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Classification of Mountain Silvopastoral Farming Systems in Walnut Forests of Kyrgyzstan: Determining Opportunities for Sustainable Livelihoods

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Abstract: Kyrgyz walnut-fruit forests are unique ecosystems inhabited by silvopastoral farm households that depend on forest resources for their livelihoods. Illegal logging, excessive collection of non-timber forest products (NTFPs), and overgrazing of forest pastures negatively affect forest regeneration and biodiversity, ultimately impacting sustainable livelihoods in the region. Understanding farm heterogeneity is critical to identify targeted interventions that have the potential to improve livelihood sustainability for local populations. This study identifies and elucidates the typology of farms in walnut-fruit forests. Data were collected from 220 farm-households in three villages located within or in the buffer zone of protected areas. Principal component analysis (PCA) and cluster analysis were used to analyze quantitative data and aggregate farms into clusters according to forest resource availability and use, production means, and socioeconomic characteristics. Three distinct silvopastoral farming systems were identified, in which farmers collect and sell NTFPs, but also have: (i) relatively high NTFP income, medium-sized livestock herds, and low off-farm income; (ii) moderate NTFP income, large livestock herds, and high off-farm income; and (iii) low NTFP income, small herds, and moderate off-farm income. Overall, all types of farms showed different livelihood strategies; specific recommendations aimed at increasing sustainability were provided for each type. While both improved forages for livestock and grazing in forests are relevant for all types of farms, in some cases, value-added processing of NTFPs and contributions from off-farm activities such as tourism are necessary for the conservation and sustainable use of forests.

Keywords: grazing in forests; remittances; Central Asia; pasture degradation; cluster analysis; NTFPs

1. Introduction

Smallholder agriculture is most important in the Central Asian agricultural sector, accounting for the bulk of food production and income [1]. The predominant land use is pastoralism [2], with rangelands comprising 65% of the land area in the five Central Asia countries (Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan)–the most extensive grazing area worldwide [3]. Livestock production on these rangelands provides the basis for the livelihoods of local agropastoral communities [4]. In Kyrgyzstan, almost 90% of the agricultural land is highland pastures, and most smallholder farms are located in mountain rangelands [5–7]. These highland farms typically combine small-scale subsistence animal husbandry, pasture management, and a mixture of staple crops [8,9].

The different ecological conditions in the mountainous landscape promote highly variable ecosystems and, consequently, farming systems. For example, the Fergana and

Chatkal ranges of the Tien Shan in southern Kyrgyzstan are home to the world's largest natural walnut-fruit forests, where the silvopastoral farming communities exist [10,11]. The immense cultural importance of farm animals, such as local steppe cattle (*Bos taurus*), horse breeds (*Equus ferus caballus*), and fat-tailed sheep (*Ovis aries*), kept for milk and meat production in this region is characterized by livestock husbandry being an integral part of local livelihoods [12–14], despite that forest environmental conditions do not facilitate maintaining large herds [11]. This unique forest area harbors more than 130 plant and food species like walnut (*Juglans regia* L.), wild species of apple (*Malus* spp.), hawthorn (*Crataegus* spp.), plum (*Prunus* spp.), rose species (*Rosa* spp.), almond (*Prunus amygdalus* Batsch), pistachio (*Pistacia vera* L.), and pear (*Pyrus* spp.) [15,16], some of them are classified as "critically endangered" according to the IUCN Red List Version 2007 [17–20], e.g., *Crataegus knorringiana* Pojark. [21], *Pyrus korshinskyi* Litv. [22] and *Malus niedzwetzkyana* Dieck ex Koehne [23]. Being the ancestors of domestic varieties [24,25], these wild relatives of crops provide an important genetic pool [26,27] for the improvement of commercial crop varieties with regard to resistance to climate change, pests, and diseases [28,29], and on which targeted conservation actions must be considered, especially for those at risk of extinction [30]. Furthermore, walnut and fruit forests provide employment and a source of income to farmers through the collection of non-timber products (NTFPs), which support the livelihoods of people in this rural area [16,31,32]. In addition, these ecosystems also frequently serve as forest pastures and provide a source of fodder for livestock [32]. While grazing is prohibited inside protected areas and only allowed on special forest pastures, these restrictions are rarely obeyed; thus, the load and type of pasture should be assessed for the purpose of preserving these habitats. Studies estimate that about one million people depend directly or indirectly on these forests for their livelihoods [16,33].

