Available online at www.ijpab.com

DOI: http://dx.doi.org/10.18782/2320-7051.2778

ISSN: 2320 – 7051

Int. J. Pure App. Biosci. **5 (2):** 215-229 (2017)

International Journal of Pure & Applied Bioscience

Research Article

OPEN ACCESS

Sustainability Assessment of Dairy Production Systems in Uttarakhand Hills of India

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Received: 31.03.2017 | Revised: 11.04.2017 | Accepted: 12.04.2017

ABSTRACT

The present study was undertaken on 300 milk producing households in Uttarakhand hills of India to identify specific dairy production typologies and study their respective sustainability characteristics. Farm household typologies were constructed by using two multivariate statistical techniques, viz. Principal Component Analysis (PCA) and Cluster Analysis (CA). Four homogenous clusters were obtained. Cluster I (28.42%) was defined as households with high stock of indigenous animals and low degree of technology adoption. Cluster II (40.75%) was defined as households with high degree of technology adoption, high indigenous animal stock with low farm family labour involvement. Cluster III (22.60%) was defined as Households with low intensity of market participation in dairying and Cluster IV (8.22%) was defined as households with high intensity of market participation, high stock of crossbred animals and high degree of technology adoption. Market oriented farms with high degree of technology adoption were the most sustainable farms on all the three dimensions, viz. economic, social and ecological. With increasing education level, size of landholding and intensity of market participation, the sustainability of dairy farms increases. On the other hand, increasing fodder grown per milch dairy animal and expenditures made on concentrate feeds had adverse effects on sustainability.

Key words: *Sustainable dairy farming; multivariate typology; principal component analysis; cluster analysis*

INTRODUCTION

The challenge for achieving economic and sustainable use of natural resources is overwhelming in a state like Uttarakhand for livelihood security on account of small and fragmented landholdings, rain-fed subsistence agriculture, low input-output production system, fragile ecosystem, low risk bearing capacity of farmers and poor agricultural productivity. The dairy sector in the state assumes greater importance on account of limited livelihood options for rural households.

Cite this article: Nazir, H., Kharkwal, S., Bardhan, D., Tripathi, S.C. and Kumar, A., Sustainability Assessment of Dairy Production Systems in Uttarakhand Hills of India, *Int. J. Pure App. Biosci.* **5(2):** 215-229 (2017). doi: http://dx.doi.org/10.18782/2320-7051.2778

Cattle constitute the major share of livestock population in the state (44.6%) and milk accounts for about 77 percent of total value of output from the livestock sector. Distribution of livestock is equitable with about 80 percent of all livestock species owned by small holders[7].

Dairying is thus considered to have high prospects to enhance the level of living of the poorest of the poor. However, the dairy sector in the state is characterized by low productivity, the average yield of dairy animals being almost half of the national average. The production potential is not realized fully because of constraints related to feeding, breeding, health and management. Half of the total loss in livestock productivity is contributed by the inadequacy of supply of feed and fodder. Production of livestock and its products has been increasing over the years but serious doubts have been expressed regarding sustainability of these trends as these are by and large population-driven[3].

Before targeting the policy interventions to enhance the sustainability of a crop or livestock production system, it is imperative to examine whether or not certain necessary conditions essential for sustainable development are present in the system.

Furthermore, it is well recognized that sustainability – in its economic, social and ecological dimensions - in milk production vary across different dairy systems categorized on the basis of relevant socio-economic and farm characteristics of milk producing households.

It thus becomes important to typify different dairy systems based upon these characteristics. Typology constitutes an essential step in any realistic evaluation of the constraints and opportunities that exist within farm households[2]. Typological studies can therefore be of great importance for exploring factors explaining economic viability and sustainability in milk production.

In the above context, the present study intends to examine the dairy sector of Uttarakhand hills through a synopsis of performance of dairy enterprises at farm level in terms of economic, social and ecological sustainability.

MATERIALS AND METHODS

Sampling and Data

Multistage purposive and random sampling was followed in the selection of ultimate sampling units. Kumaon division – out of two divisions of the state - was selected for the study on account of higher livestock density and greater economic dependence of rural people on livestock[1]. Two districts from Kumaon region, viz. Nainital and Almora, on account of rich livestock resources, were chosen purposively. From each district, three Tehsils were selected having the highest population of dairy animals, viz. Betalghat, Okalkhanda and Bhimtal from Nainital district and Hawalbagh, Takula and Chaukhutiya from Almora district. From each selected Tehsil, five villages were selected randomly. Thus, a total of 30 villages were selected for the study from the two districts. From each selected village, 10 households having at least one milch animal were selected randomly for the study. Thus, the ultimate sampling units comprised of 300 milk producing households.

The data were collected through personal interview method with the help of a well- structured, comprehensive and pre-tested interview schedule. The respondents comprised of the heads of the sample households surveyed. Data were collected on parameters like demographic particulars of households, farm inventories, technical characteristics of dairy enterprise, cost of feeding, veterinary and miscellaneous expenses, hired and family labour and prevailing wage rates, prevailing prices of milk, feed inputs etc.

