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A Proposed Typology of Farming Systems for Assessing Sustainable Livelihood Development Pathways in the Tien Shan Mountains of Kyrgyzstan

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Abstract: In Kyrgyzstan, most farming systems focus on animal husbandry, which depends on mixtures of crops and pastures around settlements and higher-elevation summer pastures. These farms face the problems of insufficient fodder production and pasture degradation due to overgrazing, resulting in low productivity of livestock and reduced household incomes. The spatial diversity of farms often hampers the development of interventions aimed at improving crop and animal productivity, as well as sustainable grassland management, while the absence of a comprehensive and systematic classification system that effectively encompasses the diverse range of livelihood strategies within farming systems presents a significant obstacle to the advancement of initiatives promoting sustainable livelihoods. This study aimed to develop a consistent typology of smallholder farms in the Tien Shan using multivariate analysis. By analyzing data from 235 farm-households and evaluating key classification variables, we identified two distinct farming systems, upper mountain farms and lower mountain farms, based on socioeconomic and agro-ecological characteristics. Our typology considers elevation, grazing period, cultivated area, and off-farm income and better captures the diversity of farming activities and household income compared to current classification models. These findings will inform and tailor policies and interventions suitable for enhancing sustainable livelihoods in Kyrgyzstan's mountain farming systems.

Keywords: pasture degradation; grasslands; agropastoralism; transhumance; subsistence; cluster analysis; principal component analysis; Central Asia

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1. Introduction

In mountainous Kyrgyzstan, agricultural production takes place primarily on small family farms, which have been shaped by the political, social, and economic reforms that followed the collapse of the Soviet Union [1,2]. The breakup fragmented large state-owned agricultural enterprises that produced meat, wool products, and large-scale crops into more than 460,000 smallholder farms with an average size of two hectares [3–5]. While mountain agriculture in Kyrgyzstan has diverse characteristics due to different elevations, climatic regimes, and landscapes, extensive pastoral systems dominate the majority of highland areas [6,7]. These mountain pastoralists face various challenges to environmental and socioeconomic sustainability, putting both agricultural production and livelihoods at risk [8,9]. The rugged terrain increases vulnerability to climatic hazards, mudslides, landslides, and marginalization due to limited access to infrastructure, markets, and technology [10,11].

As more than 80% of the country's agricultural land consists of mountain pastures, smallholder farmers face additional sustainability challenges such as rangeland degradation and biodiversity loss, mainly due to overgrazing [12–15]. Various sources indicate that degraded pastures cover at least 30% of the country's mountain lands [16–21]. Satellite imagery further attributes this land degradation primarily to an increase in livestock numbers and unsustainable pasture use [22–25]. Current crop production in the midst of the challenging mountain climate results in insufficient quantities and diversity of crop species, which are mainly intended for animal fodder [6,15]. Insufficient fodder production due to increasing livestock numbers on smallholder farms, combined with poor pasture management, leads to further pressure on grazing lands. Inadequate nutrition further contributes to declining animal health, which affects the profitability of livestock production [26]. Limited household resources and management capacity have prevented farmers from expanding or diversifying both their farming practices and livelihoods throughout the three decades of the agricultural transition process [27].

Although the main contours of agricultural transformation have been captured in the literature, in-depth knowledge of the current functioning of mountainous farming systems and the socioeconomic context of smallholder livelihoods remains limited. Previous research has extensively documented the transformation process, focusing on the impact of land reform and resource management on the performance of emerging small farms [28–31]. Such studies relied on available statistical data from official sources to characterize farm types and production systems. As a result, the farm typologies were primarily based on farm size and land ownership and distinguished three main categories of farms: (a) household plots, (b) smallholder ('peasants') farms, and (c) large agricultural enterprises, cooperatives, agricultural stock companies, and state farms [32]. Household plots have no extensive arable land, with an average-size home garden being 0.12 ha and a herd of one livestock unit (livestock unit corresponds to one cattle, 0.80 horses or five sheep/goats), and are solely for subsistence. Despite their limited resources, they make up 34% of national agricultural production, being the most common type (≈800,000). In contrast, there are only a few large market-oriented agricultural enterprises with over 1000 ha; these are highly productive but contribute less than 1% of agricultural production. As a result, the majority of agricultural production (65%) comes from smallholder farms, with the farmers using most of the available arable land and pastures to support their livelihoods. While household plots and market-oriented enterprises are mostly homogeneous, grouping smallholder farms in one category is questionable. These smallholder farms focus primarily on livestock, with a particular emphasis on household subsistence, guided by a family-centered rationale. The strategy includes marketing surpluses to generate income to purchase goods not produced on the farm. Following the collapse of the Soviet regime, only a handful of farmers have expanded their operations, while the majority continue to operate with limited resources. Despite these challenges, smallholder farmers contribute significantly to the country's agricultural production and serve as critical links connecting rural areas to markets, fostering economic exchange, trade, and integration into broader economic systems [3].

A major shortcoming of the current system of farm typology in Kyrgyzstan is that it lacks socioeconomic and agro-ecological variables, which have been demonstrated to be essential for farm classification and exhibit specific farm characteristics in other countries [33,34]. Differences in the wide range of physical environments and agro-ecological zones are crucial because they directly influence the farming practices, resource availability, and ecological conditions unique to each region [35,36]. For instance, gently sloping lowlands and valleys with fertile soils benefit from well-developed irrigation systems. On the other hand, rainfed agriculture predominates in smaller areas of mountainous regions, with pastures located at higher elevations [37,38].

