TYPOLOGY ANALYSIS OF MARGINAL AND SMALL HOUSEHOLDS PRACTICING INTEGRATED FARMING SYSTEM IN WESTERN PARTS OF TAMIL NADU, INDIA

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Abstract. Addressing food security, Integrated Farming Systems (IFS) emerged, combining various enterprises within a farm for marginal and small farmers. Typology is a significant tool in analysing the diversity among IFS. We interviewed 250 marginal and small farmers following IFS during 2022-2023 for typology assessment in the western zone of Tamil Nadu, India. Multivariate statistical analysis resulted in four distinct farm types i.e., type-1. Marginal farmers with diversified crops dominated by cereals, less owned area, a smaller number of livestock and lower income constitutes (38.4%), type-2. Marginal farmers with diversified crops dominated by fodder crops, medium number of livestock and high livestock income contributes (29.6%), type-3. Marginal farmers with various crops dominated by cash crops, medium number of livestock and medium income contributes (22.4%) and type-4. Small farmers with various crops dominated by plantation crops, higher owned area, medium number of livestock and higher income contributes (9.6%). Constraint analysis was done for various crops and livestock production systems in each farm type. To overcome these constraints, socially acceptable interventions were given to each farm type. The study advocated that the findings of typology and constraint analysis contribute to suitable interventions for specific locations.
Keywords: *Farming system, multivariate analysis, typology, constraints, interventions*

Introduction

In India, food production struggled to meet the demand of the population during the 1940's. Green revolution played a significant role in the1960's by introducing high yielding varieties which are highly responsive to chemicals and fertilizers (John and Babu, 2021). However, over time, green revolution posed a negative impact on yield and environment. The overuse of chemicals including herbicide, insecticide and fungicide, as well as inorganic fertilizers posed threats to environment by causing air, soil and water pollution (Gerage et al., 2017). Due to green revolution, monocropping cause substantial damage to the households by lowering productivity, soil health and efficiency of resources which also raises question about ecological balance and sustainability (Peyraud et al., 2014). To ensure productivity, soil health, ecology and sustainability, a sustainable approach should be adopted (Damato and Korhonen, 2021). Therefore, the Integrated Farming System (IFS), an approach to sustainable agriculture

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that ensures food security, soil health, nutritional security and livelihood of farm households (Paramesh et al., 2021).

An integrated farming system combines various farm enterprises such as crop production, livestock, horticulture, poultry, beekeeping etc. and recycles resources within the farm itself, which increases resource use efficiencies (Jayanthi et al., 2003: Lal et al., 2020). Increased adoption of IFS could result in improved yield, enhanced efficiency in resource utilization, increased profitability and ensures sustainability (Manjunatha et al., 2014). The IFS's primary steps include evaluating the existing agricultural system, identifying production limits, and maximising both productivity and profitability. This is accomplished through the use of cost-effective as well as socially acceptable technology designed to overcome these limitations. The variation in the farming system influences household reactions to various new interventions aimed at improving farm productivity and profitability (Emtage and Suh, 2005). Nevertheless, there are numerous instances of promising technologies that have not gained acceptance within farm households, particularly among small and marginal holders in developing countries. The inability of farmers to embracing new technologies is linked to farming system heterogeneity (Paramesh et al., 2019; Kaur et al., 2021). Small and marginal households show higher heterogeneity in many characters viz., land assets, cropping systems, soil health, livestock units, labour and resource availability and socio-economic traits such as income and production cost (Zingore et al., 2007). The typology is the analysis of diversity within and among the farms, and across the farm households ant it is the initial step for the proper adoption of new interventions (Goswami et al., 2014). The goal of typology is the study of variation and to finds households with homogenous features while taking into consideration heterogeneity (Shukla et al., 2019). Farm typologies can assist in summarising the diversity and heterogeneity within farming systems (Kumar et al., 2019). It is a significant tool for identifying the diversity within the farm and providing homogenous groups called farm types (Kuivanen et al., 2016). Identifying the heterogeneity at the farm level using a typology study is a significant step in analysing the farm household individually (Singh et al., 2012). Typology study gives a greater explanation of heterogenous farming systems and is used for developing farms with homogenous characters in multidimensional space (Blazy et al., 2009). Typologies facilitate a practical assessment of the challenges and opportunities encountered by farmers, aiding in the development of suitable technological solutions and policy interventions (Andersen et al., 2007). Based on interviews with the farmers Kaur et al. (2021) and Innazent at el. (2022) analysed the farm typology for marginal farmers and provided adoptable technologies according to the limitations of the farm types.

With this background, the present study has the objective of assessing the typology for small and marginal farmers following an integrated farming system in garden land conditions and to identifying the limitations for identified farm types and providing possible interventions for sustainability.

Methodology

Location and survey sites

The study was conducted during 2022-2023 at western zone, which covers Coimbatore, Erode and Tirupur districts of Tamil Nadu state, India (*Fig. 1*). A group discussion with experts having knowledge on heterogeneity of the farming system in the study area, which was helpful in framing the questionnaire (see *Appendix*). Using the

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purposive sampling method, data was collected from the 250 marginal and small households practicing garden land IFS in the western zone of Tamil Nadu, India using a survey questionnaire, i.e. 80-85 respondents were interviewed from five blocks of each district during 2022-2023. In each block, 15-18 respondents were interviewed. The questionnaire having the information on the household, labour, land use, livestock, machineries, value addition, on-farm and off-income for identifying the heterogeneity in the farming system.

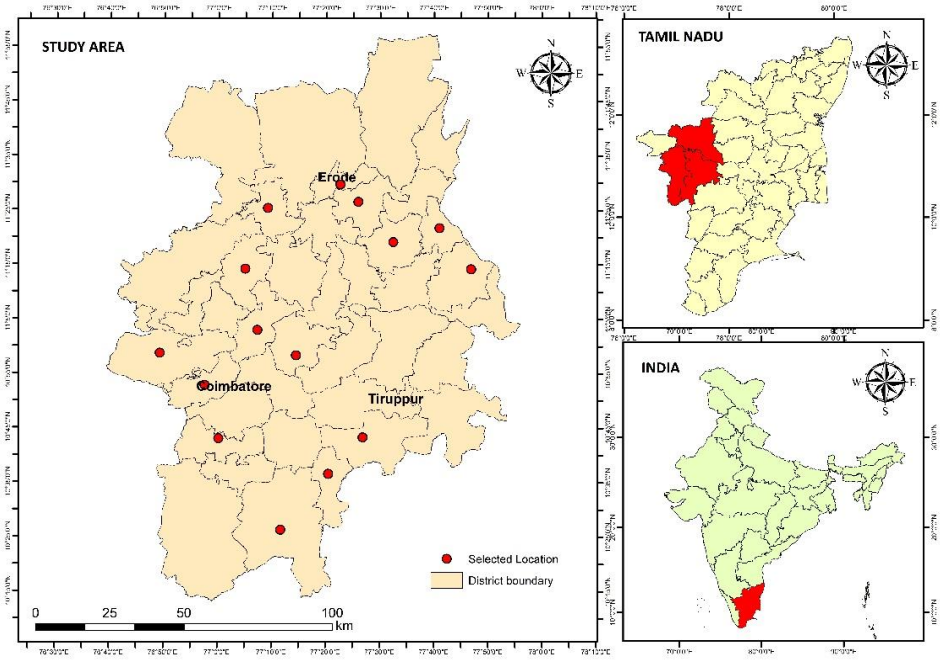

Figure 1. *Study location. (The circles denote the selected block in each district)*

Selection of key variables

After the sampling survey with 250 households, significant and functional variables from the information collected were identified with the help of experts in the study area. *Table 1* provides selected variables with variability in the farm for the characterisation of the farming system. The selected variables were used for further multivariate statistical analysis, viz., principal component analysis (PCA) and cluster analysis (CA). Before doing the statistical analysis, the data were carefully examined for missing data and outliers in the data set. The outliers in the data were detected by the box plot. Correlation analysis was done to identify the highly correlated variables used for further analysis.

