Journal of Agriculture and Rural Development in the Tropics and Subtropics
Vol. 120 No. 2 (2019) 183–195

https://doi.org/10.17170/kobra-20191127816 ISSN: 2363-6033 (online); 1612-9830 (print) – website: www.jarts.info

The impact of uncertainty on smallholder farmers' income in Kyrgyzstan

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Abstract

The farming systems in the mountain areas of Kyrgyzstan are primarily characterised by small-scale crop and livestock activities. Farmers are faced with several environmental, socio-economic and political challenges and constraints that result in significant uncertainties affecting their operations. This paper attempts to model how various sources of uncertainty collectively affected the smallholders' farm incomes during a mid-term horizon using Monte Carlo simulation. The analyses were based on data collected through a survey of 235 smallholder farms in the medium and high-elevation mountains ranges and expert interviews. We defined a static and a dynamic scenario, the latter of which incorporating likely adjustments in land use and production methods by farmers in response to changing prices and factor costs. Our results suggest that to benefit from improving market opportunities, farmers should adjust and modify their farm management by expanding cash crops in the medium-elevation ranges or increasing herd sizes and fodder cultivation in high-altitude ranges. Results also indicate that farmers in the medium elevations benefit more from these opportunities than farmers in higher altitudes. The paper concludes with some practical recommendations for agricultural policy making in Kyrgyzstan.

Keywords: Agricultural trade, farming-systems economy, Kyrgyzstan, Monte Carlo simulation

1 Introduction

With a contribution of 14 % to GDP, agriculture is an important part of the Kyrgyz economy. While 58.7 % of the county's population live in rural areas, 26.8 % of the workforce is employed in agriculture (Ministry of Economy, 2018). Following the collapse of the Soviet Union and consequent disintegration of the collective farms, >400,000 family-managed farms emerged with an average size of 3 ha (NSC, 2018), the majority of which located in rural mountain regions. Their agricultural production systems focus on animal husbandry, which depend on a mix of crop and pasture land around settlements and higher elevation summer pastures. Because of the climatic conditions in the highlands, only a limited number of crops can be cultivated and crop production mainly serves as source of livestock forage. Despite these difficult conditions, some farmers were able to expand their operations. However, most of the family farms remain with very limited resources and capacities until today. Nevertheless, these farmers contribute 97 % to the country's agricultural production (NSC, 2018).

Smallholder farmers in Kyrgyzstan are faced with various environmental, socio-economic and political challenges. While the continental climate causes semi-arid conditions during the hot and dry summers, climate change scenarios predict a further increase in temperatures during the vegetation period by 3.7°C (IPCC, 2007). The rapid retreat of many glaciers throughout Central Asia is generally causing river flows to increase, at least in the short-term (Knoche *et al.*, 2017), but as glaciers disappear or become disconnected to streams, water flow will decline rapidly causing alterations in floral composition of upland pastures that will negatively affect future farming and livestock activities. The increasing impact of severe weather events will additionally put at risk rural livelihoods (Lioubimtseva & Henebry, 2009; Farinotti *et al.*, 2015). These environmental uncertainties are further compounded by problems of limited accessibility and remoteness of agricultural areas and villages due

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Published online: 12 December 2019 – Received: 12 January 2019 – Accepted: 6 November 2019

to difficult terrain conditions and underdeveloped infrastructure. Local markets are characterised by high transaction costs for transport and middlemen (Christensen & Pomfret, 2007; Steimann, 2011). Weak natural resource governance mechanisms cause significant land degradation. Population growth, increasing urbanisation and changing lifestyles will likely increase meat and cereal demand, adding pressure for a continued expansion of irrigated lands whilst increasing the risk of water scarcity. Gradual efficiency increases in land use and relative crop yields will likely not be sufficient to meet such steep demand increase (Gupta *et al*., 2009).