Multivariate typology of milk producing households

A farm typology study was used to classify groups of farm households with similar farm and socio-economic characteristics as typology constitutes an essential step in any realistic evaluation of the constraints and opportunities that exist within farm households. For this purpose, the methodology described by

Bidogeza *et al*[2]., and Garcia *et al*[5]., were used in the study. Farm household typologies were constructed by using two multivariate statistical techniques, viz. Principal Component Analysis (PCA) and Cluster Analysis (CA). PCA was used to transform linearly an original set of 23 variables, representing farm and socioeconomic characteristics, into a smaller set of uncorrelated variables (factors) that represents most of the information in the original set. A small set of uncorrelated variables is much easier to understand and use in cluster analysis than a larger set of correlated variables. Table 1 presents the variables which were used to construct factors using PCA. Bartlett's sphericity test was carried out to address the question of whether the data set was appropriate to be factored. The decision regarding number of factors to be retained was based on Kaiser's criterion that suggests retaining all factors with eigen values greater than 1.

The factors retained from the PCA were used for cluster analysis. Cluster analysis seeks to typify entities (in this case milk producing households) M = (M1, M2, M3 ….) according to their (dis)similarity in terms of their attributes represented by the variables chosen N1, N2, N3,ϵ M. Entities within a certain group (cluster) should be very similar to each other and entities belonging to different classes should be very dissimilar[2]. A hierarchical cluster analysis using Ward's method and Euclidean distance was carried out to classify the farms households using the main factors obtained in the PCA.

Estimating sustainability index

All the three dimensions of sustainability of farming systems were considered in the study to measure the composite sustainability indices of milk producing households, viz. economic, social and ecological sustainability indices. The methodology used by Chand and Sirohi[4] - which is based upon generalization of relative approach underlying the HDI developed by UNDP (1990) - was adopted in this study to develop the sustainability index corresponding to each dimension, i.e. Economic Efficiency Index (EEI) as a measure of economic sustainability; Social Security Index (SSI) as a measure of social sustainability and Ecological Security Index (ESI) as a measure of ecological sustainability of dairy enterprises in the study area. Following sections present the measures of each of the above sustainability indices.

Estimating economic efficiency index as a measure of economic sustainability

An Economic Efficiency Index (EEI) was developed as a measure of economic sustainability of dairy enterprises in the study area. Each indicator (variable) was included as:

$$I_{jK} = (X_{jk} - \text{Min } X_{jk}) / (\text{Max } X_{jk} - \text{Min } X_{jk})$$

Where X_{jk} = Value of each indicator variable for individual observations.

I_{jK} = Value of jth variable of EEI of kth cluster.

The EEI was computed as the simple mean of their respective individual variables, i.e. $EEI_k = \sum^{n}_{j=1} I_{jk} / 4$

Four indicators were used in calculating EEI. The indicators and operational definitions of these components of EEI are elicited in Table 2.

Estimating Social Security Index as a measure of social sustainability

A Social Security Index (SSI) was developed as a measure of social sustainability of dairy enterprises in the study area. Each indicator (variable) was included as:

$$I_{jK} = (X_{jk} - \text{Min } X_{jk}) / (\text{Max } X_{jk} - \text{Min } X_{jk})$$

Where X_{jk} = Value of each indicator variable for individual observations.

I_{jK} = Value of j_{th} variable of EEI of k_{th} cluster.

The SSI was computed as the simple mean of their respective individual variables, i.e. $SSI_k = \sum^n_{j=1} I_{jk} / 5$

For construction of Social Security Index (SSI) - as a measure of social sustainability - five components were used. The indicators and operational definitions of these components of SSI are elicited in Table 3.

Estimating Ecological Security Index as a measure of ecological sustainability

An Ecological Security Index (ESI) was developed as a measure of ecological sustainability of dairy enterprises in the study area. Each indicator (variable) was included as –

$I_{jK} = (X_{jk} – \text{Min } X_{jk}) / (\text{Max } X_{jk} – \text{Min } X_{jk})$

Where X_{jk} = Value of each indicator variable for individual observations.

I_{jK} = Value of j_{th} variable of EEI of k_{th} cluster.

The ESI was computed as the simple mean of their respective individual variables, i.e. $ESI_k = \sum^n_{j=1} I_{jk} / 3$

For construction of Ecological Security Index (SSI), three components were used. The indicators and operational definitions of these components of ESI are elicited in Table 4.

Estimating Total Sustainability Index as a measure of overall sustainability

The Total Sustainability Index TSI was computed as the simple mean of respective sustainability index (viz. EEI/ESI/SSI) individual variables, i.e.

$TSI(EEI/ESI/SSI)_k = \sum^n_{j=1} I_{jk} / 3$

Factors influencing Sustainability

A multivariate regression equation as given below was fitted to identify the factors significantly influencing sustainability in milk production.

$TSI = f(X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, X_{10}, D_1)$

Where,

Y_t = Sustainability Index

X_1 = Age of Household head

X_2 = Education level of Household head (Number of years of schooling/education completed)

X_3 = Herd size (measured in terms of SAU)

X_4 = Operational landholding size (hectares)

X_5 = Proportion of milk output that is sold (Marketed Surplus)

X_6 = Fodder grown per SAU

X_7 = Milk Production (FCM)

X_8= Milk Yield (FCM/SAU)

X_9 = Expenditure incurred on Veterinary Services

X_{10} = Expenditure incurred on Concentrate Feeding.

