder yields of 29.14 and 28.02 Mg ha^{-1} yr^{-1}, respectively, which were statistically comparable and significantly superior to Gliricidia (18.75 Mg ha^{-1} yr^{-1}) and Mulberry (13.68 Mg ha^{-1} yr^{-1}). Although dry fodder yields were comparable across species, Calliandra produced the highest annual dry matter yield (7.71 Mg ha^{-1} yr^{-1}). The study demonstrates that Calliandra and Kadamba exhibit superior biomass productivity under the agroclimatic conditions of Adimali Panchayath, highlighting their potential for wider adoption in silvopastoral systems to enhance fodder security and sustainable livestock production in the region.*

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1. INTRODUCTION

Agroforestry improves agricultural resilience to climate variability and long-term climate change by integrating trees into farming systems, thereby supporting intensification, diversification, and ecological stability. As a climate-smart practice, it is especially relevant in Kerala, where land scarcity and climatic extremes in hilly terrains threaten farm productivity. By combining tree farming with agriculture, agroforestry enhances livelihoods of small farmers, the landless, and women, while also contributing to environmental greening, rural employment, and climate change mitigation through carbon sequestration.

Kerala's agriculture is experiencing declining productivity due to unscientific monocultures, compounded by floods and landslides. This calls for sustainable land-use alternatives that balance economic viability with ecological resilience. Agroforestry, by integrating trees into farm landscapes, offers both income and ecosystem benefits. Traditional homegardens of Kerala, which are multitier and crop-diverse, exemplify such resilience, having withstood recent climatic shocks. However, socio-economic pressures have led to their decline, necessitating urgent interventions to restore their ecological and economic value.

Integrating fodder trees into silvopastoral systems offers additional benefits by improving soil quality and livestock feed availability. Multipurpose species such as Mulberry *(Morus indica*), Calliandra (*Calliandra calothyrsus*), Gliricidia (*Gliricidia sepium*), and Kadamba (*Neolamarckia cadamba*) are promising candidates for humid tropical regions, serving as fodder banks that address seasonal feed shortages. Although their management practices (tree density, cutting height, harvest interval) have been standardized in on-station trials (Patric *et al*., 2020; Raj *et al.,* 2016), their performance has not been adequately tested in Kerala's Southern High Hills Agroecological Unit.

With this background, the present field study was undertaken in Adimali Panchayath with the objectives of:

- Evaluating on-farm silvopastoral trials in selected farmer fields.
- Assessing fodder yield of selected fodder trees.

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2. MATERIALS AND METHODS

Study area: The present study entitled "Investigations on agroforestry models suitable for Southern high hills of Kerala" was carried out at Adimali panchayath during the year 2020-2022. The primary goal of the study was to implement on-farm trials of silvopastoral practices on selected farmer fields. The proposed study was conducted in Adimali panchayath, Idukki districts, Kerala, which lying with the geographical location of 10° 0' 41.4144" N and 76° 57' 10.0152" E. Throughout the year, the average temperature fluctuates by 3.6°C (6.6°F). July experiences the highest relative humidity at 92.54%, while February has the lowest relative humidity at 59.26 per cent. July also receives the most rainfall, with an average of 5.97 days of rain, while January is the driest month, with 27.90 days without rain. The soil's physico chemical properties at the start of the experiment were as follows: pH 5.5, total nitrogen at 1.27 Kg ha^{-1}, available phosphorus and potassium at 19.89 kg ha-1 and 165.87 kg ha-1, and organic carbon at 0.57 %.

The fodder tree species like Mulberry, Calliandra, Gliricidia and Kadamba was intercropped in an existing homegarden. The field experiment was conducted in a homegarden with livestock component in Adimali panchayath, Idukki district, Kerala. The homegarden was selected based on diagnostic and design survey conducted in Adimali Panchayath under United Nations Developmental Programme (UNDP) Project. The major constraints for livestock rearing in this homestead are scarcity of quality fodder and acute crude protein. Hence, protein rich fodder trees like Mulberry, Calliandra, Kadamba and Gliricidia were intercropped in the homesteads to assess their forage yield and nutritive value under hedgerow planting as fodder banks.

