Silvi-Pastoral and Horti-Pastoral Models for Small Ruminant Production

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Rainfed agro-ecosystem has a distinct place in Indian Agriculture, occupying 67% of the cultivated area, contributing 44% of the food grains and supporting 40% of the human and 65% of the livestock population (Venkateswarlu, 2005). The farming systems in rainfed areas are quite diverse with a variety of crops, cropping systems, agroforestry, horticulture and livestock production. Among the livestock, small ruminants are very important resources and contribute meat, milk, fiber and other functions that are significant to the productivity, stability and sustenance of many farming systems more so on dry lands. Tree leaves and pods form a natural part of the diet of many ruminant species and have been used traditionally as sources of feed for domesticated livestock in Asia, Africa and the Pacific and serves as protein banks to supplement grass or crop residues in dry season (Bhatta *et al*., 2005). It is suggested to develop silvopastoral systems/models by introducing trees/shrubs into natural pasturelands/waste lands to provide nutritious green foliage through out the year (Singh, 1995). Similarly, horticulture and small ruminant (sheep and goat) production systems play a vital role in sustenance of livelihoods of rural poor of rainfed agro-ecosystem (Pasha 2000) in arid and semi-arid regions, where crop production is a risk-prone enterprise due to uncertain rainfall and frequent draughts. In general, farmers develop plantation trees for timber and orchards for fresh fruit production and are not considered as potential grazing resources. Moreover, small ruminants are primarily maintained on natural pasturelands/waste lands with *in situ* grazing and the productivity is constrained by the low quality of native grasses as well as the shortage of good quality forage, especially during the dry season. Hence, it is suggested to develop silvopastoral/hortipastoral systems/models by introducing pasture and foliage component under trees so as to provide nutritious green forage and foliage (Pathak and Roy 1994) to small ruminants for getting higher production from unit of land in rainfed areas.

The term ‘silvo’ means ‘tree’ and ‘pasture’ means ‘grasses’ or ‘grass + legume’ mixtures. Silvopastoral systems are defined as growing of ideal combination of grasses, legumes and trees for producing highly nutritious top fodder and forage, fuel wood, timber and optimising land productivity, conserving plants, soil and nutrients etc. on sustainable basis on the same unit of land. This involves replantation, substitution or intervention in the existing vegetation by desirable species (Deb Roy and Pathak 1974). It is an efficient and integrated land use management system of agricultural crops, horticultural/forest tree species and or livestock simultaneously on the same unit of land, which results in an increase of overall production. The important systems with livestock are

1. Silvipastoral system (Forestry + Pasture + Livestock)
2. Agrisilvipastoral system (Agriculture + Forestry + Pasture + Livestock)
3. Horti-pastoral system (Orchards+ Pasture+ Livestock)

These (Silvipasture and Agrisilvipastoral) systems are otherwise called as “Animal agroforestry” a generic name for all agroforestry systems that includes livestock as component. Silvipastoral system, where in the inter spaces between forest trees species are utilized for cultivation of grasses and grass legume mixtures, which provides a two tier grazing under *in situ*. During rainy seasons the animals prefer to graze green grass, but during dry seasons when there is no blade of grass available, they utilize foliage of the trees.

Agrisilvipastoral system, where in agricultural crops, forest tree species and grass are grown on the same land simultaneously, which provides food to the farmer and feed and fodder to the livestock. During cropping seasons the animals are fed with stored straw (hay) and supplemented with grass and foliage of the trees.

Hortipastoral system, where in the inter spaces between fruit trees species are utilized for cultivation of grasses and grass legume mixtures. Only during dormant season of the fruit tree, the livestock are allowed to graze on the available pasture for a period of 3-4 months in a year.

