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Assessment of Carrying Capacity of Crop-Livestock Silvipastoral Farming System

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On farm field experiments were conducted in three farmer's fields at dryland tracts of Tirupur district for two years from September, 2009 to March, 2011 to assess the carrying capacity of silvipastoral farming system. The treatments consisted of five silvipastoral systems *viz., Acacia leucophloea + Cenchrus ciliaris, Acacia leucophloea + Cenchrus ciliaris + Stylosanthes hamata, Acacia leucophloea + Cenchrus setigerus + Stylosanthes hamata, Acacia leucophloea + fodder sorghum + Pillipesara and Acacia leucophloea + Cenchrus setigerus + Stylosanthes hamata and fodder sorghum + Pillipesara.* One unit of Mecheri sheep of five ewes (female) and one ram (male) and two buffaloes were maintained in each location. Among the silvipastoral systems, rotational grazing of 39 numbers of sheep per ha of silvipasture land with *Cenchrus setigerus + Stylosanthes hamata and fodder sorghum + Pillipesara* system was found to be the best.

Key words: Dryland, silvipastoral farming system, carrying capacity, grazing

Dry land ecosystem has a distinct place in Indian Agriculture. In India, 70 per cent of the farming is dry land which contributes for 42 per cent of the food grain production. Out of the 143 m.ha of net cultivated area in the country, 51 m.ha area received less than 750 mm rainfall. India's population touched 1.198 billion in 2009 (Yadav *et al.,* 2009). The challenge for the research system in the 21st Century is, therefore, to increase land productivity and to evolve farm technologies suited to the local environmental conditions of different agro climatic regions. In Tamil Nadu, 49 per cent of the geographical area is under dry land condition. In dry land, variation in amount and distribution of rainfall influence the crop production as well as socio economic status of farmers. In Tamil Nadu, area under permanent pastures and other grazing land is 0.11 lakh ha and fodder crops raised under dry land condition covers an area of 1.57 lakh ha (Velayudham, 2011). Among the 32 districts of Tamil Nadu, Tirupur, Namakkal and Salem occupy 72.5 per cent of pasture area and hence considered as pasture hub of Tamil Nadu. Small ruminants are primarily maintained on natural pasturelands 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. Silvipasture is a traditional land use system used for grazing livestock. Existing silvipastoral system was not able to provide nutritious and off season fodder to animals. The pad-dock is not rotated for grazing on regular basis and leads to soil fertility deterioration. In this context, on-farm field experiment was carried out to assess the carrying capacity of crop - livestock silvipastoral farming system in dry land areas of Western Zone of Tamil Nadu.

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Materials and Methods

Field location

Based on survey, three farmers were selected for carrying out the field experiment. The experiments were conducted in farmer's field at Kilankattuvalasu, Kangeyam (location I), Pulliampatti, Mulanur (location II) and Kambaliampatti, Mulanur (location III) villages in Tiruppur district during September, 2009 to March, 2011. The farms are situated at 11_0 North latitude and 77_0 East longitude and at an altitude of 427 m above MSL.

Weather and climate

The normal climatic conditions of Tiruppur district (mean of 50 years) are as follows. The mean annual rainfall was 650 mm received in 37.5 rainy days, of which winter, summer, South west and north east monsoon recorded 16.1, 106.9, 267.2 and 259. 6 mm, respectively. The annual mean maximum temperature varied from 30_0 to 38_0 C, while the mean minimum temperature varied from 19_0 to 26_0 C. The district receives maximum amount of rain during the North East Monsoon followed by South West Monsoon (June - September). The relative humidity ranged from 61 to 91 per cent in the forenoon and 14 to 68 per cent in the afternoon. The mean bright sunshine hours per day was 7.4 with a mean solar radiation of 400 cal. cm^{-2} day^{-1}.

During the experimental period in location I (Kangeyam), the maximum temperature ranged from 32.0 to 34.0_0C and minimum temperature ranged from 21.0 to 24.0_0C. The relative humidity ranged from 58 to 71 per cent and the solar radiation received was 386.81 cal. cm^{-2} day^{-1}. The mean annual rainfall received during September, 2009 to August, 2010

and September, 2010 to March, 2011 were 830.8 mm (of which the winter, summer, south west and north east monsoon recorded 2.0, 250.5, 157.4 and 420.9 mm) and 875 mm (of which the winter, summer, south west and north east monsoon recorded 190.0, 29.0, 119.5 and 536.5 mm), respectively.