Overharvesting of forest products and overgrazing negatively affect forest conditions and biodiversity and lead to increasing forest degradation, deforestation, and conversion of forest land [10,15,31,34]. Overgrazing causes trampling and browsing of young trees, especially walnut and wild apple, thus negatively affecting forest rejuvenation [11,32]. Furthermore, heavily grazed pastures experience soil compaction, reducing infiltration and increasing surface runoff and erosion [12,35]. The dominant edible species in the study area include *Festuca rupicola* Heuff., *Dactylis glomerata* L., *Bromus tectorum* L., *Trifolium repens* L., *Poa pratensis* L., *Koenigia coriaria* (Grig.) T.M.Schust & Reveal, and *Malva neglecta* Wallr [12,36]. Limited alternative livelihood options and declining or fluctuating harvests of walnuts and other NTFPs due to climate conditions [15,16] have led farmers to increase the number of animals, illustrating the cultural importance of livestock as a major capital asset and savings mechanism in the region [9,37,38]. While some families attempted to compensate for declining incomes through migration and related remittances in times of crop failure, labor mobility restrictions during the COVID pandemic have limited the feasibility of this livelihood strategy and reduced the number of remittances [39]. The negative impact of increasing herd size is compounded by the lack of access local communities have to pastures and the limited production of winter livestock fodder [33]. Currently, governmental interventions aim to protect the remaining forests by banning unsustainable land management practices, such as poor logging practices, NTFP collection, and overgrazing. Most of the walnut-fruit forests were designated as nature reserves during Soviet times, and after independence, the State continued to designate new forest land the status of protected areas; Decree No. 405 of the Government of Kyrgyzstan [40]. Yet, these interventions disregarded the current importance of forests to local residents; thus, despite these measures, forest resources remain under pressure [16,41]. This indicates that the suitability of these measures, their consequences on local livelihoods, and response strategies by farmers have not been well understood to date.

Earlier studies illustrated the importance of NTFPs on rural livelihoods and highlighted the role of livestock and off-farm income in mitigating fluctuating NTFP income [13,42–44]. Some studies differentiated various household categories, such as poor versus wealthy households [43,45], largely based on discriminant analysis. Yet, studies classifying smallholder silvopastoral farm-households using a broader set of variables and more sophisticated approaches are rare. Likewise, detailed quantitative analyses of the various economic activities are largely lacking. This potentially limits the effectiveness of policy action aimed at more sustainable land management in the walnut forest areas. Against this background, our study aims to identify and analyze different silvopastoral systems to enable well-targeted interventions. Our objective is to classify farm typologies based on a comprehensive set of attributes related to the farmers' resource capacities and to identify constraints and opportunities specific to particular farm types. Furthermore, the role of NTFPs in the livelihoods of the identified farm typologies is explored. Such an approach enables the development of agricultural interventions and policies aimed at improving animal husbandry while simultaneously reducing the negative effects of forest grazing, thereby contributing to the conservation of these unique ecosystems.

2. Materials and Methods

2.1. Study Area

Data were collected in three villages located in the Jalal-Abad province of southwestern Tien Shan mountains of Kyrgyzstan. These include Arkit village inside the Sary-Chelek Biosphere Reserve, Kashka-Suu village near the Padysha-Ata Nature Reserve, and Kara-Alma village inside the Kara-Alma forestry preserve. These villages were selected because they are located within or proximate to protected areas, the forest resources which are directly impacted by villagers. In Kashka-Suu village, the collection of specified amounts of NTFPs and hay from forest meadows is allowed, while in Arkyt village, the collection of only walnuts and hay is allowed in certain forest areas. In the village of Kara-Alma, the collection of NTFPs, like walnuts, wild apples, and pears, as well as the collection of hay, is allowed. In addition, Kara-Alma inhabitants can also lease forests for up to 49 years from the local forestry preserve. The leaseholders, in return, have the exclusive right to harvest walnuts in these areas and work to conserve these forest areas, and donate seeds to the forestry center. However, a collection of threatened apple species like *Malus sieversii* M.Roem. and *M. niedzwetzkyana*, pear species *Pyrus asiae-mediae* (Popov) Maleev, and *P. korshinskyi* are prohibited everywhere, irrelevant of the area management status. Other NTFPs can be harvested within leased forests by all villagers. Cutting trees for firewood is prohibited in all villages. However, the collection of withered walnut trees and fallen branches in the leased forests is allowed in Kara-Alma.

The elevation of these villages ranges from 500 to 4000 m a.s.l., and the total forest area of our sites is approximately 14,000 ha. The study area is characterized by a continental arid and semi-arid climate with relatively warm winters, warm summers, and average annual precipitation of 800 to 1000 mm, peaking in winter and spring [46]. A total of 1125 families lived in the study area [47], and smallholder silvopastoral farming is the typical production system in all three villages. Most of the small silvopastoral farming systems are characterized by a collection of forest products combined with grazing in forests around settlements (Figure 1).

2.2. Household Sampling and Data Collection

A socioeconomic survey of households engaged in silvopastoral farming was conducted from June to July 2021 using a structured questionnaire. With the help of local officials, we randomly sampled 220 representative households in the three villages. The number of farm-households sampled in each village was approximately 20% of the total population of each village. Quantitative farm and household level data on the organization and economic performance of smallholder farms were collected through a structured questionnaire. The questionnaire included queries on the main aspects of local livelihoods, namely the economic contribution of the annual collection of forest products (e.g., wild apples), animal husbandry, and cultivation, as well as incomes obtained from non-agricultural activities. Questions were also asked about recent developments affecting the livelihoods of farmers, particularly at the household and farm level, as well as future plans for improving agricultural production and other sources of income.