Multivariate analysis

Principal component analysis (PCA) and cluster analysis (CA) were two multivariate tools used for the typology construction from the investigation data of households. PCA used to reduce the large household data set to few variables, i.e. principal components (PCs). *Figure 2A* shows the PCs. There are three criteria for choosing the PCs: (1) Kaiser's criterion which shows eigen value greater than 1 (*Fig. 3A*). 2. scree plot test and cumulative variation (*Fig. 3B*). 3. To assess the PCs according to the hypothesis chosen and evaluate them based on the correlation between variables and PCs (*Fig. 3C*).

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The PCs obtained from the reduced household data set are further analysed using CA. Agglomerative hierarchical clustering was performed on PCs using Ward's minimum variance method, which results in the grouping of farms or farm types (*Fig. 2B*). These clustered farms also visualised by the dendrogram (*Fig. 4*). K-means clustering is also performed in clustered farm. The significance among the indicators of various farm types was known by using the Kruskal-Wallis test. The investigated data were analysed in R 4.3.2 statistical software for a valid conclusion.

The constraint index (CI) was calculated for the identified limitations in the farm households by using the following formula developed by Innazent et al. (2022).

$$constraints\ index = \frac{\Sigma_{i=1}^{n} WiFi}{\Sigma Fi}, \text{ i = 0,1,2,3} \qquad \text{(Eq.1)}$$

where Wi is the weightage given to constraints in the category of none, low, medium and high, the weightage values are 0,1,2, and 3 and Fi is the frequency of the constraint. The constraint index was rated 0- no limitations, 0.1-1.0- low constraint, 1.1-2.0- medium constraint and 2.1-3.0-higher constraint.

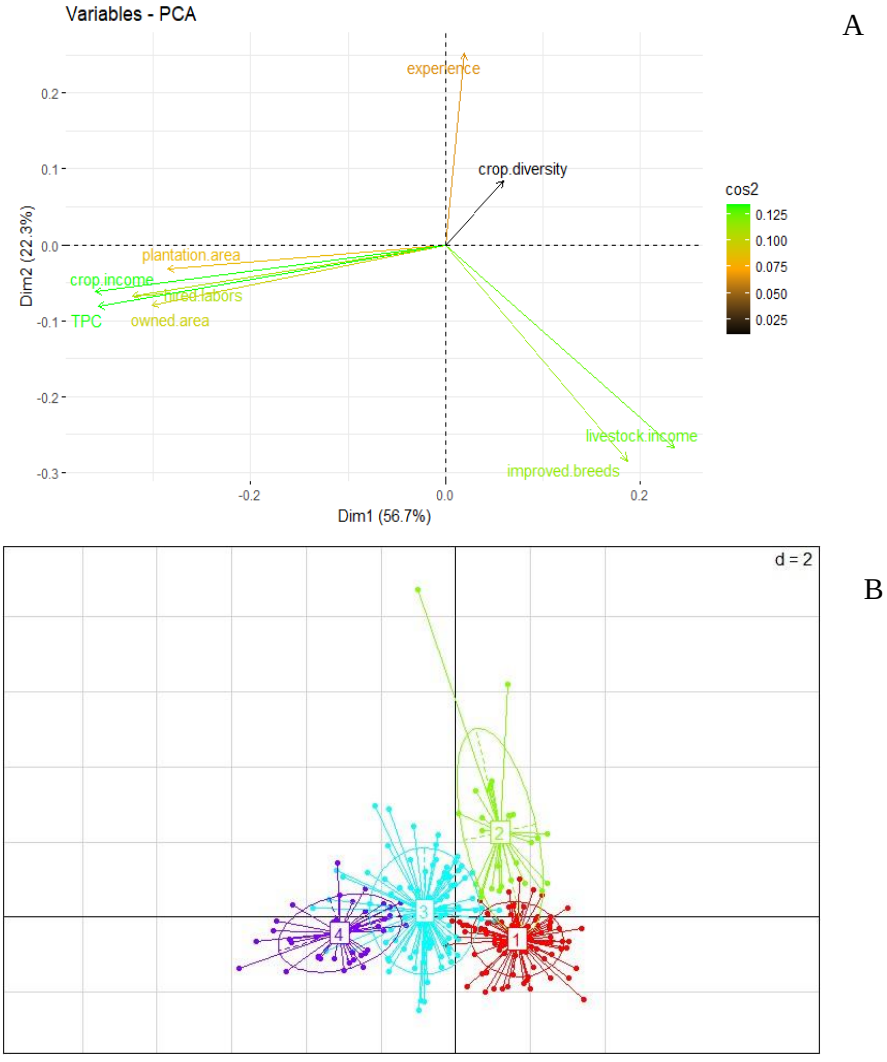

Figure 2. *Distribution of four farm types as a result of PCA and CA. The correlation effect of variables (A) and clustered farm types (B)*

