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A Study on Variability in Tribal Farming Practices for Strategic Intervention Development in the Western Himalayan Region

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Abstract - Smallholding farmers' responses to integrated farming systems interventions were diverse due to their hetero- geneous nature. To achieve the desired impact on productivity, profitability, and sustainability of tribal farming systems, there is an urgent need to understand the heterogeneity and classify them into homogenous groups. In the present study, the diversity of tribal farms was assessed using crop, livestock, and income-related characteris- tics. Using principal component analysis and cluster analysis for 100 farm households, 4 farm types were identified i.e. crop (rice-wheat) intensive farming system (26%), crop + dairy + off farm-based farming system (7%), re- source-efficient, crop cum dairy based farming system (30%), off-farm dependent resource-poor farming system (35%). The findings of the study provide insights for planning appropriate integrated farming systems for nutrition security and sustainability.

Keywords - Uttarakhand, Farm type, Heterogeneous, Sustainability, Tribal farming systems.

I. Introduction

India has the second largest tribal population in the world which constitutes 104.5 million, around 8.6% of the total population (Census 2011). Out of the total tribal population, around 0.29 million tribal people reside in Uttarakhand which constitutes around 3 percent of the state's total population. The tribal farm households are mainly characterized by low crop and livestock productiv- ity, poor income, unemployment, and small and frag- mented landholdings. The tribes constitute the weakest section of the western Himalayan region of Uttarakhand from a socio-economic and ecological point of view (Raghav and Srivastava 2014).

The income and sustai- nability of tribal farms could be improved through appro- priate integrated farming system (IFS) interventions, which is a management strategy that ensures optimal uti- lization of all resources of individual farmers within the farming system so that the productivity and profitability could be maximized and sustainability maintained (Innazent et al., 2022).

Characterizing the diversity of the farming system is the first step toward the IFS approach. Blanket recommen- dations do not suit well due heterogeneity of small farmholders. Within the single farming system, there is heterogeneity (socio-economic, biophysical) that impedes the interpretation of results in the apt planning of interven- tions. Not only social factors like caste, income, and gen- der but also factors like land, labor, and livestock have a contributory role to farmer's heterogeneity in a particular region. There is a vital need to address the heterogeneity of farming systems to understand the factors that explain the adoption or rejection of new technologies (Goswami et al., 2015, Kumar et al., 2019, Kaur et al., 2022). Con- sequently, improving the adoption rates of apt IFS inter- ventions is directly related to the increased efficiencies of agricultural research and extension systems. Higher adop- tion may lead to yield enhancement, increased resource use efficiency, producing diverse food from the same piece of land, creating opportunities for higher socio- economic impact on rural livelihoods (Innazent et al., 2022, Desai et al., 2022). Farming system typology is a tool for in-depth farming system analyses for detailed characterization. It helps to understand the factors that explain the adoption and rejection of new technologies. It integrates quantitative, participatory, and statistical meth- ods to summarize the heterogeneous population of indi- vidual farm households by clustering them into homog- enous groups (Eshetae et al., 2024, Innazent et al., 2022).

Developing a typology constitutes an essential step in any realistic evaluation of constraints and opportunities so that the appropriate technological solutions that can be pro- vided could have a higher penetration rate (Sinha et al., 2022). Many studies were carried out on the characteriza- tion of farming systems. However, there is a dearth of evi- dence regarding the use of farming system typology for the characterization and planning of targeted farming sys- tem interventions. With this background, the present study was undertaken to characterize the tribal farming systems using typology.

II. Material and Methods

Study location and survey details: The survey for farm- ing system characterization and typology construction was carried out in tribal farming systems of Tarai and Bhabhar zone, Uttarakhand of Western Himalayan Region, India which is located at (29°15'30 N to 29°16'0.07 N, 79°2'39E to 79°3'0 E) in Ramnagar block of Nainital Dis- trict. It is characterized by the average altitudes ranging from 195 to 268 m amsl. A total of 100 tribal farm fami- lies comprising a cluster of three tribal villages having more than 40 percent tribal population viz.