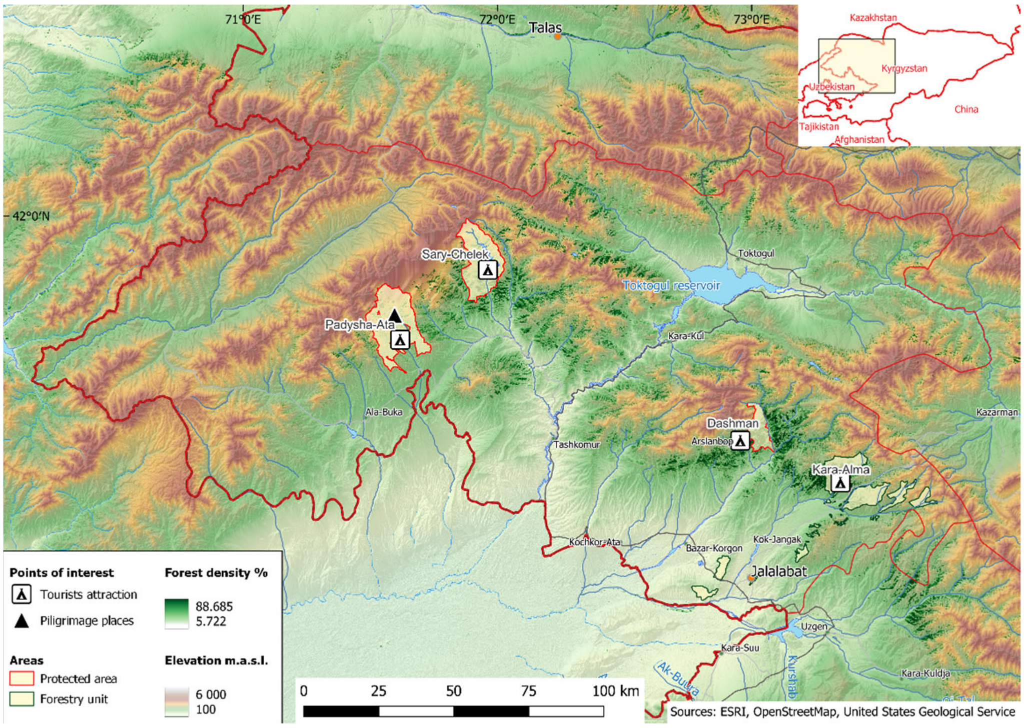

Figure 1. Study regions in Jala-Abad province, Kyrgyzstan, including selected villages.

2.3. Dataset and Statistical Analysis

Statistical analysis of survey data was performed using Statistical Package for Social Sciences (SPSS) version 21 [48] to generate descriptive trends and frequencies. In order to avoid distortions in statistical analysis, outlier detection using boxplots was employed [49]. Quantitative variables (18) selected for farm characterization were classified into the following categories: forest/land holding and use; livestock production methods, labor; socioeconomic, non-agricultural activities, and geographic characteristics of the area to explore the farming system diversity in the case study area through multivariate analysis.

2.4. Multivariate Analysis for Generating the Farm Typology

Selected classification variables were subjected to two multivariate statistical techniques to generate a typology of the surveyed farm households: principal component analysis (PCA) and *K*-means cluster analysis, as used in similar studies [50–59]. This approach allows us to classify relatively homogenous farms with similar circumstances, analyze their performance, derive appropriate recommendations, and devise respective improvement strategies [60–62].

PCA facilitates the reduction of a large number of original input variables. We conducted PCA with standardized variables to compress all the information from the original interrelated variables into a smaller set of factors called principal components (PC). Kaiser-Meyer-Olkin (KMO) and Bartlett's test of sphericity were conducted to check the validity of the dataset for PCA assessment. KMO values > 0.6 and significance levels for Bartlett's test < 0.05 indicate that variables are related and suitable for further analysis [49,63,64]. Varimax rotation was performed to put correlated variables under appropriate PCs and to facilitate interpretation [50]. PCs with eigenvalues > 1 were retained and interpreted [63]. Within each PC, we used a variable with a loading factor > 0.6 for further analysis, while variables with values < 0.5 were discarded.

In the next stage, the selected variables were subjected to a *K*-means cluster analysis, a non-hierarchical clustering technique where the squared Euclidean distances were used as metrics to establish clusters [49]. Finally, we used an analysis of variance (ANOVA) to estimate the statistical significance of differences among cluster means.

3. Results

3.1. Study Site Characteristics

Discussions with local forestry specialists, representatives of Ayil Okmotu (Village government; at the Aiyl Okmotu level, veterinarians, agricultural and pasture experts, statisticians, and other social workers are employed), and the farm households themselves were conducted to obtain general information on local livelihoods. These discussions revealed that walnut-fruit forests play an important role in the rural economy. In these forests, local households are mainly involved in the collection of walnuts and other edible non-timber forest products such as berries (*Rubus occidentalis* L., *Rubus fruticosus* L., *Berberis vulgaris* L.), mushrooms (*Morchella* sp.), wild apples (*M. sieversii*, *M. niedzwetzkyana*), wild rose (*Rosa* sp.), and hawthorn fruits (for medicinal purposes). Among all NTFPs, walnuts and wild apples, where harvested, were assessed as the most important forest products by farmers and represented the highest values. The importance of wild apples was very important when there were limited opportunities to harvest walnuts. Therefore, we differentiated between revenues from walnut, wild apple, and other NTFPs. Because NTFP yields vary across years, we requested data on average annual yields for the last three years. Average walnut revenues ($2104) and wild apple revenues ($79) accounted for 26% and 1% of total household income, respectively. Other revenues for individual NTFPs were significantly lower but collectively comprised $183, accounting for an average of 2.2% of total household income. Though almost all surveyed households collected other NTFPs, about 70% of the households collected other NTFPs specifically for sale, keeping the remaining portion for their own consumption.