Other case studies on Kyrgyzstan's agricultural transition processes have established farm typologies based on resource capacities, including livestock numbers, non-farm activities, and farmers' livelihood strategies [27,39–41]. The latter include diverse activities such as agricultural practices, off-farm employment, and off-farm diversification aimed at generating income. While these studies emphasize the importance of including additional factors in farm typology, they tend to simplify classifications using discriminant analysis and focus on distinguishing between resource-rich and resource-poor farming systems.

Given the existing limitations of farm typologies in the country, our study addresses a critical gap in existing farm typologies by introducing robust numerical clustering for smallholder farm classification that includes a broader range of socioeconomic and agro-ecological variables. The inclusion of diverse variables improves the classification methodology and provides a more nuanced understanding of farm dynamics [42–46]. The study conducts an in-depth analysis of production systems, socioeconomic performance, and specific constraints and opportunities for each identified farm type [47,48]. This approach not only contributes to the literature, but also enhances the effectiveness of agricultural interventions and policies for sustainable pasture management and livelihood development among smallholder farmers in mountainous regions of Kyrgyzstan.

2. Methodology

2.1. Study Site Characteristics

Data were collected from four rural districts in the central Kyrgyz provinces of Chuy and Naryn. The altitude in these areas ranges from 500 to 6000 m above sea level. In order to specifically study the typology of mountain agropastoral systems in Chuy province, villages below 1500 m above sea level in the plains were excluded. Attention was focused on the mountainous areas of Kemin and Jaiyl districts, located between 1500 and 2400 m, which are characterized by predominant agropastoral systems. In Naryn province, all villages fall within the elevation range of 1500–2400 m, which led to the selection of Kochkor in the north and At-Bashy in the south. The study included fifty villages of varied sizes located in high mountain valleys between 1500 and 2400 m above sea level. In Kochkor and At-Bashy districts, 36 out of 39 villages were selected, and, in Kemin and Jaiyl districts, nine out of eleven villages were included. Highland valleys in the overall study areas are characterized by a semiarid steppe climate with warm summers (from 10 to 12 °C) and long, cold winters (from −22 to −8 °C) with a lower average annual precipitation of 200 to 300 mm [35]. In total, 24,000 families live in the study area (Figure 1), reflecting the most densely populated and cultivated areas in the mountainous regions of Kyrgyzstan.

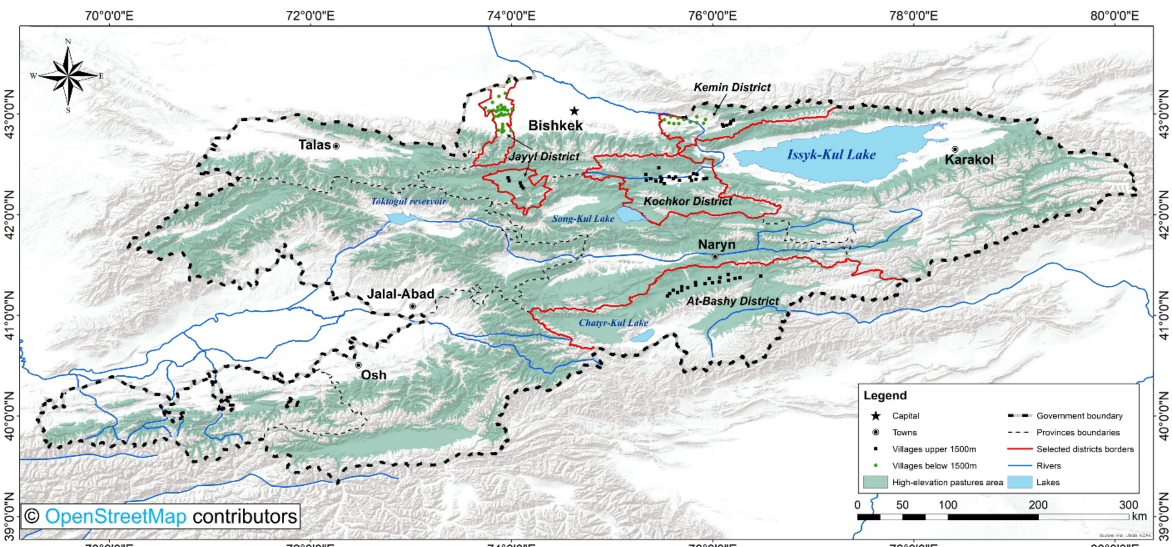

Figure 1. Study sites and selected villages located in four districts of Chuy and Naryn provinces of Kyrgyzstan.

2.2. Sampling and Data Collection

The sampling process excluded administrative centers and towns with populations of 8000–10,000 residents [49]. We used data collected in 2016, which represents a very appropriate sample to propose a new typology of smallholder mountain farming systems. Little has changed in recent years, and no new typology has been developed either. The early years of Kyrgyzstan's independence witnessed a significant transformation in the agricultural sector, with significant changes occurring in the first decade and a half. According to FAO and NSC reports [4,5], there has been a steady increase in the number of small farms. However, this numerical growth contrasts with the stagnation of the production systems within these farms, indicating a remarkable trend. The agricultural sector is moving towards greater fragmentation, mainly concentrated in rural households with limited production capacity. This pattern is particularly influenced by the absence of substantial government support, and a lack of investment in technology. This limited government involvement reflects Kyrgyzstan's classification as a low-income developing country [4]. As a result, the agricultural landscape reveals a complex interplay of economic factors and political choices, highlighting the need for a nuanced examination within the broader socioeconomic context.