D_1 = Dummy for Non-farm Income (D_1 = 1 if household has non-farm income source, D_1 = 0, otherwise)

The fitted function was estimated through OLS technique.

RESULTS AND DISCUSSION

Multivariate Typology of Milk Producing Households

In the first step, to examine the relationships between original variables, Principal Component Analysis (PCA) was applied to a set of 20 variables. Bartlett test was performed in order to check whether the data set of 300 sample households and 20 variables could be factored or not. The results of the test showed that Bartlett's sphericity was highly significant (P<0.01). This means that the use of PCA towards dimension reduction in this case is justified. The PCA identified 8 out of total 300 observations as outliers and these observations were ignored in the final PCA. Thus, further analyses were carried out on 292 households which constituted the ultimate sample size for the study.

The variables which loaded highly on Factor 1 were milk production, milk sold and use of concentrate feeding. Thus, Factor 1 was identified as 'intensity of market participation?'. Variables loading highly on Factor 2 were land holding, percentage of irrigated land and area of land under fodder. Thus, Factor 2 was identified as 'landholding'. The variables which loaded highly on Factor 3 were indigenous animal stock and herd size. Thus Factor 3 was termed as 'indigenous animal stock'. The variables which loaded highly on Factor 4 were use of Artificial Insemination Technology and adoption of vaccination. Thus, Factor 4 was termed as 'Technology adoption'. The variables which loaded highly on Factor 5 were household size, household income, dwelling structure and number of earning members in the household. Thus, Factor 5 was identified as 'household income and dwelling structure'. Only one variable each loaded highly on Factor 6 and Factor 7. Accordingly, Factor 6 and Factor 7 were identified as 'education' and 'number of family members involved in farming?.

Cluster analysis was then carried out with the above seven factors. Four distinct clusters emerged from the analysis. In order to name each of the identified cluster, one-way ANOVA was conducted to determine which classifying factors are significantly different between the clusters. Significant differences were observed in the means of various clusters for different factors, as denoted by the F-values and significance levels. The between groups means were all significant indicating that each of the identified factors reliably distinguished between the 5 clusters. With a significant ANOVA and 5 clusters, a Tukey *post-hoc* test was conducted to determine where exactly the differences lied.

Cluster 2 and cluster 3 scored significantly low on Factor 1 ('scale of production and intensity of market participation?') as compared to other clusters. Factor 2 ('landholding') significantly differentiated cluster 2 from other clusters. Cluster 3 and 4 scored significantly low on Factor 3 ('Indigenous animal productivity'), while cluster 2 scored significantly more on the same factor. Cluster 2 scored significantly more on Factor 4 ('Technology adoption') while cluster 1 and 3 scored significantly low on the same factor. Cluster 2 scored significantly high on Factor 5 ('household income and dwelling structure'), while cluster 3 and 4 scored significantly low on the same factor. Cluster 3 scored significantly high on Factor 6 ('age and educational profile of household head'), while cluster 4 scored significantly low on the same factor. Cluster 3 scored significantly higher on Factor 7 ('gender and family Labour involvement in farming'). The significant differences between factors for the clusters suggest the ways in which the clusters differ or on which they are based. From the above results (Tukey *post-hoc* test), the 5 clusters were named as under:

Cluster 1 was characterized as Households with low land holding, high stock of indigenous animals and low degree of technology adoption.

Cluster 2 was characterized as households with, high degree of technology adoption, high indigenous animal stock with low farm family labour involvement.

Cluster 3 was characterized as Households with low intensity of market participation in dairying.

Cluster 4 was characterized as households with high intensity of market participation, high stock of crossbred animals and high degree of technology adoption.

Table 5 presents the distribution of sample households across different identified clusters. Thus, it can be seen from the table that cluster 2 comprised of majority of sample households (40.75%) and cluster 4 comprised of lowest proportion of sample households (8.22%).

Socio-economic profile of respondents belonging to different clusters

Table 6 elicits the socioeconomic profile of respondents belonging to different clusters of households, as identified in the typology study. Average age of household heads across all clusters was 50.64 years. There were no significant differences in the age of the household heads belonging to different clusters. The education level of household heads of cluster 1 was significantly lower than that of other clusters. While the average years of schooling for respondents belonging to cluster 1 was only 3 years, the corresponding figures for clusters 2, 3 and 4 were 9 years, 8 years and 11 years, respectively. The average years of schooling of household heads across the all clusters were 8 years. Cluster 1 was identified as households with low degree of technology adoption in the typology study carried out earlier and this criterion for classification of this cluster is probably reflected through the comparatively lower education level of households belonging to this cluster.

