Characterizing farm households in Surkhet, Western Nepal, through a quantitative farming systems typology

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The Sustainable Intensification of Mixed Farming Systems Initiative aims to provide equitable, transformative pathways for improved livelihoods of actors in mixed farming systems through sustainable intensification within target agroecologies and socio-economic settings.

Through action research and development partnerships, the Initiative will improve smallholder farmers' resilience to weather-induced shocks, provide a more stable income and significant benefits in welfare, and enhance social justice and inclusion for 13 million people by 2030.

Activities are implemented in six focus countries globally representing diverse mixed farming systems as follows: Ghana (cereal–root crop mixed), Ethiopia (highland mixed), Malawi: (maize mixed), Bangladesh (rice mixed), Nepal (highland mixed), and Lao People's Democratic Republic (upland intensive mixed/ highland extensive mixed).

The Transforming Agrifood Systems in South Asia Initiative is a CGIAR Regional Integrated Initiative to support actions that improve equitable access to sustainable healthy diets, improve farmers' livelihoods and resilience, and conserve land, air, and water resources in South Asia.

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Abbreviations and acronyms

CGIAR	Consultative Group on International Agricultural Research
CIMMYT	International Maize and Wheat Improvement Center
DEED	The DEED framework encompasses a series of phases for systems analysis and co-design (Describe, Explain, Explore, and Design).
HH	Household
IWMI	International Water Management Institute
SI-MFS	Sustainable Intensification of Mixed Farming Systems Initiative
TAFSSA	Transforming Agrifood Systems in South Asia
WGSS	Within Group Squared Sum
WP	Work Package

Glossary

Term	Definition
HC	Hierarchical clustering process to assign studied elements across PCA dimensions.
Mg	The megagram is defined as 1,000,000 g mass measurement. Is the official name of Ton (Bureau International des Poids et Mesures, BIPM)
PCA	Principal Component Analysis, multivariate method to study relationship across variables to identify the distance between elements.
TLU	Tropical Livestock Units, estimates a numeric value for the animal individuals within a farm-system according to the type, probable average weight and fodder demand to estimate a general idea of the relevance in the system (Njuki et al,. 2011)

1. Introduction

The Sustainable Intensification of Mixed Farming Systems (SIMFS) is a CGIAR initiative. This initiative 'aims to provide equitable, transformative pathways for improved livelihoods of actors in mixed farming systems through sustainable intensification within target agroecological and socioeconomic settings. To achieve this, different methodologies, innovations, and practices have been implemented to understand and improve the agroecological/productive conditions to assess a benefit on nutrition, food security and welfare. SIMFS works closely with the CGIAR Regional Integrated Initiative on Transforming Agrifood Systems in South Asia (TAFSSA) that propels evidence into impact through engagement with public and private partners across the production-to-consumption continuum, to achieve productive, environmentally-sound South Asian agrifood systems that support equitable access to sustainable healthy diets.

The use of Principal Component Analysis through Hierarchical Clustering (PCA-HC) is a tool which provides relevant information for farmers, practitioners, and other stakeholders. The development of typologies is a methodological approach to systematically arrange and interpret data associated with the categorization of groups of variables. In farming systems analysis, household-level data are critical in delineating internal farm dynamics that include production processes, adaptive strategies, and resilience metrics. Structural variables, characterized by their stability over short to medium-term periods, are key to discerning consistent trends and patterns within farming systems. These variables assist in identifying the strategic choices made by farm households to advance their welfare and nutrition. The analytical process is structured to support the establishment of sustainable and productive mixed crop-livestock-tree farming systems.

Table 1.1 outlines the survey's scope, which was conducted in two regions of interest: Surkhet, and Khotang (as depicted in Figure 1.1), aligning with the areas of intervention for the SI-MFS, and/or TAFSSA Initiatives. The survey was carried out in the Nepali language by local enumerators, utilizing electronic devices equipped with Kobo toolbox application. Data collection occurred between March and May 2023, resulting in a total of 820 records.

This farm typology report specifically focuses on the data obtained from Gurbakhot municipality in Surkhet district, Western Nepal, encompassing 413 entries.

Table 1.1 Farm characterization survey questionnaire modules

Farm characterization survey	
Module 1	
Sub-module 1	Basic characteristics of the household
Sub-module 2	Basic farm and farming information
Module 2	Farm characteristics
Sub-module 1	Field crops
Sub-module 2	Homestead crops
Sub-module 3	Livestock and/or poultry
Sub-module 4	Aquaculture
Sub-module 5	Interactions among farming components
Sub-module 6a	Inputs
Sub-module 6b	Machinery use
Sub-module 7	Water consumption and irrigation
Module 3	
Sub-module 1	Non-farm income sources
Sub-module 2	Gender and decision making
Module 4	Farming system futures (aspirations)
Module 5	Household consumption
Module 6	Climate impacts and services

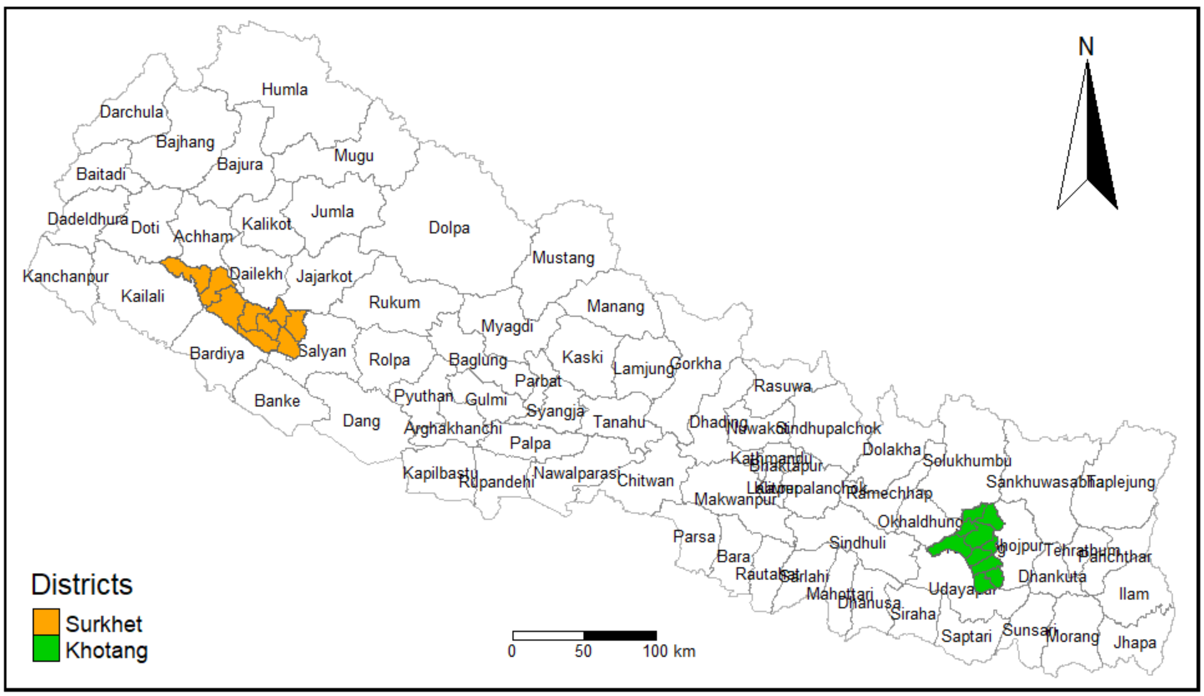

Figure 1.1 Study area of the farm characterization household survey carried out in Nepal between March and May 2023.

2. Typology construction

Data sources and processing

Data source

The original data frame was recorded in a CSV file. The land definition was provided by the farmers, and the local units were changed into a metric system. Some tests were applied to identify possible outliers in Excel of Office 360 and corrected with expertise from the CIMMYT-Bangladesh team. For the analysis some variables were used as they were collected, while others were derived from the original information, as ratios or indexes.

Software

The analysis was conducted using R (v 4.2.2), in R-Studio (v 2022.12.0 Build 353), over Windows 10 Enterprise 22H2. The packages used for analysis included dplyr, reshape, ggpubr, corrplot, psych, caret, Hmisc, agricolae for data analysis and factoextra, ade4, vioplot, sf, tmap, grid, gridExtra, ggplot2 for graphical representation.

Data cleaning. Near-Zero Variance, outliers, and collinearity

Before conducting the PCA-HC analysis, a preliminary step involved the removal of variables from the available dataset in order to mitigate dimensionality. To accomplish this, we classified variables into two distinct categories: structural and non-structural. Structural variables, exemplified by attributes such as land surface area, active subsystems within the farm, and land use, exhibit minimal year-to-year variability. In contrast, non-structural variables such as crop yields or income, can change dramatically within a year. Binomial or categorical variables were considered within the dataset, although their treatment in the analysis is not specified in this context. The decision to exclusively retain the structural variables for the subsequent PCA-HC analysis stems from their inherent stability over time.

Subsequently, all initially selected variables were tested and those having more ≥74% of the data as NA, or a prevalence of ≥80% of 0 (zero) value as responses, were consequently excluded from further analysis. This systematic approach was undertaken to augment the distinctions between farms within the PCA-HCA framework. In the context of PCA-HCA, the resulting 'reduced' dataset was used in a two-step testing process to refine and obtain a cleaner version for typological analysis:

To assess the near-zero variance of each variable, a statistical test, as outlined by Kuhn (2023), was utilized to demonstrate significant near-zero variance behavior. This test relied on the ratio of the most frequently occurring high values to the percent uniqueness of values within all data vectors. We next conducted a visual examination of the dataset's variable distributions through the use of boxplots and histograms, with the aim of identifying patterns resembling normal distributions. In order to evaluate relationships between variables, we utilized Pearson's correlation to examine data that were comprised of numerical variables. Following Barba-Escoto et al. (2019), a threshold of 0.7 was employed as a discriminating point. Any correlations exceeding this absolute reference value were scrutinized across all related variables, and for interpretation purposes, the most significant variable was selected among those with multiple correlations or varying levels of significance.

Before the cleaning process 50 variables and 413 farmer respondents' data were pre-selected for the farm typology characterization of Surkhet district. 11 variables linked to the identification of each survey were directly removed. Another 10 variables were removed after the cleaning process. The final farm type definition presented in this document is based on a matrix of 29 variables × 413 farmer household survey respondents. The ratio of surveys to variables in this analysis is 14.2, which exceeds the commonly accepted threshold of 5, indicating the reliability of the analysis. For more detailed information on the original pre-selected variables, please refer to Table 5.1, and for numerical data, consult Table 5.2 in the annexes.

PCA-HCA. Defining types

Our process of typology construction (Barba-Escoto, et al., 2019) is divided into two main processes: a) PCA relevant components definition (dimensions), and b) HCA clustering for groups definition. Thereafter, the farm types are described by the differences between the groups.

PCA-HCA

The definition of the dimensions was based on the eigenvalues of each potential component, with those having eigenvalues greater than 1 considered relevant. The scree test served as a visual aid in this process. In this particular case, a total of 10 dimensions were defined, as outlined in Table 2.1 and illustrated in Figure 2.1.

Table 2.1 Eigenvalues, PC cuts.'

	inertia	cum	cum (%)
Ax1	4.69	4.7	16.2
Ax2	3.08	7.8	26.8
Ax3	2.34	10.1	34.9
Ax4	1.89	12.0	41.4
Ax5	1.57	13.6	46.8
Ax6	1.41	15.0	51.7
Ax7	1.23	16.2	55.9
Ax8	1.20	17.4	60.1
Ax9	1.08	18.5	63.8
Ax10	1.07	19.6	67.5

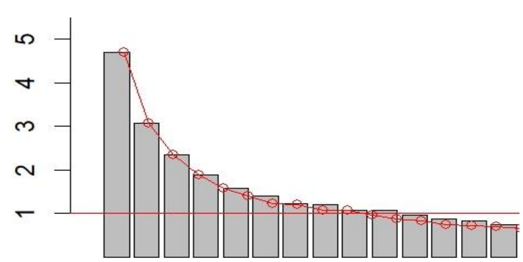

Figure 2.1: Scree test result defining 10 dimensions for PCA-HCA.

Following the preliminary assessment, the farm system components are delineated, and the districts are allocated into these components (as illustrated in Figure 2.2). This classification is based on the distance of each district's corresponding value in the vector created by each variable and the direction across these components. The significance or weighting of each selected variable can be found in Table 5.3, provided in the annexes.