Grass, Shrub and Tree Species for Development of Pastoral Systems

1.1 Arid desert and sand dunes

About 30 m ha area under arid zone of the Thar desert is sandy plains, sandy hummocks and sand dunes. The forage production from these areas can be increased from 0.50 to 3.6 t/ha by growing suitable grasses (*Lasiurus sindicus, Cenchrus ciliaris, C. setigerus*), legumes *(Clitoria ternatea, Lablab purpureus, Atylosia scarabaeoides*), shrubs (*Zizyphus numularia*) and trees *(Prosopis cineraria, P. juliflora, Azadirachta indica* and *Acacia tortilis*) with improved management practices.

1.2 Semi-arid, rocky and gravelly areas

A vast area of the country comes under semi-arid zones, where lot of area is rocky and gravelly. Simple management practices viz., protection and eradication of bushes increased production of grasslands from 0.80 t/ha to 3.5 t/ha (Shankarnarayan *et al*., 1974) and introduction of legumes (*Atylosia scarabaeoides, Stylosanthes hamata, S. humilis, Macroptilium atropurpureum, M. lathyroides, Lablab purpureus*) in natural grassland (*Heteropogon contortus and Sehima nervosum*) further, increased production from little over 3 t/ha to 5 t/ha. The suitable tree species found in this region were *Hardiwickia binata, Albizia amara, A. lebbeck, A. procera, Dalbergia sissoo, Leucaena leucocephala, Acacia tortilis, Dichrostachys cinerea, Emblica officinalis, Zizyphus mauritiana and Aegle marmales*.

1.3 Cold desert

About 10 m ha cold desert lies in the north of Great Himalayas and have only short-lived species, which provide 1-2 months grazing during summer. Several indigenous species of grasses (*Agropyron, Agrostis, Alopecurus, Bromus, Cicer, Lespedeza, Lotus, Medicago, Melilotus, Trifolium*, etc. species) are found in Ladakh region. Recently a potential hay species namely *Pronges pabularis* is identified and able to produce 1 to 1.5 t/ha with 10.4 per cent protein.

1.4 Ravine soils

About 4 m ha area is ravenous and confined largely to the states of Uttar Pradesh, Madhya Pradesh, Rajasthan and Gujarat, which could be developed as silvopastoral systems by introducing different grasses (*Cenchrus spp., Panicum antidotale, Pennisetum pedicellatum and Dichanthium annulatum*), legumes (*Macroptilium atropurpureum, Clitoria ternatea, Atylosia scarabaeoides, Alysicarpus monilifer Stizolobium deeringianum*), bushes (*Dichrostachys species, Zizyphus numularia, Capparia zeylanica*), and trees (*Acacia spp., Ficus spp. Dendrocalamus strictus, Prosopis cineraria, Dalbergia sissoo, Bauhinia purpurea*).

1.5 Saline sodic soils

About 8 million has area is affected by salinity and alkalinity in different parts of India. These soils can be developed as silvopastoral models by introducing salt tolerant grasses (*Brachiaria mutica, Diplachea fusca, Iseilema laxum, Paspalum notatum, P. dilatatum, Bothriochloa intermedia, Chloris guayana, Sporobolus marginatus, Cynodon dactylon, Panicum maximum*), legumes (*Rhynchosia minima, Clitoria ternatea, Mimosa invisa, M. atropurpureum*) and shrubs (*Sesbania, Atriplex, Acacia* and *Albizia* species).

1.6 Acidic soils

Acidic soils are most commonly seen in eastern states of India and these can be suitably developed as silvopastoral models by introduction of grasses (Pennisetum polystachyon, P. pedicellatum. P. clandestinum, Paspalum notatum), legumes (*Centrosema pubescens, Stylosanthes guianensis, Calopogonium muconoides, Pueraria phaseoloides, Desmodium* species) and trees (*Ficus numeralis, Albizia chinensis, Morus cerrata, Ulmus repalensis, Bucklandia pupulrea*).