Livestock was another significant source of income in silvopastoral households. Local steppe cattle, horse breeds suited for milk and meat, and fat-tailed sheep suited for meat production dominated. Households had an average herd of 6.5 LU (a livestock unit corresponds to one cattle, 0.83 horses, or 5 sheep/goats), and a typical herd consisted of cattle, horses, and a small number of sheep or goats. The total value of the entire herd averaged almost $4360, double the average annual NTFP revenues: that is, cash savings account for farmers. Each year about 25% of the total herd was sold; livestock were raised mainly for sale as the proportion of animals slaughtered for family consumption was negligible (about 2% of the total herd). Sheep and goats were mainly slaughtered for family consumption, while cattle and horses were only slaughtered on rare occasions, such as weddings and funerals, when many villagers were invited to such traditional events. Farmers preferred to keep more cattle and horses rather than sheep and goats, as the latter were considered unsuitable for grazing in the vast forested areas due to the frequent loss of sheep. Farmers also preferred to keep sheep rather than goats because goats harm young fruit trees and the market price of goats was much lower than sheep with the same upkeep cost per animal. Unlike sheep and goats, cattle and horses are self-sufficient and do not require constant supervision. In addition, the sale of dairy products was a significant part of farm income, with more than 90% produced for sale, indicating the importance of keeping dairy cows. Average dairy milk productivity was 500 kg for a cow's lactation cycle. Due to the lack of pastures, local silvopastoral households grazed their herds in designated forest lands, although grazing often occurred where it was forbidden. The pasturing period could extend up to 12 months, depending on environmental conditions, primarily to reduce the amount of fodder required during winter. In general, there was a shortage of fodder during winter, animals became emaciated, and farmers were forced to graze animals in forests to browse on plant remains such as branches and the bark of trees (e.g., wild apple).

More than 90% of winter fodder for livestock was purchased because farm households usually did not have substantial arable land to cultivate fodder crops, and even when such land was available (e.g., in Padysh-Ata), it was not cultivated due to the lack of irrigation systems. Most farmers have meadows that were informally allocated to households in the 1990′s, where a small part of winter fodder (mainly hay) was collected. According to many farmers, yields were low because the meadows were not hedged, and animals grazed in these meadows.

As such, cultivation occurred only on small plots of land (kitchen gardens) ranging from 0.05 to 0.3 ha in size. While mainly vegetables were grown for subsistence consumption, there were also some fruit trees (e.g., plums, apples) in these kitchen gardens. Rural managers noted that honey production has developed in recent years, and the number of beekeepers is increasing. Of the surveyed households, about 10% had apiaries.

The average annual income derived from off-farm activities was $2087, accounting for 25% of total household income, indicating that opportunities for non-agricultural employment and off-farm business opportunities were generally low in all three villages. External migration and remittances (mostly from Russia) played a huge role in the household economy and accounted for almost half of all off-farm income. According to farmers, migration has become an integral part of village life and has intensified over the last decade, mainly to compensate for the erratic walnut yields. Pensions and salaries from public institutions represented, on average, about 28% of total non-agricultural income, while the income from self-employment/private business (e.g., shops, taxi drivers, tourism) and employment in the private sector accounted for almost 25% of off-farm income. Tourism was booming, particularly in two villages, Arkyt and Padysh-Ata, because of the natural attractions. Villagers tried to capitalize on increasing tourism by selling farm produce or providing services to tourists (Table 1).

Table 1. Quantitative variables from questionnaires used in PCA (*n* = 220).

		Minimum	Maximum	Mean	Std. Deviation
1	Village/farm elevation (m above sea level)	1255	1505	1414	92.8
2	Distance to market (km)	11	55	33.6	16.0
3	Annual walnut revenues (USD [1])	0	10,628.2	2104.8	2328.9
4	Annual wild apple revenues (USD [1])	0	531.4	78.9	116.9
5	Annual other NTFPs revenues (USD [1])	0	1003.8	183.7	216.3
6	Days for walnut collection (day/year)	0	240	90.0	75.1
7	Days for NTFP collection (day/year)	0	59	15.6	16.6
8	Transportation costs of all NTFP (USD [1])	0	200	101.3	46.8
9	Total herd size (LU [2])	0	20.1	6.5	4.3
10	Number of cattle (LU [2])	0	13	4.1	2.5
11	Number of horses (LU [2])	0	12.3	1.8	2.3
12	Average winter fodder expenses (USD [1])	0	3309.9	818.4	674.6
13	Other farm income (USD [1]/year)	0	3678.6	617.3	1255.7
14	Revenues from dairy products (USD [1])	0	2952.3	355.4	547.5
15	Total off-farm income (USD [1])	0	6140.8	2087.2	1536.0
16	Total number of migrants (person)	0	3	0.6	0.6
17	Size of arable land (ha)	0	0.22	0.03	0.06
18	Size of leased forest (ha)	0	20	3.3	4.2