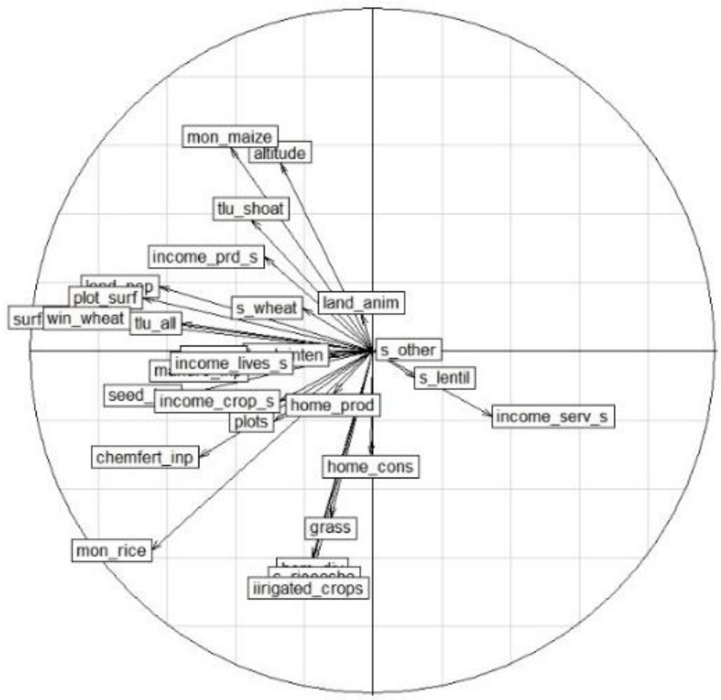

Figure 2.2 Variables weight through PCA.

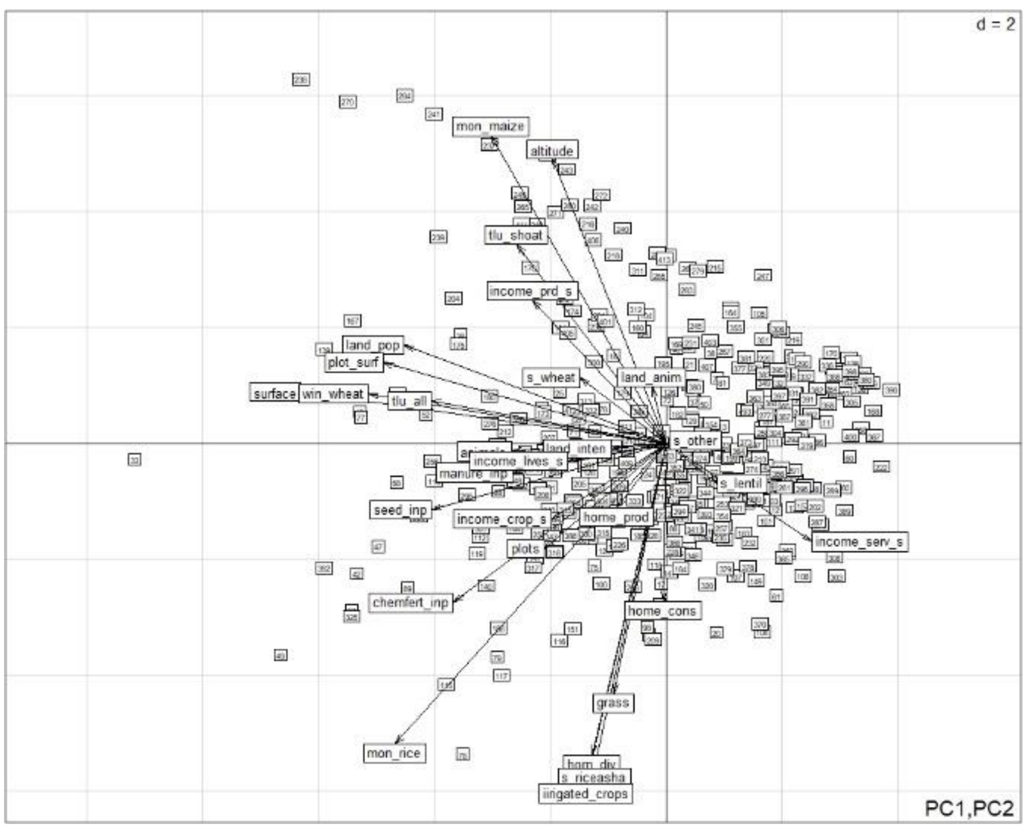

Figure 2.3 Observations in dimension 1-2 of CPA.

Clustering (HCA)

In the second phase of the typology construction, the grouping process is established, guided by the Within Group Squared Sum (WGSS) and a hierarchical classification (as depicted in Figure 2.4). Combining the insights derived from both methods, five distinct farm types were defined. Subsequently, each record was categorized and allocated to one of these five groups, as depicted in Figure 2.5. Table 2.2 summarizes the distribution of the records into the different farm types.

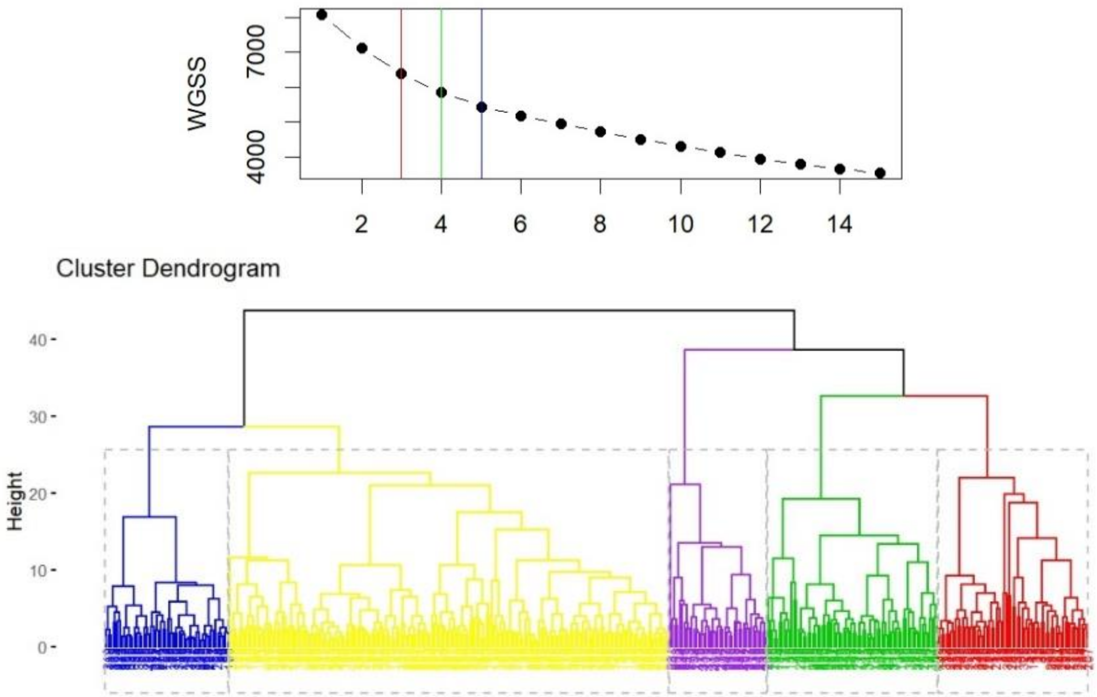

Figure 2.4 WGSS (above) and hierarchical dendrogram (below).

Table **¡Error! Usa la pestaña Inicio para aplicar Heading 1 al texto que quieres que aparezca aquí.**.2 Types distribution within the study area of Gurbakhot municipality, Surkhet district.

Type	**T1**	**T2**	**T3**	**T4**	**T5**
n	63	185	72	52	41
%	15.3	44.8	17.4	12.6	9.9

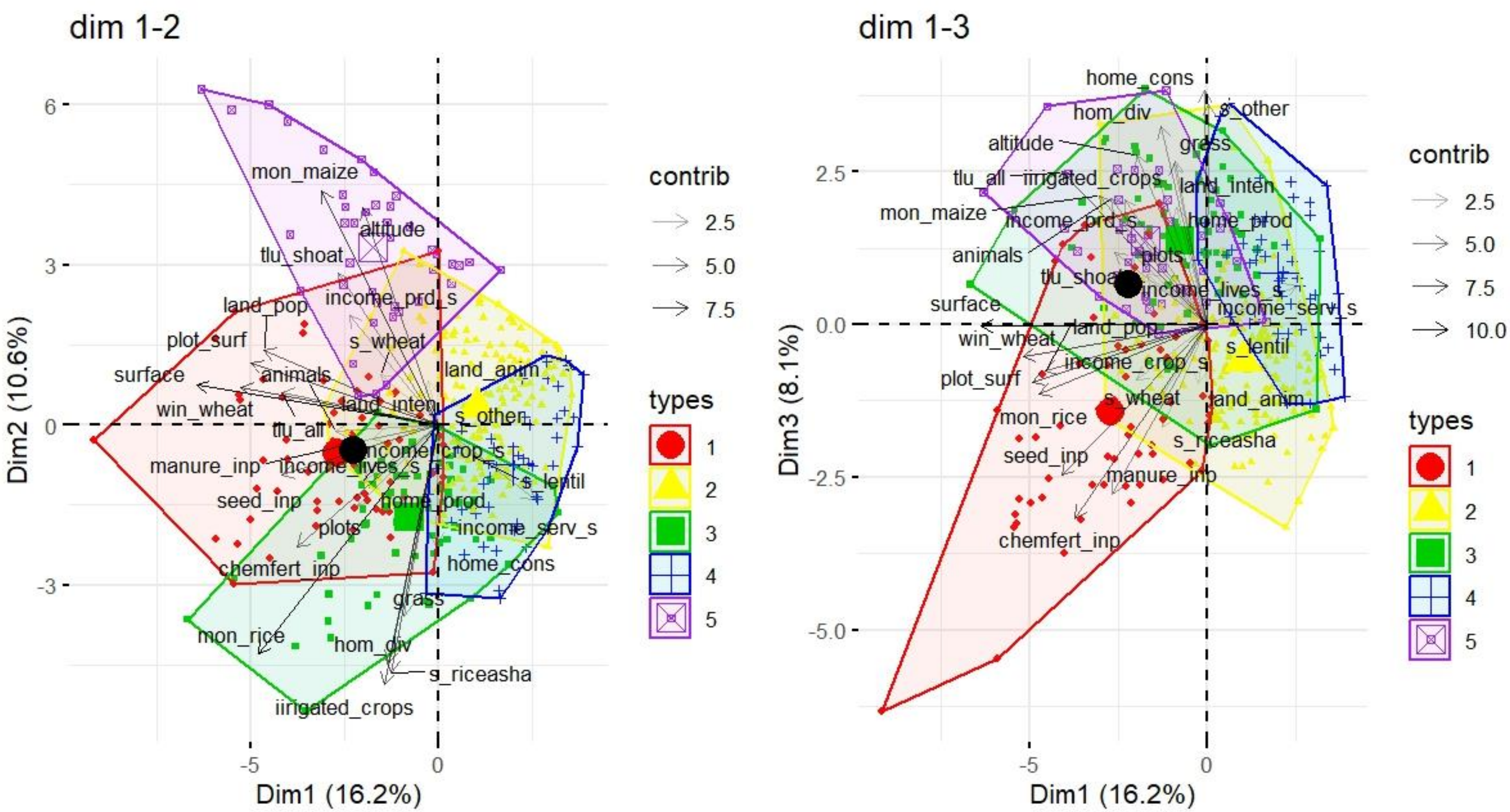

Figure 2.5 Types clustering (dimension 1-2 and 1-3).

Definition of farm types

As described in the previous section, utilizing the PCA-HCA approach, five distinct farm types have been identified. It is essential to note that the farm type descriptions presented below provide a relative perspective on the characteristics among these farm types. The variables employed in designing the farm types are visually represented in a heatmap (Table 2.3) to emphasize group differences. For each farm type a graphic representation showing the average component characteristics as well as the average interactions/flows between components is given (Figures 2.6 to 2.10).

Note that (i) the TLU score, based on the simplified model by Njuki et al. (2011), considers solely the reported number of animals to derive a value based on weight and fodder requirements; and (ii) there are three primary productive seasons: spring (*kharif*-1), monsoon (*kharif*-2), and winter (*rabi*) seasons ; (iii) naming of the farm types was done with the support of Chat GPT (3.6 v); (iv) these are preliminary results.

Supplementary information is available in the annexes, it includes:

i. A map displaying the surveyed farms and their corresponding farm types (Figure 5.1).
ii. The results of a Bonferroni test carried out to assess significant differences between farm types for the definitive variables (Table 5.4) as well as the results of a Chi-squared test applied to analyse the variables (Table 5.5).
iii. A comprehensive visualization of variables across all districts presented through boxplots (Figures 5.2 to 5.7). It's important to note that this information relies on the same dataset; however, additional outliers were removed specifically when examining production. The key topics addressed encompass household information, income sources, land allocations, production, and indicators of system resilience.