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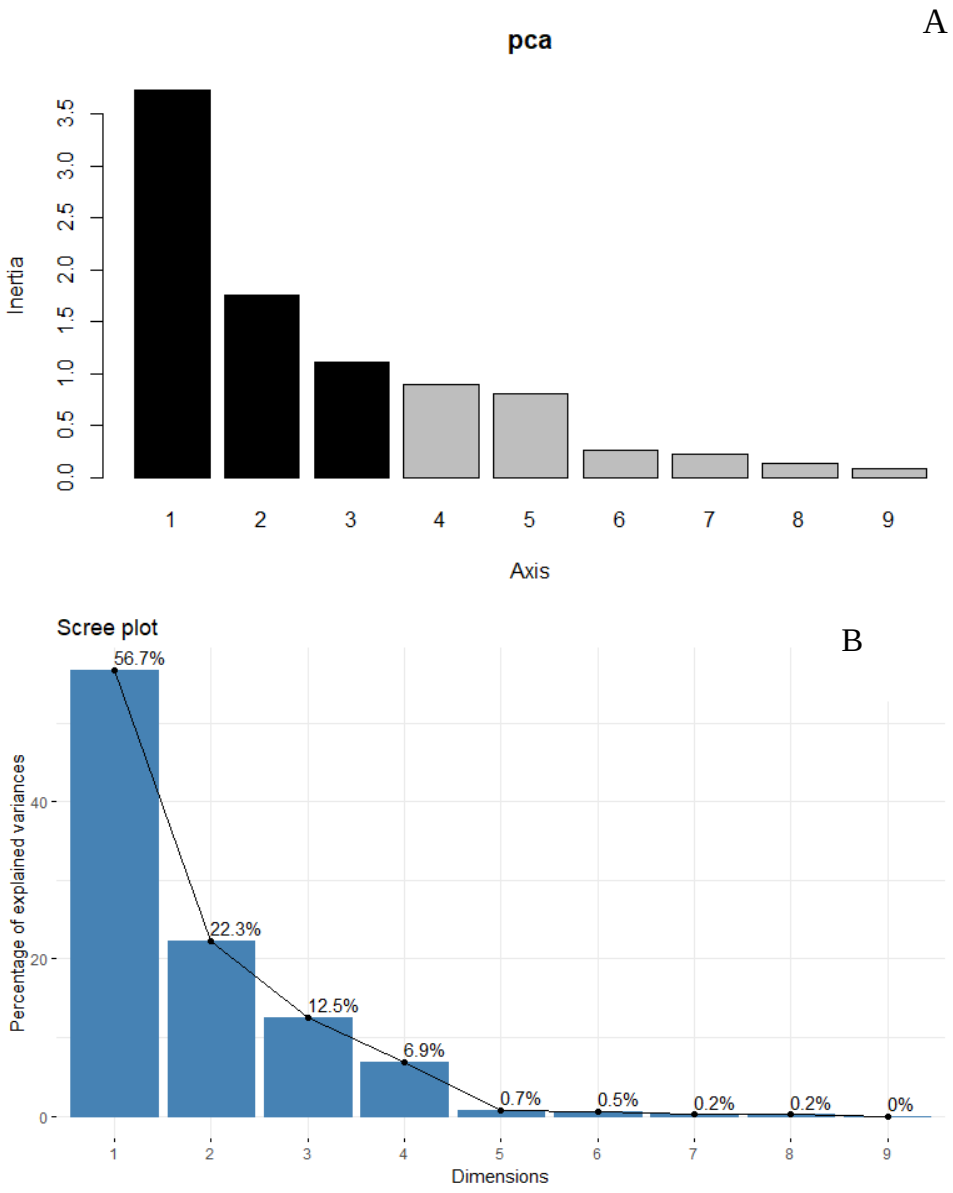
Results

Farm type characterization

Principal component analysis

The result of PCA stated that three PCs were retained based on the eigen value >1 (Kaiser criterion). *Figure 3B* explains that 56.7% variation shown by PC1 followed by PC2 having 22.3% variation and the third PC showing 12.5% variation. Based on the inertia values, three PCs were selected. The PC1 showed higher diversity due to the greater correlation with variables including owned area, plantation area, hired labour and crop income from the investigation of farm households (HH). PC2 was highly correlated with the variables including improved breeds and livestock income. The variables obtained from the investigation includes experience and crop diversity showing a greater correlation with PC3. The maximum variance in these three PCs provided the household, crop, production, livestock and income components of the HH. The negative value does not have any effect in the data set.



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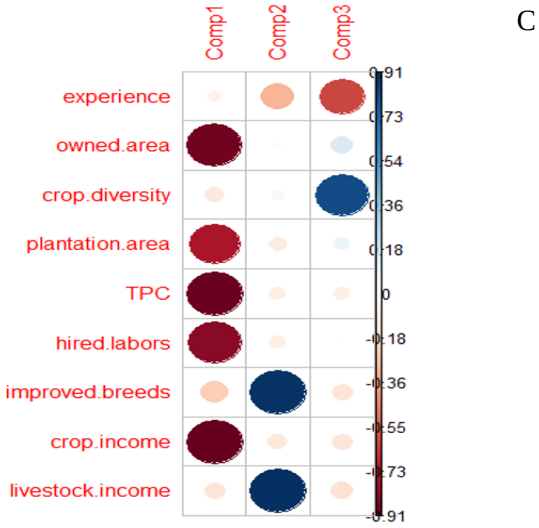

Figure 3. *Inertia which is the eigen value >1 is selected as PCs (A), scree plot (B) and Correlation plot (C)*

Cluster analysis

The household (HH) survey containing 250 data sets, from these 3 PCs were retained, which were further performed with cluster analysis. Four clusters have been found after performing 3 PCs with cluster analysis. The farm types are grouped based on the structural, functional and socio-economic characteristics of the farm HH. Agglomerative hierarchical clustering produces a dendrogram. The dendrogram also generated four clusters (*Fig. 4*). These clusters are called farm types. The typologies have been generated in term of household land area, production cost, livestock and income.

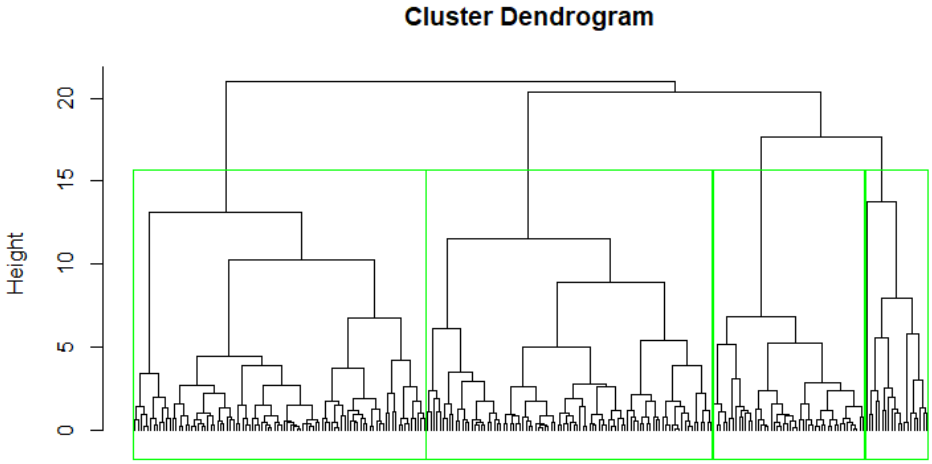

Figure 4. *Dendrogram plot*

Farm type-1: Marginal farmers with diversified crops dominated by cereals, less owned area, a smaller number of livestock and lower income

This type-1 had the largest number of HH compared to all other farm types. It is distinguished from others by the higher cereal area (0.45 ha), other crop area, lower no.

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of livestock (15 numbers) and less income from the crops and livestock (*Table 1*). This farm type has a diversified cropping system with cereal and other crops viz. oilseeds and pulses being more dominant than plantation, vegetables and fodder crops. Livestock numbers were lower than other farm types. Expenses for the crop and livestock production are also low with less milk yield in this farm type-1 HH which resulted in lower on-farm income than other farm types. The lesser income was due to the low yield from the cereals with a higher no. of fallow days.

Farm type-2: Marginal farmers with higher fodder area with more no. of livestock population than other farm types of HH.