Vast majority of household heads across all the clusters pursued agriculture + Animal husbandry (AH) as their principal occupation (69.88%, 73.95%, 65.15% and 87.50%, respectively, for clusters 1, 2, 3 and 4). Across all clusters, 74.12 per cent of respondents had agriculture + AH as their principal occupation. In contrast, substantially smaller proportions of respondents reported that they follow agriculture (2.11%), agriculture + others (3.14%), private job (4.95%) and business (5.85%) as their principal occupation, across all the clusters. No significant differences were observed between different clusters in regard to the proportions of respondents who pursued these occupations. Overall, 10 per cent of respondents reported that they have government services as their main occupation. About 8.43 per cent, 11.76 per cent, 15.15 per cent and 4.17 per cent of respondents from clusters 1, 2, 3 and 4, respectively, had government services as their main source income. The above results indicate that for round the year sustainable income and livelihood security, farmers prefer to maintain dairy animals.

Average household size for all clusters was 4.25 adult equivalents. No significant difference in household sizes was observed across different clusters. Proportions of households having non-farm income source for clusters 1, 2, 3 and 4 were 51.86 per cent, 55.46, per cent, 56.06 per cent and 54.16 per cent, respectively. There were no significant differences between different clusters in regard to this parameter. Average annual household income for clusters 1, 2, 3 and 4 were Rs. 1, 29, 036, Rs. 1, 75, 412, Rs. 1, 35, 454.5 and Rs. 1, 35, 000, respectively. The overall household income across all clusters was Rs. 1, 43, 726.

Cluster 1 had 3.60 per cent, 55.42 per cent and 40.96 per cent of households inhabiting kuccha, semi-pucca and pucca houses, respectively. Cluster 2 had 5.84 per cent, 54.62 per cent and 39.50 per cent of households inhabiting kuccha, semi-pucca and pucca houses, respectively. The corresponding figures were 1.51 per cent, 63.64 per cent and 34.85 per cent for cluster 3 and 0 per cent, 70.83 per cent and 29.17 per cent for cluster 4 in case of kuccha, semi-pucca and pucca houses, respectively. Significantly higher proportions of respondents from cluster 1 and cluster 2 lived in kuccha houses than their counterparts from cluster 3 and 4. Proportion of respondents living in semi-pucca houses was significantly lower in cluster 2 and cluster 1 as compared to cluster 3 and cluster 4. Significantly lower proportion of respondents from cluster 4 resided in pucca houses than their cluster 1 counterparts. Overall, proportions of respondents inhabiting kuccha, semi-pucca and pucca dwellings were 2.74 per cent, 61.13 per cent and 36.12 per cent, respectively.

Average herd size in terms of standard animal units (SAU) per household was 1.27, 1.24, 0.78 and 1.34 SAU for clusters 1, 2, 3 and 4, respectively. No significant differences in herd size holdings were observed across different clusters. Overall, dairy animal holding, across all clusters, was 1.16 SAU. Average land holding per household was significantly lower for cluster 1 (0.20 hectares), cluster 3 (0.23 hectares) and cluster 4 (0.22 hectares) as compared to the corresponding figure for cluster 2 (0.32 hectares). Overall, landholding size across all clusters was 0.25 hectares. Proportions of irrigated land for cluster 1, cluster 2, cluster 3 and cluster 4 were 15.59 per cent, 25.25 per cent, 21.95 per cent and 20.50 per cent, respectively. Overall, 20.82 per cent of land was irrigated land as compared to other clusters.

Economic Efficiency Index

The values of respective efficiency indices across different clusters are presented in Table 7, Livestock productivity was highest for cluster 1 (6.15 litres/SAU), followed by cluster 2 (5.70 litres/SAU), cluster 4 (5.57 litres/SAU) and cluster 3 (2.17 litres/SAU). Labour productivity was highest for cluster 4 (2.21 litres/labour hour), followed by cluster 1 (2.15 litres/labour hour), cluster 2 (1.75 litres/labour hour) and cluster 3 (0.68 litre/labour hour). Intensity of market participation in terms of proportion of milk produced that is sold was highest for cluster 4 (52.22%) and lowest for cluster 3 (10.26%). The corresponding figures for cluster 1 and cluster 2 were 39.30 per cent and 36.67 per cent, respectively. Output-input ratio (measured as ratio of value of output as a ratio of value of inputs that went into milk production) was highest for cluster 4 (2.86), followed by cluster 2 (2.65) and cluster 1 (2.52). Output-input ratio for cluster 3 (0.55) was lowest among all clusters.

The final values of respective efficiency indices across different clusters are presented in Table 8. In case of livestock productivity index, highest value was observed in case of cluster 1 and lowest in case of cluster 3. In case of labour productivity index, cluster 4 recorded the highest value while cluster 3 got the lowest. In case of marketed surplus index, the highest value was observed in case of cluster 4, while the lowest value was observed in case of cluster 3. In case of output-input ratio index, cluster 4 ranked first, while cluster 3 was ranked last. The composite EEI was calculated as an arithmetic mean of all the constituent indices for all the clusters. The composite EEI was highest in case of cluster 4 (0.96), followed by cluster 1 (0.87), cluster 2 (0.80). Cluster 3 had the lowest EEI (0.00). Chand and Sirohi[4] (2012) had in an earlier study categorized farms into various groups based on values of ESI, viz. low economic sustainability (ESI<0.3), moderate economic sustainability (ESI between 0.3 and 0.5) and high economic sustainability (>0.5). Based on the same criteria, cluster 1, cluster 2 and cluster 4, in this study, belonged to high sustainability category, while cluster 3 belonged to low economic sustainability categories. Thus, the above analyses provided clear evidence that households with market oriented milk production are not only the most profitable, but were also most economically sustainable farms.