During the experimental period in location II & III (Mulanur), the maximum temperature ranged from 31.0 to 33.0^{o}C and minimum temperature ranged from 21.0 to 23.0 ^{o}C. The relative humidity ranged from 58 to 64 per cent and the solar radiation received was 372.77 cal. cm^{-2} day^{-1}. The mean annual rainfall received during September, 2009 to August, 2010 and September, 2010 to March, 2011 were 675.5 mm (of which winter, summer, south west and north east monsoon recorded 1.5, 143.5, 119.0 and 411.5 mm) and 705.0 mm (of which the winter, summer, south west and north east monsoon recorded 0.0, 0.5, 149.0 and 555.5 mm), respectively.

Treatment details

i. Silvipastoral farming

SFS_1	- *Acacia leucophloea* + *Cenchrus ciliaris*	: 0.20 ha
SFS_2	- *Acacia leucophloea* + *Cenchrus ciliaris* + *Stylosanthes*	: 0.20 ha
SFS_3	- *Acacia leucophloea* + *Cenchrus setigerus* + *Stylosanthes hamata*	: 0.20 ha
SFS_4	- *Acacia leucophloea* + fodder sorghum + *Pillipesara*	: 0.20 ha
SFS_5	- *Acacia leucophloea* + *Cenchrus setigerus* + *Stylosanthes hamata* & fodder sorghum + *Pillipesara*	: 0.20 ha

ii. Animal component

Sheep - (5 ewes + 1 ram), Buffalo – 2 No's.

Sheep

Mecheri sheep of five ewes (female) and one ram (male) were maintained in each location. The lambs were disposed at six months of age. Sheep were allowed to graze in the established pasture for eight hours per day. The animals were reared mainly by grazing and were housed in an open enclosure (*patti*) near farmer's house.

Silvipastoral system, where the inter spaces between trees were utilized for cultivation of grasses and grass legume mixtures, provided a two tier grazing *in-situ*. During rainy season the livestock prefer to graze green grass, but during dry season when there is no blade of grass available, they utilize foliage and pods of the *Acacia* trees. During off season, 2 kg of the mixture of *Acacia* pods and groundnut haulm per day was fed to each sheep.

Buffalo

In each location, two buffaloes were maintained. The buffaloes were allowed to graze in the established pasture for eight hours per day. During off season, 20 kg of sorghum straw and groundnut haulm and 1.5 kg of concentrate feed was fed to each buffalo per day.

iii. Trees

Acacia leucophloea trees were maintained approximately at a spacing of 8m x 8m. The trees were five year old and there were 30 number of *Acacia leucophloea* trees existed randomly in each treatment. The interspaces of the trees were utilized for raising forage crops. The land was ploughed between tree rows for sowing the seeds of forage crops.

Carrying capacity

Carrying capacity is the stocking rate, calculated by using four factors viz., annual forage production, utilization rate, average daily intake and length of the grazing season. From these observations, carrying capacity was calculated using the formula given by Jim Gerrish (1998).

$$\text{Carrying capacity} = \frac{\text{Annual forage yield (kg ha}^{-1}\text{) X Utilization rate (\%)}}{\text{Average daily intake (kg day}^{-1}\text{) X Length of grazing season (days)}}$$

Annual forage yield

Annual forage yield was calculated by totalling the three cuts (70 DAS, 115 DAS and 160 DAS) biomass yield.

Utilization rate

At the beginning of each grazing period, forage samples were collected and weighed immediately before and after grazing to estimate the utilization rate. Forage biomass was determined by harvesting the forage using quadrat (0.5 m x 0.5 m) in four places at random. On a five day rotation, utilization rate of forage was calculated and expressed as percentage.

$$\text{Utillization rate} = \frac{\text{Forage yield before grazing (kg ha}^{-1}\text{) – Forage yield after grazing (kg ha}^{-1}\text{)}}{\text{Forage yield before grazing (kg ha}^{-1}\text{)}}$$

Average daily intake

Average daily intake of sheep varies according to the body weight. On an average 2.5 kg of fodder is required for sheep per day and this was taken for working out the carrying capacity.