This is the second largest farm type characterised by the marginal HH having a higher fodder area (0.2 ha) and cereal area than other farm types (*Table 1*). The higher no. of livestock (22 numbers) with greater livestock income (USD 4573 per year) and large fodder area show variation from other farm types. The income from the crop area was less than that from livestock (*Table 1*). The higher livestock income was due to a higher no. of improved cows. The higher milk yield (10,850 L/year) also contributed to higher livestock income than other yields from crops.

Farm type-3: Marginal farmers with various crops dominated by cash crops and medium no. of livestock and medium income

Farm type-3 has a higher cash crop area (0.94 ha) followed by plantation crop area (0.45 ha). The livestock number was medium (20 numbers) similar to type- 4 (*Table 1*). The expenses for the production of cash crops were higher and milk yield was similar to farm type-2 HH. The farm type-3HH was getting the highest income in term of marginal farmer. This might be due to the higher crop income from cash crops and plantation crops than cereals, vegetables and other crops. *Table 1* provides the livestock income, which also contributed for the on-farm income (USD 13,248).

Farm type-4: Small farmers with higher plantation crops and higher income from crops with medium no. of livestock

The farm type-4 cluster was the smallest grouping (n = 24) among all other farm types and had a higher land area. This farm type-4 has various cropping systems dominated by plantation crops (1.62 ha) with medium no. of livestock (n = 17) which contributed to medium livestock income (*Table 1*). The higher crop income was due to higher income from plantation crops than other farm types. *Table 1* shows that farm type-4 was differentiated from the other farm types by variables like higher owned area (2.29 ha), lesser fallow days (1 month) and higher crop income (USD 15,112).

Characteristics of the farming system

The classified farm types have been differentiated by location, income, cropping system, livestock numbers, labours etc. These factors for the classified farm types have been discussed below and have an effect on the four farm types.

Structural characteristics

The number of HH is the most important factor and statistically not significant on all farm types (*Table 1*). The average no. of farm HH on the farm was 4.0. The head of the

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farm is the key component in managing the farm activities. Age of the head is also a significant factor in decision-making process leads to the development of a farm. Farm type-3 HH head had the age of 59, followed by type-1 HH and farm type-4 and 2 are on par with each other. The average age of the farm HH was 54. The educational qualification of the HH head is an important character in deciding farm activities and the adoption of new interventions on the farm. HH head age and educational status were highly correlated. The farm type-1, 2, 3 were less educated than farm type-4 (*Table 1*). *Table 1* also shows that a higher number of aged HH head are illiterate. The higher owned area was observed in the farm type-4 HH having >2.0 ha (*Table 1*). Farm type-2 and 3 had similar land size (1.51 ha and 1.76 ha) and farm type-1 observed a lesser land size (0.92 ha). The crop diversity had no significant effect on the farm types. All the farm types had an average crop diversity of four crops per year.

Land use pattern

In the western zone of Tamil Nadu, especially in the surveyed area, a higher proportion of plantation crops includes coconut and banana are cultivated under garden land conditions. The major cereal crop cultivated are maize and sorghum. Cash crops like sugarcane and turmeric are also dominant in some parts of the western zone. Only a small portion of oil seeds such as ground nut and pulses like cowpea were grown. Vegetable crops like cabbage, cauliflower, brinjal, tomato, ladies' finger and vegetable cowpea are also grown in some parts of the surveyed zone. The results show that farm type-4 dominated by plantation crops, type-3 dominated by cash crops, fodder crops in type-2 and cereal crops in type-1 (*Table 1*). This clearly shows that small farmers (>2.0 ha) are producing more plantation crops than any other crop. So, the income for the farm type-4 HH also high. Next to farm type-4 HH, cash crops produce a higher income in farm type-3. Farm type-2 has a higher fodder area which clearly shows that the HH in farm type-2 has more no. of livestock which lead to more income from livestock. The lowest income (USD 6746) was observed in farm type-1 HH due to lesser land size, low cereal yield and fewer livestock which led to lesser livestock income (*Table 1*).

Labour

Each of the farm types had an average farm labour about 2 which is not statistically significant. But the hired labour per farm per year was statistically significant on fam HH. Farm type-4HH has a more significant hired labour per year than other farm types. In farm type-2 and 3, the hired labour per year per farm was on par with each other. Farm type-1 has a lesser frequency of hired labours per year (*Table 1*). From the investigation with the farm HH, the male labour had a higher wage around USD 8.5 for a day of work and wages for the female labour was around USD 3.5. The wages of the hired labours may highly depend on the location. Farm type-1 has a higher no. of family members working on the farm than other farm types. In contrast, farm type-4 HH had a lower no. of family labour working on the farm. This indicates that larger the farm size, higher the dependency on hired labour.

Livestock

Livestock is an important component included in the farming system, which helps in increase the income of the HH. The livestock which are found mostly in the surveyed

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area are improved cows rather than native cows. This might be the major reason for the increased milk yield and higher income than other livestock components. The other livestock found in investigated area are goats, buffalo's and poultry birds. Higher no. of livestock found in farm type-2 where it contributes higher fodder area and a higher milk yield (10,850 L/year) (*Table1*). The presence of improved breeds is the reason for higher milk yield. Farm type-3 and 4 had a similar no. of livestock. Farm type-1 HH contributed to the low no. of livestock but had a higher no. of goats resulted in a lesser yield and lower livestock income. Type-4 HH observed lesser no. of goats (n = 3) among other farm types. The average number of goats on all other farm types was five.

Income

Farm income is the key decision-making factor. The components included in the farm are mainly based on the farm income. On-farm income is the income from crops and livestock. Crop income was found to be higher on the farm type-4 followed by type-3 and type-2. Farm type-1 HH observed the lowest among farm types. Livestock income was found maximum (USD 4574) in farm type-2 due to the larger livestock population. Higher total income (USD 18,447) was achieved in farm type-4 and farm type-1 observed to have lower on-farm income (USD 7203) from all the components (*Table 1*).

Expenses

For crops, expenses were greater in farm type-4 (USD 4116) due to the larger owned area and higher cost of production for plantation crops (*Table 1*). Next to farm type-4, the second highest expenses were found in farm type-3 due to the larger cash crop area, which contribution results in a greater cost of cultivation. Lowest expenses were observed in farm type-1 due to a less owned area with a high proportion of cereal crops. *Table 1* shows that farm type-2 contributed the maximum expenses (USD 1315) for livestock production due to the purchase of more concentrates at a higher price. Farm type-3 and 4 have similar contributions to the livestock production system. Farm type-1 had lesser expenses on livestock due to smaller livestock population.

Constraints identified for investigated farm households and some possible interventions

The farm HH in the typology assessment has diversity. The results from the multivariate analysis have identified four farm types in HH based on their structural and functional characteristics includes land size, cropping system followed, livestock production system and income. Among various farm types, the agricultural and livestock production system has limitations. The limitation on farm have to be solved by developing suitable interventions that address their limitations. The suitable interventions should be socially acceptable and cost effective for overcoming the limitations. *Table 2* gives the constraint index for each farm type by using the constraint index formula.

The results show that farm type-1 is endowed with a lesser owned area and higher cereal crops (*Table 1*). For the cropping system in farm type-1, the low productivity is due to a lack of credits, a lack of farm machinery at the right time, the non-availability of high-quality seeds, higher weed infestation, grain damage due to birds and lowered income due to price fluctuation.