Raising of tree seedlings/ saplings: Seedlings of Calliandra and saplings of Mulberry (var. V1) and Gliricidia were raised in a nursery before field planting. Calliandra seeds were procured from the Kerala Livestock Development Board, Dhoni Farm, Palakkad, and pre-treated by soaking in concentrated sulfuric acid for 4 minutes, followed by washing in hot water (80 °C), before sowing in standard nursery beds. Uniform seedlings were transplanted into polythene bags after one month and later transferred to the main field upon attaining a height of 20–30 cm to ensure better establishment.

Mulberry seedlings were raised from uniform stem cuttings (6–8 months old, 20 cm long, with three nodes and pencil thickness), initially grown in polythene bags and transplanted to the field after three months. Similarly, Gliricidia was propagated using mature stem cuttings of 50 cm length and 3–3.5 cm diameter, raised in polybags for about three months prior to transplanting. Raising healthy and uniform planting material in the nursery ensured better field establishment and higher survival rates across all species.

***Field culture*:** The preparation of the field area within the homesteads was carried out during the months of April-May, when the land was cleared of weeds, stubbles, and roots. This ensures a clean environment for planting and minimizes competition for nutrients. The land was then ploughed twice to achieve a fine tilth, making the soil suitable for seedling growth. A crop-free zone of 1-1.5 meters radius was maintained around the existing trees within the homestead to avoid competition and allow proper root expansion for the new plants. The layout was carefully planned, with each treatment receiving a designated plot size of 3 m x 3 m (9 sq. m), and pits were dug at a spacing of 45 cm x 45 cm for optimal growth conditions for each species.

Seedlings and saplings of Mulberry, Calliandra, Gliricidia, and Kadamba were transplanted to the main field with the onset of pre monsoon showers, which helps in ensuring better survival rates and quicker establishment in the soil.

Harvest of fodder trees: After the plants had reached a height of over 1 meter, an initial uniform cut was made in April 2021 at the prescribed pruning height of 1 meter. This early pruning helps promote lateral branching and encourages better growth for subsequent harvests. Following the initial pruning, subsequent cuttings were taken at 12-week intervals up to January 2023. This regular harvesting schedule ensures a steady supply of fresh fodder throughout the period. Once all harvests were completed within a year, the yield from each harvest was pooled to determine the annual yields. The total yield from the harvested area was measured in fresh weight, and this data was then scaled up to a hectare basis to estimate the annual green fodder yield for the entire area. For each cut, the biomass from 5 trees per plot (excluding the border plants) was carefully separated into leaf and stem components. The fresh weight of each component was measured individually, and the total biomass was then determined by summing the weights of both the leaf and stem components. Subsamples of 200 grams from both the leaf and stem were taken and subjected to oven drying at 70°C to determine the dry matter content, following standard procedures. This step ensures that the moisture content of the samples is removed, providing a more accurate measurement of the biomass.

Green fodder yield from trees: For each cut, the biomass from 5 trees per plot (excluding the border plants) was separated into leaf and stem components. The fresh weights of the leaves and stems were determined individually, and the total biomass for each cut was calculated by summing the fresh weights of both components. This step ensures a precise measure of the biomass produced during each harvest. Subsequently, the yield from all harvests in a year was pooled together to calculate the annual gross yield. This total yield represents the cumulative biomass produced throughout the year from the selected trees

Dry fodder yield from trees: After each harvest, the biomass from each plot was weighed fresh to determine the total yield produced during that cutting. The biomass was then separated into leaf and stem components, with the fresh weight of each component recorded separately. To determine the dry matter (DM) content, 200-gram subsamples from both the leaf and stem components were oven-dried at 70°C for 48 hours. This process removes moisture, leaving behind the solid organic material, allowing for accurate measurement of the dry matter content. The annual fresh fodder yields were then multiplied by the dry matter content to convert the fresh weight into dry fodder yield.

Statistical analysis: The data were subjected to statistical analysis by analysis of variance (ANOVA) in SPSS version 18 to ascertain the significance of yield and quality parameters. The Duncan's Multiple Range Test (DMRT) was used to separate the differing treatment means at 5 % significance level.