1.7 Swampy and wet lands.

The extent of wetlands is more than 6 m ha apart from the permanent water bodies posing different kind of problems. Marshlands and swamps are usually found in southern and eastern India. Biomass production from such areas can be improved by growing suitable species of grasses (*Brachiaria mutica, Iseilema laxum, Dichanthium caricosum, Paspalum notatum, Brachiaria decumbens*), legumes (*Sesbania species, Lotononis bainesii, Desmanthus virgatus, Pueraria phaseoloides, Glycine wightii*) and trees (*Salix tetrasperma, Lagerstroemia flosreginae, Dalbergia latifolia, Eucalyptus robusta, Barringtonia acutangula, Populus euphratica, Glyricida maculata*) to increase green forage production from 20 to 40 t/ha.

1.8 Cho and riverbed affected soils

The shallow hill torrents have seasonal flows, which are called Cho's and are largely observed in the sub-mountain regions of the Himalayan. These soils need a permanent vegetation cover of economic importance like fuel cum fodder trees. Grasses (*Chrysopogon fulvus, Dichanthium annulatum, Bothriochloa pertusaz, Pennisetum pedicellatum, Eulallopsis binata*), legumes (*Stylosanthes guianensis, Calapogonlum mueunoldes*) and trees (*Salix spp. Dalbergia sissoo, Glyricida maculata, Acacia catechu, Zizyphus spp., Psidium guajava*) have shown great promise in such situations (Singh, 1987).

1.9 Mines affected areas

In India coalmines affected large area and these soils could be developed by introducing suitable grasses (*C. fulvus, B. pertusa, D. annulatum, P. pedicellatum, P. maximum*), legumes (*S. hamata, A. scarabaeoides, M. atropurpureum*) and trees (*Acacia species, Albizia species A. indica, D. cinerea, Z. mauritiana*).

2 Spacing and Design of Silvopastoral Systems

Spacing of 1x1 meter is common for many species. Fodder production and accessibility can be improved by using double rows of fodder tree/shrubs at wider spacing. Rows are established about 50 cm apart with 1-1.5 meters between double rows. In row spacing of tree/shrubs varies from 5-50 cm. Ideally, rows are oriented along the contours in an east-west direction. Once the fodder tree/shrubs are well established, grass should be allowed to grow in the area between double rows. Competition between tree/shrub and grass should be monitored constantly so that fodder productivity does not decrease.

3 Management of Silvopastoral Systems

Age at first harvest: In most circumstances the first harvest should be delayed until the fodder tree/shrub is 12-16 months old depending on the species. Under arid or poor soil conditions growth will be slow and the first harvest should be later. When growth is fast, the first harvest may be sooner. The goal is to allow fodder tree species to establish deep roots and thick trunk diameters.

Grazing: Small ruminants can directly graze fodder tree/shrubs. This system saves labor and effort but can lead to plant damage and fodder waste from trampling. The key to direct grazing is subdivision of the fodder plot into paddocks. Grazing periods are generally 1-2 weeks, followed by recuperation periods of 3-6 week (or three times the grazing period). Under arid conditions the recuperation period may need to be longer.

3.4 Cut-and-carry: Most fodder tree/shrubs are managed through a cut-and-carry system in which the fodder is harvested and then 'carried' to feed the small ruminants. A cut-and-carry system decreases fodder waste from animal damage and the necessity to monitor animals. However, labor inputs may be greater than with direct grazing systems. Important management factors to consider for a cut-and-carry system are cutting height, cutting frequency, and dry season management.

3.5 Cutting height: Review of results suggests a standard cutting height of 50-150 cm is optimum depending upon the tree/shrub species.

3.6 Cutting frequency. The most common recommended cutting frequencies are 6-18 weeks. Generally, longer cutting frequencies, 12-18 weeks generate more total biomass but increase the proportion of small wood production. Shorter cutting frequencies, 6-12 weeks, favor fodder yields and fodder quality

3.7 Dry-season management: Six to eight weeks before the beginning of the dry-season trees should be cut to the recommended height. The new foliage produced over the next few weeks will be retained well into the dry-season when it is most needed. When the dry-season is very long or the area of fodder bank very large, the pre-dry-season harvest should occur in phases. This will assure that fodder is available throughout the dry-season. The excess may be used to include in animal rations, make silage for dry-season use, or mulch crops.