Type 1 (63 n / 15.3%) – Smallholder Intensive Rice-Wheat Farm households.

The T1 farm type has, together with T5, the highest landholding size (0.6ha). They are situated at a lower altitude (530 masl) and are quite close to the nearest market (3.8km). They have the least number of months with water available (10.5) are however cultivating a similar share of land in both monsoon and winter season (95.8 and 94.5, respectively). The main crops grown are rice and wheat (33.5% and 35% of the land across seasons, respectively) and a smaller percentage of land is allocated to maize (18.9%). Land occupancy for T1 farms is 191.6%. Irrigation is applied to 16.7% of the plots under production.

T1 farms are further characterized by the highest amount of input used: seeds (407.7 kg), chemical fertilizers (537.8 kg) and manure (54 Mg); as well as the highest income share from crop production (34.3%), while the income from livestock is the second lowest (13.4%). Indeed, they only own moderate amounts of animals: TLU scores are 1.5, 0.9 and 0.4 for all animals, cattle and buffalo and goat and sheep, respectively.

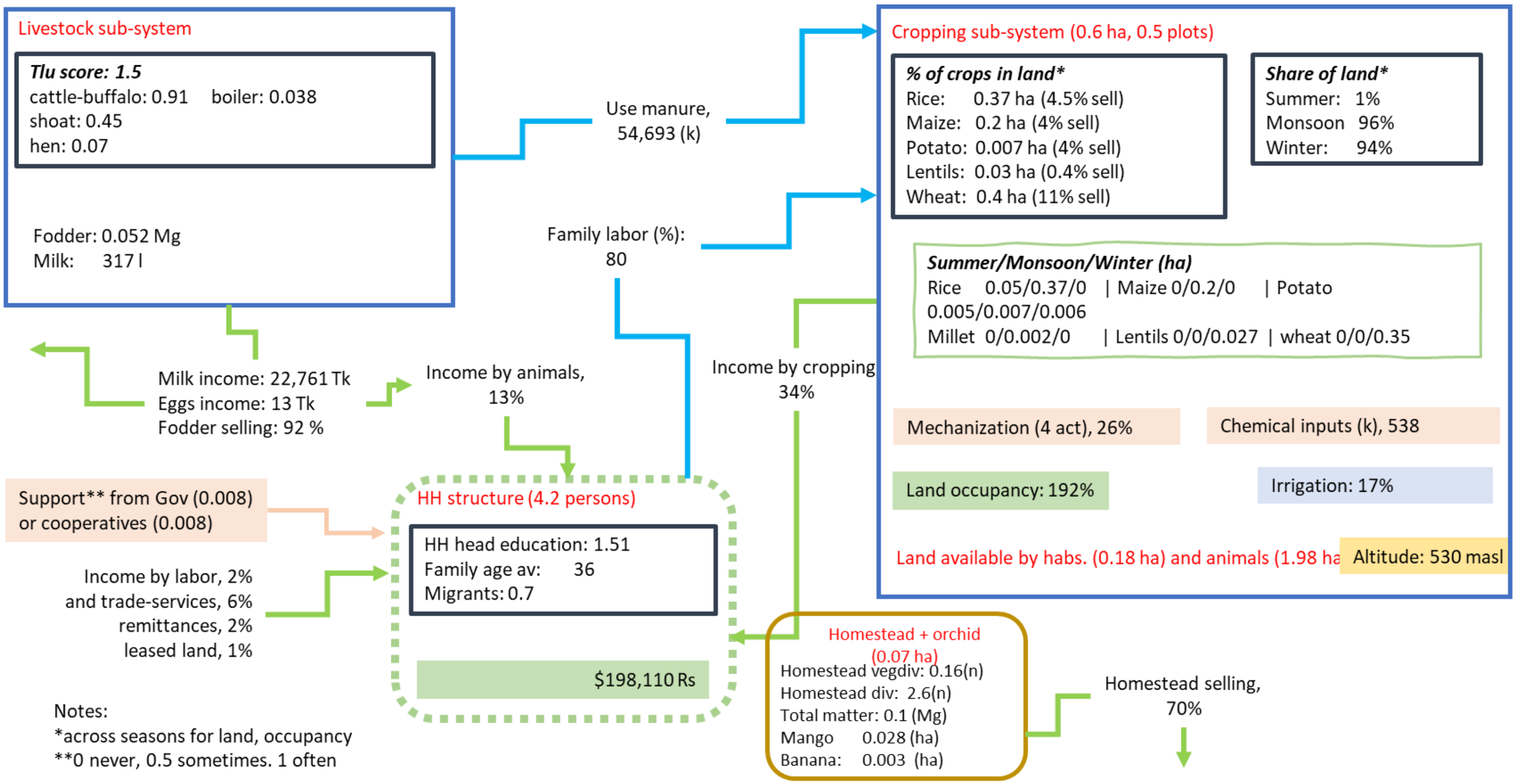

Figure 2.6 Farm type map-diagram, T1-“Smallholder Intensive Rice-Wheat Farm households” (63 n, 15%).

Type 2 (185 n / 44.8%) – Small-Scale Intensive mixed crop-livestock farm households.

T2 farms have landholdings of only 0.3ha on average. Like T1 they are at a low altitude (520 masl) and are quite close to the market (3.6km). They have water available for 11.6 months per year but cultivate only 87.8% of their land in winter, as opposed to 98.1% during monsoon season. Their land occupancy (193%) is similar to T1, they also allocate land to growing rice (25.4%) and wheat (29.9%), but a higher proportion goes to maize (30.1%) and they grow lentil on 5% of their land too. Only 11.7% of the plots under production are irrigated.

These farms used much less inputs than the T1 farms with 76 kg of seed, 119 kg of chemical fertilizer and 19 Mg of manure. They have a negligible income share generated from crop production (2.4%). On the other hand, their biggest share of income comes from animal production (21.9%; which is also the second highest across all farm types), even if TLU scores are the second lowest across all farm types, with 0.9, 0.5 and 0.3 for all animals, cattle and buffalo and goat and sheep, respectively. Another 20.6 % income share is generated from off-farm income related to farm assets. And although homestead production is only 0.1 Mg T2 farms have the lowest percentage of homestead production that is self-consumed (25.7%), which might be an indication of cash constraint households that sell whatever is available when money is needed.

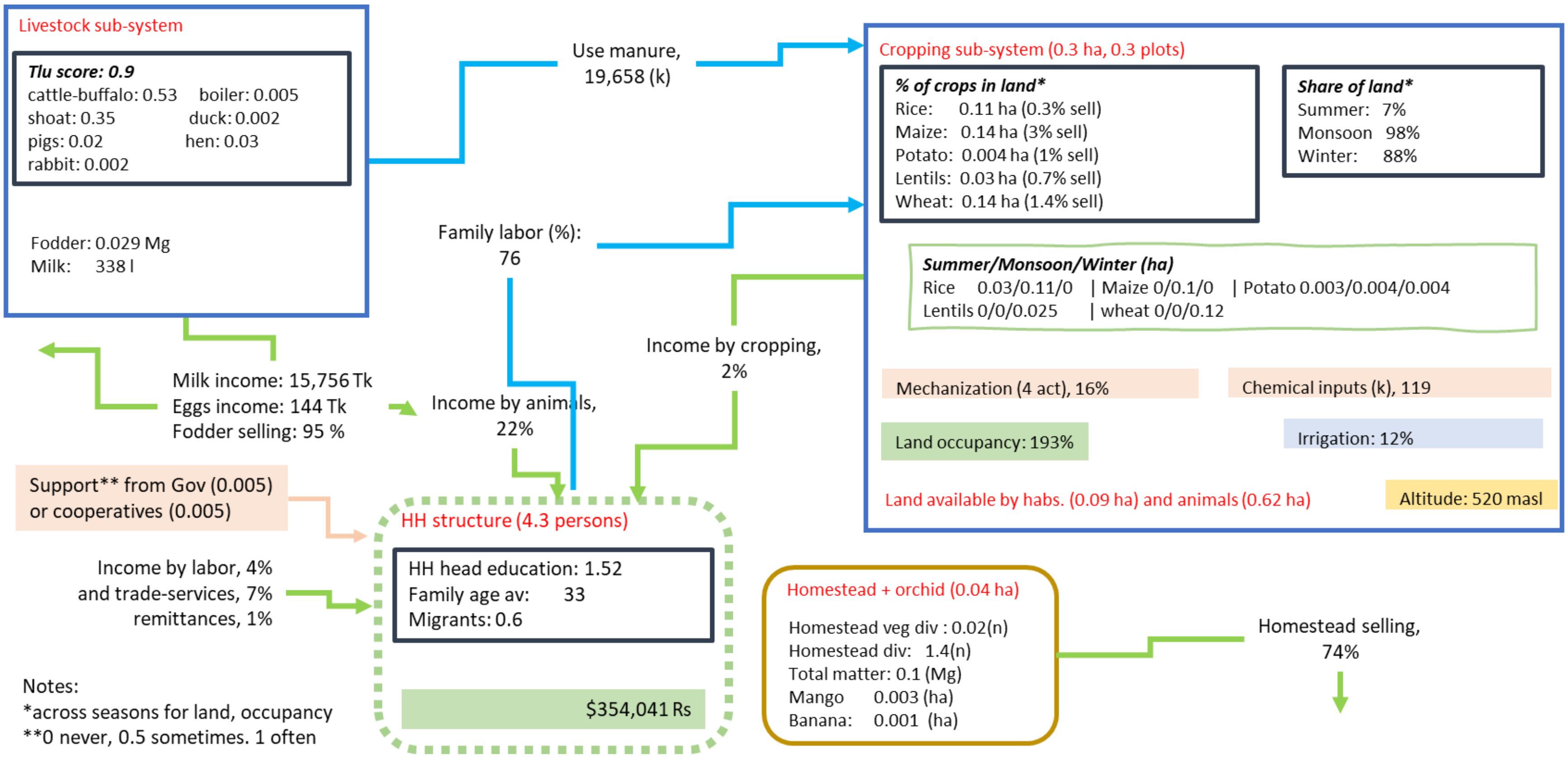

Figure 2.7 Farm type map-diagram, T2-“Small-Scale Intensive mixed crop-livestock farm households” (185 n, 45%).

Type 3 (72 n / 17.4%) – Diversified farm households with off-farm and livestock driven income.

T3 farms have landholdings of 0.4ha on average and are at a slightly higher altitude (577 masl) and at a further distance from the closest market (5.7 km) than the 1st two farm types. They have water available for 11.1 months/year and cultivate the highest share of land in both monsoon and winter season (99.7% and 99.1%, respectively). They also have the highest proportion of their plots irrigated (32.1%), which goes hand in hand with the highest share of land allocated to rice cultivation (42.3%). Further, among all farm types, they cultivate the highest share of land with lentis (8.2%), while having the least land allocated to maize and wheat cultivation (16.3% and 19.3%, respectively). They also have the second highest amount of land allocated to other crops (12.6%). Their land occupancy is the highest (219%) among all farm types.

These farms use similar amounts of chemical fertilizer (117 kg) and manure (18.7 Mg) but almost double the amount of seed (112 kg) than the T2 type. In their homesteads they have the highest crop diversity score (3.9 for all crops; 2.6 for vegetables) and production (0.4 Mg), with the second highest self-consumption rate (67.1%).

T3 farms are further characterized by the highest number of times grass is planted for livestock (0.8, same as for T4 farms), the second highest TLU score for all animals (1.9) and the highest for cattle and buffalo (1.5), which translates into the highest income share coming from animal production (25.7%). They have the second highest income shares among the five farm types coming from crop production (10.8%) and off-farm income related to farm assets (46%).