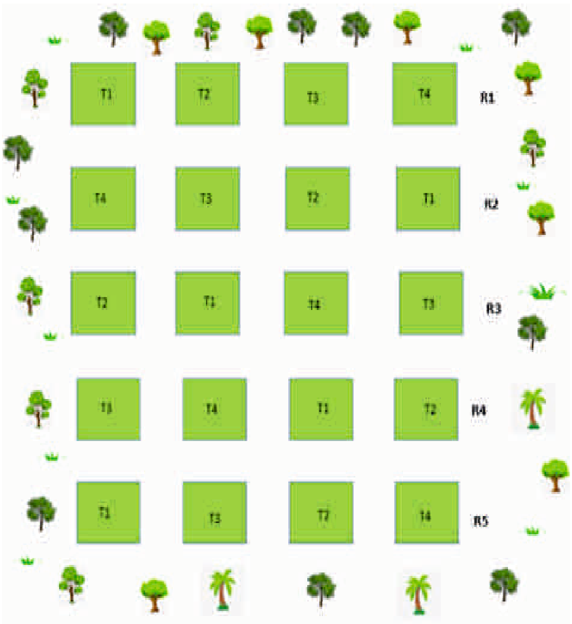

Figure 1. Layout of the silvopastoral trial

T1-Calliandra (*Calliandra calothyrsus*)
T2-Mulberry (*Morus indica*)
T3- Kadamba (*Neolamarckia Kadamba*)
T4- Gliricidia (*Gliricidia sepium*)

3. RESULT AND DISCUSSION

Annual fresh forage yield: The results in Table 1 reveal significant differences ($p < 0.001$) in annual fresh fodder yields among the four fodder tree species tested, both in terms of fractional (leaf and stem) and total yields.

Leaf yield was highest in *Calliandra calothyrsus* (T1) at 17.78 Mg ha^{-1} yr^{-1}, closely followed by *Neolamarckia Kadamba* (T3) with 17.43 Mg ha^{-1} yr^{-1}. Both species performed significantly better than *Gliricidia sepium* (T4; 11.94 Mg ha^{-1} yr^{-1}) and *Morus indica* (T2; 8.66 Mg ha^{-1} yr^{-1}). This suggests that Calliandra and Kadamba have superior leaf biomass production potential, which is advantageous for livestock feed since leaves generally contain higher protein and digestibility compared to stems.

Stem yield followed a similar trend, with Calliandra again leading (11.36 Mg ha^{-1} yr^{-1}), followed by Kadamba (10.59 Mg ha^{-1} yr^{-1}), both significantly higher than Gliricidia (6.81 Mg ha^{-1} yr^{-1}) and Mulberry (5.03 Mg ha^{-1} yr^{-1}). The higher stem yield in Calliandra and Kadamba may indicate more robust woody growth, contributing to higher total biomass but potentially lower digestibility compared to leaf fractions.

Total fresh fodder yield was maximized in Calliandra (29.14 Mg ha^{-1} yr^{-1}) and Kadamba (28.02 Mg ha^{-1} yr^{-1}), which were statistically similar but significantly higher than Gliricidia (18.75 Mg ha^{-1} yr^{-1}) and Mulberry (13.68 Mg ha^{-1} yr^{-1}). These findings clearly demonstrate the superior biomass productivity of Calliandra and Kadamba under the given experimental conditions.

From a practical standpoint, while Calliandra and Kadamba are top performers in terms of yield, the choice between species should also consider nutritive value, regrowth rate, seasonal availability, and farmer preference. For example, Calliandra is known for high crude protein content, while Kadamba might be preferred for its faster establishment and shade tolerance. Gliricidia and Mulberry, despite lower yields, may still hold value in specific contexts due to their adaptability, palatability, and multiple uses.

Overall, these results suggest that integrating Calliandra or Kadamba into fodder production systems can substantially enhance biomass availability for livestock, improving feed supply security in smallholder mixed-farming systems.