In collaboration with local administrations, 235 randomly selected smallholder farmers were interviewed by the authors using a structured questionnaire on production systems, resource capacity, household income, off-farm activities, and remittances. To comply with statistical parameters, a narrower confidence interval of 90%, coupled with a margin of error of 6%, was established to ensure complete coverage of the population. Thus, farms in each district were selected based on an approximate proportion (2.0–2.2%) of the total population in each village. The decision to use a narrower confidence level was primarily motivated by the limited and resource-intensive data collection, especially considering the large size of the study area.

2.3. Data Analysis and Construction of a Farm Typology

Quantitative data collected from household surveys were processed and analyzed using the Statistical Package for Social Sciences (SPSS) version 21 (Armonk, NY, USA). Variables related to farm typology were classified to explore the diversity of smallholder farms in the study sites through multivariate analysis: (1) agro-ecological and socioeconomic, (2) land use, (3) labor, (4) livestock capacity, (5) production inputs, and (6) production methods. Data examination using box plots indicated positive skewness due to outliers at the 90th percentile of land holdings greater than 30 ha and livestock holdings greater than 40 livestock units. These outliers were discarded to improve the multivariate analysis and its generalization to the entire population. Out of the 235 households surveyed, two households had extremely large herds and cultivated areas and were therefore excluded from further data analysis.

Two multivariate techniques (principal component analysis (PCA) and cluster analysis) were used sequentially to generate a typology of the farms [50–54]. PCA was performed on standardized variables to condense all the information from the original interrelated variables into a smaller set of factors called principal components (PCs). The Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy and the Bartlett test of sphericity were performed out to check the suitability of the data for PCA evaluation (KMO value 0.6 absolute minimum). Factors were rotated using the orthogonal Varimax method to subsume the correlated variables into a respective PC, making the loadings more pronounced and revealing a simple structuring of the variables into theoretically meaningful subdimensions. PCs were selected based on the eigenvalue ($\geq$1) criterion and explained by the collective variables [55]. Furthermore, correlated variables within a PC were represented by the variable with the highest loading coefficient [45].

Finally, correlation analysis was performed using Pearson's correlation coefficient to evaluate the relationship between the selected variables and to eliminate one of the two strongly related variables to avoid double weighting of factors [56]. The variable with the largest standard deviation was selected for further analysis [42]. In the next step, the farms were grouped using agglomerative hierarchical cluster analysis based on four variables identified by PCA and Pearson's correlation matrix (see Supplementary Materials). Ward's method and Euclidean squared distance were used as metrics to establish clusters [57]. An independent *t*-test was used to compare the means of two independent groups to determine whether there were statistical differences. We then conducted a comparative analysis of household income, which consists of farm income and off-farm activities, to evaluate the economic performance of identified farm types. Farm income includes a variety of sources, including crop and livestock production systems, beekeeping, processing and sale of dairy products, and surplus produce from home gardens; in addition, some families earn income through service provision, using farm machinery (e.g., tractors) and providing herding services.

3. Results

3.1. Farming Systems Overview

Discussions with local government officials and farmers revealed that approximately 90% of the agricultural land in the study area relies on highland and nearby settlements for fodder. These sources are intensively used in the spring and fall, resulting in significant degradation from trampling and soil compaction due to insufficient winter forage. As livestock numbers increase, pressure on pastures escalates.

Livestock is the main economic activity and the main source of income for smallholder farmers. The average herd size is 16.3 livestock units and consists of almost equal numbers of fat-tailed sheep, local cattle, and horse breeds suitable for meat production. Most farmers use the services of professional herders whose grazing practices are based on the transhumance system. Each village has several dozen family herders who, after collecting all the livestock from the villagers, move to remote highland summer pastures ("jailoo" in the Kyrgyz language) and remain there throughout the summer. During the rest of the year, livestock graze on pastures, meadows, and arable land near settlements and are additionally fed with produced or purchased winter fodder. Animals often lose considerable weight during the winter due to lack of feed.

On average, farmers own 5.3 ha, half of which is non-irrigated (meadows). Most of the cultivated land is used to grow grass, fodder legumes for hay, and fodder cereals, mostly barley and, very rarely, oats. Potatoes, wheat, and vegetables are grown on smaller plots, mostly in kitchen gardens for home consumption. Farmers often use contractors for plowing and harvesting as few farmers own adequate machinery. Little fertilizer is used.

Income from off-farm activities contributes significantly to the total family income. Opportunities for off-farm employment and business are generally low; some farmers derive a large part of their income from off-farm sources. Pensions and salaries from public institutions account, on average, for more than half of total off-farm income. There is also seasonal internal migration (mostly in summer) to nearby larger towns. It is noteworthy that remittances from Russia, Kazakhstan, and other countries contribute a relatively small amount (12%) to total off-farm income, but their importance has increased in recent years. Markets are available in the district capitals, including the two largest livestock markets in Central Asia, where farmers sell mainly livestock and crop products. The average distance to markets ranges from 40 to 115 km, which creates some difficulties for more remote villages and increases the cost of transporting agricultural produce to market.