[1] In USD: average exchange rate in July 2021, $1.00 = 84.68 Kyrgyz som (KGS) (www.oanda.com, accessed on 20 November 2022). [2] Livestock unit corresponds to one cattle, 0.83 horses, or 5 sheep/goats.

3.2. Quantitative Variables Selection

A 'middling' KMO value (0.719) [63] and a significant Bartlett's test of sphericity (level of 0.00) suggest that 18 classification variables are suitable for further analysis using PCA (Table 1). The rotated factor matrix of independent variables with factor loadings is below. Five PCs had eigenvalues above Kaiser's criterion of >1 and explained 76.3% of the total variability. PC1 contains diverse variables, including geographical characteristics (distance to market) and farm resources (substantial arable land size). In contrast, forest-related variables included those such as the size of the leased forest, working days for wild apple and walnut collection, revenues, and some costs from their collection. PC2 explicitly includes livestock production variables: herd size, number of animals, and winter fodder costs. PC3, like PC1, is comprised of heterogeneous variables, including geographic characteristics (elevation of village/farm), working days for other NTFPs collection (excluding walnuts), and revenues from other NTFPs as well as wild apple revenues. PC4 covers all other farm income (excluding income from the sale of animals) and revenues from the sale of dairy products. PC5 covers variables related to off-farm income (total off-farm income, number of migrants) (Table 2).

Table 2. Loading variables in the selected principal components.

	Principal Component [1]				
	1	**2**	**3**	**4**	**5**
Distance to market (km)	0.922				
Annual walnut revenues (USD)	0.859				
Days for walnut collection (day/year)	0.848				
Size of leased forest (ha)	0.848				
Size of arable land (ha)	−0.793				
Transportation costs of all NTFP (USD)	0.713				
Annual wild apple revenues (USD)	0.624		0.537		
Total herd size (LU)		0.910			
Average winter fodder expenses (USD)		0.860			
Number of horses (LU)		0.794			
Number of cattle (LU)		0.730			
Annual other NTFPs revenues (USD)			0.908		
Days for NTFP collection (day/year)			0.906		
Village/farm elevation (m above sea level)			0.557		
Other farm income (USD/year)				0.781	
Revenues from dairy products (USD)				0.767	
Total off-farm income (USD)					0.828
Total number of migrants (person)					0.814

[1] Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

3.3. Cluster Profiles

Before conducting a cluster analysis using the *K*-means method, we tested the classification variables derived from the PCA for correlation. As the PC4 variables were correlated with the selected classification variables of PC2 and PC3, we removed both PC5 variables (i.e., other farm income and revenues from dairy products).

We generated three clusters with the *K*-means method. They correspond to three different types of farming systems. The three clusters of silvopastoral farming systems were generated based on a distinct set of variables derived from the PCA and the correlation analyses.

3.3.1. Type I: Silvopastoral Farming Systems with Higher NTFP Income, Medium-Sized Livestock Herds, and Low Off-Farm Income

Type I farm-households are the second largest cluster and represent 35% of the surveyed farms. Farms with a large annual income from collecting and selling forest products ($4602), practicing silvopastoralism with an average herd of 5.48 LU and a total value of $3826 were grouped into this cluster. Farm-households in this group have leased forests with an average area of 7.2 ha. It is not surprising that the farmers in this group were entirely from the village of Kara-Alma, where leasing forests, primarily for walnut collection, is allowed. The level of income from the collection of other NTFPs (i.e., excluding walnuts) depended on the availability of labor and transport capacity (including horses) on the farm. About 15% of farmers in this cluster lacked labor and did not collect other NTFPs, while 64% of farmers who collected other NTFPs joined with other farms to collect and sell NTFPs (e.g., wild apples). The average annual income from other NTFPs was $231, with the collection and sale of wild apples accounting for 69% of other NTFPs. Mushrooms

(12%), wild onions (9%), rose hips (7%), and red and yellow hawthorns (4%) accounted for the remainder of the collection and sales from other NTFPs. Hiring additional labor for walnut collection occurred only in this cluster; on average, 45% of surveyed farmers hired people during the last three years. However, during a good walnut harvest, this increased to more than 70%.

