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Analysis of sustainable pastureland farming in tropics of Deccan Plateau

NAGARATNA BIRADAR[1], ANIL KUMAR[2], S NATARAJAN[3], AMARESH CHANDRA[4] and B K TRIVEDI[5]

Indian Grassland and Fodder Research Institute, Southern Regional Research Station, Dharwad, Karnataka 580 005 India

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ABSTRACT

A study was conducted by an interdisciplinary team covering pasturelands of 9 blocks of Coimbatore, Erode and Karur districts of Tamilnadu, together referred as Kangaym grasslands. Survey of grasslands, laboratory analysis of grass species, seed bank analysis, market study, stakeholder interviews, secondary and primary data collection were the methods employed. *Aristida setacea* had the highest importance value index (126.9) in species composition followed by *Cenchrus ciliaris* (49.2). Contribution of grasses to the total dry matter production was 82.50% and that of legumes was 12.42% with an average production of 1.61 t/ha/year. *Acacia leucocephala* was the most widely planted tree species with an average density of 358.42 plants/ha with DBH of 7.16±1.13 cm. Among the 10 *C.ciliaris* accessions, the maximum similarity obtained was 89% between Cenchrus-6 with Cenchrus-4 and 2 major clusters were indicated by dendrogram. *Cenchrus* spp. dominated the seed bank composition (72.7%). Majority of the farmers (65%) owned sheep. On an average, respondent graze animal for about 6.2 months in the paddocks that contributed more than 80% to its total diet. *Balsamodendron berryi* was the most commonly used live fence for the paddocks. One-fifth of the respondents reported that livestock contribution to their total farm income was between 75 and 99%. The average family size was 1.55 (G-1), 2.15 (G-2) and 2.4 (G-3) helping them to defer land fragmentation and maintain the big land size (average 10.9 ha).

Key words: *Cenchrus ciliaris*, Grassland, Mecheri sheep, Live fence, Livelihood

Grasslands in India often invoke an image of a vast tract of degraded, denuded, overgrazed piece of land. The grasslands are mostly under community ownership, resulting in over-exploitation by all. Thus, the famous Hardin's theory (1967) of "The tragedy of the commons", is in full play. On the other hand, the grasslands of the Kangayam region located though in the tropical region belie the above description. Located in the rain shadow region of the western *Ghats* in Tamil Nadu, farmers practice the sustainable management under low rainfall conditions since ages. They could be called sedentary pastoralists, who through collective action and use of innovative skills managed their grassland that sustained their livelihood for hundreds of year, preventing the land going barren and becoming wasteland. However, the Kangayam grasslands have remained unheard beyond their immediate vicinity. The ownership rights coupled with planned human interventions in the grasslands aid in their sustainability. This is, though uncommon in rest of India, is being practiced in Kangayam tract of Tamil Nadu in Deccan plateau. Therefore, a study was undertaken to analyse the Kangayam grasslands to (i) know the vegetative composition of Kangayam grasslands and their dry matter production potential, (ii) find out the differences in grass accessions grown by the farmers, (iii) study the role of seed bank on persistency of pastures, (iv) find out the management aspects of live fence, and (v) analyze the livestock production system being followed by the farmers and its contribution to the household income.

MATERIALS AND METHODS

A study was conducted by an interdisciplinary team. Spread of grasslands and its history was collected by consulting literature. Team traversed Coimbatore, Erode, Karur, Nammakal and Dindigul districts extensively, but last 2 districts did not have significant area under paddock system. Thus, the study area was delineated which spread over in 9 blocks of 3 districts (Coimbatore, Erode and Karur) covering approximately 3841 sq km area. This area is referred to as

Present address: [1]Senior Scientist (nagaratna123@gmail.com), [5]Formerly Principal Scientist (Economic Botany) (bktrivedi@gmail.com). [2] Principal Scientist (LPM), Directorate of Research on Women in Agriculture, Bhubaneshwar 751 003 (anil.drwa @gmail.com). [3]Senior Scientist (Seed Technology), Directorate of Seed Research, Mau 275 101 (natarajan @scientist.com). [4] Principal Scientist and Head, Crop Improvement Division, Central Institute for Subtropical Horticulture, Lucknow 227 107 (amaresh62 @yahoo.com).