Social Security Index

The mean values of respective components of SSI are presented in Table 9. Women participation in dairying was highest for cluster 2 (78.2 %), followed by cluster 4 (72.1 %), cluster 1 (66.4 %) and cluster 3 (64.5%). Proportion of technology adopters was highest for cluster 4 (93.5%), followed by cluster 2 (88.23%), cluster 3 (52%) and cluster 1 (15.67%). The distance to institutional infrastructural facilities for livestock was less for cluster 4 (1.67 Km) and more for cluster 3 (9.75 Km). The corresponding figures for cluster 1 and cluster 2 were 8.20 kilometres and 3.06 kilometres, respectively. Percentage dairying income (measured as ratio of income generated from dairying to total household income expressed in percentage) was highest for cluster 4 (20.33%), followed by cluster 2 (14.40%), cluster 3 (12.61%) and cluster 1 (12.61%). Women literacy was highest for cluster 4 (91.70 %), followed by cluster 2 (84.87 %), cluster 3 (74.25 %) and cluster 3 (66.27%). The final values of respective security indices across different clusters are presented in Table 10. In case of women participation in dairying index, highest value was observed in case of cluster 2 and lowest in case of cluster 3. In case of Technology adoption index, cluster 4 recorded the highest value while cluster 3 got the lowest. In case of Access to infrastructure for livestock index, the highest value was observed in case of cluster 4, while the lowest value was observed in case of cluster 3. In case of dairying income index, cluster 4 ranked first, while cluster 1 was ranked last. In case of female literacy index, cluster 4 ranked first, while cluster 1 was ranked last.

The composite SSI was highest in case of cluster 4 (0.91), followed by cluster 2 (0.74) and cluster 3 (0.19). Cluster 1 had the lowest SSI (0.07). Chand and Sirohi[4] (2012) had in an earlier study categorized farms into various groups based on values of SSI, viz. low social sustainability (SSI<0.3), moderate economic sustainability (SSI between 0.3 and 0.5) and high economic sustainability (SSI>0.5). Based on the same criteria, cluster 4 and cluster 2, in this study, belonged to high sustainability category, while cluster 1 and cluster 3 belonged to low social sustainability categories. Thus, the above analyses provided clear evidence that full farm households with market oriented milk production are not only the most profitable and technically efficient, but were also most socially sustainable farms.

Ecological Security Index

The mean values of respective components of ESI are presented in Table 11. Percent utilization of Dung as Manure was highest for cluster 4 (100%), followed by cluster 2 (66.39%), cluster 3 (45.43%) and cluster 1 (35.53%). Methane Emission (calculated as Kg methane per head per year) was highest for cluster 1 (68.83 Kg/ head/ year), followed by cluster 2 (60.48 Kg/ head/ year), cluster 3 (41.64 Kg/ head/ year) and cluster 4 (40.28 Kg/ head/ year). The methane emission in this study was calculated as per the specifications given by Shukla *et. Al*[6]. (2004) , wherein the average methane emission by buffalo, crossbred cattle and indigenous cattle was reported as 76.65 Kilogram per head per year, 38.83 Kilogram per head per year and 35.97 Kilogram per head per year, respectively. Based on these specifications, the methane emission per household was computed on the basis of number of different breeds/species of dairy animals owned by the household. Ratio of Surplus land in relation to carrying capacity of animals (Total Land/ SAU) was highest for cluster 2 (2.56) and lowest for cluster 3 (1.50). The corresponding figures for cluster 1 and cluster 4 were 1.62 and 1.69, respectively.

The final values of respective Ecological Security indices across different clusters are presented in Table 12. In case of dung as manure index, highest value was observed in case of cluster 4 and lowest in case of cluster 1. In case of Methane Emission Index, cluster 4 recorded the highest value while cluster 1 got the lowest. In case of Surplus land Index, the highest value was observed in case of cluster 2, while the lowest value was observed in case of cluster 3.

The composite ESI was highest in case of cluster 4 (0.73), followed by cluster 2 (0.60), cluster 3 (0.38) and cluster 1 had the lowest ESI (0.03). Chand and Sirohi[4] (2012) had in an earlier study categorized farms into various groups based on values of ESI, viz. low ecological sustainability (ESI<0.3), moderate ecological sustainability (ESI between 0.3 and 0.5) and high ecological sustainability (>0.5). Based on the same criteria, cluster 4 and cluster 2, in this study, belonged to high sustainability category, while cluster 1 and cluster 3 belonged to low and moderate ecological sustainability categories respectively. Thus, the above analyses provided clear evidence that full farm households with market oriented milk production are not only the most profitable and technically efficient, but were also most ecological sustainable farm.