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Table 1. *Key variables used for the characterization of farm households*

Variables	Units	Farm type 1 (n = 96)		Farm type 2 (n = 74)		Farm type 3 (n = 56)		Farm type 4 (n = 26)	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
HH members	Number	3.73^{b}	1.0	4.54^{a}	1.1	4.12^{ab}	1.3	5.17^{a}	1.7
Age	Year	54.93^{b}	8.6	47.70^{c}	7.4	59.98^{a}	7.5	54.6^{bc}	6.2
Educational status	Number	1.66^{b}	1.1	2.66^{a}	1.8	0.98^{c}	2.1	2.27^{a}	0.8
Experience	Year	30.17^{b}	9.8	22.38^{d}	7.3	35.75^{a}	8.9	28.08^{c}	7.6
Owned area	Hectare	0.92^{d}	0.4	1.51^{c}	0.5	1.76^{b}	0.5	2.29^{a}	0.3
Crop diversity	Crop number per year	3.57^{a}	0.9	3.82^{a}	1.1	3.67^{a}	1.5	3.56^{a}	1.2
Fallow days	Fallow months in year	3.18^{a}	1.7	2.35^{ab}	1.3	2.69^{b}	1.4	1.00^{c}	0.9
Cereal area	Hectare	0.45^{a}	0.3	0.48^{b}	0.2	0.26^{bc}	0.1	0.21^{c}	0.2
Other crops area	Hectare	0.18^{a}	0.2	0.08^{ab}	0.1	0.12^{ab}	0.2	0.05^{b}	0.1
Vegetable area	Hectare	0.14^{a}	0.2	0.27^{a}	0.3	0.26^{a}	0.3	0.17^{a}	0.2
Plantation area	Hectare	0.10^{c}	0.3	0.32^{ab}	0.4	0.45^{b}	0.3	1.62^{a}	0.2
Cash crop area	Hectare	0.01^{c}	0.2	0.15^{ab}	0.2	0.94^{a}	0.4	0.21^{b}	0.2
Fodder area	Hectare	0.03^{c}	0.03	0.2^{a}	0.06	0.07^{ab}	0.05	0.06^{b}	0.08
Cereal cost	USD	323^{a}	284	301^{ab}	338	228^{bc}	378	194^{c}	232
Other crops cost	USD	78^{a}	125	34^{ab}	84	56^{ab}	118	37^{b}	110
Vegetable cost	USD	279^{a}	372	335^{a}	482	289^{a}	350	278^{a}	336
Plantation cost	USD	346^{d}	458	1026^{c}	895	1619^{b}	827	3074^{a}	1030
Cash crop cost	USD	176^{c}	337	217^{b}	551	480^{a}	655	530^{ab}	770
Fodder cost	USD	2^{c}	3	7^{a}	5	3^{ab}	6	4^{a}	5
Total Cost of Production	USD	1205^{d}	502	1916^{c}	789	2672^{b}	757	4116^{a}	961
Family labour on-farm	Number	1.94^{a}	0.4	1.87^{a}	0.3	2.00^{a}	0.4	2.06^{a}	0.5
Family labour on non-farm	Number	1.85^{c}	0.9	2.63^{ab}	1.0	2.11^{bc}	1.1	3.08^{a}	1.3
Hired labours	Numbers per year	150.80^{d}	66	196.24^{c}	90	274.81^{b}	91	386.45^{a}	116
Water source	Number	2.65^{ab}	0.4	2.82^{a}	0.4	2.79^{ab}	0.4	2.81^{a}	0.4
Livestock	Number	15.00^{ab}	12	23.28^{a}	15	20.41^{ab}	12	17^{b}	13
Total cows	Number	3.60^{c}	1.2	6.10^{a}	2.4	5.69^{b}	2.2	5.06^{ab}	1.3
Native breeds	Number	0.33^{a}	0.8	0.15^{a}	0.5	0.15^{a}	0.7	0.14^{a}	0.5
Improved breeds	Number	1.73^{c}	0.9	4.59^{a}	1.9	3.71^{b}	1.3	2.83^{ab}	0.8
Calves	Number	1.60^{c}	0.8	2.50^{a}	1.2	1.98^{b}	0.9	2.16^{ab}	0.7
Goats	Number	5.56^{a}	3.4	5.75^{a}	5.6	5.83^{a}	5.0	3.27^{a}	6.0
Poultry	Number	5.75^{c}	9.4	10.78^{a}	13.2	8.81^{ab}	10.5	6.72^{b}	12.8
Feed quantity	Kilogram per year	4280^{c}	1865	8575^{a}	4207	5838^{b}	3283	6886^{ab}	2956
Feed expenses	USD per year	629^{c}	418	1315^{a}	898	941^{ab}	530	1034^{b}	764
Milk yield	Litres per year	5390^{c}	2567	10850^{a}	6848	8226^{ab}	4712	7575^{b}	2739
Crop income	USD	4306^{d}	1790	7049^{c}	3036	9624^{b}	2824	15112^{a}	3877
Livestock income	USD	2440^{c}	989	4574^{a}	2629	3623^{ab}	1836	3051^{b}	944
On-farm income	USD	6746^{d}	2009	11623^{c}	3880	13248^{b}	3222	18164^{a}	3937
Value addition income	USD	24^{b}	67	567^{a}	106	33^{ab}	79	9^{c}	58
Off-farm income	USD	434^{b}	1439	1507^{a}	2391	109^{b}	645	275^{b}	1084
Total income	USD	7203^{d}	3270	13187^{c}	4361	13390^{b}	6921	18447^{a}	10575

*USD- United States dollar; **SD-Standard deviation. The values should be either negative or positive. *** The table with letters (a,b,c,d) shows the significance among the means of 4 farm types

Government takes the initiative to provide financial support for increasing their productivity and use of high yielding varieties, mulching for weed management. Farm type-3 and 4 had excessive fertilizer usage. This can be reduced by the balanced application of organic and inorganic fertilizer. The introduction of mechanization and herbicide usage at the right time will increase the income of cereal crops.