Farm herds consisted of local steppe cattle (67% of total animals), horses suitable for milk and meat production (27%), and sheep suitable for meat production (6%). Farmers raised livestock mainly for sale, with an average of 28% of their herd sold annually, with the remainder kept for herd reproduction. The share of slaughtered cattle and horses for household consumption was negligible. The average grazing period was 7.4 months per year; during the remainder of the year, animals (except horses) were kept in sheds and fed mainly on purchased fodder. The share of farms using fodder was the greatest of all clusters, reaching over 97%. Type I cluster is also characterized by the lowest income from off-farm activities ($1429) and the greatest share from remittances (61%) compared to other clusters. Revenues from other farming activities had the lowest value ($295) among the clusters. Dairy products and apiary accounted for 63% and 24% of total other farm income, while plums and meadow hay accounted for 10% and 4% of other farm income, respectively. While the average level of sales rate of all products produced and collected exceeded 95%, meadow hay was typically not sold and remained entirely for feeding household animals. In this cluster, no farmers had substantial arable land, only small (on average 0.14 ha) kitchen gardens where vegetables and fruit trees were grown for family consumption. On average, 0.1 ha of meadows were used by farmers to make hay for the winter.

3.3.2. Type II: Silvopastoral Farming Systems with Moderate NTFP Income, Large Livestock Herds, and High Off-Farm Income

This is the smallest cluster representing 19% of all surveyed farm-households. The cluster is classified as farms with moderate annual NTFP income of $1911 and the largest livestock herds (12.8 LU), with an average total value of $8010. Farmers in this cluster were mainly from Arkyt, with a smaller amount from Kara-Alma village, who did not have leased forest land. Compared to Type I, the smaller revenues from walnut collection in Arkyt village are attributed to collection limitations due to the lack of leased forests. The annual share of revenues from other NTFP collection (excluding walnuts) was $180 on average. Similar to the Type I farm system, wild apple revenues dominated and accounted for 55% of total other NTFP revenues, while mushroom and wild onion revenues accounted for 27% and 8%, respectively. NTFPs such as hawthorn and rose hips accounted for the remaining 10% of other NTFP revenues. Most of the NTFPs were collected by farmers from Kara-Alma village, while Arkyt farmers collected only mushrooms.

Animal husbandry also dominated in Type II farms: herds were composed of cattle (53%), followed by horses (35%) and sheep (12%). The share of sold livestock was greatest in this cluster (36%), and the slaughter of livestock for family consumption, although small (5% of the herd on average), was the greatest among all clusters. As with Type I farms, mainly sheep and goats were slaughtered for home consumption. The livestock grazing period was identical to Type I and lasted 7.5 months (excluding horses). Farmers had the highest income from off-farm activities among all clusters (on average, $3231 per year). The share of remittances was also dominant compared to other off-farm income sources–51% of total off-farm income. Of these off-farm income sources, the income from private business constituted 21%, which was greater than for Type I, while incomes from the public sector and pensions were generally small–15% and 12% of total annual off-farm income, respectively. Income from other farming activities was the greatest among the clusters due to the sale of dairy products, accounting for 54% of other farm income. This is not surprising as this cluster had the largest livestock herds, particularly dairy cows. Type II farmers had an average of 0.5 ha of meadowland, and hay production accounted for 32% of other farm income, which was significantly greater than in the other two clusters. Hay was used entirely by farmers as winter fodder for their herds, and, similar to Type I, more than

90% of the dairy products and plums were sold. Apiaries played an important role in this cluster, accounting for an average of 13% of other farm incomes, while income from plums was negligible. In addition to relatively large meadows, the average areas of substantial arable land and kitchen gardens were 0.05 ha and 0.1 ha, respectively. Vegetables and other horticultural products were grown in kitchen gardens for household consumption, while the broader arable land was fallow.

3.3.3. Type III: Silvopastoral Farming Systems with Low NTFP Income, Small Livestock Herds, and Moderate Off-Farm Income

Type III systems represent 46% of all surveyed farms and is the largest of the three clusters. This cluster included farmers mainly from Kashka-Suu and fewer from Arkyt village; no farmers in this cluster leased forest land. Type III farmers are characterized by low NTFP income ($604 per annum), small herd size (4.63 LU) with a total value of $2854, and moderate off-farm income ($2114 per annum on average). Annual income from other NTFPs was the least among all clusters ($132), likely due to limitations and restrictions on the collection and because no walnut forests existed in Kashka-Suu village. Furthermore, only a few farm-households were hired to collect walnuts in a neighboring forest preserve where it was allowed. In Arkyt village, the small walnut revenues were attributed to the lack of labor resources. Other NTFP income was dominated by wild raspberries (89%), while the contribution from selling wild apples and mushrooms constituted only 1% and 10% of other NTFP income, respectively. The share of cattle family herds was the greatest among the clusters (73%), while horses comprised only 20% of herds. The share of sheep/goats was 7%, similar to Type I. The share of livestock sold was the least of the three clusters–14% of the total herd. The number of animals slaughtered for family consumption was small, similar to other clusters. The average pasturing period was the shortest (6.7 months) among the clusters due to strict grazing restrictions. Farmers in this cluster obtained moderate income from non-agricultural employment–an average of $2114 per year. Although remittances dominated total off-farm income (37%), this share was the smallest among the three clusters. Income from private business and employment services was much more developed (32%). Pensions and the public sector were also important, accounting for 19% and 13% of total off-farm income, respectively. The annual average "other farm" revenue was $541 with milk products constituting the highest share (59%) followed by income from meadow hay (22%) and beekeeping (17%). In contrast to Types I and II, farmers in cluster III had an average of 0.1 ha of substantial arable land, relatively large kitchen gardens (0.23 ha), and largest meadows (0.6 ha). Kitchen gardens were used to grow vegetables and fruits for both home consumption and sale, while the substantial arable land was fallow (Table 3).