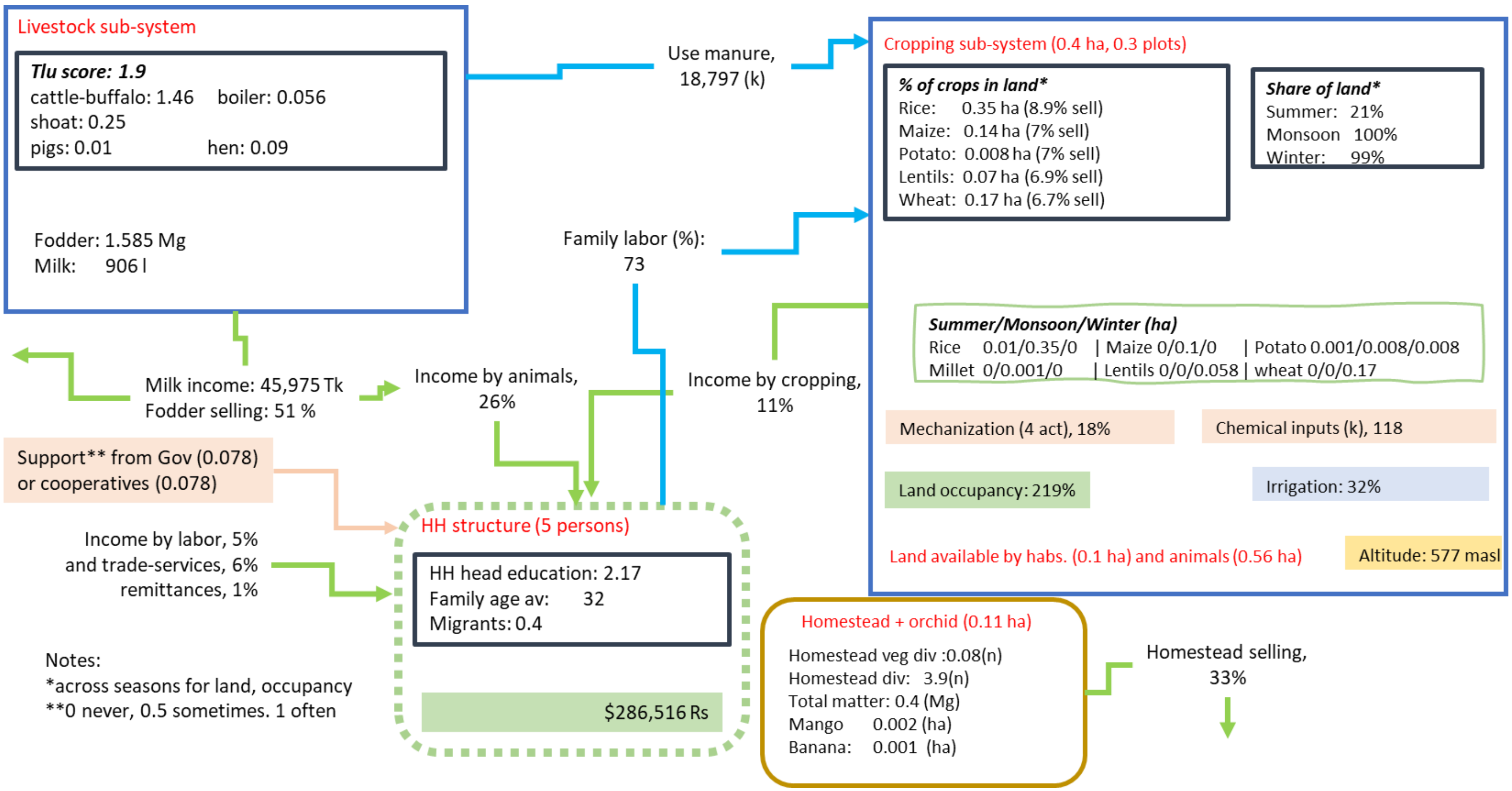

Figure 2.8 Farm type map-diagram, T3-“Diversified farm households with off-farm and livestock driven income” (72 n, 17%).

Type 4 (52 n / 12.6%) – Marginal micro-farms reliant on non-farm income.

T4 farms have the smallest landholdings (0.2 ha), are at similar altitude than T3 (578 masl) but are closest to the market (3.1 km). They also have water available all year (12 months). While the cultivate 97.4% of their land during the monsoon season, during winter only 86.9% is cultivated (the lowest share across all farm types), resulting in the lowest land occupancy as well (186.4%).

Overall, these T4 farms are characterised by the lowest input use and lowest animal ownership, translating into marginal income share derived by crop (1.5%) and animal (1.7%) production. On the other hand, the share of income derived from other sources and commerce is 76%.

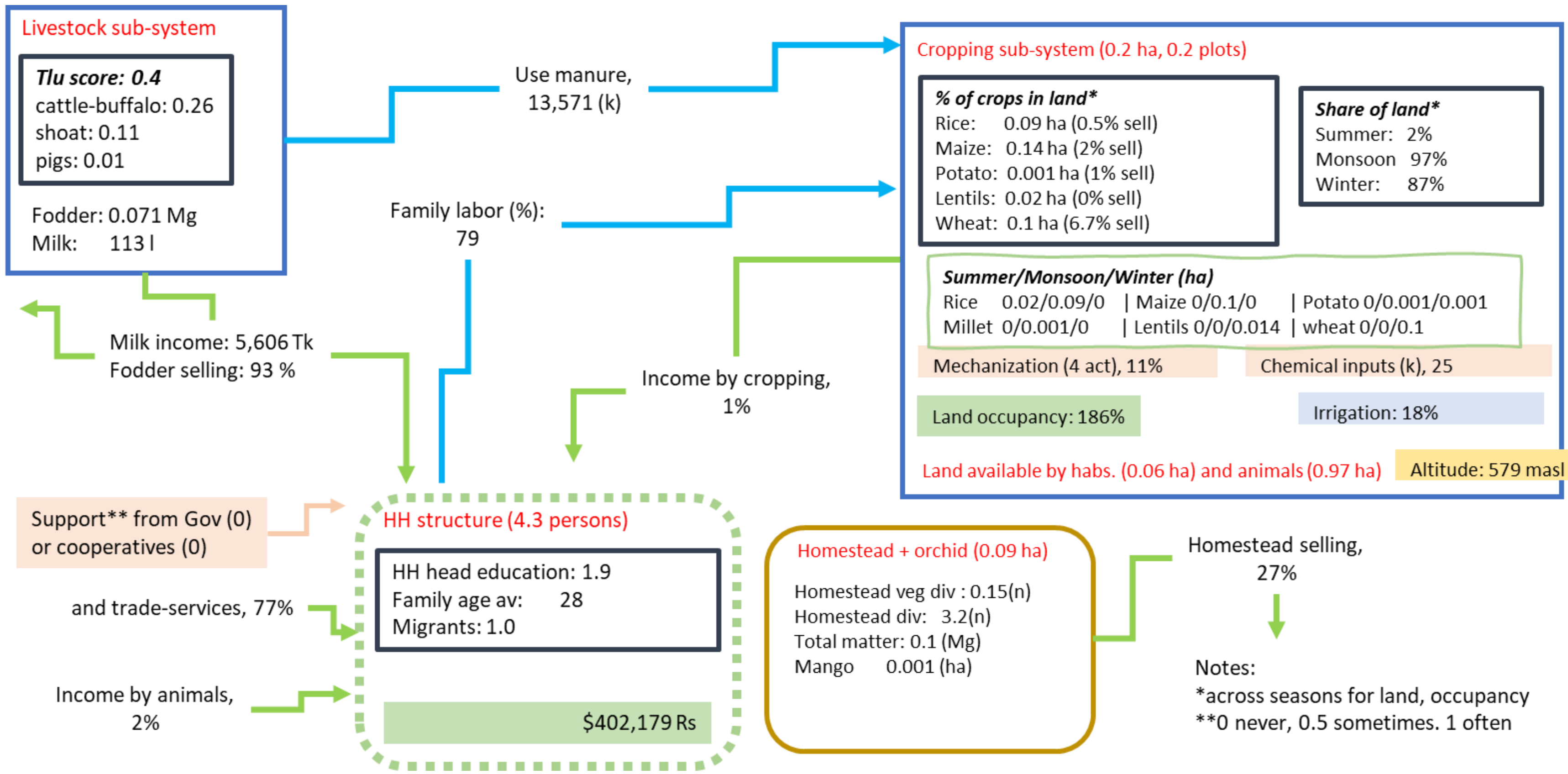

Figure 2.9 Farm type map-diagram, T4-“Marginal micro-farms reliant on non-farm income” (52 n, 13%).

Type 5 (41 n / 9.9%) – High-Altitude and remote livestock and off-farm income-based households.

Together with T1, T5 farms have the biggest average landholdings (0.6ha). They are also at a higher altitude (1342 masl) than any of the other types and more remote (12.5 km to the nearest market). They are the only farm type where the share of land cropped during winter (99.6%) is higher than the one cropped during monsoon season (97%). Nevertheless, they have the second highest land occupancy (204%). Water is available year-round (11.9 months), however these farms have the lowest share of cropped plots that is irrigated (6.7%). This is probably linked to the fact that they have the highest share of land allocated to maize (43%) and wheat (37.4%) with 0.4 ha of maize during monsoon and 0.3 ha of wheat during winter season.

T5 farms have low input use and a negligible share of income derived from crop production (1%; the lowest among all farm types). On the other hand, they have the highest values for all animal TLU (2.6), with goat and sheep TLU being highest (1.0) and cattle and buffalo second highest (1.3) compared to the other types. This reflects into a significant share of income from animal production (18.2%).

Another characteristic of this farm type is that although homestead crop diversity is lowest (0.6 for vegetables and 0.8 for all crops) the production is second highest (0.3 Mg) and only 36.6% is consumed within the household. The highest share of income for this farm type comes from off-farm income related to farm assets (72.3%).

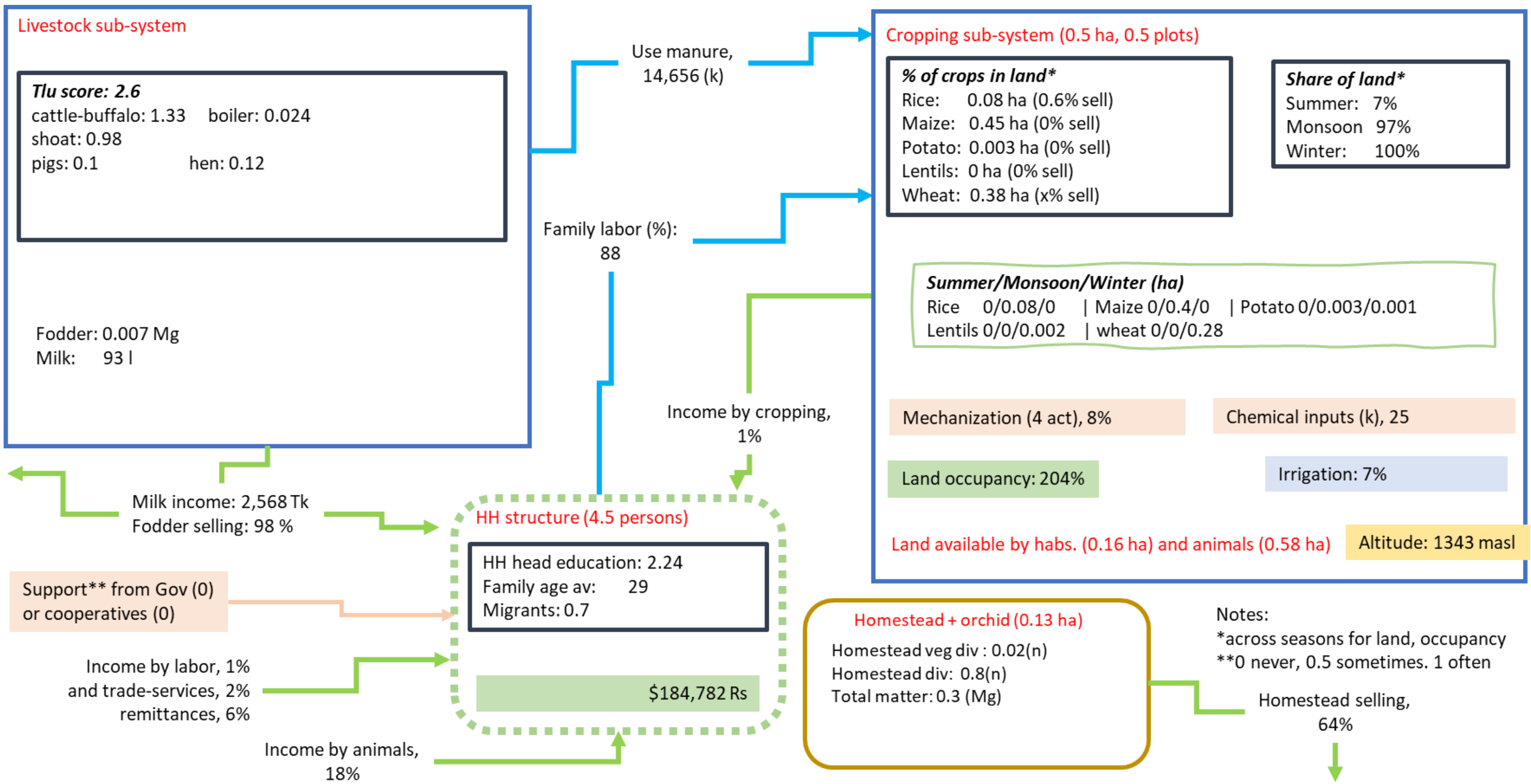

Figure 2.10 Farm type map-diagram, T5-“High-Altitude and remote livestock and off-farm income-based households” (41 n, 10%).