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Table 2. *Constraints on crop and livestock systems and their interventions with a constraint analysis rate of 0-none, 0.1-1.0-low, 1.1.2.0-medium and 2.1-3.0-high*

Constraints encountered		Type 1	Type 2	Type 3	Type 4	Possible interventions
Cropping system						
Cereal crops						
Reduced productivity	Lack of credits	2.7	1.0	0.8	0.3	Government provide financial support
	Lack of high-quality seeds	1.8	0.9	1.0	0.7	Providing highly improved seed material
	Lack of farm machinery	2.8	1.6	1.8	0.8	-
	Weed infestation	2.2	1.5	1.3	1.3	Intercropping and herbicide application
	Pest and disease attack	1.7	1.9	1.5	2.0	Intercropping with pulses and sowing at right time
	Crop damage due to anthropogenic agents	1.8	1.4	1.7	1.0	Using low-cost net to reduce birds attack
Low income	High cost of production	2.6	1.8	1.1	1.0	Farm mechanization and crop diversification with legumes
Vegetable crops						
Reduced productivity	Higher seed/seedling cost	2.1	1.8	1.6	1.8	Government set up a seed centre and nursery and provide seed material at low cost
	Weed infestation	1.6	1.9	1.4	1.4	Stale seed bed and mulching
	Pest and disease attack	2.2	3.0	2.8	2.8	Remove crop residues, sowing at correct time and use of pesticides at right quantity
	Lack of hired labours	1.7	2.6	2.7	2.5	Do harvesting operations at right time and follow contract farming for availability of labours
Low income	Fluctuation in price of produce	2.9	2.8	2.7	2.4	Farm households advised to take the produce directly to local market
	High cost of production	2.1	1.1	0.9	0.8	Practicing of mulching, intercropping for plant protection activities
Cash crops						
Reduced productivity	Lack of high-quality seed	0.8	1.0	1.6	1.4	Seed treatment with carbendazim and Pseudomonas florescence
	Excessive fertilizer usage	1.4	1.8	2.3	2.0	Balanced fertilization using organic and inorganic fertilizers
	Lack of hired labours	1.9	2.1	2.4	2.3	Farm mechanization can reduce labour shortage
Environment damage	Crop residue burning	2.0	1.8	2.5	3.0	Use the residue for mulching and compost preparation
Low income	High cost of production	1.8	1.3	0.9	0.6	Use of high yielding varieties to get higher yield, Reduced use of excessive fertilizers and intercropping can increase the income
Plantation crops						
Reduced productivity	Higher input cost	2.7	2.0	2.2	1.8	Government provide training on making own nursery at low-cost technologies
	Weed infestation	1.0	1.0	0.0	0.0	Mulching and intercropping can reduce weed infestation
	Pest and disease attack	1.5	0.8	1.5	2.3	Remove the residues from field and alternate host plant
	Excessive fertilizer usage	1.8	1.8	2.6	2.5	Rationalised fertilizer application
	Crop damage due to anthropogenic agents	1.8	1.6	2.0	2.6	Provide the strong fence with animal repel sound system
	Crop failure due to natural calamities	1.3	1.7	2.4	2.3	Provide windbreaks and shelterbelts
Environment damage	Crop residue burning	0.6	0.9	1.8	2.0	Use the residues as raw material for compost preparation

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	Fluctuation in price of produce	1.7	0.9	1.9	1.8	Farmers are encouraged to add the value to crops and sell at higher price
Other crops (oilseeds and pulses)						
Reduced productivity	Lack of high-quality seed	2.8	0.9	0.9	1.4	Seed treatment with carbendazim and high yielding variety seeds
	Weed infestation	2.9	2.0	1.5	1.9	Stale seed bed, mulching, intercropping can reduce weed competition
	Crop damage due to anthropogenic agents	2.6	2.1	0.4	0.7	Provide the strong fence with animal repel sound system
	Fluctuation in price of produce	2.8	2.0	1.4	1.8	Households are encouraged to take their produce to local markets
Livestock production system						
	Lack of green fodder	2.7	0.8	1.8	1.4	Growing high yielding fodder crops
	Lack of high-quality feed	1.8	2.0	1.5	1.6	Addition of mineral mixture to feed
	Increased cost of feed/concentrates	2.7	2.1	2.0	1.6	Farmers are trained to make their livestock feed in their own by using locally available food grains, production of azolla as alternative as feed
	Pest/diseases in livestock	0.8	1.8	0.7	0.8	Regular medication should be provided like deworming, washing of cattle with disinfectant
Low income	Reduced fat per cent in milk	2.3	0.9	1.3	0.6	Inclusion of mineral mixture and reducing the dry fodder to cattle
	Mortality rate	2.0	1.4	1.6	0.5	Construction of livestock shed and providing the optimum temperature to the livestock

Farm type1 and 2 have a higher constraint index followed by farm type-3 and 4 in higher cost of seedlings and seeds, pest and disease attack and non-availability of labour during the time of harvest. Because vegetables need multiple harvest. The government or any agricultural institution may keep a seed centre and nursery at sale of lesser price. Intercropping vegetables and sowing at the right time will reduce the weed infestation and pest and disease attack. Thereby, reduces the cost of cultivation. The lesser income of vegetables is due to the price fluctuations. The farm HH is encouraged to take their produce to the local market rather than give it to the middle man.

The major cash crops grown are turmeric and sugarcane. Farm type-3 had a higher area followed by farm type-4 (*Table 1*). The lower yield of cash crops is reduced by the less high-quality of seeds, larger the fertilizer requirement which also reduces the soil health and the lack of hired labour. The quality of the seed can be improved by treating them with pesticides. Balanced fertilization as per the guidelines given by the government and agricultural institutions should be followed to reduce excessive fertilizer and increase soil health. The constraint index shows that farm type-3 and 4 show as higher limitation in the non-availability of labours for harvest and post-harvest operations. Farmers are encouraged to follow contract farming practices and mechanization for shortage of labour problems. The family members in type-3 and type- 4 farm were not involved in the farm operations of cash crops. This is also another constraint experienced by the farm type4 and 3. The burning of sugarcane trash and banana residues for clean cultivation cause air pollution which is a serious threat to environment especially in type-3 and type- 4 farm. The residue can be used as a bedding material for vermicompost and as a soil and water conservation practice. Farm type-1 and 2 have constraints in high cost of cultivation of cereal crops. This can be reduced by crop diversification with legumes, which can reduce fertilizer consumption for succeeding crops.

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The plantation crops grown in these regions are coconut and banana. The limitations in production of plantation crops include as higher input costs like a high price for seedling, high fertilizer usage. The farm HH is encouraged to make its own nursery of plantation crops, which will reduce higher price of seedling. All farm types have experienced the above limitations. Pest and disease attacks were medium in farm type-3 and 4. The bananas grown in the foothills may experience damage to the crops due to elephant attacks in farm type 3 and 4 which have a higher constraint index. Provide a strong fence and set up an automatic sound system that will repel the animals. Farm type-1 and 4 have a medium constraint index and type-2 and type-3 have a high constraint index due to higher wind velocity. Provide wind breaks and shelterbelts around the field reduce the wind speed. Also, farm type-3 and 4 uses excessive fertilizer for higher productivity. But use of excessive fertilizer can stagnate yield of crops and also reduce soil health. Farm households uses rational fertilization practices. In some places, the coconut leaves are burned for clean cultivation. The coconut leaves are used for making compost and broom sticks which will increase the farm household's income.

Farm type-1 and 3 HH have a higher constraint index in the production of oilseeds like groundnut and pulses like cow pea due to less quality of seeds, higher weed competition. Introduction of high yielding varieties can increase productivity. Intercropping oilseed and pulses with vegetables and cereals can reduce weed competition. Farm type-1 HH are experienced a limitation in the productivity of groundnut due to wild boars attacks. Provide a strong fence system around the field. Low income of the groundnut and cow pea might be due to a lack of market facilities. Farmers are encouraged to sell their produce directly to the local market for increasing their income.