Kangayam grassland in the subsequent parts of the paper and is located between 77º 17" E and 77º 55" E longitudes and 10º 44" N and 11º 03" N latitudes. The East-West spread of the grassland is 70 km and the North-South spread is 45 km.

Survey of grasslands, laboratory analysis of grass species, seed bank analysis, market study, stakeholder interviews, secondary and primary data collection were the methods employed. Extensive field surveys were carried out to study the grasslands, livestock, and input-output relations in the system, vegetation, soil, seed and socio economic aspects.

Phyto-sociological study of herbaceous vegetation was carried out during growth period through line interception (2 m) method and importance value index (IVI) was computed for all species encountered in the fields using the relative density (RD), relative dominance (RDom) and relative frequency (RF) (Kershaw and Looney 1985, Roberts-Pichette and Gillespie 1999). For woody species quadrats of 100 m^2 was adopted for the purpose. The diameter of the woody vegetation was measured at breast height (DBH). The biomass was calculated by taking at least 5 quadrats of 4 m^2 from each site. Biomass in the grazing paddocks, were estimated at 12 sites in the grassland. Similarly, soil samples were taken from 8 sites to assess their physico-chemical properties. Forage production of the sites was done through harvest method and clipped material was sorted out into prominent species and species groups. Litter was collected separately. Forage production was computed on dry weight basis.

Ten distinct accessions of *Cenchrus* collected from different parts of the Kangayam region were used to assess the differences, if any in *Cenchrus ciliaris* accessions. Genomic DNA from 10 embryos of each of accessions was isolated following the methodology of Iqabal *et al.* (1997) with suitable modifications (Chandra *et al*. 2004). For each species, 2g leaves were ground in liquid nitrogen to a fine powder and mixed with CTAB total DNA extraction buffer (CTAB 2% (w/v), NaCl 1.4%, Tris-HCl 100 mM, EDTA 20 mM and 2–mercaptoethanol 100 mM (added freshly) in a 1: 2 ratio (w/v)) and incubated at 65 ºC for 1 h with occasional swirling. After incubation, the mixture was emulsified with an equal volume of 24: 1 (v/v) chloroform-isoamyl alcohol and centrifuged at 5000 rpm for 15 min. The process was repeated once. The aqueous phase was removed and DNA was precipitated with 0.6 volume of isopropanol by keeping at –20 °C for 2–3 h. The DNA pellet was dissolved in 10 mM TE buffer (pH 8.0) and kept at 4 ºC overnight. The nucleic acid solution was treated with RNase and after incubation for 30 min at 37 °C, was extracted twice with phenol-chloroform and finally with chloroform. DNA was precipitated in 100% ethanol and pelleted at 5000 g for 10 min and finally washed with 70% ethanol. After a brief period of air-drying, DNA was suspended in 2 ml TE buffer (pH 8.0). The presence and quality of genomic DNA was confirmed by electrophoresis on a 0.7% (w/v) agarose gel. The concentration was adjusted to 5 ng/ml for use in PCR analysis. Each PCR amplification was performed in a final volume of 20 ml of reaction mixture containing 67 mM TRIS-HCl (pH 8.0), 16.6 mM $(NH_4)_2SO_4$, 0.45% (v/v) Triton X-100, 4 mg BSA, 3.5 mM $MgCl_2$, 150 mM of each of dATP, dCTP, dGTP and dTTP, 7.5 pmol (15 ng) primer, 25 ng genomic DNA template and 0.5 unit Taq polymerase, and finally it was overlaid by 5–10 ml light mineral oil. Amplifications were performed on a DNA thermal cycler PTC-200 with the cycling program consisting of 94 ºC for 1 min, 37 ºC for 1 min and 72 ºC for 2 min for 40 cycles followed by 41st cycle at 37 ºC for 1 min and finally at 72 ºC for 10 min extension. The amplified products were kept at 4ºC until loaded on to the gel. Amplification products were separated by electrophoresis on 1.6% agarose gel in 0.5X TBE buffer (pH 8.0) to which ethidium bromide was added for visualization with UV light. Along with the unknown samples 100 base pair DNA ladder was also loaded to know the size of the amplified products. PCR reactions were repeated at least once to establish reproducibility of results under strict control of the reaction conditions. Input binary data matrix of *Cenchrus* accessions was developed by entering the data by assigning 1 to presence or 0 to absence of bands. Only reproducible and unambiguous RAPD fragments were used for scoring. The NTSYS program version 2.0 was used to produce the similarity matrix. Dice similarity coefficient was used to estimate the genetic similarity. The resulting data were further processed for SAHN cluster analysis using the un-weighted pair group average method (UPGMA) and tree display was followed for generation of dendrogram (NTSYS tree phenogram).