Total Sustainability Index

The final values of respective Total Sustainability Indices across different clusters are presented in Table 13. The TSI was calculated as an arithmetic mean of all the constituent indices for all the clusters. The TSI was highest in case of cluster 4 (0.86), followed by cluster 2 (0.71), cluster 1 (0.32), while cluster 3 had the lowest ESI (0.19). Chand and Sirohi[4] (2012) had in an earlier study categorized farms into various groups based on values of TSI, viz. low total sustainability (TSI<0.3), moderate total sustainability (TSI between 0.3 and 0.5) and high total sustainability (>0.5). Based on the same criteria, cluster 4 and cluster 2, in this study, belonged to high total sustainability categories, while cluster 1 belonged to moderate total sustainability category and cluster 3 belonged to low total sustainability category. Thus, the above analyses provided clear evidence that households with market oriented milk production and households with high degree of technology adoption are not only the most profitable, but were also most sustainable dairy farms with high sustainability index.

Determinants of Sustainable Dairy Farming

A multivariate regression equation as given below was fitted to identify the factors significantly influencing sustainability in milk production. The fitted function was estimated through OLS technique and results obtained are shown in Table 14. Among the Significant variables, three variables showed positive effect on the sustainability index and two variables showing negative effect on sustainability index.

Variables having positive effect on Sustainability Index are enlisted below;

Education of Household: Education is one of the prior factors for the sustainability at household level. Higher the education of household, higher will be its sustainability. The relevance of education in improving the sustainability of any production system needs no emphasis and has also been brought about by data in the present study. The point that needs to be emphasized here is that vocational and other short and medium term trainings regarding scientific dairy farming practices particularly to woman folk can be instrumental in enhancing the sustainability of this labour intensive enterprise. Besides, that Education level increases the technical efficiency as well as managerial efficiency of the household. They can manage the farm in a better way by adopting the new and advanced technology for their farm.

Land Holding: From the regression results, it can be seen that land holding is the most significant factor affecting sustainability at household level. The farmer which owns larger operational land holding has high sustainability index. The variable captures the mixed farming concept where a farmer can use his land more efficiently and produce milk both by growing fodder crops in their owned lands and by utilizing crop by-products for feeding of animals. This is all the more important as feed and fodder costs account for the highest proportion of total cost in milk production. Thus, it becomes evident that land area available to farmers is an important determinant both for profitability and sustainability of dairying in mixed farming systems. Ali (2007) had also stressed upon the importance of land in the profitability of dairy enterprises.

Milk Marketed Surplus: The positive affect of milk marketed surplus implies that higher the proportion of milk sold by the farmer, higher will be its sustainability index. This variable captures the market orientation of households. Undoubtedly, greater access to market has a direct positive bearing on the economic dimension of sustainability. At the same time, it may also be critical in bringing out structural changes in the society such that greater income and more commercial nature of dairy farming empower the dairy farming community.

Variables having negative effect on the Sustainability Index are enlisted below:

Fodder grown per SAU: From the above regression results it has seen that higher the proportion of fodder grown per SAU, lower will be the sustainability at household level as more fodder grown per SAU increases the fodder cost incurred on animal which signifies the less Feed Conversion Efficiency (FCE) of the animal. Thus, less fodder grown per SAU increases the Sustainability of the household.

Expenditure incurred on Concentrate Feeding: Regression analysis shows that higher the amount spends on Concentrate feeding, lesser will be the sustainability of household as expenditure incurred on concentrate feeding increases the total feed cost resulting in less profitability. Besides that, over feeding of concentrate diet only increases the feed cost not the milk yield.

Table 1: Variables considered for constructing factors using Principal Component Analysis (PCA)

S.No.	Variabl	Descriptions
1	Household Size	No. of members in Household
2	Dwelling Structure	Kuccha=1, Semi-pucca=2, Pucca=3
3	Gender of Household Head	Female=0, Male=1
4	Age Household Head	Age in No. of years
5	Education Household Head	No. of years of formal schooling
6	HH Income	Annual income in Rs.
7	Family labour employment in farming	No. of family members involved in farming
8	Non Farm Income	Presence of NFI=1, Absence=0
9	Number of Earning Members	No. of earning members of the Household
10	Landholding	Total land holding size of Household (acres)
11	Proportion of Irrigated land	Proportion of irrigated to total land
12	Land under Fodder	Area of land under fodder cultivation
13	Herd Size	Total no. of dairy animals owned by household (measured in SAU)
14	CB animal	Presence=1, Absence=0
15	Milk Production	Fat corrected total milk in litres
16	Milk Sold	Fat corrected total milk sold in litres
17	Milk Yield	Fat corrected total milk / SAU
18	Vaccination	were vaccinated in last one year: Yes=1, Otherwise=0
19	Artificial Insemination	Whether AI is followed? Yes=1, Otherwise=0
20	Concentrate Usage	Whether concentrate is fed to animals: Yes=1, No=0

Table 2: Indicators and operational definitions of components of Economic Efficiency Index as a measure of sustainability