Table 1 presents eighteen classification variables selected to represent agro-ecological conditions, the resource base and use of farm households, agricultural production systems, and off-farm activities. These variables show significant variation, which is essential for a satisfactory classification of farm populations.

The PCA analysis (KMO = 0.668 and BTS $\leq$ 0.01) generated 18 PCs, out of which five PCs with eigenvalues >1, accounting for 64.4% of the variability, were selected. The first PC explains 20.4% of the data variability, while the second and third PCs explain 14.9% and 10.2%, respectively. The fourth and fifth components explain 7.6% and 6.3% of the variance, respectively. The PCs were characterized according to the loading factors within each PC. PC 1 includes variables related to livestock production, i.e., herd size, number of horses, cattle, and sheep. The second PC includes variables related to crop production (cultivated area, fodder, and fallow land). The third PC includes a combination of variables such as elevation, which influences crop yield, the size of irrigated area, and the use of fertilizers. The fourth PC covers livestock production, but refers to local livestock management practices, including the grazing period. The fifth PC includes non-agricultural sources of income, such as total off-farm income and remittances (Table 2).

Table 1. Descriptive statistics for focused farms (n = 233).

Variable	Mean	SD	Min	Max	Median
Agro-ecology and socioeconomic					
Elevation of village (m a.s.l.)	1910	211	1600	2300.0	2000
Remittances (USD)	261	811	0.00	6276	250.0
Off-farm income (USD)	2249	2060	0.00	14,811	1882
Farm income (USD)	3797	4154	0.00	26,008	2510
Land use	4.90	2.93	0.00	16.60	4.50
Fallow (ha)	1.41	4.15	0.00	27.00	0.00
Cultivated area (ha)	5.32	5.08	0.00	30.00	4.08
Irrigated area (ha)	2.45	2.66	0.00	16.50	2.00
Labor					
Length of grazing (hired herder) (months)	5.87	0.88	3.50	7.70	5.60
Grazing period (months)	7.83	1.38	4.00	11.00	8.00
Livestock capacity and production methods					
Herd size (livestock units)	16.30	8.94	1.10	42.20	14.20
Horses (heads)	5.30	4.83	0.00	31.00	4.40
Sheep (heads)	3.80	4.04	0.00	36.00	4.80
Cattle (heads)	4.90	2.93	0.00	16.60	4.50
Fattened-up livestock (heads)	1.05	1.89	0.00	14.45	1.00
Production inputs and methods (crops)					
Fodder (grain) (t)	2.34	4.22	0.00	30.00	1.20
Fodder (hay) (kg)	690	751	0.00	8695	751
Usage of fertilizer (kg/ha)	20.40	73.25	0.00	500.0	0.00
Barley yield (t/ha)	1.26	1.35	0.00	6.00	1.05

Correlation was tested for five classification variables obtained from the PCA. For "cultivated area" and "herd size", a positive relationship (r = 0.70) was obtained. Therefore, the variable "cultivated area" was selected (see non-collinear variables in Supplementary Materials). Hierarchical clustering based on Ward's method was used to group similar farms. Figure 2 displays the dendrogram showing the range of cluster solutions resulting from Ward's method. The dotted line shows the cut-off point, which indicates a two-cluster solution. The 'Height' shows the agglomeration coefficient or distance between the clusters merged at each step.

Table 2. Rotated component matrix of classification variables with factor loadings grouped into five principal components (n = 233).

	Principal Component				
	1	2	3	4	5
Herd size	0.932				
Horses	0.795				
Farm income	0.699				
Sheep	0.672				
Cattle	0.659				
Fattened-up livestock	0.545				

Table 2. *Cont.*

	Principal Component				
	1	**2**	**3**	**4**	**5**
Cultivated area		0.883			
Fodder (grain)		0.824			
Fodder (hay)		0.623			
Fallow		0.548			
Usage of fertilizer			0.693		
Elevation of village			–0.647		
Irrigated area			0.624		
Barley yield		0.521	0.584		
Grazing period				0.904	
Length of grazing (hired herder)				0.901	
Remittances					0.843
Off-farm income					0.806

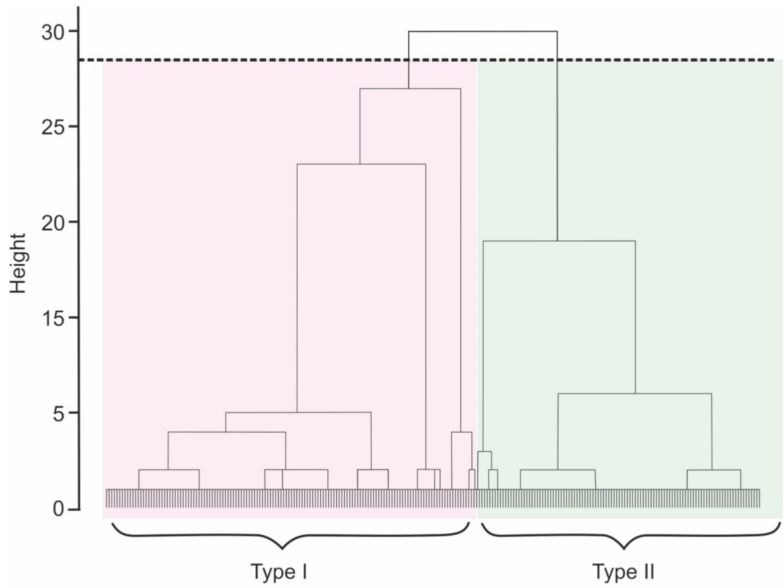

Figure 2. Dendrogram showing the range of cluster solutions resulting from Ward's method. The dashed line represents the cutoff point, which denotes a two-cluster solution: pink—Cluster I and green—Cluster II. The term 'Height' shows the distance between the merged clusters at each step.