Seed bank analysis of pastures was done by survey and sampling of paddocks in alternate years because large proportion of seeds of perennial grasses are viable up to 2 years. The sampling was done with soil sampler 10 cm diameter core to a depth of 5 cm. In proportion with the size of the paddock, number of soil samples were collected, the average weight however was 350g. Soil samples were sieved using fine sieves and then the seeds of the grasses and forbs were separated manually and counted.

Socio economic survey was conducted using a structured, pre-tested interview schedule comprising 28 parameters. Personal interview technique was used to collect the data. Forty farmers belonging to four districts were interviewed, ensuring representative sample from all categories of farmers. The results were analyzed using simple statistics. It was observed that the family size in the study area was different from the usual trend in the country. Hence a separate survey was taken up in the second phase to study the family structure of the families of Kangayam over the generations and the results of the same were also analysed and presented.

RESULTS AND DISCUSSIONS

Vegetation composition of grasslands

Grasslands comprised 8 species of perennial grasses, 6

annual grasses, 9 legumes and 16 forbs. Importance value index of these herbaceous vegetation indicated that *Aristida setacea* had the highest IVI (126.9) followed by *Cenchrus ciliaris* (49.2), *Blumea* sp. (37.9), *Brachiaria repens* (22.0) and others (Table 1). However the *Heterotropiums* indicated least IVI.

Contribution of different vegetation components to dry forage of grasslands

In 36 sites of the study area the samples were collected to assess the dry forage yield of different vegetation. The results (Table 2) indicated that the grasses alone contributed 82.50% of total dry forage production from the grasslands. The contribution of legume was 12.42% and that of forbs was 5.08%. However in all the 3 components the production range varied widely. Average dry forage yield of grasses ranged from 204.25 to 42.9 g/m^2, legumes from 35.05 to 6.90 g/m^2 and that of forbs from 20.86 to 1.63 g/m^2. This indicated that the management of paddock by the farmers varied as is influenced by many other factors. However, the grasslands contributed an average of 1.61 t/ha/year dry matter that ranged from highest production of 8.26 t/ha/year to the minimum of 0.39 t/ha/year. The average dry matter yield is adequate to meet the dry matter requirement of 6–7 adult cattle units constituting 2 cattle and 25 to 30 sheep for 8 months between July and February.

Table 1. Analytical characters of herbaceous vegetation at Kangayam tract

Species	Relative dominance (%)	Relative density (%)	Relative Frequency (%)	IVI
Aristida setacea	76.8	32.5	7.6	126.9
Cenchrus ciliaris	14.1	17.5	17.6	49.2
Brachiaria repens	2.8	7.5	11.7	22.0
Alysicarpus monilifera	0.9	7.5	5.8	14.2
Zornia gibbosa	1.0	7.5	11.7	20.2
Blumea sp.	2.8	17.5	17.6	37.9
Cyperus sp.	0.7	5.0	11.7	17.4
Heterotropiums	0.5	2.5	5.8	8.8

Frequency: no. of plots in which a species occurs/total no. of plots × 100.Relative density (RD): no. of individual of a species/ total no. of individual of all species × 100. Relative frequency (RF): frequency of a species/total frequency of all species × 100. Relative dominance (RDom): total basal area of a species/basal area of all species × 100. Importance value index: IVI = RD + RF + RDom.