Livestock component

Farm type-1 HH has experienced constraints in low milk yield due to a lack of green fodder and a higher cost of concentrates (*Table 2*). Farmers in farm type-1 are encouraged to grow green fodder in small areas that will reduce fodder shortages. All the farm types have a high constraint index in increased cost of concentrate feed. Farm type-3 and 4 have a medium constraint index in fodder shortages. Farm HH gets trained about making own concentrated feed using the farms available grain flours to combat the increased cost of concentrates. All farm types HH except farm type- 4 HH experienced high mortality rates for goats. Proper medication is given to the goats every year to avoid mortality rates. Low income from the livestock on farm type-1 due to the low fat per cent in milk. This might be due to high quantity of dry fodder given to the cattle. Growing perennial green fodder in back yard of the farm and providing the concentrates with all available nutrients will address the low-fat content of the milk.

Discussion

Conventionally, one or two variables can be used for easy classification of farm households. Haileslassie et al. (2016) classified farms into five types based only on the size of the land i.e. marginal, semi-medium, medium and large. In this study, farms are classified based on a number of variables. The typology is developed based on the variability among the farm households. Some of the study findings tackle the heterogeneity among farming system (Robert et al., 2017: Lopez-Ridurara et al., 2018). Bidogeza et al. (2009) used variables such as available resources and technology, as

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well as socio-economic data for typology development. This is also similar to the results of Pacini et al. (2014), Alary et at. (2016) and Chopin et al. (2015). We used principal component analysis (PCA) for the reduction of quantitative variables into principal components (PCs) and agglomerative hierarchical cluster analysis for the grouping of key quantitative variables into small groups. Numerous researchers also used PCA and cluster analysis for typology construction (Sanogo et al., 2010; Kaouche et al., 2015; Alemu et al., 2016). Various methods are employed for the data collection i.e. survey using a questionnaire and the participation approach which is normally followed. We collected data from respondents using a questionnaire. Similarly, the study of Innazant et al. (2022) and Sinha et al. (2022) collected information based on questionnaire prepared. This is also similar with the study of Tittonell (2014) for typology assessment based on market acceptability among farm HH. In our study, four types of farm HH were identified based on the structural, functional and socio-economical characteristics of farm HH. Similar reports were employed in the Indo-Gangetic plains of India (Kaur et al., 2021) and the southern coastal plains of Kerala (Innazent et al., 2022). Goswami et al. (2014) constructed typology based on the income from various crop components, while Kumar et al. (2019) also classified the farms based on structural and economical characteristics. Also, Sinha et al. (2022) did a typology analysis based on the income from various activities and enterprises. The farm type-1 has less areas and smaller number of livestock which results in lower income due to lower production. Ponnusamy and Devi (2017) found that having fewer land areas resulted in less income. The farm type-2 dominated by a higher number of livestock which results in a higher income from animals than crops. This is confirmed by previous study of Papic and Bogdanov (2015). The farm type-3 has a diversified cropping system with cash crop dominance followed by plantation crops which leads to the second most income generating farm. The higher income was due to a higher yield. The inclusion of a larger number of crops resulted in a higher income (Innazent et al., 2022). The farm type-4 has diversified crops with a higher area dominated by plantation crops and having a higher income. This might be due to higher production and higher market availability of the produce. The market availability with a diversified cropping pattern results in a higher source of income. It is also similar with results of Riveiro et at. (2013) The constraints in the farm types have been identified as high cost of seed and seedlings, excessive fertilizer usage, pest and disease attack, higher weed competition, residue burning and price fluctuations in crop components. Fodder shortages, increased feed costs and low fat per cent in milk in the livestock production system. Some of these constraints were reported in the findings of Kumar et al. (2019), Kaur et al. (2021) and Innazant et at. (2022). Some interventions have been given to overcome the limitations of each farm type. Ponnusamy and Gupta (2009) reported that adding more components will reduce the dependence of one component and increase farm HH income. Specialized farming practices increase the cost of production through excessive fertilizer usage, high labor costs etc. (Reddy, 2014). The higher milk yield was obtained by using cross breeds than native breeds. Similar findings have been reported by Shindu et al. (2014). Climate resilient crops, introducing high yielding varieties, intercropping, crop rotation, balanced fertilization, soil and moisture conservation methods like mulching increase the productivity of the crops resulting in increased income (Rajasekharan et al., 2014). Getting continuous income from the crops alone is not possible all the time. Crops have been damaged by anthropogenic agents and natural calamities. So, integration of the animal components in the crops under a suitable environment will provide continuous

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cash flow throughout the year and lead to sustainability (Rahman et al., 2012). Kumar et al. (2019) reported similar findings of integration of other components in crops results in 300% more income. The sugarcane and coconut leaves are burned for clean cultivation practices. These residues can be used as a material for composting and soil and water conservation practices. The results of Ramrao et al. (2006) and Rathore et al. (2009) supports similar findings. Sanjeev et al. (2012) reported that the combination of various components on the farm reduces the production cost through resource recycling.

Conclusion

In the present work, we demonstrated the use of multivariate statistical tools to characterize the variation of marginal and small households. Our findings indicate that four farm types have been defined based on structural, functional, and socio-economic features in three districts of Tamil Nadu, India. The typology revealed heterogeneity within the current homogenous farms. Constraints were also assessed for each farm type and interventions were designed to address the issues. Interventions developed based on identification of the farm types assist households by improving income and minimising cultivation costs. In essence, the typology assessment with constraints analysis offers vital insights for policymakers in developing agricultural policies based on identified distinctive farm types to elevate the economy, particularly for marginal farmers with resource constraints. Furthermore, similar analysis might be conducted in areas where marginal farmers prevail for focused agricultural development and computational models could also be developed to evaluate the interventions.

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APPENDIX

Survey Questionnaire

Typology analysis of Garden Land Integrated Farming System in Western zone of Tamil Nadu, India
Tamil Nadu Agricultural University, Coimbatore, India

Part-A

1) Name of district: :
2) Name of Block :
3) Name of village :
4) Name of farmer :
5) Contact number :
6) Family members and Educational status :
: Illiterate/Literate/primary/Middle/Secondary/College
7) Farming experience (years) :
8) Occupational status
Farming alone
Farming + wage earner
Farming + Business Farming + government job
9) Annual income (Rs.)
On farm income :
Off- farm income :
Total income :
10) Farm size (ha)
Marginal (<1 ha)
Small (1-2 ha)
Semi – medium (2-4 ha)
Medium (4-10 ha)
Large (>10 ha)
11) Total area (ha) :
a) Total Cultivable area :
i) Irrigated area :
ii) Rainfed area :
b) Non-cultivable area :
12) Owned land (ha) :
13) Rented land (ha) :
14) Soil type :
15) Source of irrigation :

S. No	Sources	Total (No's)	Area (ha)
1	Canal		
2	Open well		
3	Bore well		
4	Tank irrigation		

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16) Types of irrigation

S. No	Types	Area (ha)
1	Flood irrigation	
2	Furrow irrigation	
3	Check basin irrigation	
4	Drip irrigation	
5	Sprinkler irrigation	

Part-B

17) Crop diversity (No of crops/year/farm) :
18) Area under cereals crops :
19) Area under cash crops :
20) Area under vegetables :
21) Area under plantation crops :
22) Land for fodder production fodder crops :
23) No. of fallow days in year (months) :
24) Cropping sequence :