Length of grazing season

Length of the grazing season is number of days that the pasture is available for grazing the sheep. Grazing season starts 70 days after the receipt of rain. Actual number of days that the sheep was allowed for grazing in the pasture land was taken as length of grazing season.

***Cenchrus* equivalent yield (CEY)**

The productivity of each crop component was converted into *Cenchrus* equivalent yield for better comparison and expressed in tonnes.

$$CEY = \frac{\text{Productivity of crop component/ livetock (t) X Cost of crop component/ livestock (Rs.t}^{-1}\text{)}}{\text{Cost of } \textit{Cenchrus} \text{ (Rs.t}^{-1}\text{)}}$$

Results and Discussion

Annual *Cenchrus* equivalent yield

Annual *Cenchrus* equivalent yield was recorded in each silvipastoral system at all the three locations. During 2009-10, among the different silvipastoral systems, *Cenchrus setigerus* + *Stylosanthes hamata* and fodder sorghum + *Pillipesara* (SFS_5) recorded higher annual *Cenchrus* equivalent yield of 12.09, 9.00 and 9.82 t ha^{-1} in location I, II and III, respectively. However, this was followed by fodder sorghum + *Pillipesara* (SFS_4) with an annual *Cenchrus* equivalent yield of 10.53, 7.53 and 8.26 t ha^{-1} in location I, II and III, respectively, whereas, *Cenchrus ciliaris* alone (SFS_1) recorded lower annual *Cenchrus* equivalent

Table 1. Annual *Cenchrus* equivalent yield (t ha^{-1})

Treatment	2009-10			2010-11		
	Location I	Location II	Location III	Location I	Location II	Location III
SFS_1	4.02	2.97	3.27	4.73	3.36	4.39
SFS_2	6.04	4.46	4.15	7.49	5.32	5.77
SFS_3	5.53	4.06	4.43	6.38	4.53	5.12
SFS_4	10.53	7.53	8.26	12.22	8.69	11.05
SFS_5	12.09	9.00	9.82	14.05	9.98	11.12

yield of 4.02, 2.97 and 3.27 t ha^{-1} in location I, II and III, respectively. During 2010-11, *Cenchrus setigerus* + *Stylosanthes hamata* and fodder sorghum + *Pillipesara* (SFS_5) recorded higher annual *Cenchrus* equivalent yield of 14.05, 9.98 and 11.12 t ha^{-1} in location I, II and III, respectively. However, this was comparable with fodder sorghum + *Pillipesara* (SFS_4) with an annual *Cenchrus* equivalent yield of 12.22, 8.69 and 11.05 t ha^{-1} in location I, II and III, respectively followed by *Cenchrus ciliaris* + *Stylosanthes hamata* (SFS_2) with an annual *Cenchrus* equivalent yield of 7.49, 5.32 and 5.77 t ha^{-1} in location I, II and III, respectively. *Cenchrus ciliaris* alone (SFS_1) recorded lower annual *Cenchrus* equivalent yield of 4.73, 3.36 and 4.39 t ha^{-1} in location I, II and III, respectively (Table 1). Annual *Cenchrus* equivalent yield was higher in *Cenchrus setigerus* + *Stylosanthes hamata* and fodder sorghum + *Pillipesara*. The forage production was increased by 60 – 70 per cent as compared to that of grasses alone which might be due to the combined production of grasses and legumes. As per the findings of Ibrahim *et al*. (2001).