Table 2. Extent of contribution of different components of grasslands to dry forage production

Components	Max production (g/m^2)	Min production (g/m^2)	Per cent contribution
Grasses	204.25	42.9	82.50
Legumes	35.05	6.90	12.42
Forbes	20.86	1.63	5.08
Total dry forage (t/ha)	1.61 t/ha/year		
Minimum	0.39 t/ha		
Maximum	8.26 t/ha		

Woody vegetation in grasslands

Grasslands are interspersed with the tree species that provide shade to the livestock besides contributing fodder in the form of leaves and pods especially in the summer. Among the 7 tree species found (Table 3), *Acacia leucocephala* was the most widely planted tree species with the average density of 358.42 plants/ha with a DBH of 7.16±1.13 cm. The density of *A. leucophloea* varied from 56 to 460 trees/ha at different sites. There was also occasional presence of *Acacia nilotica, A. tortilis, A. amara, Azadirachta indica* and *Zizipus zuzuba* species in the grazing paddocks. Hence, the grassland is better wooded than many other regions with similar rainfall and open grazing areas. Littlewood (2004) reported that, Dharapuram taluk where private pasturage was common was possibly one of the best wooded of any agricultural taluk, and the bulk of these trees are grown in private pastures. The *Acacia* trees in the grazing areas provide shade to the animals during hot sun, provide nutritious pods (14.7% crude protein) during summer (Pattabhiraman 1958) and they are regularly felled at 9 – 11 years and sold off, while new plants take root. The trunk of the trees is also regularly shoved off up to the height of cattle/buffalo so that the animals do not injure themselves with the spines of tree.

Differences in C. cenchrus *accessions*

Cenchrus ciliaris is the most commonly grown grass in the pastures. Hence a total of 229 RAPD markers were scored from 19 RAPD primers. The similarity matrix developed using NTSYS computer software, which ranged from 0.63 to 1.00. None of the 2 lines showed 100% similarity to each other. The maximum similarity obtained was 89% between Cenchrus-6 with Cenchrus-4. Dendrogram showed 2 major clusters wherein cluster-1 embodied only Cenchrus-1 whereas rest of the accessions grouped into cluster-2. This cluster was further divided into 2 sub-clusters. Of these 2

Table 3. Distribution of woody vegetation in grasslands

n=19

Tree species	No. of sites in which found	Av density (plants/ha)
A. leucophloea	19	358.42
A. nilotica	2	1.5
Albizia amara	2	10
Azadiracta indica	2	51
A. tortalis	1	4
Zizyphus zuzuba	1	3

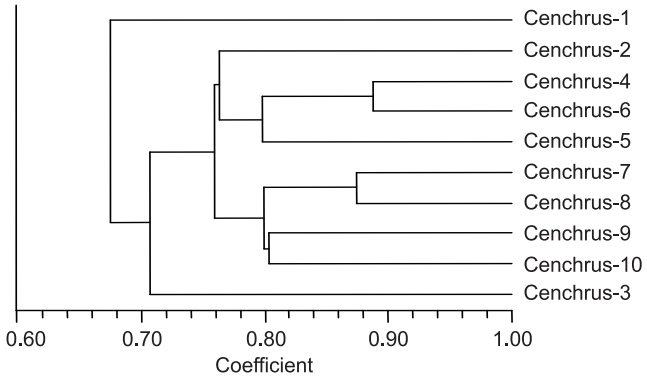

Fig. 1. Dendrogram developed with 229 RAPD markers using dice coefficients and UPGMA module.

sub-clusters, one accession of Cenchrus namely Cenchrus-3 formed distinct node whereas rest of the accessions of this cluster was divided into 2 groups each having 4 accessions (Fig. 1).