4 Predicting YieldoOf Forage and Fodder

Potential yield is the foliage available from defoliation. Lopping yield is the amount of foliage available through strategic and systematic defoliation.

4.1 Grass and ground legume: The simplest method is by using a quadrate. The vegetation inside the quadrate is cut. Sampling is repeated in the center, diagonal crossing and the edge of the field and yield per hectare can be estimated by using an equation: Y=R x10000, where Y is fresh weight yield in one hectare and R is yield in one square meter.

4.2 Fodder shrub and fodder tree: Leaf yield of a tree can be predicted by using allometric equation of log W= 2.24 log DT-1.50, where W= leaf yield in kilograms of dry weight and DT is trunk diameter (cm) at 130cm height. For shrubs with many primary branches, the equation Y= 0.28 + 3.62

x predicts leaf yield (Y) in grams of DW per tree, where x is the sum of the diameter of stem and primary branches.

5 Means and Ways of Increasing Yield

- Fertilizer: *Cenchrus ciliaris* responds highly to P application
- Grass-legume mixture: At least 20-30% legume component is required in mixed pasture
- Association: *Pennisetum* grass under A*cacia* trees is around two times higher productive
- Shrub and tree spacing
- Weed control
- Irrigation

Many species make excellent fodder tree components. In general those species establish readily, grow fast, out-compete weeds, produce high-quality fodder, remain productive under repeated harvest, remain productive during dry seasons, survive on poor sites, tolerance to shading and drought should be selected. The following considerations should be kept in view for increasing the productivity

6 Production Potential of Silvopastoral Systems

6.1 Forage production

The degraded waste lands (shallow red gravelly soils) under semi arid condition at Jhansi producing 1 t/ha/year have been improved to produce upto 10 t/ha/year at a 10 years rotation through silvopastoral systems (Pathak et. al., 1996). Besides yield improvement by 8 to 10 times, the quality of mixed forage has also improved by 6 to 7 times. The comparative study at NRCAF, Jhansi on forage and / or top feed production from silvopastoral system and natural grassland for 8 years revealed that on an average 5.06 t/ha/year (4.55 t from pasture + 0.51 t from tree leaves and pods through pruning) was produced from silvopastoral system, which is about 2 times higher than yield obtained from natural grassland. These results showed that it is possible to get more biomass through established silvopasture on the land, which is producing less than 2 t/ha/year forage through natural vegetation. The forage production from single (*Cenchrus* pasture alone), two (*Cenchrus* + *Ailanthus excelsa*) and three (*Cenchrus* + *A. excelsa* + *Dichrostachys cinerea*) tier systems were compared with natural pasture at CSWRI, Avikanagar, Rajasthan under semi arid condition. Results showed that three tier silvopastoral system provided maximum average forage production (t/ha) (2.78 dry forage from pasture + 0.95 green tree leaves) followed by two tier and single tier.

Silvopastoral system consisting of *A. nilotica* + *C. ciliaris* and *A. tortilis* + *C. ciliaris* planted at 3x3 m spacing produced on an average biomass yield (ha/year) of 2.5 t and 2.7 t, respectively. Studies on the production potential of pasture alone (*C. ciliaris*), fodder trees alone (*H. binata* + *C. mopane*) and silvopastoral system (*C. ciliaris* + *H. binata* + *C. mopane*) were compared at CAZRI, Jodhpur for nine years. On the basis of the results, it was observed that silvopastoral system was better for higher average forage production and livestock maintenance (4.1 ACU/ha) followed by pure pasture and pure trees block (Harsh et. al., 1992). In alkali soils at Karnal, Singh (1995) reported that 0.81 t pod + 7.7 t green forage/ha/year was obtained from silvopasture (*P. juliflora* + *Leptochloa fusca*) as compared to sole planting of *P. juliflora* (0.85 t pod/ha/year) at 6th year of plantation.