Utilization rate

Utilization rate was computed by using annual *Cenchrus* equivalent yield before and after grazing in three locations during the years of study. During 2009-10, higher utilization rate of 75 per cent was recorded in *Cenchrus ciliaris* + *Stylosanthes hamata* (SFS_2) followed by fodder sorghum + *Pillipesara* (SFS_4) and *Cenchrus setigerus* + *Stylosanthes hamata* and fodder sorghum + *Pillipesara* (SFS_5) with a utilization rate of 73 per cent in location I, whereas in location II and III, *Cenchrus ciliaris* + *Stylosanthes hamata* (SFS_2) recorded higher utilization rate of 84 per cent and 83 per cent, respectively followed by fodder sorghum + *Pillipesara* (SFS_4) and *Cenchrus setigerus* + *Stylosanthes hamata* and fodder sorghum + *Pillipesara* (SFS_5) (Table 2). During 2010-11, higher utilization rate of 88 per cent was recorded in *Cenchrus setigerus* + *Stylosanthes hamata* & fodder sorghum + *Pillipesara* (SFS_5) followed by fodder sorghum + *Pillipesara* (SFS_4) with a utilization rate of 87 per cent in location I. Lower utilization rate of 79 per cent was recorded in *Cenchrus ciliaris* alone (SFS_1). In location II and III, higher utilization rate of 83 per cent was recorded in *Cenchrus ciliaris* + *Stylosanthes hamata* (SFS_2) followed by *Cenchrus setigerus* + *Stylosanthes hamata* & fodder sorghum + *Pillipesara* (SFS_5) with a utilization rate of 81 and 79 per cent, respectively and it was comparable with fodder sorghum + *Pillipesara* (SFS_4) with a utilization rate of 80 and 77 per cent, respectively (Table 3). Higher utilization rate of 82 per cent was observed in *Cenchrus ciliaris* + *Stylosanthes hamata*. This might be due to higher palatability and preference of legume fodder by the sheep. This also depends on rotational frequency and length of grazing season. Jim Gerrish (1998) also inferred that rotational grazing of livestock in small pad-docks maximized the efficiency of grazing and sustainability of pasture land.

Table 2. Cenchrus equivalent yield and utilization rate (2009-10)

Treatment	Location I			Location II			Location III		
	Cenchrus equivalent yield (kg ha^{-1})		Utilization rate (%)	Cenchrus equivalent yield (kg ha^{-1})		Utilization rate (%)	Cenchrus equivalent yield (kg ha^{-1})		Utilization rate (%)
	Before grazing	After grazing		Before grazing	After grazing		Before grazing	After grazing	
SFS_1	1290	370	71	950	284	70	1050	324	69
SFS_2	2110	518	75	1560	245	84	1450	252	83
SFS_3	1500	414	72	1100	278	75	1200	338	72
SFS_4	8940	2400	73	6390	1196	81	7010	1311	81
SFS_5	7550	2007	73	5620	1075	81	6130	1173	81

Data not statistically analysed.

Length of grazing season

In Location I, the actual length of grazing season was 95 and 120 days during 2009-10 and 2010-11, respectively (Table 4). In location II and III, the actual length of grazing season was 75 and 95 days during 2009-10 and 2010-11, respectively (Table 5 and 6). The reason attributed to the variation in length of grazing season over location might be due to variation in total rainfall and distribution of rainfall.

Carrying capacity

Carrying capacity of grazing land was assessed by using annual *Cenchrus* equivalent yield, utilization rate, average daily intake of sheep and length of grazing season in three locations during 2009-10 and 2010-11. In location I (Table 4), higher carrying capacity of 37 numbers of sheep ha^{-1} was obtained in *Cenchrus setigerus* + *Stylosanthes hamata* and fodder sorghum + *Pillipesara* (SFS$_5$) followed by fodder sorghum + *Pillipesara* (SFS$_4$) with a carrying capacity of 32 numbers of sheep ha^{-1} and lower carrying capacity of 12 numbers of sheep ha^{-1} was obtained in *Cenchrus ciliaris* alone (SFS$_1$) during 2009-10. During 2010-11, higher carrying capacity of 41 numbers of sheep ha^{-1} was obtained in *Cenchrus setigerus* + *Stylosanthes hamata* and fodder sorghum + *Pillipesara* (SFS$_5$) followed by carrying capacity of 35 numbers of sheep ha^{-1} with fodder sorghum + *Pillipesara* (SFS$_4$). It was followed by *Cenchrus ciliaris* + *Stylosanthes hamata* (SFS$_2$) with a carrying capacity of 21 numbers of sheep ha^{-1} in location I.

Table 3. Cenchrus equivalent yield and utilization rate (2010-11)

Treatment	Location I			Location II			Location III		
	Cenchrus equivalent yield (kg ha^{-1})		Utilization rate (%)	Cenchrus equivalent yield (kg ha^{-1})		Utilization rate (%)	Cenchrus equivalent yield (kg ha^{-1})		Utilization rate (%)
	Before grazing	After grazing		Before grazing	After grazing		Before grazing	After grazing	
SFS$_1$	1530	315	79	1090	326	70	1420	379	73
SFS$_2$	2560	417	84	1820	302	83	1970	344	83
SFS$_3$	1790	357	80	1270	321	75	1440	408	72
SFS$_4$	10320	1319	87	7340	1476	80	9330	2116	77
SFS$_5$	9940	1198	88	7060	1350	81	7870	1627	79

Data not statistically analysed.