Table 3. Cluster characteristics derived from *K*-means clustering.

Variable	**Clusters/Types**		
	1	**2**	**3**
	(*n* = 101) Type III	**(*n* = 42) Type II**	**(*n* = 77) Type I**
Elevation of village, household location (m above sea level)	1390	1423	1440
Family size	5.5	6.6	6.6
Average annual walnut revenues * (USD [1])	**472**	**1911**	**4352**
Average annual NTFPs revenues * (USD)	**132**	**186**	**250**
Wild apples (%)	7	55	69
Wild raspberry (%)	84	27	0
Mushrooms (%)	9	8	12
Other NTFP (%)	0	10	19

Table 3. *Cont.*

Variable	Clusters/Types 1	2	3
	(*n* = 101) Type III	**(*n* = 42) Type II**	**(*n* = 77) Type I**
Herd size * (livestock units)	**4.63**	**12.83**	**5.48**
Total herd value *, (USD)	2854	8010	3826
Herd composition:			
Cattle (%)	73	53	67
Horses (%)	20	35	27
Sheep/goat (%)	7	12	6
Pasturing period (months)	6.7	7.5	7.4
Off-farm income * (USD)	**2114**	**3231**	**1429**
Shares of off-farm income sources:			
Pensions (%)	19	15	15
Public sector (%)	13	12	12
Private business/employment services (%)	32	21	13
Remittances (%)	37	51	61
Other farm revenues * (USD)	541	1400	291
Revenues from milk products (%)	59	54	63
Revenues from meadow hay (%)	22	32	4
Revenues from plum (%)	2	1	10
Beekeeping (%)	17	13	24
Leased forest (ha)	0.0	0.0	7.2
Arable land (ha)	0.1	0.05	0.0
Kitchen garden (ha)	0.23	0.09	0.14
Meadow (ha)	0.6	0.5	0.1

Classification parameters are displayed in bold; * Statistical significance, $p < 0.01$. [1] In USD: average exchange rate in July 2021, $1.00 = 84.68 Kyrgyz som (KGS) (www.oanda.com, accessed on 20 November 2022).

4. Discussion

The lack of opportunities to harvest NTFPs was identified as a major problem affecting livelihood strategies in local silvopastoral farming systems. The degree of exposure to NTFP crop failure (especially walnuts) for a particular group of farmers can be determined by their revenues from harvesting forest products. For example, Type I and Type II farmers were more dependent on revenues from NTFP collection as the share of NTFP in total family income was substantial (45.3% and 14.2%, respectively). We are not advocating that poor households collect only other NTFPs and fewer walnuts, as indicated in other studies [42,43]. All households collected NTFPs if they had available labor and permission to collect NTFPs [65]. Type I farmers had access to more NTFPs (particularly walnuts) with the greatest yields because of the leased forests at their disposal, and they were allowed to harvest walnuts and wild apples without restrictions [66]. Farmers in Type II had less access to harvesting and less income from walnuts compared to Type I because of the lack of leased forests, which also applies to farmers from Kara-Alma and Arkyt villages due to harvesting restrictions and the conservation status of forests. Type III farmers had the least access to collect NTFPs and the smallest income from NTFPs compared to the other systems, mainly due to the prohibition or restrictions on the collection and lack of walnut forests. The collection of prohibited NTFPs (e.g., mushrooms, hawthorn) often occurs in all farm types despite the restrictions. Thus, there appears to be an increase in the collection of protected NTFPs during stressful times [44]. The collection of banned NTFPs has also been recognized by both nature reserves and forestry officials, and it is obvious that prohibitive measures are not enough to stop the collection of such NTFPs [16]. It is noteworthy that no surveyed farms that collected NTFPs processed these products for family consumption (e.g., by drying and making jam), which implies the sale of NTFPs without added value [66].