Thari, Veerpur Tara, and Mallapuri were selected using a clustered sam- pling frame. The survey instrument was organized into (i) general farm and household characteristics, food con- sumption pattern, and chronic energy deficiency status, (iii) farm input and labor use (iv) field crop and horticul- tural production technologies and practices (v) dairy and other livestock production (vi) crop residue management including use as animal feed (vii) off-farm income sources and expenditure. Apart from detailed farming system char- acterization, a quick survey for typology construction of these 100 tribal farm households was conducted with a focus on socio-economic information and income of the farms from different farm enterprises. This data gathered was used for identifying predominant farm types.

Food consumption pattern and chronic energy defi- ciency status: A modified version of the food frequency questionnaire method was administered to the selected samples of clustered villages to capture the nature of food, intake amount, and frequencies (Bingham et al., 2012, Thompson and Subar 2017).

The mean/median intakes of food were expressed in g/ml/capita/day compared with the suggested balanced diet provided in Recommended Di- etary Intakes for Indians (RDI). The height and weight of all the household members in the study areas were mea- sured using standard equipment (weight balance and stadiometer). The percent distribution of preschool chil- dren (0-5 years) and school-age children (6-10 years) and (11-19 years) according to stunted (height-for-age Z-score (HAZ) at least 2SD below the median), undernourished (BMI-for age Z score (BMIZ) at least 2SD below the me- dian). School-age children including preschool (0-10 years for underweight (weight-for-age Z-score (WAZ) at least two standard deviations (SD) below the median) and preschool children (0-5 years for wasted (weight-for- height (WHZ) Z-score at least 2SD below the median) was determined based on the World Health Organization child growth standards (WHO 2006) and adult nutritional status was categorized by BMI according to WHO cut off levels for Asians (Chronic Energy Deficiency (CED) <18.5 BMI).

Typology construction

The diversity of tribal farming systems of the Tarai and Bhabhar zones was explored using typological analysis. Variables for typology were selected and computed repre- senting structural (farm assets and resources) and func- tional (livelihood pursuits) features of farming systems related mainly to farmer's primary crop and livestock sys- tems. Eighteen variables were computed in total.

Data clustering

Three steps were taken to build HH typology. The first step reduced the dimensionality of the data and identified primary patterns and variability by applying principal component analysis (PCA) using R software. Selection of the relevant principal components was performed by the screen test. In the second step, hierarchical clustering analysis on the new orthogonal data projection made by the selected PCs. Cluster numbers were determined in the last step, after which a dendogram was constructed by ascendant hierarchical classification performed using the ward's criterion. A decision rule set was enforced regard- ing where to cut dendogram branches by searching for the maximum average silhouette width (measures derived from the comparison of intra-class similarity, with high and low inter-class similarity separated) of different k- means clustering solutions with varying cluster numbers.

Results and Discussion

Description of existing farming systems

Crops (paddy-wheat) were the dominant farming sys- tem found in around 44 percent of households followed by crop (paddy-wheat) + dairy farming system (30%). The resource characterization survey revealed around 1.23 tonnes per household per annum of wheat straw has been produced at tribal farmer's fields. Amongst the total pro- duction 0.73 tonnes/household/ annum of wheat straw has been sold by farmers @ ₹5,230/tonne/household which is very less. Similarly, around 1.43 tonnes/household/annum of paddy straw has been produced at tribal farmer's fields,

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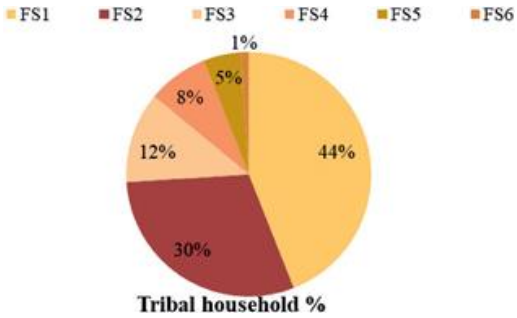