Studies conducted from 1980 - 1993 at Dehradun in degraded river bed bouldery land with 4 trees (*A. lebbeck, B. purpurea, G. optiva and L. leucocephala*) managed with 2 lopping intensities of crown (50 and 75%) and with 2 grasses at inter spaces (*C. fulvus* and *Eulaliopsis binata*) revealed that

on an average dry forage yield of 4.55 t/ha/year can be obtained from different silvopastoral systems on such bouldery lands.

In Himanchal Pradesh, the carrying capacity of Palanpur, Phuttakhal and Bara Bangahal pastures were 1.31, 1.05 and 0.4 ACU/ha/year, respectively (Katoch and Dogra, 1993). Under improved silvopastoral systems i.e. the introduction of *Setaria sphacelata* + *Macroptilium atropurpureum* + *Robinia pseudoacacia or S. sphacelata* + *M. atropurpureum* + *L. leucocephala* in the natural grassland, the dry matter yield and carrying capacity increased by more than 2.5 times over control. Similarly, at CIRG, Makhdoom, a 3 tier silvopastoral system consisting of *A. nilotica* + *L. leucocephala* + *C. ciliaris* produced total forage production of 8.0 t with gross energy of 33,866 Mcal and 1270 kg crude protein in ravenous grazing lands per hectare. The minimum dry forage (0.13t top feed + 2.27 t pasture), gross energy (12, 624 Cal) and crude protein (10.0 kg) per hectare were recorded with natural silvopasture (Bhattacharya and Sharma, 1993).

6.2 Top feed production

The leaf fodder yield per tree varies considerably and it depends on species, initial age, lopping intensity and interval as well as agro-climatic conditions. In semi-arid conditions from 8-9 years old silvopastoral system, mean green and dry leaf fodder production of 9.63 and 5.28 t/ha, respectively was reported (Deb Roy, 1990) with annual lopping at 1/3 intensity in *Albizia procera,* where as 6.24 and 2.78 t/ha, respectively in case of *A. lebbeck* through biannual lopping at 2/3 intensity. Similarly, from 8-10 years old *A. tortilis* - *Cenchrus* silvopastoral system, top feed yield of 2.75 to 3.50 kg/tree was recorded on annual lopping. Annual lopping (2/3 intensity) of *A. amara* produced 10.9 t/ha (green) or 5.6 t/ha (dry) leaf fodder. A five years old plant of *D. cinerea* provided dry leaf fodder of 2.4 kg/tree/year when biannual lopping was done at 50% intensity (Roy et. al. 1987).

A five year old *Bahunia purpurea* yielded green leaf fodder of 10.02 kg/tree/year at Jhansi (Roy and Deb Roy, 1983). Top feed production (kg/tree) from six fodder trees of Bundelkhand region showed the maximum dry leaf fodder of 11.38 in *A. procera* followed by *A. amara* (11.20), *A. lebbeck* (4.21), *H. binata* (3.67) and *D. cinerea (*2.76) and a minimum of 0.51 in *A. tortilis*, respectively in 10 years old plantation. In *S. grandiflora* and *S. sesban,* the dry leaf fodder yield of 0.3 kg/tree was recorded after 3.5 years of establishment when grown at the density of 5000/ha (Gupta et. al., 1983).

A three tier silvopastoral system developed at NRCAF, Jhansi with woody components of *D. cinerea* + *A. amara* + *L. leucocephala* showed top feed (dry leaf + pod) production of 0.04, 0.26, 0.48, 1.15, 0.53, 0.55 and 0.54 t/ha during I, II, III, IV, V, VI and VII year, respectively when pruned upto 50% height of the trees from ground level. The average leaf fodder yield in young trees of *A. excelsa, P. cineraria, A. indica and D. cinerea* was 21.13, 25.70, 12.65 and 0.67 kg/tree, respectively. The corresponding yields of older trees were 46.14, 57.81, 46.45 and 1.12 kg/tree, respectively.