Table 2.3 Farm types variables heatmap, where in grey and aligned to the right are the variables used for PCA, while the others (in white and aligned to the left) are the variables that were excluded during the cleaning (by near zero analysis, correlation, and visualization).

Variable	Unit	T1 *63n* *15.3 %*	T2 *185n* *44.8 %*	T3 *72n* *17.4 %*	T4 *52n* *12.6 %*	T5 *41n* *9.9 %*	All
Altitude	m	530	520	577	579	1,343	621
Number of months with water availability	Months	10.50	11.60	11.10	12.00	11.90	11.40
Distance for market	km	3.80	3.60	5.70	3.10	12.50	4.80
Number of HH plots	n	1.80	1.60	2.00	1.20	1.40	1.60
Surface (declared)	ha	0.60	0.30	0.40	0.20	0.60	0.4
Land occupancy	ha	191.60	193.2	219.4	186.4	203.8	197.6
Land availability by hh habitants	ha / hab	0.20	0.10	0.10	0.10	0.20	0.1
Land availability by TLU score	ha / tlu	2.00	0.60	0.60	1.00	0.60	0.90
Max total land + leased in	ha	0.60	0.30	0.40	0.20	0.50	0.4
Share of land in monsoon	%	95.80	98.10	99.70	97.40	97.00	97.80
Share of land in winter	%	94.50	87.80	99.10	86.90	99.60	91.8
Main plot surface	ha	0.50	0.30	0.30	0.20	0.50	0.30
Times grass planted for cattle	n	0.30	0.10	0.80	0.80	0.00	0.3
Diversity for animals	n	2.30	1.60	2.20	1.90	2.40	1.9
Seed input usage	Kg	407.70	76.40	120.10	46.10	89.70	132.1
Manure input usage	Kg	54,693	19,658	18,797	13,571	14,656	23589
Chemical fertilizers usage	kg	537.80	119.10	117.90	24.80	24.80	161.5
TLU value for cattle (cattle, buffalo)	index	0.90	0.50	1.50	0.30	1.30	0.80
TLU for shoat (sheep+goats)	index	0.40	0.30	0.30	0.10	1.00	0.4
TLU for hen	index	0.10	0.00	0.10	0.00	0.10	0.00
TLU all animals	index	1.50	0.90	1.90	0.40	2.60	1.2
Homestead diversity veggies	n	2.10	1.10	2.60	2.10	0.60	1.6
Homestead diversity all crops	n	2.60	1.40	3.90	3.20	0.80	2.2
Total homestead production (matter)	Mg	0.10	0.10	0.40	0.10	0.30	0.20
Self-consume of homestead production	%	29.60	25.70	67.10	73.10	36.30	40.5
Income from livestock	%	13.40	21.90	25.70	1.70	18.20	18.4
Income from crops	%	34.30	2.40	10.80	1.50	1.00	8.50
Other services or sources-commerce	%	5.80	6.80	6.20	76.70	1.80	14.90
Farm products into off farm activities	%	26.30	20.60	46.00	4.60	72.30	29.00
Share of land dedicated to lentil	%	2.50	5.10	8.20	2.60	0.10	4.4
Share of land dedicated to maize	%	18.60	30.10	16.30	39.20	43.00	28.4
Share of land dedicated to rice	%	33.50	25.40	42.30	17.60	8.20	26.9
Share of land dedicated to wheat	%	35.00	29.90	19.30	21.90	37.40	28.6
Share of land dedicated to other crops	%	6.40	6.70	12.60	18.10	11.00	9.5
Irrigated crops selected average	%	16.70	11.70	32.10	17.60	6.70	16.3
Maize surface in monsoon	ha	0.20	0.10	0.10	0.10	0.40	0.2
Rice surface in monsoon	ha	0.40	0.10	0.40	0.10	0.10	0.2
Lentils surface in winter	ha	0.00	0.00	0.10	0.00	0.00	0
Wheat surface in winter	ha	0.40	0.10	0.20	0.10	0.30	0.2

Note: The heatmap is based on 3-colour scale for numerical values for each variable, with green for the larger value and red for lowest, to facilitate visual analysis. For deeper analysis in important to evaluate the larger distances between values as a broad description. Grey colour in the variable name highlights those variables included in the PCA-HC.

3. Conclusions

Small scale farming systems are often complex combining several farm (e.g. crop, livestock, aquaculture) and non-farm activities for the livelihood of rural families. This complexity often generates, within the same region or agroecological zone such as Surkhet district, a large diversity of farming systems with, for example, different levels of specialisation on certain crops of livestock activities, their reliance on farming and non-farming activities for the generation of income or for labour engagement.

Capturing such diversity and complexity of farming systems is an essential step towards developing suitable (baskets of) socio-technical innovation bundles (Barret, et al, 2022) that i) address the main challenges for the sustainability of specific types of farming systems and ii) identify distinctive (best fit) opportunities and entry points for improving their performance. No all farmers are the same and no innovation fits all.

In this analysis we have identified five relatively homogeneous and significantly different types of farming systems for Surkhet district based on a survey applied to 413 farm households in Gurbakhot municipality: Type 1 (T1) - High inputs, wheat-rice lowland farms; Type 2 (T2) - Small scale livestock lowland farms; Type 3 (T3) - Rice-livestock highly intensive input-land farms; Type 4 (T4) - Transitional farms with low resources, and; Type 5 (T5) - Highland maize-wheat-livestock farms.

For each of these farm household types we have identified their distinctive features, the main components of the farming systems and their relative importance, some internal and external flows. This systemic characterization of the diversity of farming systems in Surkhet district can be conceived as a first step toward the analysis and design of more sustainable Mixed Farming Systems in the region.

In the OneCGIAR SI-MFS initiative the DEED framework has been adopted for the co-design of more sustainable MFS. The DEED framework encompasses a series of phases for systems analysis and co-design (Describe, Explain, Explore, and Design; Figure 3.1) (Gebreyes et al., 2023).

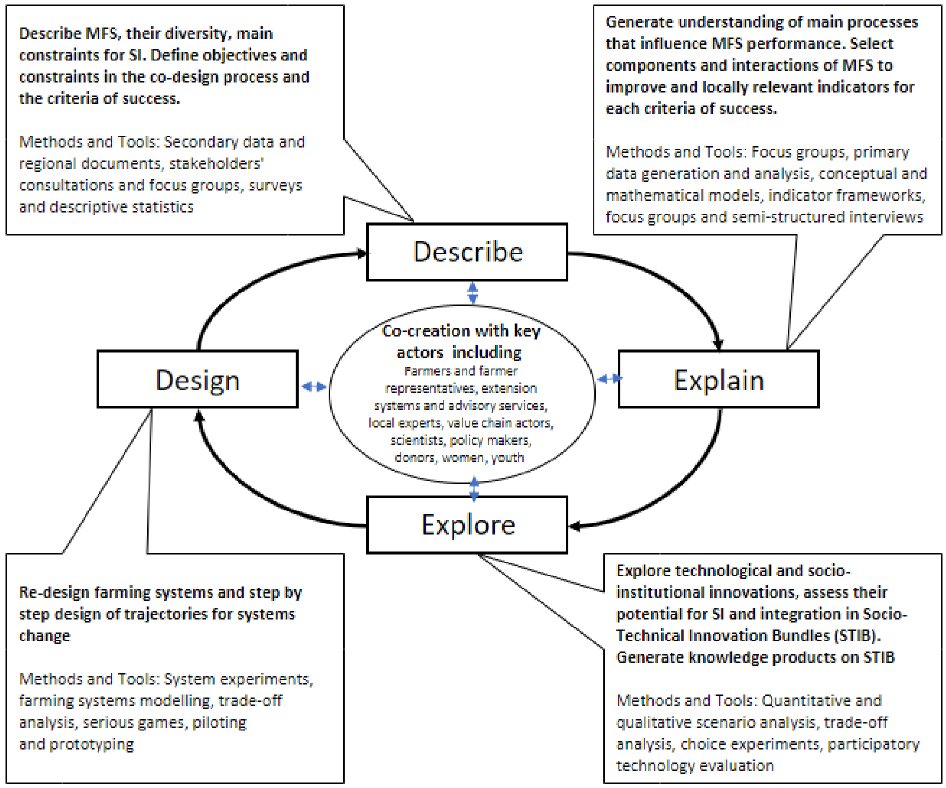

Figure 3.1 The DEED cycle for co-designing more sustainable Mixed Farming Systems and examples of methodological tools (https://hdl.handle.net/10568/128746).

For example, based on this typology developed for Surkhet district, further analysis of the detailed dataset for the different types as well as FGD and semi-structured interviews, would allow to identify the main limitations and inefficiencies for different types of farming systems, their differentiated priorities and indicators of success and assess their performance through multi-criteria assessment. For example, T1 have the more land and the less pressure by habitants or animals, with the larger income from cropping using the more inputs, with a potential use of livestock or homestead technologies for enhancing resilience with other farm products. The T3 farms are based on homestead and livestock, with off-farm activities, and more irrigation access, they could be interested on cropping accessible technologies with low labour requirement and pasture varieties for the cattle. The T5 farms are based on livestock and off-farm activities, but in high and far lands, and could use more resilient innovations and recycling technologies to avoid the external use of inputs, and the same way improve staple crops or homestead foods for self-consume. On the other extreme, the T2 face a small surface availability, with low animal diversity and restricted homestead self-consume, then can be enhanced with intensification low-cost innovations to increase food products availability. Finally, the T4 farms face small land access, low animals' capacity, and trade-services income from outside farms, they could use highly intensive innovations to reduce staple foods purchase from outside, but low labour and cost technologies. Formalising these hypotheses and assessing specific process trough empirical or analytical pathways would need to be carried out during the Explain phase of the DEED cycle.

Exploring the potential effect of specific socio-technical innovation bundles for different types of farm households would allow to identify type-specific areas of improvement and identify potential trade-offs and synergies that need to be addressed or exploited in the process of co-design of more sustainable MFS. Such trade-off and synergies would be different for different farm types and will delimit their specific window of opportunities for improving systems performance and will inform the most promising pathways for successful co-design. Finally, based on action research and informed y previous phases of the DEED cycle, novel practices and systems configurations can be designed, suitable for different types of farming systems and engage in a process of co-innovation where farmers and researchers put together their learning tools to improve the sustainability of mixed farming systems.

4. Literature

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5. Annexes

The information used for this analysis can be public accessed in official repository, after anonymizing as CIMMYT-IREC protocols in CKAN repository: https://doi.org/10.25502/xmy5-mx73/d

Table 5.1 Description of the structural variables used for this farm typology analysis.

Variable	Unit	Description
Altitude	m	Altitude in m
Number of months with water availability	Months	Water availability across year
Distance for market	km	Distance of main market to HH
Number of HH plots	n	Number of plots in HH
Surface (declared)	ha	Total declared surface by interviewed
Land occupancy	ha	Sum of the area cultivated of all crops in the three seasons, divided by "Surface", multiplicated by 100. (Ranges from 0-300%)
Land availability by hh habitants	ha / hab	Land available by HH habitants
Land availability by tlu score	ha / tlu	Land available for TLU score
Max total land + leased in	ha	Estimated total HH surface considering the max land reported across season and leased land
Share of land in monsoon	%	Monsoon share of used land
Share of land in winter	%	Winter share of used land
Share of total fallow	%	Fallow share of used land
Total fallow land	ha	Total fallow land in the HH in all seasons
Main plot surface	ha	Area of main plot
Diversity of fruit trees	value	Amount of fruit trees diversity (species) in HH
Diversity for animals	value	Amount of animals species in HH
Seed input usage	k	Total k of seed sowed
Manure input usage	k	Total k of manure applied
Chemical fertilizers usage	k	Total k of chemical fertilizers applied
Tlu value for cattle (cattle, goru, bull, buffalo)	index	TLU score for all land animals
Tlu for shoat (sheep+goats)	index	TLU score for goats and sheep
Tlu for pigs	index	TLU score for pigs
Tlu for hen	index	TLU score for hens
TLU all animals	index	General TLU score, all animals
Homestead diversity veggies	n	Homestead diversity of vegetables
Homestead diversity all crops	n	Total homestead diversity of products

Variable	Unit	Description
Total homestead production (matter)	Mg	Total organic matter as products (Mg) production on homestead
Self-consume of homestead production	%	Homestead self-consume share
income from livestock	%	Income share from livestock
income from crops	%	Income share from cropping
Remittances	%	Income share from remittances
Farm products into off farm activities (leasing land, animals, crops)	%	Income share from off-farm activities related to farm or farm labor
Share of land dedicated to banana	%	Surface share of land dedicated to crop, all year
Share of land dedicated to maize	%	Surface share of land dedicated to crop (all seasons) over cropping surface by 100
Share of land dedicated to masayng	%	Surface share of land dedicated to crop (all seasons) over cropping surface by 100
Share of land dedicated to millet	%	Surface share of land dedicated to crop (all seasons) over cropping surface by 100
Share of land dedicated to other crops	%	Surface share of land dedicated to crop (all seasons) over cropping surface by 100; the other crops are different to banana, mango, masayng, lentils, millet, potato, maize, rice and wheat.
Maize surface in monsoon	ha	Total crop surface in season
Masayng surface in monsoon	ha	Total crop surface in season
Millet surface in monsoon	ha	Total crop surface in season

Table 5.2 Variables included for analysis.