Fig. 1. Prevailing farming systems in the region

FS1, crop (paddy-wheat); FS2, crop (paddy-wheat) + dairy; FS3, crop + horticulture (vegetables); FS4, crop (paddy-wheat) + dairy + hor- ticulture (vegetables/fruits); FS5, crop (paddy-wheat) + livestock (cow/goat); FS6, crop (paddy-wheat) + livestock (cow/poultry) + horticulture (vegetables) out of which 0.77 tonnes of paddy straw has been sold at ₹1,245/tonne/household which is meager. Further study shows that around 2.61 tonnes/household/annum of farm yard manure has been produced at tribal farmers' fields which is entirely consumed at tribal farmers' fields having less nutrient, ecological, and economic value.

Dietary intake of tribal households

Data presented in Fig. 3 shows that the diets of tribal farm households are devoid of green leafy vegetables, pulses, and milk as compared to RDA. However, in terms of other vegetables and animal foods, tribals were found to consume only 62.5 and 73% respectively as compared to RDA.

It was noticed from Table 1 that around 85.71% of pre- school male children of 0-5 years were found stunted (<-2SD) with a mean value of -3.25 ± 0.81 and about 60.00% of preschool female children of 0-5 years were found stunted with a mean value of -1.5 ± 1.91 whereas 80.00% of pre-school female children of 0-5 years were found wasted (<-2SD) with a mean value of -2.38 ± 1.42. Around 85.71% of preschool male children of 0-5 years were found underweight (<-2SD) with a mean value of - 2.74±1.31 and around 60.00% of preschool female chil- dren of 0-5 years were found underweight (<-2SD) with a mean value of -2.54 ± 1.59 whereas, 80.00% of pre-school female children of 0-5 years were found undernourished (<-2SD) with a mean value of -3.0 ± 1.09. Amongst school-age children of 11-19 years stunting amongst males was found at 48.27% (<-2SD) with a mean value of -2.06 ± 1.23 and around 50.00% of females were found stunted (<-2SD) with a mean value of -1.87 ± 1.06.

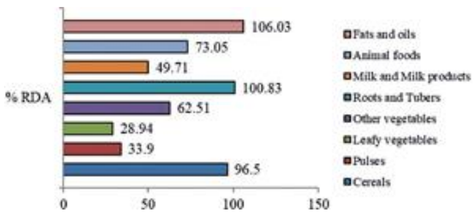

Fig. 2. Average dietary intake of household's g/capita/day as % RDA

Farming System Typology

A farming system typology study has been conducted to know more about the classifications like farm size, in- come sources of the farm income, and cost of cultivation per ha. For example, it is difficult to understand the impor- tance of small animals (only 6%) or strategize reducing the cost of cultivation practices, nutrition interventions so forth and so on.

Table 1. Nutritional status (<-2SD) in children of tribal farm households

Age/Gender	BMIZ	HAZ	WAZ	WHZ
	(Undernourishment %)	(Stunting %)	(Underweight %)	(Wasting %)
Male (0-5 yrs)	-0.34 ± 1.62 (14.28)	-3.25±0.81 (85.71)	-2.74±1.31 (85.71)	-0.92±1.53 (14.28)
Female (0-5 yrs)	-3.0 ± 1.09 (80.0)	-1.5 ± 1.91 (60.0)	-2.54 ± 1.59 (60.0)	-2.38 ± 1.42 (80.0)
Male (6-10 yrs)	-1.0 ± 3.39 (33.33)	-1.91 ± 4.98 (33.33)	-1.77± 4.69 (33.33)	-
Female (6-10 yrs)	1.8 ± 0.6 (0.0)	-1.8 ± 5.29 (33.33)	-1.16 ± 1.23 (33.33)	-
Male (11-19 yrs)	-1.10 ± 1.50 (27.58)	-2.06 ± 1.23 (48.27)	-	-
Female (11-19 yrs)	-1.19 ± 1.17 (18.18)	-1.87 ± 1.06 (50.00)	-	-