Constituents of EEI	Indicat	Operational Definition
Livestock Productivity	FCM / SAU	Amount of Fat corrected milk produced per SAU
Labour Productivity	(FCM / SAU) / Man labour hours equivalent	Amount of Fat corrected milk produced per SAU per labour employed in dairy production
Marketed Surplus	% of FCM sold	Mean percentage of FCM sold
Output - Input ratio	Milk production per day per SAU / Total variable cost per day per SAU	Price of produced milk per total variable cost employed

Table 3: Indicators and operational definitions of components of Social Security Index as a measure of sustainability

Constituents of SSI	Indicators	Operational Definition
Woman's participation in dairying	Total work hours of woman in dairying / Total work hours in dairying	Percent woman work contribution in dairying
Technology Adoption	Technology adapters/ Total house holds	Percentage of persons who are adopting new technology
Access to public infrastructure for livestock	Nearest distance from the house hold.	Average distance to access infrastructure for livestock
Income from dairying	Income earned from dairying/ total household income	Percentage of dairying income in total household income
Female literacy	No. of woman's literate/ total woman households.	Percentage of woman which are literate.

Table 4: Indicators and operational definitions of components of Ecological Security Index as a measure of sustainability

Constituents of ESI	Indicators	Operational Definition
Utilization of Dung	Percent households used dung as a manure	Utilization of dung for the purpose of manure and cow dung cakes.
Methane Emission	Contribution of different animals to methane production	Kg production of methane per head per year
Surplus land	Total Land/ SAU	Surplus land in relation to carrying capacity of animals.

Table 5: Distribution of sample households across different clusters

Cluster	Cluster Name	Number of Sample households	% of sample households
Cluster 1	Households high buffalo stock and low degree of technology adoption	83	28.42
Cluster 2	Households with high degree of technology adoption, high buffalo stock with low farm family labour involvement	119	40.75
Cluster 3	Households with low intensity of market participation in dairying	66	22.60
Cluster 4	Households with high intensity of market participation, high stock of crossbred animals and high degree of technology adoption	24	8.22

Table 6: Profile of respondents belonging to different clusters

Sr No.	Particulars	Cluster – 1	Cluster – 2	Cluster – 3	Cluster – 4	Overall
A.	**Respondent Specific Characteristics**					
1	Age	50.89	49.97	49.71	52	50.64
2	Education*	3.89	9.05	8.03	10.75	7.93
3	Principal Occupation (In %)					
3.a	Agriculture + AH	69.88%	73.95%	65.15%	87.50%	74.12%
3.b	Agriculture	1.20%	4.20%	3.03%	0.00%	2.11%
3.c	Agriculture + Other	4.82%	1.68%	6.06%	0.00%	3.14%
3.d	Govt. Job	8.43%	11.76%	15.15%	4.17%	9.88%
3.e	Private Job	6.02%	3.36%	6.06%	4.17%	4.90%
5.f	Business	9.64%	5.04%	4.54%	4.17%	5.85%
B.	**Household Specific Characteristics**					
1	HH Size**	4.12	4.34	4.24	4.33	4.25
2	Percentage of Households having Non Farm Income	51.86	55.46	56.06	54.16	54.39
3	Total HH Income (In Rs.)	129036.1	175411.8	135454.5	135000	143725.6
4	Dwelling Structure					
5.a	Kacha	3.60%	5.84%	1.51%	0.00%	2.74%
5.b	Semi Pucca	55.42%	54.62%	63.64%	70.83%	61.13%
5.c	Pucca	40.96%	39.50%	34.85%	29.17%	36.12%
C.	**Farm Specific Characteristics**					

1	Total Livestock SAU***	1.27	1.24	0.78	1.34	1.16
2	Percentage of FCM Sold	4.01	3.76	1.03	5.22	3.50
3	Land Total (In Nali****)	10.33	16.13	11.64	11.08	12.29
4	Percentage of Irrigated land	15.59	25.25	21.95	20.50	20.82

*Education: Given as number of years of formal education; ** 4 children=3 adult women=2 adult men, Given: Average

** 4 children = 3 adults females = 2 adults males

*** 1.4 CB cow = 1.3 Buffalo = 1 indigenous cow

****1 acre = 20 Nali

Table 7: Mean values of respective components of EEI

Mean Values of EEI constituents				
	Milk Productivity (FCM / SAU)	**Labour Productivity**	**Marketed Surplus (% of FCM Sold)**	**Output - Input Ratio**
CL1	6.15	2.15	39.30	2.52
CL2	5.70	1.75	36.67	2.65
CL3	2.17	0.68	10.26	0.55
CL4	5.57	2.21	52.22	2.86

Table 8: Final values of EEI across different clusters

Clusters	**Livestock Productivity**	**Rank**	**Labour Productivity**	**Rank**	**Marketed Surplus**	**Rank**	**Output Input Ratio**	**Rank**	**EEI**	**Composite Rank**
CL1	1	1	0.96	2	0.69	3	0.85	3	0.87	2
CL2	0.89	2	0.70	3	0.70	2	0.90	2	0.80	3
CL3	0.00	4	0.00	4	0.00	4	0.00	4	0.00	4
CL4	0.85	3	1	1	1	1	1	1	0.96	1