Unit	Variable	Mean	Median	St dev
m	Altitude	620.51	533.40	305.26
Months	How months water is available	11.43	12.00	2.24
km	Distance for market	4.80	3.00	4.68
n	Number of HH plots	1.64	2.00	0.83
ha	Surface (declared)	0.40	0.36	0.23
ha	Land occupancy	199.56	200.31	33.74
ha/hab	Land availability by hh habitants	0.11	0.09	0.08
ha/tlu	Land availability by TLU score	0.87	0.31	3.30
ha	Max total land + leased in	0.36	0.31	0.22
%	Share of land in monsoon	97.81	100.00	10.93
%	Share of land in winter	91.83	100.00	23.78
ha	Main plot surface	0.33	0.25	0.25
n	Times grass planted for cattle	0.34	0.00	0.68
n	Diversity for animals	1.92	2.00	1.05
k	Seed input usage	132.09	50.00	204.35
k	Manure input usage	23,589.21	12,000.00	52,619.69
k	Chemical fertilizers usage	161.54	44.00	297.71
index	TLU value for cattle (cattle, goru, bull, buffalo)	0.79	0.70	1.04
index	TLU for shoat (sheep+goats)	0.36	0.20	0.49
index	TLU for hen	0.05	0.00	0.22
index	TLU all animals	1.25	0.90	1.27
n	Homestead diversity veggies	1.61	1.00	1.53
n	Homestead diversity all crops	2.16	2.00	2.02
Mg	Total homestead production (matter)	0.16	0.05	0.65
%	Self-consume of homestead production	40.54	25.00	43.22
%	Income from livestock	18.36	0.00	29.69
%	Income from crops	8.48	0.00	22.97
%	Other services or sources-commerce	14.85	0.00	33.69
%	Farm products into off farm activities (leasing land, animals, crops)	29.05	1.80	36.27
%	Share of land dedicated to lentil	4.42	0.00	9.98
%	Share of land dedicated to maize	28.38	23.50	24.87
%	Share of land dedicated to ashare rice	26.88	28.60	23.73
%	Share of land dedicated to wheat	28.58	30.00	18.08
%	Share of land dedicated to other crops	9.52	2.86	12.80
%	Irrigated crops selected average	16.28	13.89	13.36
ha	Maize surface in monsoon	0.18	0.15	0.17
ha	Rice surface in monsoon	0.19	0.15	0.19
ha	Lentils surface in winter	0.03	0.00	0.07
ha	Wheat surface in winter	0.18	0.15	0.17

Table 5.3 Variable's weights across components.

Variable	Comp1	Comp2	Comp3	Comp4	Comp5	Comp6	Comp7	Comp8	Comp9	Comp10
Altitude	-0.27	0.55	0.38	-0.03	-0.1	0.2	0.05	-0.2	0.12	-0.17
Number of HH plots	-0.29	-0.2	0.16	0.15	-0.19	-0.22	0	0.21	0.44	0.38
Surface (declared)	-0.87	0.1	0	0.31	0.01	0	0.06	0	0.01	0.02
Land occupancy	-0.13	-0.01	0.36	0.09	-0.3	0.27	-0.41	0.28	-0.16	0.05
Land availability by hh habitants	-0.63	0.19	-0.1	0.34	-0.05	-0.05	0.03	-0.13	0.05	0.21
Land availability by TLU score	-0.03	0.11	-0.13	0.49	-0.03	0.2	0	-0.15	0.1	0.17
Main plot surface	-0.67	0.16	-0.13	0.24	0.05	0.06	0.14	-0.09	-0.13	-0.19
Times grass planted for cattle	-0.12	-0.48	0.36	0.18	0.35	0.06	-0.16	0.07	-0.09	-0.19
Diversity for animals	-0.37	-0.01	0.28	-0.34	0.25	-0.28	0.21	-0.18	-0.31	0.17
Seed input usage	-0.56	-0.13	-0.33	-0.01	0.15	-0.08	-0.1	-0.03	-0.11	0.03
Manure input usage	-0.37	-0.06	-0.38	0.15	0.01	0.05	0.13	0.24	0	-0.49
Chemical fertilizers usage	-0.51	-0.31	-0.43	-0.09	0.14	-0.06	0.07	0.17	0.17	-0.21
TLU for shoat (sheep+goats)	-0.36	0.38	0.16	-0.46	0.06	-0.24	-0.06	-0.02	0.08	-0.16
TLU all animals	-0.56	0.08	0.34	-0.45	-0.05	-0.26	0.13	-0.09	-0.13	-0.01
Homestead diversity all crops	-0.18	-0.6	0.44	0.01	0.35	0	-0.18	0.06	0	-0.09
Total homestead production (matter)	-0.12	-0.12	0.26	-0.13	-0.04	0.02	-0.38	-0.05	0.49	-0.42
Self-consume of homestead production	-0.01	-0.3	0.52	0.05	-0.01	0.32	0.25	0.15	-0.09	0.02
Income from livestock	-0.23	-0.03	0.11	-0.25	-0.24	-0.08	0.41	0.58	0.13	0.07
Income from crops	-0.27	-0.15	-0.12	0.06	0.37	-0.37	-0.48	-0.06	-0.01	0.24
Other services or sources-commerce	0.35	-0.19	0.09	0.2	0.43	0.24	0.34	-0.21	-0.06	-0.09
Farm products into off farm activities (leasing land, animals, crops)	-0.32	0.28	0.28	-0.05	-0.44	0.13	-0.18	-0.32	-0.19	-0.13
Share of land dedicated to lentil	0.12	-0.08	0	0.26	-0.25	-0.33	-0.13	0.33	-0.55	-0.18
Share of land dedicated to ashare rice	-0.17	-0.63	-0.23	-0.18	-0.42	0.02	0.1	-0.37	0.05	-0.01
Share of land dedicated to wheat	-0.21	0.13	-0.19	-0.55	0.29	0.55	-0.12	0.14	-0.04	0.19
Share of land dedicated to other crops	0.01	0.01	0.49	0.28	0.17	-0.32	0.29	-0.11	0.18	-0.11
Irrigated crops selected average	-0.19	-0.66	0.33	0.01	-0.2	0.17	0.01	-0.06	-0.02	0.18
Maize surface in monsoon	-0.42	0.59	0.29	0.39	0.12	0.06	-0.04	0.16	0.01	0.08
Rice surface in monsoon	-0.65	-0.58	-0.16	0.06	-0.25	0.08	0.06	-0.14	-0.07	-0.01
Wheat surface in winter	-0.71	0.1	-0.07	-0.11	0.21	0.33	-0.01	0.11	-0.04	0.08

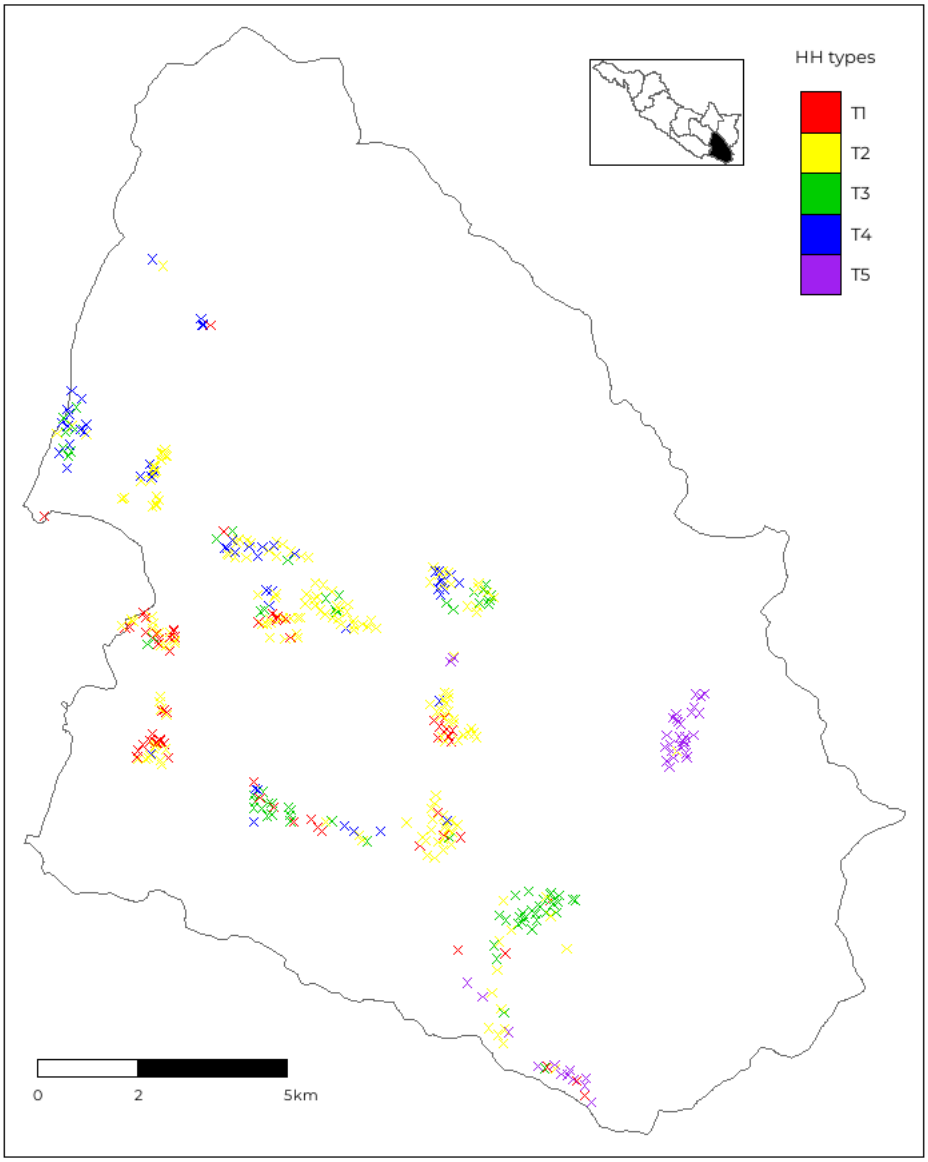

Figure 5.1 Farm type distribution across the survey locations in Surkhet district, Nepal. **T1-** Smallholder Intensive Rice-Wheat Farm household; **T2-**Small-Scale Intensive mixed crop-livestock farm householders; **T3-**Diversified farm households with off-farm and livestock driven income; **T4-**Marginal micro-farms reliant on non-farm income, and; **T5-**High-Altitude and remote livestock and off-farm income-based households.

Table 5.4 Bonferroni test result to show significant differences between farm type definitory variables.

Variable	T1	T2	T3	T4	T5
Altitude	bc	c	b	bc	a
Number of HH plots	a	b	a	c	bc
Surface (declared)	a	c	b	d	a
Land occupancy	b	c	a	c	ab
Land availability by hh habitants	a	bc	b	c	a
Land availability by TLU score	a	b	b	ab	b
Main plot surface	a	c	b	c	a
Times grass planted for cattle	b	b	a	a	b
Diversity for animals	a	b	a	ab	a
Seed input usage	a	b	b	c	b
Manure input usage	a	b	b	b	b
Chemical fertilizers usage	a	c	b	d	d
TLU for shoat (sheep+goats)	a	b	b	c	a
TLU all animals	b	c	ab	d	a
Homestead diversity all crops	b	c	a	ab	c
Total homestead production (matter)	b	c	a	b	c
Self-consume of homestead production	b	b	a	a	b
Income from livestock	bc	b	a	c	ab
Income from crops	a	b	a	b	b
Other services or sources-commerce	b	b	b	a	b
Farm products into off farm activities (leasing land, animals, crops)	c	c	b	d	a
Share of land dedicated to lentil	ab	ab	a	bc	c
Share of land dedicated to ashare rice	a	b	a	bc	c
Share of land dedicated to wheat	a	ab	c	bc	a
Share of land dedicated to other crops	bc	c	ab	a	abc
Irrigated crops selected average	b	c	a	b	d
Maize surface in monsoon	b	c	bc	bc	a
Rice surface in monsoon	a	b	a	b	b
Wheat surface in winter	a	cd	bc	d	ab

Note: each variable compares the media's types assigning a letter, in which similar letters imply no-statistical difference between types. The green colour highlights statistical difference between types.