Table 2. Eigenvalues and percentage variance explained by five principal components (PCs)

PC	Eigenvalue	Variance (%)	Cumulative Variance (%)
1	5.550	5.550	30.83
2	3.541	9.091	50.50
3	2.249	11.339	63.00
4	1.708	13.047	72.48
5	1.189	14.236	79.09

Out of 18 variables measured in the survey, screen plots of the Eigenvalues resulting from the PCA indicated that the diversity in the farm household characteristics was

associated with the first five components together explain- ing 79% of the variability in the dataset (Table 2, Fig 3a). The first PC explained the greatest part of the variation, about 30.83% of the variability in the data. The first com- ponent (PC1) was closely related to the variables describ- ing the percentage of area under fodder, cattle no, milch animal, and total livestock unit (TLU). Thus, it seemed to explain the livestock capital of the farm households (Fig 3b). The second component (PC2) correlated highly with the percentage of area under rice, the percentage of area under wheat, and cereal intensity. Thus, it explained the crop production of the farm households. Combined the two principal components explained 50.50% of variabil- ity. The third component (PC3) described off-farm labor, off-farm income, and crop income. Combined the three principal components explained 63% of variability. Thus, it explained the off-farm activities/ income of farm house- holds.

The fourth component (PC4) was related to household size, household head, and on-farm labor and is explained the human capital of the farm households. Combined the

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four principal components explained 72.48% variability. The fifth component (PC5) was related to small animal numbers (Fig 3b). Combined the five principal compo- nents explained 79.09% variability. Hierarchical cluster- ing analysis indicated four main types of farm households across the cluster of three villages examined. Projecting these on five principal components, four groups are ob- served (Fig 3c). Summing household farm types across the study cluster first cluster discernable is a group of 26

Table 3. Farming system typology

	Crop (Rice-wheat) intensive farming system (26)		Crop + dairy + off- farm-based farming system (7)		Resource-efficient, crop cum dairy-based farming system (30)		Off farm dependent resource-poor farming system (35)	
Variables	Mean	S Dev	Mean	S Dev	Mean	S Dev	Mean	S Dev
HH Size	4.11	1.27	4.571	1.61	4.766	1.25	5.17	1.58
HH Head Age	40.07	12.70	45.28	14.77	45.93	11.24	40.71	10.72
On farm Lab	2.65	1.129	3.42	1.133	3.66	1.32	3.4	1.45
Off-farm Lab	0.038	0.196	0.28	0.75	0.23	0.43	0.91	0.50
Total Land	0.54	0.23	0.37	0.19	0.88	0.52	0.24	0.197
Area Rice %	99.27	1.63	87.12	4.27	99.57	1.12	100	0
Area Wheat %	99.27	1.63	87.12	4.27	99.57	1.121	100	0
Area Fodder %	0.002	0.01	0.054	0.038	0.088	0.034	0.004	0.017
Cattle No	0.038	0.19	1.57	1.13	2.1	1.18	0.085	0.37
Small Rumi No	0	0	0	0	0.133	0.43	0	0
Small Animal No	0.038	0.19	0	0	0.13	0.73	0.2	0.71
Milch Animal	0	0	0.85	0.89	1.33	0.80	0.057	0.23
Cereal Intensity	198.55	3.27	174.3	8.56	199.14	2.24	200	0
Crop Income %	99.23	3.92	40.46	32.84	90.19	15.63	35.28	29.10
Livestock Income.	0	0	30.96	29.92	3.64	11.53	1.14	4.71
Off Farm Income.	0.76	3.92	28.57	38.04	7.66	15.74	63.57	28.76
Total TLU	0.027	0.13	1.1	0.79	1.47	0.82	0.062	0.26
Cost of cultivation/ha	27,371.80	16,605.18	20415.8	13,745.32	41,070.74	20,168.88	10,154.86	5,805.28