Table 9: Mean values of respective components of SSI

Mean Values of SSI constituents					
	% woman participation in dairying	**% Technology Adopters**	**Distance to infrastructure for livestock (Km)**	**% Dairying Income**	**% Female literacy**
CL1	66.4	15.67	8.20	12.61	66.27
CL2	78.2	88.23	3.06	14.40	84.87
CL3	64.5	52	9.75	13.80	74.25
CL4	72.1	93.5	1.67	20.33	91.70

Table 10: values of SSI across different clusters

Clusters	**Woman participation in Dairying Index**	**Rank**	**Technology Adoption Index**	**Rank**	**Access to Infrastructure Index**	**Rank**	**Dairying Income Index**	**Rank**	**Female Literacy Index**	**Rank**	**SSI**	**Composite Rank**
CL1	0.14	3	0.00	4	0.19	3	0.00	4	0.00	4	0.07	4
CL2	1	1	0.93	2	0.83	2	0.23	2	0.73	2	0.74	2
CL3	0.00	4	0.47	3	0	4	0.15	3	0.31	3	0.19	3
CL4	0.55	2	1	1	1	1	1	1	1	1	0.91	1

Table 11: Mean values of respective components of ESI

Mean Values of ESI constituents			
	Utilisation of Dung (% dung used for manure)	**Methane Emission (Kg CH4/head/year)**	**Land/ SAU Ratio**
CL1	32.53	68.83	1.62
CL2	66.39	60.48	2.56
CL3	45.43	41.64	1.50
CL4	100	40.28	1.69

Table 12: Final values of ESI across different clusters

Clusters	Dung as Manure Index	Rank	Methane Emission Index	Rank	Surplus Land (Land/SAU) Index	Rank	Composite ESI	Composite Rank
CL1	0.00	4	0.00	4	0.11	3	0.03	4
CL2	0.50	2	0.29	6	1	1	0.60	2
CL3	0.19	3	0.95	2	0	4	0.38	3
CL4	1	1	1	1	0.18	2	0.73	1

Table 13: Final values of TSI across different clusters

Clusters	Composite Economic Efficiency Index	Rank	Composite Social Security Index	Rank	Composite Ecological Security Index	Rank	TSI	Composite Rank
CL1	0.87	2	0.07	4	0.03	4	0.32	3
CL2	0.80	3	0.74	2	0.60	2	0.71	2
CL3	0.00	4	0.19	3	0.38	3	0.19	4
CL4	0.96	1	0.91	1	0.73	1	0.86	1

Table 14: Regression values of factors influencing Sustainability

Coefficients[a]				
Model				Sig.
		β	S.E.	
	(Constant)	-.971	.834	.248
1	Age of the Household	.005	.003	.115
2	Education of the Household	.026	.011	.023**
	Non Farm Income	-.030	.043	.491
3	Land Holding	.065	.017	.000***
	Fodder Grown per SAU	-.179	.093	.058*
4	Herd Size (SAU)	.547	.672	.419
5	Milk production	-.135	.118	.258
	Marketed Surplus Milk	.060	.017	.001***
6	Milk Yield	.171	.145	.242
7	Veterinary Expenditure	.012	.013	.366
	Concentrate Expenditure	-.005	.002	.023**
	R^2 = 65.7			

CONCLUSION

Significant heterogeneity of small-scale dairy farms was observed in the study area in regard to socio-economic and farm characteristics. Multivariate statistical techniques like principal component analysis and cluster analysis proved to be great tools in identifying important socio-economic characteristics of typical milk producing households. The study clearly identified four clusters of milk producing households, in the study area, based upon socio-economic and farm characteristics. These were households with high stock of indigenous animals and low degree of technology adoption, Cluster I (28.42%); households with high degree of technology adoption, high indigenous animal stock with low farm family labour involvement, Cluster II (40.75%); households with low intensity of market participation in dairying, Cluster III (22.60%) and households with high intensity of market participation, high stock of crossbred animals and high degree of technology adoption, Cluster IV (8.22%). Government policies regarding dairy development are likely to be more effective if they consider the heterogeneity of farms in the design and delivery of extension approaches and interventions. Approaches that work with farmers that are considered to be representative of the groups in terms of characteristics may be most effective.

In regard to sustainability of different production systems, it was observed that market oriented farms with high degree of technology adoption were the most economically, socially and ecologically sustainable farms. In regard to factors influencing Sustainability of dairy systems, the study concluded that with increasing education level, size of landholding and intensity of market participation, the sustainability of dairy farms increases. On the other hand, increasing fodder grown per milch dairy animal and expenditures made on concentrate feeds had adverse effects on sustainability.

Households with market oriented milk production owned high-yielding species/breeds of dairy animals and were also economically, socially and ecologically most sustainable. It thus implies that there is scope of realizing greater degree of sustainability by increasing farmers' market integration. For this, there is need for linking farmers to the market not only by providing remunerative prices for milk, but also by investing on roads and transport infrastructure and chilling centres as this would help in increasing the degree of commercialization/market participation of the milk producers. Households with low education level were least sustainable in milk production. It thus becomes imperative to give greater focus on training especially for female workforce in dairying in order to enhance their competitiveness.

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