In location II (Table 5), higher carrying capacity of 39 numbers of sheep ha^{-1} was noticed in *Cenchrus setigerus* + *Stylosanthes hamata* and fodder sorghum + *Pillipesara* (SFS$_5$) followed by fodder sorghum + *Pillipesara* (SFS$_4$) with a carrying capacity of 33 numbers of sheep ha^{-1} and it was comparable with *Cenchrus ciliaris* + *Stylosanthes hamata* (SFS$_2$) with a carrying capacity of 20 numbers of sheep ha^{-1} during 2009-10. During 2010-11 Continuous missing rainfall, higher carrying capacity of 34 numbers of sheep ha^{-1} was obtained in *Cenchrus setigerus* + *Stylosanthes hamata* and fodder sorghum + *Pillipesara* (SFS$_5$) followed by carrying capacity of 29 numbers of sheep ha^{-1} with fodder sorghum + *Pillipesara* (SFS $_4$). However, it was followed by *Cenchrus ciliaris* + *Stylosanthes hamata* (SFS$_2$) with a carrying capacity of 19 numbers of sheep ha^{-1} in location II. In location III (Table 6), higher carrying capacity of 42 number of sheep ha^{-1} was observed in *Cenchrus setigerus* + *Stylosanthes hamata* & fodder sorghum + *Pillipesara* (SFS$_5$) followed by fodder sorghum + *Pillipesara* (SFS$_4$) with a carrying capacity of 36 numbers of sheep ha^{-1} during 2009-10. During 2010-11, higher carrying capacity of 37 numbers of sheep ha^{-1} was obtained in *Cenchrus setigerus* + *Stylosanthes hamata* & Fodder sorghum + *Pillipesara* (SFS$_5$) and it was followed by fodder sorghum + *Pillipesara* (SFS$_4$) with a carrying capacity of 36 numbers of sheep ha^{-1}. *Cenchrus ciliaris* + *Stylosanthes hamata* (SFS$_2$) registered a carrying capacity of 20 numbers of sheep ha^{-1}.

Table 4. Carrying capacity of grazing lands (Location I)

Treatment	Annual Cenchrus equivalent yield (kg ha^{-1})		Utilization rate (%)		Average daily intake (kg day^{-1})	Length of grazing season (days)		Carrying capacity (No. of sheep ha^{-1})	
	2009-10	2010-11	2009-10	2010-11		2009-10	2010-11	2009-10	2010-11
SFS$_1$	4020	4730	71	79	2.5	95	120	12	13
SFS$_2$	6040	7490	75	84	2.5	95	120	19	21
SFS$_3$	5530	6380	72	80	2.5	95	120	17	17
SFS$_4$	10530	12220	73	87	2.5	95	120	32	35
SFS$_5$	12090	14050	73	88	2.5	95	120	37	41

Data not statistically analysed.

The mean of two years (Fig. 1) indicated that, higher carrying capacity of 39, 37 and 40 numbers of sheep ha^{-1} was obtained in *Cenchrus setigerus* + *Stylosanthes hamata* & fodder sorghum + *Pillipesara* (SFS$_5$) in

location I, II and III, respectively. It was numerically comparable with fodder sorghum + *Pillipesara* (SFS_4) with a carrying capacity of 34, 31 and 36 numbers of sheep ha^{-1} in location I, II and III, respectively However, it was followed by *Cenchrus ciliaris* + *Stylosanthes hamata* (SFS_2) with a carrying capacity of 20, 20 and 19 numbers of sheep ha^{-1} in location I, II and III, respectively. Due to overuse of the grazing land, vegetation cover declines and thus reduces the soil organic matter content and soil infiltration capacity. This corroborate with the findings of Padmakumar (2007) that high stocking rates in small paddocks could force the animals to consume forage fully, this affect regeneration capacity of the forage. Under heavy grazing pressure, plants might not be able to compensate sufficiently for the biomass removed by grazing animals.

Table 5. Carrying capacity of grazing lands (Location II).