One source of uncertainty for farmers in Kyrgyzstan was the country's accession to the Eurasian Economic Union (EAEU) in 2015 (World Bank, 2016). The EAEU is an international organisation for regional economic integration aimed at promoting the free flow of goods, services, capital and labour among its members (EAEU, 2015; Smutka *et al*., 2016; Saritas *et al*., 2017). Potential benefits that were expected included an improved status of working migrants in Russia and increased remittance payments to Kyrgyzstan, an increase in Russian direct investments (Tarr, 2015); and the stimulation of agricultural exports to EAEU member countries (NISI, 2011; Pavlov, 2012; Ministry of Economy, 2015). On the other hand, several studies questioned the benefits from EAEU membership (Pavlov, 2012; World Bank, 2014; Mogilevskii *et al*., 2014). Hence, there was significant uncertainty about the consequences of this political decision on smallholder farmers.

Against this background, the paper investigates how the various bio-physical, economic and political sources of uncertainty affected the farm income of smallholder farmers during a mid-term horizon. While it is notoriously difficult to establish causality and to quantify the effect of single sources of uncertainty on farm incomes, this paper attempts to assess how they collectively affected prices and factor costs for the smallholder farmers in the mountain areas of Kyrgyzstan. These changes may in parts have been caused by political decisions such as the accession to the EAEU, and in parts by long-term macro-economic trends and short-term market fluctuations. We cannot therefore attribute the observed consequences in smallholders' farm systems to a single source of uncertainty. Despite this caveat, the current analysis is useful as it enables a more complete understanding of the constraints under which smallholder farmers in Kyrgyzstan operate, and the formulation of appropriate development strategies.

2 Study site

Data were collected in four districts of Chuy and Naryn provinces in the northern and central parts of Kyrgyzstan. The elevation in these districts ranges between 1,500 and 6,000 m a.s.l. The study villages are in highland valleys or in upper mountain watersheds between 1,500 and 2,400 m a.s.l. Valleys were characterised by a semiarid steppe climate with warm summers and cold and long winters and an average precipitation of 200 to 300 mm per year (Bobojonov *et al*, 2014). Prevailing land use types were mixed cropping and pasture use around the settlements, and extended summer pastures in higher elevation ranges. Thus, the study districts were prototypical of the majority of inhabited and cultivated land of the country (Figure 1).

3 Methodology

3.1 Farm economic model

A baseline socio-economic survey was conducted in the study districts between February and July, 2014 using a structured questionnaire. A total population of approximately 24,000 families lived in the 60 villages of various sizes (NSC, 2013). A 1 % stratified sample of the farming population consisting of 235 households was drawn randomly. Stratification of households was performed based on village household statistics on livestock and land property. Questionnaire chapters included questions on agricultural production systems, level and type of mechanisation, resource endowment, debt status, family-household economy, off-farm activities and remittances and social status of the family. Information on costs and prices was collected in actual terms net of inflation.

Based on this survey data, we developed a farm economic model that captured the impact of expected changes in factor costs and prices on the smallholders' farm income for two distinct mixed crop-livestock farming systems identified during the baseline survey, which significantly differed in terms of their agro-ecological and socio-economic conditions, i.e. (1) medium-elevation mountain ranges between 1,500–2,000 m, called *Jailoo-mid-level* (JM) and (2) high-elevation mountain ranges located between 2,000–2,400 m, called *Jailoo-high* (JH) in this paper. The models describe the annual net profit from crop and livestock production of an average farm-household in each of the two farming systems and the relationship between independent variables (e.g. product price, yields, factor costs) and target output (i.e., net gains from crop and livestock production) through a mathematical relationship.