The most diverse accession among these 10 lines was Cenchrus-1 which showed 67% similarity with rest of the accessions. Followed by this accession, Cenchrus-3 showed distinctness among the investigated lines as it formed separate cluster and showed 70% similarity with rest of the member of cluster-2. Apart from these two accessions, rest of the accessions were more similar to each other.

Seed bank estimation

The seed bank estimation of initial survey had shown that *Cenchrus spp* has dominated the seed bank composition with 72.7% followed by *Chrysopogon fulvus* (4.23%). Leguminous seeds composed of only 0.78% while rest 21.9% were of forbs and weeds (Fig. 2). The total number of seeds in each sample ranged from 9 to 434 depending on the density and diversity of the above ground extant species. Poschlod *et al*. (2004) reported that the grasses are ubiquitous and found everywhere in all continents. The way by which it is surviving these centuries (ages) is by means of establishing own reserve in the substratum and subsequent sequential revival called

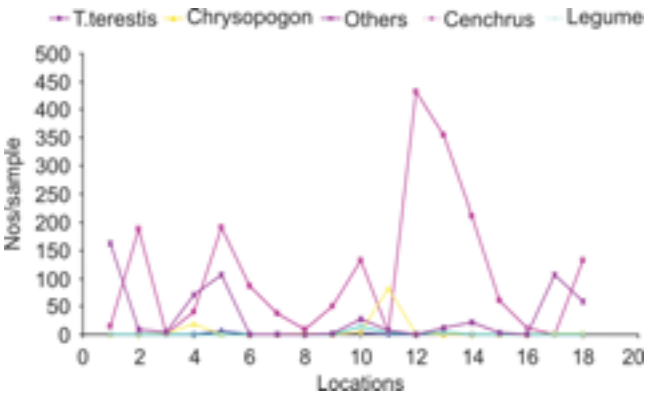

Fig. 2. Composition of soil seed bank from the grasslands of Kangayam.

Seed Bank. The soil seed banks also called as diaspore banks, consists of seeds and fruits as well as of vegetative parts of plants.

Density of the seeds of *Cenchrus spp* was more in the surface and gradually decreased with increase in depths. Most of the paddocks are being maintained with self-sown seeds of *Cenchrus* spp, as is evident from the diameter of the tussock of recruited seedlings. The diameter of tussock ranged from 1.9 to 6.3 cm with mean of 3.6 cm. The average number of tussock/m^2 of *Cenchrus* spp is 19.4, besides the presence of other spp like *Zornia, Boerhavia* and *Indigofera* spp. Survey results reflected that the farmers practice reseeding of their pastures with seeds of *Cenchrus* spp once in 2–3 years depending on reduction in tussock density due to poor regeneration or uprooted while ploughing with tractor followed by failure of expected rainfall.

Balsamodendron berryi, a time tested proven species used for live fencing the paddocks with fodder value also regenerates from the soil seed bank under natural conditions. Seeds of *Acacia leucophloa* added to soil bank after ingestion by sheep as pods comprise an important component of seed bank dynamics helping to sustain the pasture paddocks.

Distribution of livestock in Kangayam

Majority of the farmers owned sheep as compared to goats and large ruminants (Table 4). Majority farmers (65%) owned 20 or more number of sheep reflecting a big herd size. Less than one-fifth of the farmers (17.5%) did not own sheep at

Table 4. Distribution of livestock in Kangayam region

Particulars	Respondents	
	Number	Percentage
Distribution of large ruminants		
0	3	7.5
1–2	14	35
3–4	14	35
5–6	5	12.5
7–8	0	0
9–10	0	0
Above 12	4	10
Distribution of sheep		
0	7	17.5
1–5	1	2.5
6–10	2	5
11–15	4	10
16–20	9	22.5
21–25	8	20
Above 25	9	22.5
Distribution of goats		
0	34	85
1	3	7.5
2	1	2.5
5	1	2.5
20	1	2.5