Evaluation of tree species under natural grassland in red gravelly soils in semi-arid region showed mean maximum dry leaf fodder of 2.69 and 3.80 kg/tree when pruned upto 50 and 75% of the tree height, respectively with *L. leucocephala* followed by *A. procera* and minimum yield was observed with *A. pendula*. Similarly in medium black soils, under rangeland condition produced the mean maximum dry leaf fodder of 0.31 and 0.58 kg/tree with *L. leucocephala* when pruning was done upto 50 and 75% height, respectively followed by *A. amara*, *D. cinerea, A. tortilis, Dendrocalamus strictus*. Harvesting of multipurpose tree species at 8 years of growth showed the maximum dry leaf

fodder of 10.6 kg/tree with *A. lebbeck* followed by *L. leucocephala* (5.4 kg/tree), *A. amara* and *P. pinnata* (Rai, 1999). Similarly, harvesting of tree species at 10 years of age and grown in red gravelly soils showed the maximum dry leaf fodder of 3.81 t/ha with *A. procera* followed by *L. leucocephala* (3.7 t/ha) and *D. sissoo* (2.52 t/ha).

In Rajasthan a full grown tree of *P. cineraria* was reported to yield 59 kg/tree green leaf on complete lopping leaving the central leading shoot, where as 28 kg/tree when lower 2/3 crown is lopped and 20 kg/tree when lower 1/3 crown is lopped (Bhimaya et. al. 1964). Over 30 years age of *P. cineraria* with well spread crown produced 25 kg air dried leaves, 5 kg pods and 2 kg seed/tree / year in 300-400 mm rainfall zone.

6.3 Nutritive Value of Top Feed from Silvipastoral System

In many parts of India, livestock feed on shrubs and trees than on the surface fodders like grasses and grass-legume pastures. Top feed is a rich source of crude protein and may be useful as protein supplements for low quality fodder and straws. The dry matter (DM) content of the various tree leaves ranges from 20 to 40 %, with 8 to 23 % crude protein (DM basis). The ether extract fraction is also fairly high compared with annual and perennial, natural and cultivated grasses and hays. The tree leaves contain comparatively low percentage of crude fibre than in grasses and hays. A wide variation was observed in the concentration of fibre fractions (neutral detergent fibre (NDF), acid detergent fibre (ADF), hemi-cellulose and cellulose). Their fibre is so complex and highly lignified at maturity. Crude protein content decreases and crude fibre content increases with increasing age of maturity. Dry matter (DM) digestibility ranges from 50 to 88% and crude protein (CP) digestibility from 38 to 91% (Ramana *et.al*, 2000). *In –vivo* digestibility trial conducted at Kattupakkam, Tamilnadu on Lannea coromandelica, *Artocarpus heteophyllus, Albizia lebbeck, Leucaena leucocephala, Ficus bengalensis, gliricidia septum and Millingtonia hortensis* revealed a better nutritive value comparable to other feed ingredients in most of the tree leaves and all these leaves found to be useful in feeding small ruminants. Calcium content of the tree leaves is 2-3 times more than that of the cultivated fodder and grasses. The phosphorus content is, in general low, resulting in wide calcium to phosphorus ratios. No significant variation was observed in the major mineral concentration of tree leaves collected from drought prone and non- drought prone areas and also legume and non-legume tree leaves (Valli and Murugan, 1998). Palatability, digestibility and nutritive value of the tree fodder decreases as the leaf advances in maturity. The palatability, digestibility and nutritive value of the tree leaves are higher with goats than with sheep (Bohra, 1980).

Plant secondary metabolites “tannins” are the one commonly found anti-nutritional factor in shrubs and tree fodder and pods. Prolonged consumption of tannin- rich leaves and pods induces toxicity, however when the concentration is below 4% of dry matter, they improve the nutritive value of herbage by binding to plant proteins and protecting them from excessive degradation in the rumen. Although the anti-nutritional factors create some problems and deleterious effects on small ruminants, there are differences between breeds within species concerning utilization and threshold of tolerance. Sheep is slightly more susceptible to toxicity, where as goat seems to be resistant as no effect found even with whole feeding.