Two main clusters of farming systems can be distinguished based on a distinct set of variables derived from PCA and correlation analysis:

- Cluster I: Upper mountain farms (UMF) located in high-elevation mountains between 2000 and 2400 m above sea level, mainly based on livestock and fodder production and characterized by a reduced grazing period and a low off-farm income;
- Cluster II: Lower mountain farms (LMF) located in medium-elevation mountain ranges between 1500 and 2000 m above sea level, based on livestock production fodder and other crops and characterized by a longer grazing period and a low off-farm income;
- Figure 3 shows the locations and distribution of the upper mountain farms located between 1500 and 2000 m a.s.l. in Kochkor and Kemin districts (red dots) and the lower mountain farms located above 2000 m a.s.l. in Suusmayr, At-Bashy, and Kochkor districts (green dots).

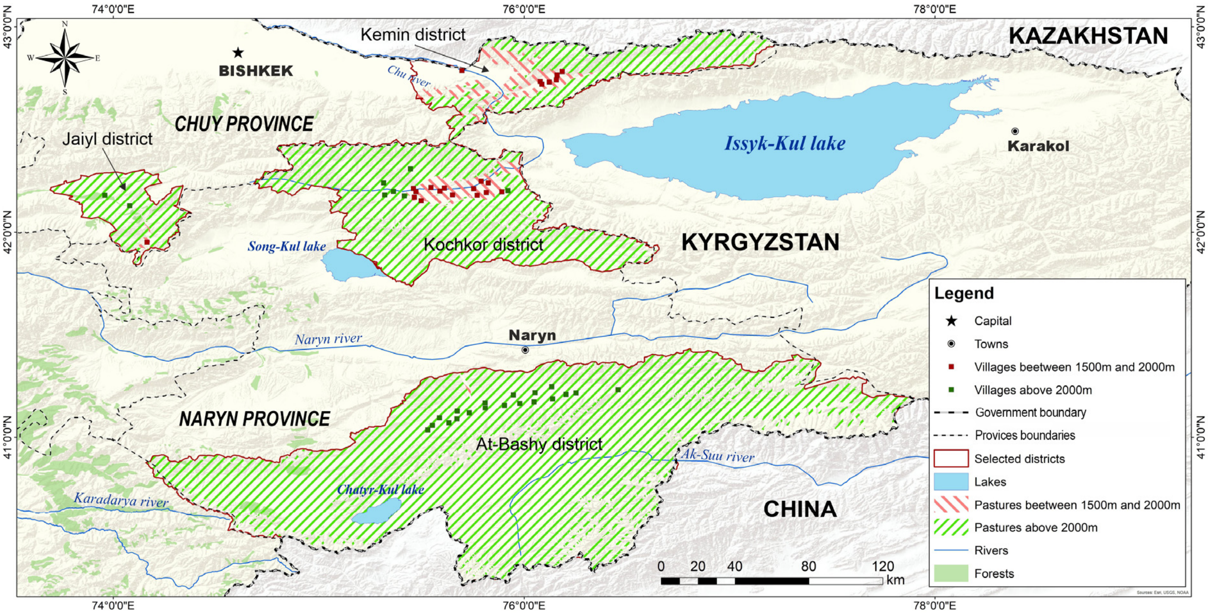

Figure 3. Distribution of the classified farming systems across central Tien Shan mountains.

3.2. Type I: Upper Mountain Farms (UMF)

UMF are the largest cluster, representing 54% of the farms surveyed. Livestock production is the most common economic activity and the main source of income (Table 3). The total herd size averages 16.4 livestock units, including roughly equal numbers of sheep/goats (35%), horses (30%), and cattle (31%). Farmers keep a small number of other animals such as yak (3%) and poultry (0.05%).

The average grazing period is 7.2 months due to environmental constraints during the cold season. Most farmers use the services of seasonal professional herders who stay on the high pastures one month less than the average total grazing period. Farmers generally try to keep their animals on pasture or cropland, when possible, to minimize the amount of feed needed for on-farm animals during the winter. Most farmers purchase supplemental feed during the winter or early spring due to a shortage of home-prepared winter feed and a lack of available pasture, highlighting the difficulties during this period.

On average, farmers have 8.4 ha of arable land. The proportion of non-irrigated land is 75%, contributing to the low productivity of agricultural land at higher elevations. About 2.5 hectares of fallow land was recorded per farm-household, mostly due to low fertility or remote locations and limited access to agricultural machinery. Farmers in some villages complained about the need to rehabilitate irrigation canals and the unreliability of water supplies from the mountains. Fodder crops account for the largest share of the cropland. Nearly 97% of the actual cultivated land (both irrigated and rainfed) is used to grow grass (47%), and sainfoin for hay making (27%), and fodder cereals, mostly represented by barley (22.5%). Potatoes, wheat, and vegetables are grown on the remaining land. Vegetables are mainly grown in home gardens for household consumption. Most of the non-irrigated land consists of rainfed lands or meadows with natural grasses used for hay production. On the irrigated land, legumes are typically grown, along with sainfoin and insignificant amounts of alfalfa. Sainfoin is a major crop on almost half of the farms, and its area has increased due to a proportional reduction of wheat, barley, and other crops in recent years. This increase has been driven by the high profitability of sainfoin cultivation due to low labor requirements (including minimal soil tillage) and the lack of harvesting equipment for cereals such as wheat or barley. Low yields and profitability of cereals continue to limit their cultivation. Wheat is mainly used for household consumption, while straw is fed to animals in winter. Barley is the most important crop, especially for concentrated animal feed and for its role in crop rotation.