Patric (2019), where Gliricidia yielded higher biomass than Calliandra when nursery raised cuttings planted in field. This difference might be due to difference in method of planting as stem

Table 1. Effect of fodder trees species on annual fresh fodder yields

Treatments	Fractional and total harvested fresh fodder yield (Mg $ha^{-1}yr^{-1}$)		
	Leaf	Stem	Total
Calliandra(T1)	17.78a	11.36a	29.14a
Mulberry(T2)	8.66c	5.03c	13.68c
Kadamba (T3)	17.43a	10.59b	28.02a
Gliricidia(T4)	11.94b	6.81bc	18.75b
F value	12.54	13.67	11.84
P Value	0.000***	0.000***	0.000***

*** significant at p<0.001, ** significant at p,0.01, * significant at p<0.05, ns=not significant p>0.05; values with the superscripts in a column do not differ significantly.

Table 2. Effect of fodder trees species on annual dry fodder yields

Treatments	Fractional and total harvested dry fodder yield (Mg $ha^{-1}yr^{-1}$)		
	Leaf	Stem	Total
Calliandra(T1)	4.45a	3.27a	7.71a
Mulberry(T2)	1.84d	1.55bc	3.39d
Kadamba (T3)	2.59b	1.63b	4.22b
Gliricidia(T4)	1.99c	1.51bc	3.49c
F value	19.20	0.49	23.56
P Value	0.000***	0.001**	0.000***

*** significant at p<0.001, ** significant at p,0.01, * significant at p<0.05, ns=not significant p>0.05; values with the superscripts in a column do not differ significantly.

cuttings were directly planted in field, severe mortality and lag period was noticed. Although yielded higher biomass per individual, a smaller number of individuals decreased total fodder yield per ha basis. Vennila *et al*. (2016) in Tamil Nadu, India reported that 2- or 4 month lopping interval is more efficient as it resulted in higher number of branches, leaves and leaf weight, thus increased total fodder yield for Gliricidia sepium that also with more succulent leaves and branches, preferred by livestock. On farms in central Kenya, Calliandra is planted in hedges that are cut at 0.6 m to 1 m height, five times each year. Each tree produces 1.5 Kg of dry matter (Paterson *et al*., 1998). Raj (2016) reported higher dry foliage yields (7.14 Mg $ha^{-1}yr^{-1}$) from Mulberry and Subabul trees at highest plant density (49,382 trees ha^{-1}) than that of lowest plant density (27,777 trees ha^{-1}). Sagaran (2017) reported fresh yield of 42.93 Mg ha-1 from Calliandra fodder banks with 27, 777 plants ha-1 density, pruned at 1 m, at interval 12 weeks.

Annual Dry fodder yield: Table 2. shows the effect of fodder trees on annual fresh fodder yield. Among fodder trees, Calliandra yielded the maximum dry fodder (7.71 Mg $ha^{-1}yr^{-1}$) and was significantly superior to Kadamba (4.22 Mg ha-1 yr^{-1}), Gliricidia (3.49 Mg ha^{-1}) and Mulberry (3.39 Mg ha^{-1}). Calliandra (4.45 Mg ha^{-1}) recorded significantly the highest leaf dry fodder yield than that of other fodder trees.

Patric (2019) found higher dry fodder biomass in Gliricidia and Calliandra followed by Agathi, Mulberry and Moringa during first year. Establishment of Mulberry in the farmland was slower. Mulberry takes long time to establish itself and hence its growth in first year is slower but later it increased. Similar observation also noted by Raj (2016) where she found lower yield in the first year for Mulberry.

4. CONCLUSION

The comparative evaluation of fodder tree species under silvopastoral conditions revealed significant differences in biomass productivity. Among the species studied, Calliandra and Kadamba recorded the highest total fresh fodder yields (29.14 and 28.02 Mg ha^{-1} yr^{-1}, respectively), which were statistically comparable and significantly superior to Gliricidia and Mulberry. These findings demonstrate the strong potential of Calliandra and Kadamba to enhance fodder biomass availability when integrated into silvopastoral systems. The superior yield performance of these species indicates their suitability for improving feed supply security in smallholder mixed-farming systems, particularly in the agroclimatic conditions of the high-range regions of Kerala. Their integration can contribute to sustainable livestock production by increasing on-farm fodder availability and reducing dependence on external feed resources.

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