all. The sheep hence constituted half of the livestock in the grassland. The Mecheri breed of sheep, introduced just 2 decades before by replacing Madras Red, is reared in the region. Mecheri is a promising hairy breed, which occupies the first position in population and area of distribution in Tamil Nadu. The average flock size of this breed includes about 16.6 breeding ewes, 1.02 breeding rams and 4.12 lambs. The coat colour of this breed is mixture of brown and white. The Mecheri sheep farming in the breeding tract was characterized as "Low input low output" production system in which the major source of feeding for sheep is grazing in the dry rainfed grazing land. The Mecheri sheep skin was found to be superior for the quality, viz. softness, grain tightness, fullness, surface smoothness, uniformity of colour and general appearance, hence makes export quality leather. It was revealed that the Mecheri sheep skin fetches very good price as compared to the Madras red, though the latter had better disease resistance.

Large ruminants were owned by almost all the respondents (92.5%). Nearly two- thirds of the respondents however owned 2–4 livestock units. During the study it was observed that those villages located near to the city rear cross bred cattle as compared to the small ruminants for reasons of accessibility to milk market and non availability of labour to herd the sheep.

Goats were sparsely distributed, as 85% of the farmers did not own them. Goats were, hence, least preferred as only 15% of the farmers owned them, mainly of 1– 2 goats. In many villages social sanction has been accorded not to rear goats, as it was perceived that goats browse extensively damaging the vegetation. The goats are not preferred in the Kangayam grassland because they demand constant attention of their keepers and damage the fence of *B. berryi*. Some farmers in Aravakurichi block in Karur district reported that several village panchayats of the area had resolved in the past to banish goats from the region and impose heavy fine on the keepers whose goats were found straying into the grazing paddocks.

Management of live fence in Kangayam

Farmers divided their grasslands into paddocks by separating them through a live fence. All the paddocks of Kangayam invariably, were protected by one or the other type of live fence. *Moringa pterygosperma*, *Helicteres isora, Opuntia dellieni, Agave americana* and *Balsamodendron berryi* were though used for live fence, but first four were sparsely distributed (Table 5). *Balsamodendron berryi* known locally as *Kiluvan*, is a highly drought tolerant thorny shrub and closely planted to form a barrier that does not allow sheep or cattle to pass through it. The live fence of *B.berryi* prevalent in the region is more than 50–70 years old (some farmers opined that it is more than even 100 years old). On an average, it had a width of 0.6 to 0.75m and height of 1.5m (Table 5).The fence was very thick as stalks were closely placed. It was observed that 16 stalks were arranged in 2 rows of 8 each in 1m. The gaps if any occur any time are filled every year during July-August by planting stalks upon onset of north-east monsoon giving out new branches. In many paddocks, a shallow trench was dug along the fence with the objective to conserve moisture so as to maintain the vigour of the fence. The pruning of the fence was done once in 2–3 years, spending about Rs 500–600/ha towards skilled labour. It is reported that pruning results in root die back and release of nitrogen to the soil. The entrance of the paddock was made of shift gate of 1m × 1m with frame of *Acacia leucocephala* or other locally available wood with fillings of thorny *B.berryi.* Voelcker (1893) had reported that hedges of *B. berryi* were found over the greater part of Coimbatore and cattle trespass was rare, cattle and crops were protected, large quantities of fuel supplied, and protection was given to growing trees.

Table 5. Live fence in Kangayam

Most common species	*Balsamodendron berryi*
Planting	16 stalks in 1m
Width	0.6 to 0.75 m
Height	1.5 m
Gap filling	July-August
Pruning	Once in 2–3 years, expenditure ₹ 500–600 ha^{-1}
	Support to the fence Planting trees of *Azardicta indica* and *Albizia amara*

Grazing system being followed by the farmers

The animals are grazed exclusively in the paddocks for 4 months as per 25% respondents; 40% (Table 6) of the respondents however grazed their animals for 6 months. Remaining 35% of them graze for more than 6 months. On an average respondent graze animal for about 6.2 months in the paddocks. During this period, contribution of grazing to total diet of the animal was more than 80%; and 50% respondents though reported its contribution to total diet was 100%. A paddock usually has 1 or 2 cattle/buffalo and 25–30 sheep. The animals are kept in the paddock throughout the day for months together and they are rotated between the paddocks as per the fodder availability. Though the rainfall received in the region is not sufficient to grow the cereal crops but adequate for the healthy growth of the grasses. The animals are withdrawn from the pasture for 1 month after rain in May and September to allow the growth of grass in the pasture. Nicholson (1889) also reported that grazing in these paddocks were regulated, pastures not overstocked and manures not removed from the ground, which resulted in excellent pasturage.