Table 5.5 Chi-square test for variables.

Variable	Chisq	Df	p.chisq
Altitude	112.71	4	0.000
Number of HH plots	50.84	4	0.000
Surface (declared)	161.27	4	0.000
Land occupancy	97.49	4	0.000
Land availability by hh habitants	109.30	4	0.000
Land availability by TLU score	23.92	4	0.000
Main plot surface	131.06	4	0.000
Times grass planted for cattle	116.63	4	0.000
Diversity for animals	39.14	4	0.000
Seed input usage	134.27	4	0.000
Manure input usage	54.81	4	0.000
Chemical fertilizers usage	126.03	4	0.000
TLU for shoat (sheep+goats)	65.14	4	0.000
TLU all animals	104.24	4	0.000
Homestead diversity all crops	113.18	4	0.000
Total homestead production (matter)	78.23	4	0.000
Self-consume of homestead production	78.81	4	0.000
Income from livestock	51.34	4	0.000
Income from crops	99.50	4	0.000
Other services or sources-commerce	156.18	4	0.000
Farm products into off farm activities (leasing land, animals, crops)	118.78	4	0.000
Share of land dedicated to lentil	27.41	4	0.000
Share of land dedicated to ashare rice	81.90	4	0.000
Share of land dedicated to wheat	51.41	4	0.000
Share of land dedicated to other crops	41.22	4	0.000
Irrigated crops selected average	129.33	4	0.000
Maize surface in monsoon	70.27	4	0.000
Rice surface in monsoon	168.67	4	0.000
Wheat surface in winter	81.82	4	0.000

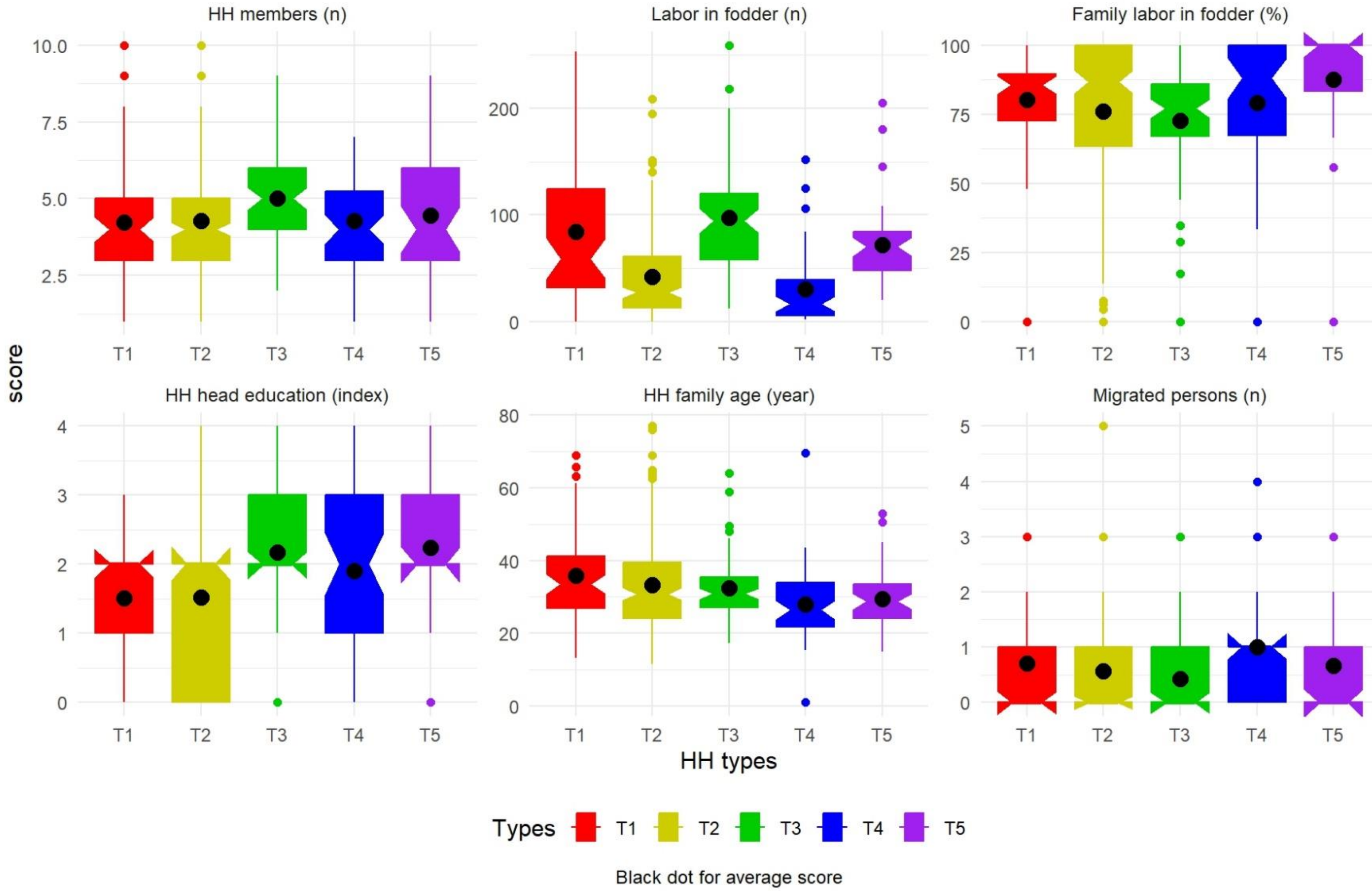

Figure 5.2 Family characteristics, Nepal, Surkhet.

Note: for 'HH head education: informal, 1; informal with read skills, 3; elementary, 6; secondary, 9; college or above, 16'.

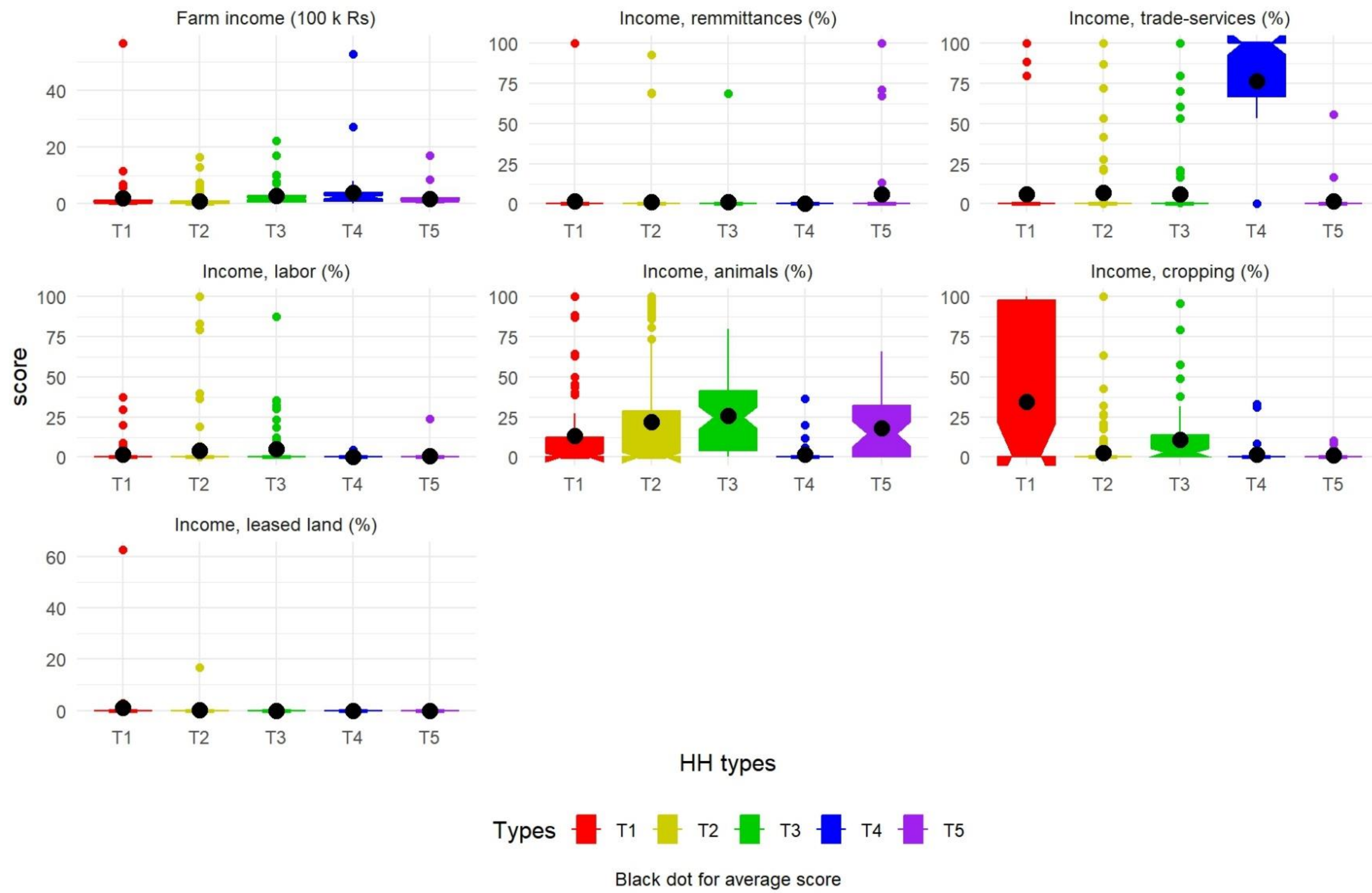

Figure 5.3 Income characteristics, Nepal, Surkhet.

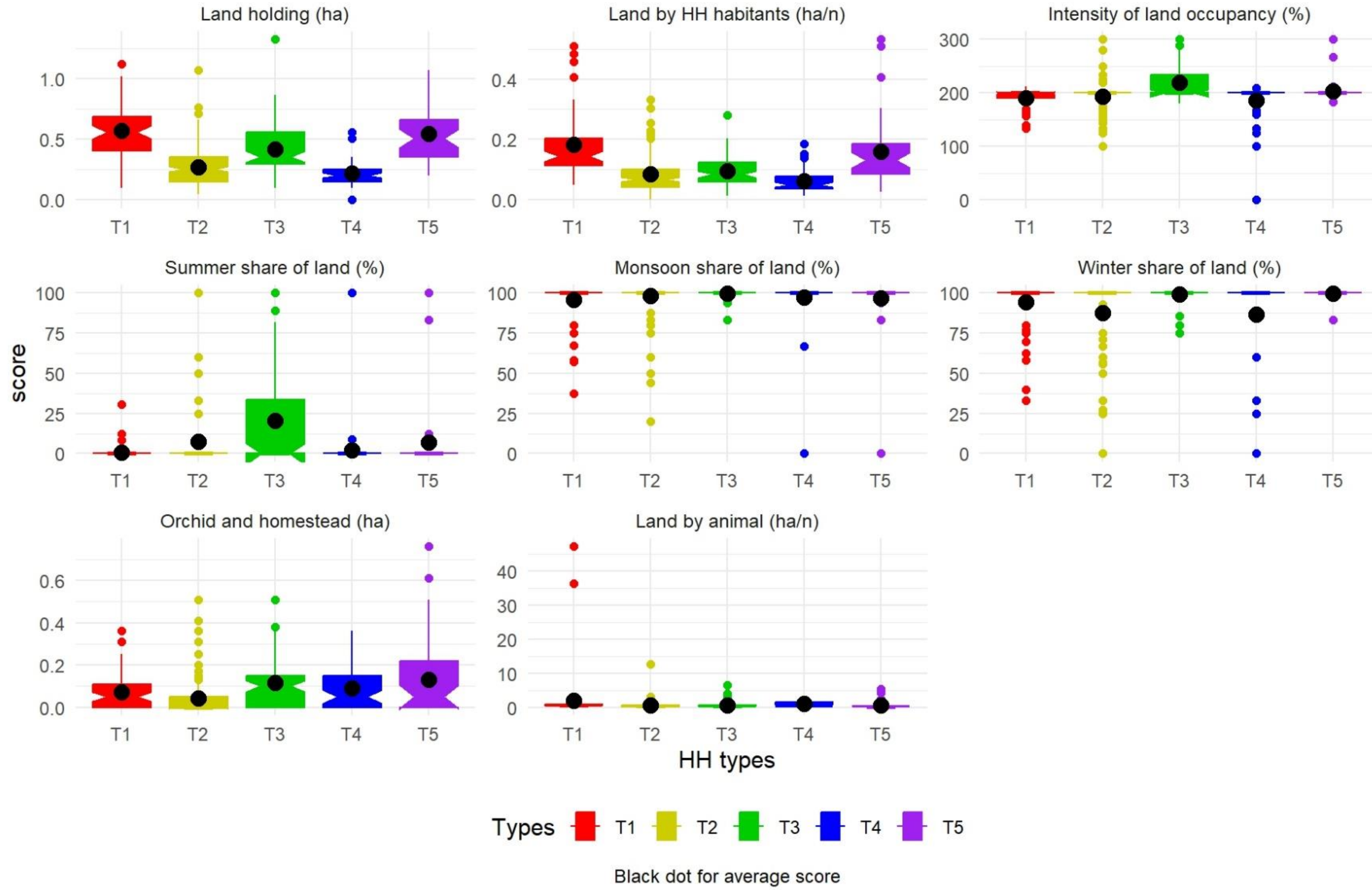

Figure 5.4 Land characteristics, Nepal, Surkhet.