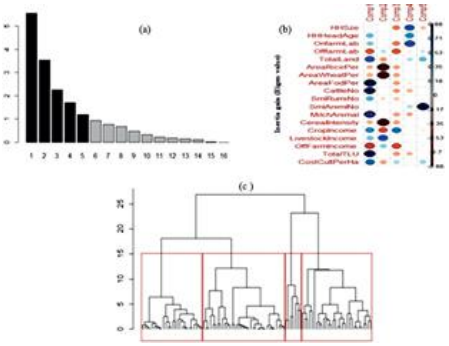

Fig. 3. (a) Screen plot PCA, (b) Contribution of variables to principal components, (c) Cluster Dendogram

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farmers who can be described as taking part in crop pro- duction (rice-wheat-based) activities only (26.53% of the sample). The group has mid-level resource endowments in terms of land with a mean value of 0.54 ± 0.23, having a large area under cereal crops (198.55 % cereal intensity). These farmers can be differentiated due to their primary source of income from crop production with a mean value of 99.23 ± 3.92%. Conversely, no income from livestock. The second cluster of 7 households can be described as resource-poor crop cum dairy-based farmers representing only 7.14% of the sample. Diversified in cropping system having 174.3% cereal intensity.

The group has mid-level resource endowments in terms of land and livestock with a mean value of 0.36 ± 0.19 and 1.57 ± 1.13, respectively. These farmers can be differentiated due to their primary source of income from crop production with a mean value of 40.46 ± 32.84% and livestock production with a mean value of 30.96 ± 29.92. The group has having 28.57% share of off-farm income.

The third cluster of 30 house- holds can be described as resource-efficient crop cum dairy-based farmers representing 30.6% of the sample. The group is characterized by the largest landholdings 0.88 ± 0.52 and livestock at 2.1 ± 1.18, TLU 1.47 ± 0.82. The group has the second largest cereal intensity (199.14%). The primary source of income of these farm- ers is crop production with a mean value of 90.19 ± 15.63%. However, the off-farm income with a mean value of 7.66 ± 1.47% was due to farm machinery provided on rent. Milk and meat were utilized for family consumption despite large no of livestock and TLU. The fourth cluster of 35 households can be described as off-farm dependent resource-poor farmers representing 35.7% of the sample. The group has poor resource endowments in terms of land and livestock with a mean value of 0.24 ± 0.197 and 0.085 ± 0.37 respectively. However, the group cultivated the largest area (200% cereal intensity) under cereals (rice- wheat). These farmers are primarily dependent on off-farm income with a mean value of 63.57 ± 28.76%.