Table 3. Farm and household characteristics of both farming systems (n = 233).

Variable	Unit of Measurement	Farming System Type	
		Upper Mountain (n = 125)	Lower Mountain (n = 108)
Elevation of village, location *	m a.s.l.	2200	1700
Grazing period *	month	7.2	8.5
Length of grazing (hired herder)	month	6.3	5.5
Herd size	livestock unit	16.4	16.2
Herd composition:			
Cattle	%	31	30
Sheep/Goat	%	35	34
Horses	%	30	35
Yak	%	3	<1
Poultry	%	1	<1
Farm size:	ha	8.4	4.9
Cultivated land *	ha	5.9	4.7
out of which irrigated land	ha	1.3	3.8
Uncultivated land	ha	2.5	0.2
Land use system:			
Meadows	%	47	17
Legumes for fodder	%	27	38
Barley	%	23	23
Wheat	%	<1	10
Potatoes	%	2	8
Other crops	%	<1	4
Farm income	USD	4430	6111
Farm income sources:			
Livestock	%	49	38
Crops	%	40	52
Other	%	11	10
Proportion of market sales in farm:			
Share of total farm product sales	%	26.5	35.2
Share of sales in livestock production	%	35.7	33.2
Share of market sales in crop production	%	17.3	37.2
Off-farm income *	USD	1933	2616
Off-farm income sources			
Public sector	%	18	25
Pensions	%	55	42
Business/employment	%	16	17
Remittances	%	11	16
Household income		6363	8727

* Variables of the final classification.

Livestock account for the largest portion of farm income, contributing about 49% compared to 40% from crops. Livestock sales are twice as large as crop sales, although the latter tends to fluctuate more. Notably, crops are grown for farmers' own animals, but farmers reported selling hay and other crops, including grain, to contractors immediately after harvesting due to cash shortages. This highlights the dependence of farmers on livestock sales, while the number of agricultural products sold to the market varies considerably among farm households. Additional farm income is generated from services provided by farm machinery (e.g., tractors) or herding services, beekeeping, processing, and sale of dairy products and crops, which account for 11% of farm income. Together, all sources of farm income account for 70% of household income.

A substantial share of the household income is derived from off-farm activities, averaging 30% of total household income. Pensions and salaries from public institutions account for more than 73% of the total off-farm income, followed by employment/private business (16%) and remittances (11%), reflecting poor access to off-farm employment and business opportunities. It is noteworthy that remittances have not contributed significantly to off-farm income, but their role has been growing in recent years. Remittances are mainly from Russia and less frequently from other far-abroad countries.

3.3. Type II: Lower Mountain Farms

The average total herd size and structure in this cluster are similar to those of the UMF, except that LMF farmers keep more horses (35% of total herd size) because they require less labor and feed in winter. Horses graze for up to twelve months and do not require the presence of a herder. Farmers achieve slightly higher milk (mostly dairy cows) and meat yields because animals are in better condition at these lower elevations due to more abundant forage. LMF animals graze significantly longer, averaging 8.5 months, and animals suffer from feed shortages during the winter months, but to a lesser extent than UMF animals.

LMF farmers have an average of 4.9 hectares of arable land and 0.2 hectares of fallow land, significantly less than UMF farmers. On average, 80% of the cultivated land is irrigated, while the rainfed land is mostly meadow. Farmers produce a wider variety of crops, but most of the cropland is used for hay (50%) and feed grains, especially barley (23%). Wheat (10%), potatoes (8%), and cash crops, such as sugar beets and haricot beans, are also important. Crop yields are higher than in UMF due to favorable climatic conditions and better irrigation infrastructure (allowing two, very rarely three, harvests per year), accompanied by slightly increased use of chemical fertilizers. In contrast to UMF, vegetables and fruits grown in home gardens are mostly sold in local markets.

LMF farmers generate more income from livestock sales due to better market access and more intensive feeding. Despite a longer grazing period, average feed costs per livestock unit are higher because of the use of high-quality feeds (hay and concentrates). Similar to those on UMF, some farmers within the groups do not rely on additional sources of farm income (10%), while others are highly dependent and derive a significant portion of their income from beekeeping, herding and contracting services, and milk processing.

Pensions and salaries from public institutions are also an important source of household income for LMF farmers. Although LMF show a higher degree of market orientation (35.2%) compared to UMF, subsistence production continues to dominate. Crop production contributes significantly more to total farm income, despite the higher productivity of animal production.

Household income is one-third higher in LMF than in UMF (USD 8726 and USD 6363, respectively), reflecting better farming conditions, access to quality inputs, and off-farm opportunities.

4. Discussion

The official delineation of smallholder farms on the basis of size and legal status alone, without considering additional socioeconomic and agro-ecological parameters, neglects the diversity of smallholder farms [27,41]. While our theoretical classification approach using multivariate statistical methods to identify farm types is not new, it is a fundamental step in describing the socioeconomic conditions of farmers [48].