25) Crops cultivated, season and area :

S.No	Crops	Season	Area (ha)

27) Fodder cultivation

Fodder	
Season	
Type of irrigation	
Fertilizer application (Kg)	
Manure application (kg)	
Annual / Perennial	
Harvest	

28) Farm power possession

S.no	Materials	Aware	Not-aware	Possessed/not possessed with numbers
1	**Land preparation**			
	Tractor			
	Mouldboard plough			
	Cultivator			

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	Rotavator			
	Disc plough			
	Power tiller			
	Draught animals			
	Country plough			
	Iron plough			
2	**Sowing equipment's**			
	Seed driller (tractor drawn)			
	Seed cum fertilizer driller			
3	**Intercultural operations**			
	Hand hoe			
	Spade			
	Crow bar			
	Sickles			
	Rotary weeder			
	Knapsack sprayer			
	Power sprayer			
4	**Harvesting operation**			
	Thresher			
	Harvester (tractor drawn)			
	Combine harvester			

28)	**Crops**								
		Quantity	Expenses	Quantity	Expenses	Quantity	Expenses	Quantity	Expenses
1	Seed rate (kg)								
2	Seed from farm (kg)								
3	Seed from outside farm (kg)								
4	Source of organic manure								
5	Organic manure from farm								
6	Organic manure from outside								
7	Fertilizer application (kg)								
A	N								
B	P								
C	K								
D	Minor nutrients								
8	Plant protection								
9	Herbicide (L or Kg)								
10	Insecticide (L)								
11	Fungicide (L)								
12	Grain yield (Kg)								
13	Straw yield (Kg)								
14	Straw as feed (Yes/No)								
15	Income								

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Part-C

29) No. of family labours :

30) Wages for hired Labours:

a) Men -
b) Women -

31) Usage of farm machinery

S.no	Type of machine	Owned/Rental	If owned		If rented Charges/hour
			Age	Maintenance cost per year	

32) Labours for different farm operations

Crop- I

S.no	Operations	Family labours	Hired labours		Working time (hrs)			Fuel (L/hr) if owned	Electricity		Expenses		
			Men	Women	Machinery	Men	Women		Unit	Time	Machinery	Men	Women
1	Field preparation												
2	Transplanting												
3	Direct sowing												
4	Irrigation												
5	Manure application												
6	Weed management												
7	Herbicide application												
8	Harvesting												
9	Post harvest operation												
10	**Total**												

Crop-II

S.no	Operations	Family labours	Hired labours		Working time (hrs)			Fuel (L/hr) if owned	Electricity		Expenses		
			Men	Women	Machinery	Men	Women		Unit	Time	Machinery	Men	Women
1	Field preparation												
2	Transplanting												
3	Direct sowing												
4	Irrigation												
5	Manure application												
6	Weed management												
7	Herbicide application												
8	Harvesting												
9	Post harvest operation												
10	**Total**												

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Crop-III

S.no	Operations	Family labours	Hired labours		Working time (hrs)			Fuel (L/hr) if owned	Electricity		Expenses		
			Men	Women	Machinery	Men	Women		Unit	Time	Machinery	Men	Women
1	Field preparation												
2	Transplanting												
3	Direct sowing												
4	Irrigation												
5	Manure application												
6	Weed management												
7	Herbicide application												
8	Harvesting												
9	Post harvest operation												
10	**Total**												

Crop- IV

S.no	Operations	Family labours	Hired labours		Working time (hrs)			Fuel (L/hr) if owned	Electricity		Expenses		
			Men	Women	Machinery	Men	Women		Unit	Time	Machinery	Men	Women
1	Field preparation												
2	Transplanting												
3	Direct sowing												
4	Irrigation												
5	Manure application												
6	Weed management												
7	Herbicide application												
8	Harvesting												
9	Post harvest operation												
10	**Total**												

Crop- V

S.no	Operations	Family labours	Hired labours		Working time (hrs)			Fuel (L/hr) if owned	Electricity		Expenses		
			Men	Women	Machinery	Men	Women		Unit	Time	Machinery	Men	Women
1	Field preparation												
2	Transplanting												
3	Direct sowing												
4	Irrigation												
5	Manure application												
6	Weed management												
7	Herbicide application												
8	Harvesting												
9	Post harvest operation												
10	**Total**												

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Part-D

Livestock's

33)	**Total no of livestock's**	**:**

34)	**Types**			**Size (No's)**	**Age**
	a)	Native breeds			
	b)	Improved breeds			
	e)	Calves			
	f)	Poultry			
	f)	Goat	a) kid b) male c) female		

35) Feed source

a) Purchase from outside :

b) Available from farm :

S.no	Type of feed	Quantity per day	Rs. Per kg

36)	**Livestock productivity**	
	a) Milk (L/year)	:
	b) Egg (No's/year)	:
	c) Meat (Rs/kg)	

37) Diseases and their treatment in livestock			
Diseases	**Treatment**	**Months**	**Cost**

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Part-E

38)	**Farmers participation**	
a)	Awareness programme on global warming	Yes / No
b)	Conservation agriculture	Yes / No
c)	Zero tillage	Yes / No
e)	Precision agriculture	Yes / No
f)	Residue burning awareness programme	Yes / No
g)	Introduction of new crops	Yes / No
h)	Introduction of new technologies	Yes / No
i)	Other skills	Yes / No

39)	**Biogas plant**		: Yes/ No
	If yes	a) Quantity of cow dung used/month	:
		b) How much gas produced (approximately)	:
		c) Type of biogas plant	:
		d) Uses of gas produced	:

40) Recycling

S.No	**Materials recycled**	**Yes/No**	**Quantity**
1	Cow dung used as manure		
2	Straw/haulm used as feed		
3	Biogas slurry as manure		
4	Poultry droppings as manure		
5	Seeds used for planting		

41)	**Vermicompost unit**		**Yes/No**
	Types of waste used for vermicompost preparation		**:**
	If yes	a) Quantity of waste for preparation	
		b) where they get waste for preparation	
		c) how much vermicompost prepared	
		d) how much time takes for preparation	
		e) used for own farm or sold for money	
		f) If sold, how much income from vermicompost	

42) Value addition

S.no	**Components**	**Quantity**	**Income**

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Part-F

43) Marketing behavior					
Particulars	**Crop-I**	**Crop-II**	**Crop-III**	**Crop -IV**	**Crop-V**
Mode of transportation					
Mode of selling					
Collected from farm					
Taken to market					
Charges for produce per kg					

44) Income			
	1)	Income from on-farm	
		Income from cereals Income from vegetables Income from cash crops Income from plantation crops Total income from crops	
		b) Income from milk per year	
		c) Income from poultry per year (meat and egg)	
		d) Income from goat per year	
		d) Income from recycle waste	
		e) Income from value addition per year	
		f) Income from vermicompost	
	2)	Income from off-farm	
	3)	Total income	

45) Constraints		
S.No	**Constraints**	**Suggestions**
	Constraints in crop production	
	Constraints in livestock production	

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