According to the farmers in Type I and II clusters, good walnut harvests occur every 2–3 years, as noted in other studies [16,43,44]. Consequently, all silvopastoral families have seen increases in the number of livestock to compensate for the fluctuating NTFP revenues, particularly in Type II farms. Livestock has become a savings account on farms in our study area, which is typical of mountain farmers throughout Kyrgyzstan [8,9]. A major challenge in livestock production is the lack of winter fodder, which was in short supply on all farm types observed. This was not surprising as mountain farmers did not have large-scale arable land (unlike in other parts of the country) where fodder crops could be grown, and the available forest meadows did not provide sufficient fodder [31,32]. Thus, more than 90% of all fodder was purchased by farmers (often at a high price), and this was the only factor limiting farmers from further increasing their herds. To save fodder, farmers try to keep livestock in forest pastures if possible, including during winter. In all farming systems, livestock became emaciated from winter to mid-spring due to a lack of roughage in their diet [67,68]. Grazing in autumn and spring has a negative impact on the forest soil, particularly in wet areas [12,35]. Every second farmer admitted that the increase in livestock negatively influences the forest. This was confirmed in a study that observed traces of animal damage on almost every wild apple and other fruit tree [11]. Although the grazing system has generally remained the same, with distant and village pastures allocated to livestock for specific periods [43], there remain no clear management strategies for forest pastures that are developed by a nature reserve and forestry staff. That is, there is either a ban on grazing in the forest areas or forest pastures are specifically designated. Local experts (nature reserve and forestry staff) note that there are no specific norms and regulations which can be used to introduce quotas on livestock numbers and pasture rotation to reduce grazing pressure [69,70] and pasture committees in other regions of the country. It is obvious that bans on livestock grazing in unauthorized areas of nature reserves are the only current measures preventing pressure on forest pastures; however, this ignores the importance of livestock for silvopastoral family livelihoods, especially during times of low NTFP harvest [10,32]. Therefore, improving pasture management and controlled grazing in the villages studied is necessary to ensure the sustainable use of forest pastures, conserve biodiversity, and protect soils. Some studies from other silvopastoral communities have shown the positive effects of proper grazing on forest biodiversity [10,11]. Other studies report that for silvopastoral households, fodder cultivation (including fodder trees) and stall feeding can be a way of combining livestock production and forest conservation [71].

According to farmers, remittances from abroad have become a more profitable source of income in comparison to incomes from animal husbandry and NTFP collection. During times when NTFPs could not be harvested (particularly in Type I and Type II farms), this increased migration of family members, mostly to Russia. In Type II and Type III farms, the share of income from the private business was quite high due to the increased involvement of local silvopastoral families in tourism (e.g., hotel services, cafés, horse rentals) in recent years. Due to the natural tourist attractions (e.g., Sary-Chelek Lake, Padysh-Ata pilgrimage site) as well as the improvement of roads to these destinations, the number of tourists has increased [72,73]. Almost half of the Type III farmers plan to invest their savings in tourism development, while 20% of Type II and 11% of farmers plan to invest in tourism. For these latter farms, herd expansion, NTFP processing, and beekeeping appear to be more attractive investments.

Overall, the typology of farming systems showed three different categories of farms with different livelihood strategies. Although most farm types note that their livelihoods will remain as they are in the near future, there is strong evidence to strengthen their farming and non-farming activities. In reference to off-farm income, we are not referring to migration, although migrant remittances are currently an important livelihood strategy. In the long run, this can lead to a high dependency on remittances, non-return of migrants, and breakdown of the family unit and, subsequently, labor shortages, as confirmed in other studies in agropastoral communities [37,74,75]. These studies also note that in most cases, migrant remittances are mainly invested in livestock production (i.e., increasing the number of livestock), which may further increase pressure on already degraded pastures. These findings are applicable to silvopastoral families because migration has become a more profitable source of income, given that many farms have increased and are planning to increase livestock holdings. Our typology can clarify specific measures and interventions that are more effective in improving sustainable livelihoods in the walnut and fruit forests, as subsequently described.

Firstly, for farmers of all systems, the importance of income from livestock is indisputable, and it is necessary to introduce sensible pasture stewardship as well as adequate supplies of available forage, thus reducing pressure on forest pastures. Secondly, there is a tendency in all systems to generate income from off-farm activities. Current efforts to develop sustainable rural tourism, therefore, are promising strategies and should be continued in the future. Such efforts should primarily be directed to farms of Type II, which possess good prospects for tourism development. This coincides with recommendations for agropastoral families in other regions of the country [76]. In addition, given the importance of income from NTFP collection, particularly for Type I households, efforts to increase local value added through NTFP processing, direct marketing, and other approaches should be primarily targeted at these farmers. Training and the introduction of processing technology, along with the establishment of markets, is an obvious need [41,77]. Although there have been numerous projects supporting the development of local small and medium-sized food processing enterprises (SMEs) in the past, most of these efforts have terminated with the withdrawal of funding, indicating the importance of more long-term support. Lastly, as farmers of Type II are the most involved in livestock production and their profitability is much higher compared to the other two types, efforts to improve grazing management as well as enhance supplies of affordable fodder should focus on this farm type. In addition, beekeeping has good potential for development on Type II farms.

5. Conclusions

Three farm types were identified in the study area, namely silvopastoral farming systems with (i) higher NTFP income, medium-sized livestock herds, and low off-farm income; (ii) moderate NTFP income, larger livestock herds, and high off-farm income; and (iii) low NTFP income, small herds, and moderate off-farm income. We used a multivariate analysis that allowed us to delineate farms into clusters that provide insight into the characteristics and type of strategic livelihoods of local silvopastoral farm groups within each cluster. Lack of access to income from NTFPs affects clusters differently and leads farmers to pursue livelihood strategies oriented to livestock production, which in turn affects the sustainability of forest resources and potentially degrades the land. In order to sustainably improve livelihoods in each cluster, it is necessary to identify the challenges and opportunities within the cluster context and recommend appropriate sustainable interventions.

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