Our descriptive statistics reveal significant discrepancies with the official data on smallholder farms, especially in key variables such as the size of cultivated land. According to the NSC [5], the average size of smallholder farms is 2–3 ha, while our system shows averages of 5.3 ha in agropastoral areas and 0–0.12 ha in silvopastoral areas. Similarly, the official figures indicate an average of three livestock units per smallholder farm [5], while, in our system, the values range from 4.5 to 16.3 livestock units. Discrepancies are also observed in the distribution of cultivated crops; in agropastoral farms, fodder crops predominate, in contrast to the dominance of cereals (wheat) in the official statistics [4,5]. In addition, our analysis includes detailed insights into cropping and livestock systems, labor inputs, and economic performance, which are essential to classify farms with different means of production [58]. The inclusion of agro-ecological parameters influenced by climate, topography, and land cover [59] further contributes to a nuanced division of farming systems, as evidenced by the "village elevation". Importantly, our results highlight the substantial contribution of off-farm activities to family income, an aspect overlooked in the official delineations of smallholder farms. By integrating off-farm and non-farm activities, we aim to comprehensively understand their roles and interactions, in line with similar farm typology studies [54,60,61].

For a better understanding of the diverse social, technological, and economic characteristics of mountain farms and their agro-ecological environment, we have classified farming systems using internal criteria such as the size of the farm and livestock systems and external factors such as elevation and off-farm income. Similar to other studies that have focused on developing typologies for livestock and mixed farming systems, our research considers the production and resource base of farms, including factors such as farm size, livestock numbers, grazing systems, and crop production. This consideration is crucial, as farm system management and production decisions play an important role in influencing both farm economics and environmental impacts [62–66]. Furthermore, the specific characteristics of livestock and mixed farming systems are determined by specific opportunities and constraints, which, in turn, are shaped by various factors beyond the farm-household scale, such as agro-ecological, elevation, climate, and soil characteristics [43,61,67].

While typologies are usually relevant within their development context, comparative categorization methods offer opportunities for their further development [48]. In mountainous regions of developing countries, smallholder farmers dominate livestock-based farming systems and have diverse livelihood strategies. This highlights the need to consider local context and diversity when developing interventions and policies to improve agricultural productivity and livelihoods in mountain areas [68]. Furthermore, there are similarities in the challenges faced by mountainous regions, particularly in Central Asia, including difficult terrain, long distances to markets, seasonal feed shortages, severe winters, and degradation of natural resources (pastures, forests) due to unsustainable management.

These challenges are also present in other mountainous regions of Central Asia [6,69–71], northwestern China [72], the northern Pakistani Hindu Kush Himalayas and Nepal [73–75], African highlands [76–78], and South American highlands [79,80]. In these studies, typical criteria for classifying small agropastoral systems in mountainous areas, in addition to farm size (including pasture and herd size), include elevation and agro-ecological conditions. For example, in arid and semiarid regions such as Pakistan, India, China, Nepal, and African countries, farms at higher elevations prioritize livestock production on extensive rangelands, emphasizing it as the primary livelihood strategy in highland conditions. In the mid-highlands, a mixed farming system prevails, with livestock and crop production as the main sources of income. At lower elevations, irrigated crop production becomes more important and animal husbandry becomes less important [81]. In the agropastoral systems we studied, this trend is clear to see; LMF operate more intensively and productively on arable land with improved irrigation practices, allowing for increased fodder production. They also grow a more diverse range of crops than UMF, highlighting the influence of agro-ecological conditions on farming practices.

Farm categorization in developed European mountain livestock systems often aims to refine existing typologies and provide a detailed description of farming activities and changes at farm level [82,83]. These studies include quantitative variables such as farm size, herd size, and animal specialization, including sheep, goats, and dairy cow specialization. Variables indicating the availability of different animal species are also commonly used [84–87]. In the proposed typology, a similar approach is possible, with clusters specializing in individual animals or intensive crop production. The typology of farming systems and subsequent analysis identify distinct categories of smallholder farms with different means of production and varying degrees of involvement in achieving livelihood goals. This insight into the social, technical, and economic context enables tailored recommendations to address specific issues and guide development trajectories [58].

Given the importance of livestock in UMF for both subsistence and financial security [88], ensuring an adequate supply of fodder is crucial. To increase fodder yields, support is needed to improve irrigation facilities, develop road infrastructure in remote areas (fallow), and engage agricultural contractors. At the production level, farmers should adapt farm management by increasing the use of productive inputs such as fertilizer, expanding the cultivation of legume fodder, using better quality seeds, adopting more efficient cultivation techniques, and improving irrigation systems. For instance, WOCAT (World Overview of Conservation Approaches and Technologies) has introduced and disseminated sainfoin cultivation practices in the highlands through demonstration studies. Improved and low-input cultivation practices have resulted in higher yields. Sustainable approaches are crucial as livestock numbers increase across the country [89], leading to pressure on pastures through issues such as overgrazing [90]. Small investments are particularly important as they are manageable for smallholder farmers who can only afford such adaptations. In addition, increased fodder stock allows farmers to keep animals indoors longer and prevents pasture degradation, especially during the wet early spring [26,91].