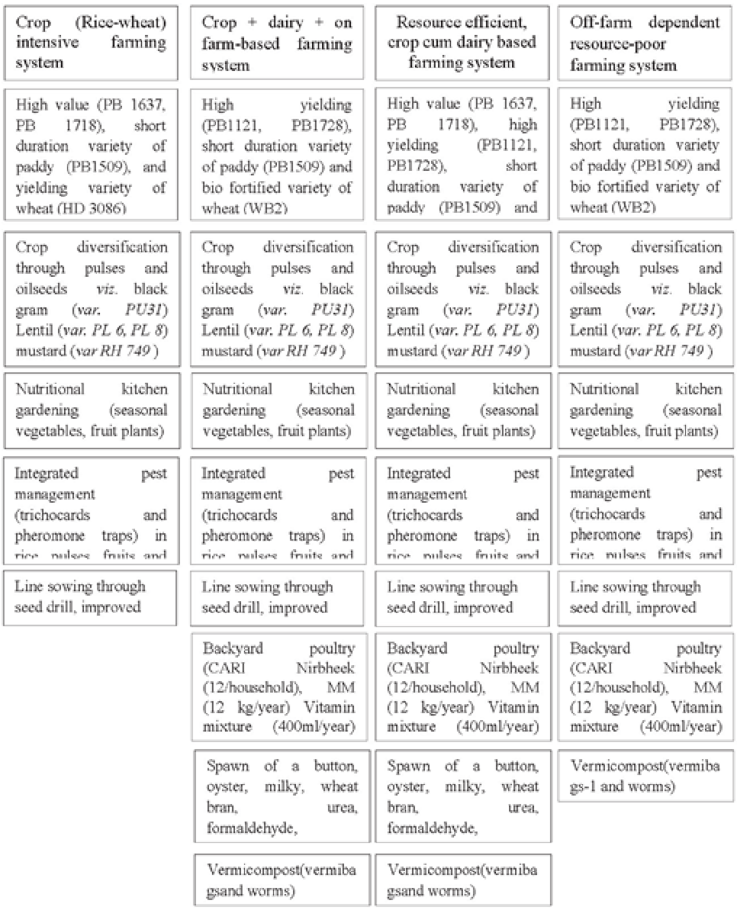

Fig. 4. A methodological framework for planning targeted farming system interventions

Planning of Targeted farming System Interventions

A methodological framework for planning targeted farming system interventions has been proposed to ensure food and nutritional security and overall sustainability in different farm types. The planning of a set of technologies in different farm types is based on integrating the results of farm typology (farmer's resources) and participatory farmer's interest. Farmers were asked to prioritize these interventions based on their interests, marketability, skillset, and cultural practices through focused group dis- cussion.

The priority ranking varied according to different farm types. High value (PB 1637, PB 1718) variety of Basmati rice was preferred by rice-wheat intensive farm- ing system High yielding (PB1121, PB1728) variety of Basmati rice was preferred by crop+dairy+on farm-based farming system to fulfill the requirement of dry fodder in their animals. Farm type 2 and Farm type 3 showed inter- est in a maximum set of interventions due to their previ- ous resource base. All the farmers showed interest in crop diversification to get maximum profit and a higher ben- efit-cost ratio. The findings are in line with Kumar et al., 2019, Sinha et al., 2022 and Kaur et al., 2022) who pro- posed typology-based targeted intervention strategies for livelihood security of the different regions.

For regular cash flow combination of the crop with ju- dicious enterprises suitable to agro-ecology of particular region. A previous study done by Kumar et al. (2018) cropping system (Rice–wheat) was combined with other enterprises (cropping + poultry + goat + mushroom) and provided an enhanced net return of 302% as compared to cropping systems alone. Targeted interventions based on farm typology if done in an integrated manner could pro- vide risk coverage against price fluctuations and climatic conditions as farmers can typically adjust the allocation of input across and within enterprises (Kaur et al., 2022).

Thus, it can be concluded that farm typology classifica- tion offers an enhanced approach over traditional classifi- cations based on the size of landholding and other farm characteristics. The considerable impact on the future pro- duction systems would highly depend on the pre-existing farm characteristics and livelihood strategies including crop, livestock, off-farm, etc. The results obtained from this study can be used as input to plan appropriate farming system interventions for food and nutritional security and sustainability of the tribal households.

III. Conclusion

The present study highlights the rich diversity and contextual adaptability of tribal farming practices across the Western Himalayan region. Despite facing harsh terrain, climatic uncertainties, and limited access to modern agricultural inputs, tribal communities have sustained productive and resilient systems through their deep ecological knowledge, crop diversification strategies, and community-based management of resources. The variability observed across regions and groups underscores that no single intervention can effectively address the needs of all communities; instead, strategies must be tailored to specific agro-ecological and socio-cultural contexts.

The findings emphasize the importance of integrating traditional knowledge with appropriate modern technologies to enhance productivity, climate resilience, and livelihood security. Strengthening value chains, improving market access, and expanding extension services remain critical for enabling tribal farmers to benefit from emerging opportunities. Equally essential is the preservation of indigenous seeds, organic practices, and customary resource-governance systems, which form the backbone of sustainable hill agriculture.

Overall, the study concludes that a participatory, location-specific, and culturally sensitive approach is vital for developing strategic interventions. Such an approach will not only enhance agricultural outcomes but also support the broader goals of ecological conservation, food security, and socio-economic empowerment of tribal communities in the Western Himalayas.

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