6.4 Productivity of Sheep and Goat under Silvipastoral System

The comparative growth performance of sheep and goats were studied at NRCAF, Jhansi on 15 months old silvopastoral system consisting of *A.amara* and *L. leucocephala* as tree component, and *D. cinerea* as shrub. The under story vegetation of the silvopastoral system consists of perennial grasses

such as *Chrysopogon fulvus* and pasture legumes as *Stylosanthes hamata* and *S. scabra*, while *Sehima - Heteropogon* as natural grassland. Results showed that goats and sheep grazed on silvopastoral system gained (head/day) in their body weight at the rate of 28.6 and 2.1 g, where as on natural grassland the gain was 10.8 g in goats. However, sheep lost their weight (head/day) at the rate of 27.4 g in a total grazing period of 241 days even after supplementation of 1.5 kg (head/day) of *L. leucocephala* as top feed (Rai, et. al., 1994).

Grazing studies (August 1992 to June, 1994) with 6 male lambs + 6 male kids (4-6 months old) on two years old silvopastoral system and natural grassland revealed that animals grazing on both the pasture continued to gain in their weight up to November, 1993. Lambs and kids grazed on silvopasture gained in their body weight at the rate (head/day) of 54.8 and 36.8 g, where as on natural grassland showed 41.2 and 26.4 g weight gain, respectively in the total period of 478 grazing days. This indicates that lambs and kids of Muzzafarnagari and Barbari breed respectively were able to gain continuously on the both the pasture up to 1.8 years of their age without any supplementation of concentrate feed. However, gain in body weight of lambs and kid grazing on silvopasture was 33.0 and 39.4% higher as compared to natural grassland, respectively. Thus, the results proved that under silvopastoral systems more number of sheep and goats could be reared with better performance as compared to natural grasslands as the area of natural grassland was 2 ha and silvopasture was 1 ha.

Feeding trial conducted at Institute of animal nutrition, Kattupakkam on performance and nutrient utilisation in small ruminants fed with top feeds revealed significant ($P<0.01$) increase in feed efficiency and reduction in feed cost per kg body weight gain, when 50% of the DM requirement was met with tree leaves mixture (TLM) contained equal proportion of the leaves of *A. lebbeck, G. sepium, L. leucocephala* and *F. bengalensis* than green grass. In another trial, highest average daily weight gain was observed in Madras Red ram lambs fed with a ration in which 50% of green grass was replaced with TLM contained equal proportion of the leaves of *A. lebbeck, L. leucocephala* and *F. bengalensis*. Feeding grass and tree leaves each at 50% level was found economically superior than feeding grass and concentrate mixture in lambs (Parthasarathy, *et.al*, 1998). The performance of sheep was found better when integrated with the Bajra+ Neem agrisilvi system, where Bajra was raised as fodder and supplemented with tree leaves.

A live weight gain of 20-22 kg with average daily gain (head/day) of 56-61 g and 93-102 g in lambs and kids, respectively were recorded on two tier (*Cenchrus ciliaris + A. excelsa*) and three tier (*C. Ciliaris + D. cinerea + A. excelsa*) silvopastoral systems with stocking density of 14 animals/ha (lambs and kids). Silvopastoral system with rotational grazing was adequate to support ewes during pregnancy and lactation (Sankhyan et. al., 1997). The small ruminants (lambs and kids) can be maintained on silvopastoral system consisting of *Leucaena leucocephala* as a tree component and *Dichrostachys cinerea* as shrub along with natural vegetation with optimum live weight gain. The performance of kids were better than lambs and grazing was found better than stall feeding to achieve maximum live weight gain (Ramana *et.al*., 2000). A total of 12 kids and 6 lambs were added to the flock by kidding and lambing, respectively over a period of 12 months from 11-12 months old sheep (9+1 ewe and ram, respectively) and goat (9+1 doe and buck, respectively) based 2 ha silvopastoral system consisting of *Leucaena leucocephala* as a tree component and *Dichrostachys cinerea* as shrub along with natural vegetation at NRCAF, Jhansi. A daily weight gain (g/head) of 72.04 and 104.29 was also observed, respectively in newborn kids and lambs.