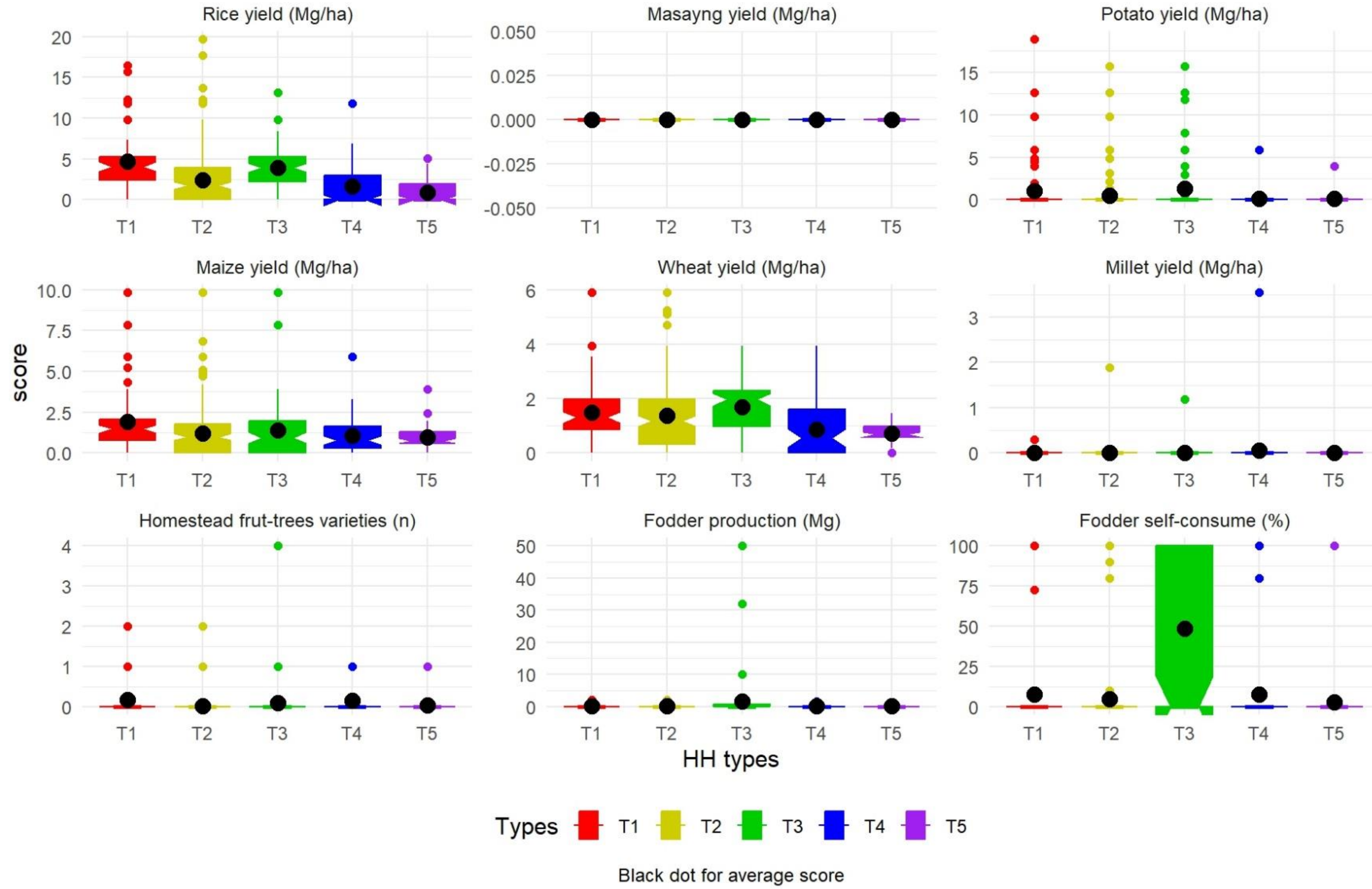

Figure 5.5 Production characteristics, Nepal, Surkhet.

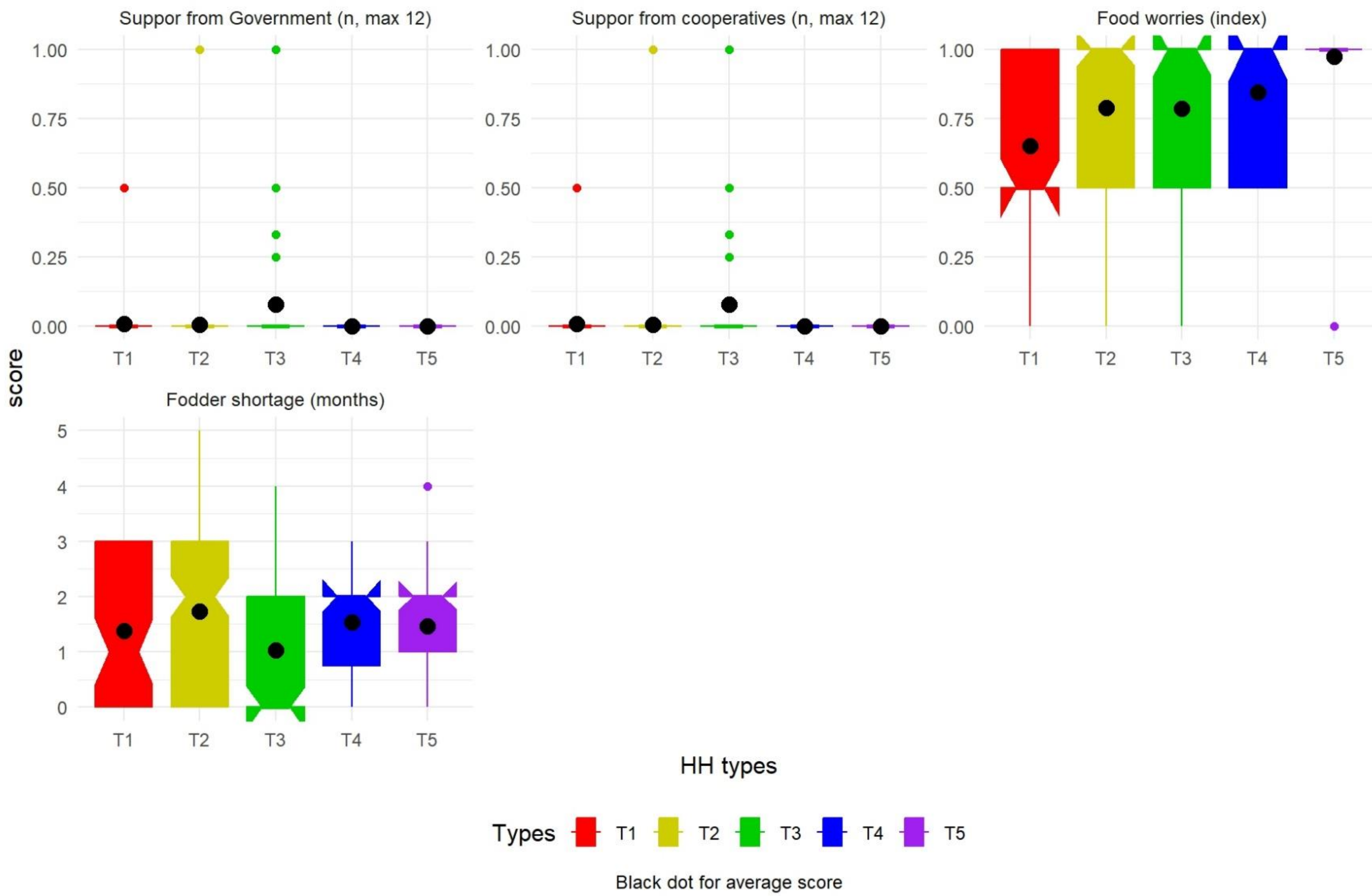

Figure 5.6 Resilience characteristics, Nepal, Surkhet.

Note: for ‘Food worries’: never, 0; sometimes, 0.5; often, 1.

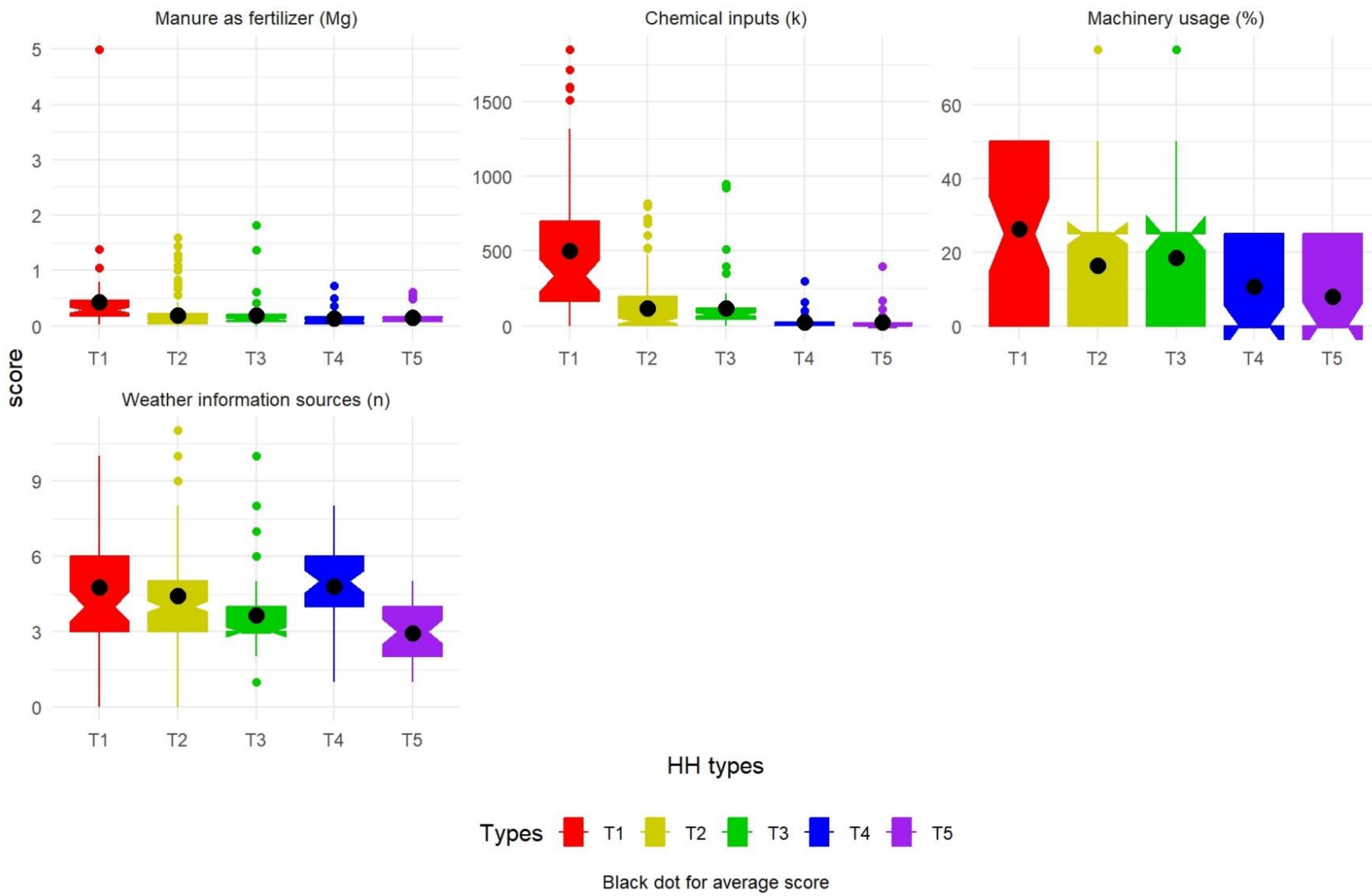

Figure 5.7 System characteristics, Nepal, Surkhet.

cgiar.org/initiative/mixed-farming-systems

cgiar.org/initiative/transforming-agrifood-systems-in-south-asia-tafssa/