During non grazing period while half of the respondents resorted to only stall feeding, another half reported that they would follow grazing along with stall feeding. Among different fodder types used in this period all of them reported that they depend heavily on sorghum stover, followed by

Table 6. Grazing system followed by the Kangayam farmers

Particulars	Respondents	
	Number	Percentage
Grazing months		
4	10	25
6	16	40
8	10	25
10	4	10
Mean	6.2	
Grazing contribution to total diet		
Up to 80%	4	10
90%	14	35
100%	22	55
Feeding method in non grazing period		
Only stall feeding	20	50
Grazing and stall feeding	20	50
Fodder/feeds used		
Sorghum stover	40	100
Cotton seed cake	15	37.5
Concentrate	20	50
Rice bran	34	85

Table 7. Extent of contribution of livestock to the total annual income of the farm family

Percent contribution	Number	Percentage
Sole	3	7.5
75–99	8	20
50–75	10	25
25–50	17	42.5
Below 25	2	5
Total	40	100

rice bran (85%), branded concentrate (50%) and cotton seed cake (37.5%).

Extent of contribution of livestock to the total income of the farm family

As per 20% of the respondents livestock contribution to their total farm income was between 75 and 99% (Table 7), and the rest was from other sources like crops, service, weaving etc. One-fourth of the respondents reported that livestock contributed to their annual income to the extent of 50–75%. Three farmers reported that the livestock is the sole income source for them.

Family structure of the respondents over the generations

It is clear from the Fig. 3 that, irrespective of child's gender the family was restricted to 1 to 2 children over the generations (G). The average family size was 1.55 (G-1), 2.15 (G-2) and 2.4 (G–3). This enabled them to defer land fragmentation and maintain the big land size (average 10.9 ha). Even landless families maintained small family size which is not so in other parts of the country as they prefer for big family size to have more earning hands as wage laborers. Also, in many cases gender of the child did not influence the family size. This is in contrast to what is

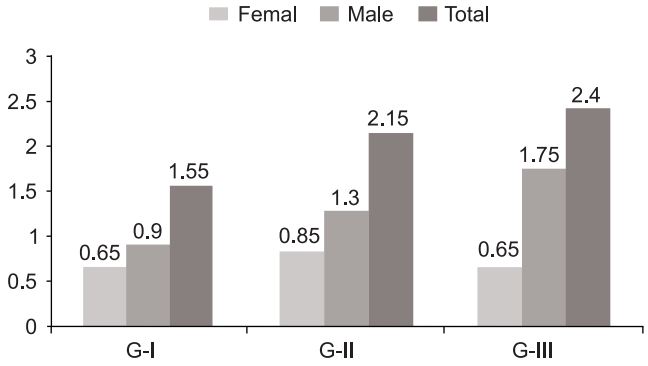

Fig. 3. Mean size of family and members over the generations (G).

practiced in other parts of the country, as the rate of population growth in the study area was only 0.45% per annum against the 1.47% per annum of the country.

Farmers of the region have opted for livestock based livelihood system owing to their ecological conditions. Low input based grassland management supported their livelihood making it self-sustainable over the years. Their grassland management system comprised paddocks, rotational grazing, live fence, small ruminants, suitable mix of grasses and trees species, no land fragmentation due to small family size, social sanctions and no external inputs like chemical fertilisers is unique. Grasslands are fairly well balanced from biophysical and socio economic point of view. It is an exemplary example available in our own country. It is worth emulating in other fragile and susceptible arid and semi-arid parts of the country more so when frequent droughts have become a common phenomenon.

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