LMF, which are smaller but more mechanized (i.e., have easy access to contractors' services) than UMF, integrate livestock and crop production, focusing on income-generating fodder and diversified crops [92,93]. LMF also achieve significantly higher land productivity. Leveraging advantages such as irrigation, a warmer climate, fertile soils, and improved infrastructure, farms can expand cash crops including horticulture areas to increase production and support food security. Analysis shows that crop production is more profitable than livestock, highlighting the need for extension services to help farmers balance the benefits and costs of both. Substantial livestock production among LMF, together with insufficient fodder supply, also forces farmers to use pastures intensively in spring, which highlights the need for sustainable fodder strategies. The expansion of legume crops such as lucerne alone is not sufficient to provide feed for LMF. Silage production is currently neglected, but silage crops could offer a solution, with community silage production as a potential option [94]. Meeting the demand for fodder and cash crops can provide incentives for diversification or specialization, reducing reliance on subsistence production.

Our classification approach is not without limitations. Although early attempts at cluster analysis suggested a three-category division using a slightly different set of classification variables, resulting in a division of farms into three categories of resource rich, medium resource, and poor, we considered such a categorization simplistic and independent of multivariate analysis. Ultimately, our study characterized two types, supported by significant differences revealed by *t*-tests (see Supplementary Materials). This nuanced classification, which emphasizes differences in resource endowments and farm production systems, provides tailored recommendations for agricultural improvement. We found that resource-rich, medium-resource, and poor farms differ significantly. In contrast to official categorizations, our approach provides a more detailed understanding of smallholder farms. While the survey data were collected in 2016, Kyrgyzstan's status as a developing country and the continued socio-environmental stability in rural mountain areas support the relevance of these data. Recent official statistics, including FAO reports [4], indicate minimal changes in production in recent years, confirming the relevance of the study. Despite such limitations, the uniqueness of our study lies in the unprecedented collection of data before and after 2016. It provides a comprehensive picture of production systems and household economic outcomes, includes interviews with livestock and crop farmers, and includes off-farm income and resource bases. Thus, we affirm that our study provides valuable insights into the evolution of smallholder agropastoral households following the Soviet collapse.

5. Conclusions

This study aimed to fill the current gap in the typological delineation of farming systems in Kyrgyzstan, recognizing that similar gaps also exist in many mountain farming systems worldwide. The multivariate classification methodology developed in this study offers clear advantages over typologies based on farm size and legal status, which do not consider the diversity among size classes and ignore the agro-ecological conditions as well as the socioeconomic situation of the farms. The methodology we used can be modified for different farm typology conditions, for example, by using different variables depending on the classification objectives. Our results suggest that two primary farm types have emerged in Kyrgyzstan's mountain areas, providing a basis for differentiating planning and extension intervention strategies to sustainably improve farm livelihoods. These are upper mountain farms (UMF), located at altitudes between 2000 and 2400 m above sea level, which focus primarily on livestock and fodder production. UMF are characterized by shorter grazing seasons and lower off-farm incomes. Lower mountain farms (LMF), located at mid-elevations between 1500 and 2000 m above sea level, are based on livestock, forage, and other crops. LMF are characterized by a longer grazing season and lower off-farm income. Although the agricultural production system of both identified farming systems can be characterized as low input low output, there is a clear difference between them. The altitude of the villages has a significant impact on the farmers, creating a clear divide between those in lower and higher zones. In the lower zones, with better access to off-farm activities and longer growing seasons, farmers have higher productivity, increased crop income, and improved food security. Their easy access to markets and technology, supported by strong infrastructure, boosts their agricultural efforts. Livestock also benefit, with increased productivity and minimal winter problems.

Challenges arise in higher regions. The shorter growing season and harsh climate limit farmers to a few crops and a short grazing season. Livestock face problems due to insufficient winter fodder, resulting in health problems and low income from livestock production. Located in remote and inaccessible places, farmers in these areas face geographic isolation and inadequate infrastructure, which affects their access to knowledge and technology.

To improve livelihoods in each cluster, we recommend tailored interventions that address specific challenges and leverage opportunities in each altitude zone. This focused approach ensures that the solutions provided are tailored to the unique realities of farmers in different topographical areas.

Based on our results, policy recommendations for improving smallholder farming systems in mountain areas include:

- Implement policies to facilitate smallholder and family farmer access to quality seeds and fertilizers. In addition, introduce new crop varieties to improve agricultural productivity;
- Provide extension services to farmers to encourage the adoption of sustainable grazing practices. Include education on the benefits of adopting newly improved livestock breeds to increase productivity;
- Provide resources to improve rural infrastructure, including irrigation systems, roads, sanitation, and access to clean water. This initiative aims to address rural underdevelopment and promote overall agricultural growth;
- Introduce a new methodology and redefine the criteria for smallholders and family farms in public policy. Work with government statistical agencies to develop an updated approach that ensures accurate representation and targeted support for these farming entities.

In addition, the following recommendations for future research are derived from the findings of our study:

- Conduct research focusing on cost-effective methods suitable for use by smallholder farmers to improve their fodder base. This may include advances in agricultural production technology, storage, and harvesting, with an emphasis on approaches that provide environmental benefits without requiring substantial investment;
- Undertake studies to explore conditions conducive to the adoption of income diversification strategies in farming systems. In particular, focus on off-farm activities such

as sustainable tourism or other value-added enterprises to provide additional sources of income for farmers;

- Examine grazing alternatives that will reduce ongoing land degradation and yet provide sufficient pasture use for cattle production.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/land13020126/s1; Table S1: Non-collinear variables used in hierarchical agglomerative cluster analysis; Table S2: Independent samples test.

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