6.5 Productivity of ram lambs under Hortipastoral System

Three on farm experiments – experiment 1 (E1, 130 days), experiment 2 (E2, 120 days) and experiment 3 (E3, 120 days) were carried to evaluate the performance of Nellore Zodpi ram lambs under hortipastoral systems (mango and sweet orange orchards above 5 years old with *C. ciliaris, S. hamata* and *C. ciliaris + S. hamata* established pastures and boundary plantation of *L. leucocephala*) developed by the farmers in rainfed areas. The lambs with complementary grazing on established pasture or supplemented with *L. leucocephala* foliage in addition to grazing on natural pasture gained significantly ($P < 0.01$) higher live weight than grazed solely on natural pasture. This is because of availability of sufficient quality foliage and forage from the established pastures compared to natural under orchards and increased digestibility of the feed. Supplementation of plant protein sources, which contain medium to high CP levels (Kaitho, 1997; Solomon, 2001) will alleviate CP deficiency of fibrous feeds, reduce feed retention time and improve feed intake (Melaku *et al*., 2005). Further, Kronberg and Malechek (1997) reported CP intake was probably more essential for maintenance and production needs of the sheep. Significantly ($P < 0.01$) higher ADG was observed with complementary grazing on *S. hamata* and *C. ciliaris + S. hamata* forage. This could be due to relatively high content of nitrogen and carbohydrate fractions featured by slow-rate of degradation of *S. hamata* forage. Relatively lower ADG observed in the lambs supplemented with *L. leucocephala* foliage than complementary grazing on *S. hamata* forage although the former had higher CP. The *L. leucocephala* foliage contained phenolics (18.6 g kg^{-1} DM) and tannins (23.5 g kg^{-1} DM) (Ramana *et al.,* 2000) and these antinutritional factors lower feed digestibility (Mangan, 1988; Makkar, 1989) and nutrient utilization in ruminants (Aerts *et al*., 1999). Significantly ($P < 0.01$) higher ADG was observed in E 1 followed by E 2 and E 3. The differences in ADG among the experiments could be due to the differences in availability of pasture interms of quality as the experiments conducted in different periods. Low pasture quality impairs the productivity of ruminant livestock especially when grazing is the main feeding system (Devendra and Burns, 1983; Pamo *et al*., 2001). Further, it could be due to decreased intake rate of forage for lambs with changing maturity from the vegetative to reproductive stage and that effects the availability of nutrients in forage (Gong *et al*., 1996). Higher ADG in E 1 could be due to marked increase in availability of feed resources in rainy season (Maurya *et al*., 2004) as the experiment initiated during the middle of rainy season (September month).

Income from ram lamb production under hortipastoral systems seems to be quite remunerative in all the experiments in addition to better utilization of natural resources. Net gain (Rs. ha^{-1}) from the hortipastoral systems ranged from 1320 to 3120 through ram lamb production. Further, higher income was observed with complementary grazing on established pasture or supplementation of *L. leucocephala* foliage from the orchards.

In India, the forage production potential could be doubled by establishment of suitable silvopastoral systems in wastelands and further, practice of proper rotational grazing will allow to belittle damage to tree and grass component of the system by browsing and grazing (goat and sheep, respectively). This approach would enhance the supply of nutritious fodder year-round and meet the feeding requirements of sheep and goat and results in higher production and maximum return to the farmer. The problem, fodder scarcity also gradually disappears with the establishment of the silvopastoral systems on community and wastelands. Further, translation of orchards (mango and sweet orange) over 5 years old into hortipastoral systems with boundary plantation of *L leucocephala* for ram lamb production would provide additional income to the farmers.

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