Treatment	Annual ***Cenchrus*** equivalent yield (kg ha^{-1})		Utilization rate (%)		Average daily intake	Length of grazing season (days)		Carrying capacity (No. of sheep ha^{-1})	
	2009-10	2010-11	2009-10	2010-11	(kg day^{-1})	2009-10	2010-11	2009-10	2010-11
SFS_1	2970	3360	70	70	2.5	75	95	11	10
SFS_2	4460	5320	84	83	2.5	75	95	20	19
SFS_3	4060	4530	75	75	2.5	75	95	16	14
SFS_4	7530	8690	81	80	2.5	75	95	33	29
SFS_5	9000	9980	81	81	2.5	75	95	39	34

Data not statistically analysed.

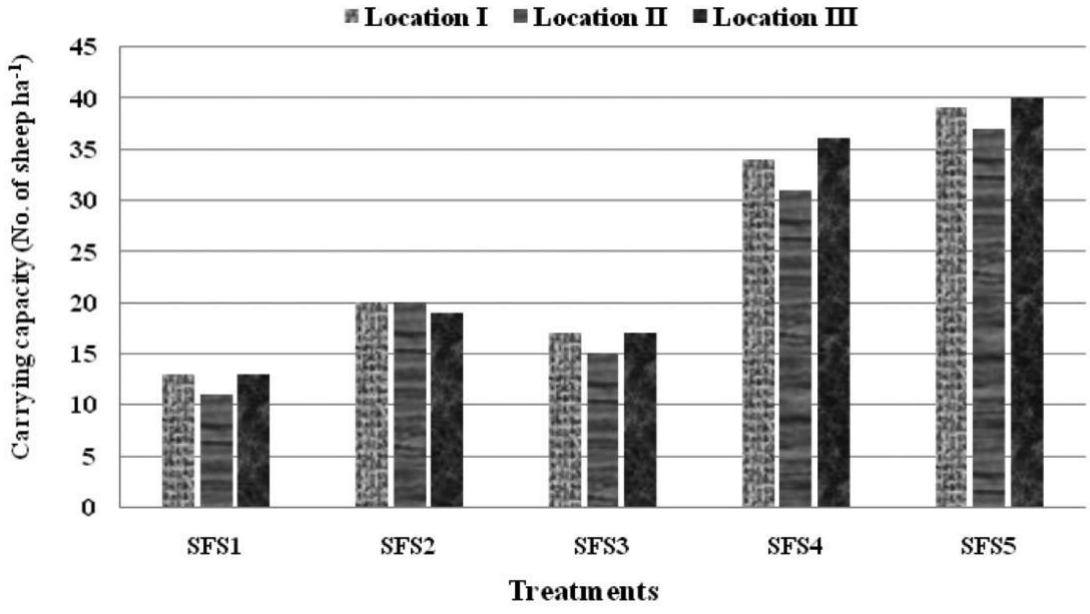
Table 6. Carrying capacity of grazing lands (Location III)

Treatment	Annual Cenchrus equivalent yield (kg ha^{-1})		Utilization rate (%)		Average daily intake	Length of grazing season (days)		Carrying capacity (No. of sheep ha^{-1})	
	2009-10	2010-11	2009-10	2010-11	(kg day^{-1})	2009-10	2010-11	2009-10	2010-11
SFS_1	3270	4390	69	73	2.5	75	95	12	14
SFS_2	4150	5770	83	83	2.5	75	95	18	20
SFS_3	4430	5120	72	72	2.5	75	95	17	16
SFS_4	8260	11050	81	77	2.5	75	95	36	36
SFS_5	9820	11120	81	79	2.5	75	95	42	37

Data not statistically analysed.

Among the different silvipastoral systems, *Cenchrus setigerus* + *Stylosanthes hamata* and fodder sorghum + *Pillipesara* (SFS_5) recorded higher annual *Cenchrus* equivalent yield and utilization rate with more number of grazing days. Rotational grazing

Fig. 1. Carrying capacity of silvipastoral farming system (mean of two years)



of 39 numbers of sheep ha^{-1} of silvipasture land with *Cenchrus setigerus* + *Stylosanthes hamata* and fodder sorghum + *Pillipesara* system would imply relatively less pressure on land that would help for sustaining the carrying capacity of grazing land.

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