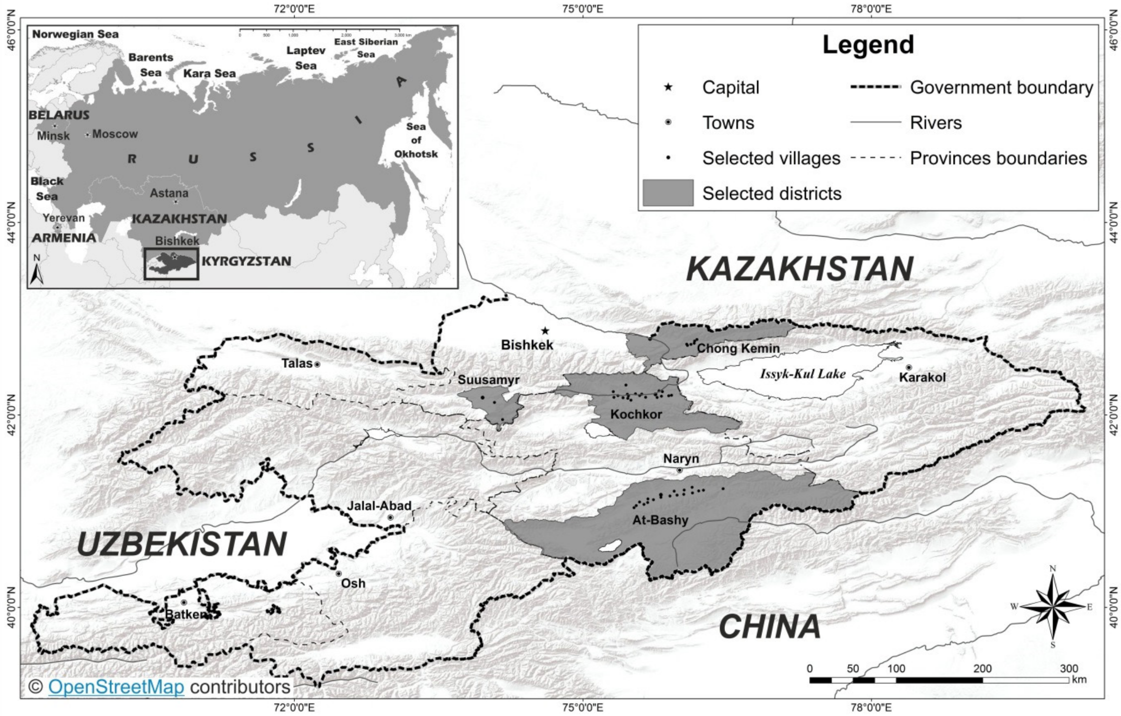

Fig. 1: *Study region and selected villages*

3.2 *Impact of uncertainty*

Expected changes in product prices and factor costs reflecting the various bio-physical, economic and political sources of uncertainty were estimated by ten local experts. Face to face interviews were conducted with these experts representing the Ministry of Economy and the Ministry of Agriculture of the Kyrgyz Republic, the National Institute of Strategic Research, the Kyrgyz National Agrarian University, the Kyrgyz-Turkish Manas University, as well as local crop and livestock traders in Tokmok and Naryn towns. The experts were selected according to the following criteria: knowledge and experience in the field of agricultural production, and competence in carrying out economic evaluations. This ensured that estimates predicted the development of factor costs and prices with reasonable accuracy (see Appendix 1). Experts were asked to estimate an increase or a decrease of product prices and factor costs (e.g. sheep, wheat, diesel, fertilisers) and to give the most likely price within a 3-year horizon (Table 2). Data was collected by means of a structured questionnaire; an interview lasted 40-60 minutes.

3.3 *Static and dynamic scenarios*

Furthermore, we distinguished between static and dynamic scenarios in our simulations. The static scenario assumed that farmers will not undertake changes in management practices, land uses, or herd sizes; thus, simulations were therefore performed with fixed parameters. The dynamic scenario considered likely adjustments in land use and production methods by farmers in response to expected changes of cost and price levels. This served to capture the likely development trajectories of the farm production system. To obtain this information, a group of 20 farmers of the original sample representing the full range of farm characteristics was interviewed in July 2016.

3.4 *Monte-Carlo simulation*

Based on these data we conducted Monte-Carlo simulations to analyse the likely impact of the expected changes in prices, factor costs and production methods on smallholders' farm income. Given the highly uncertain nature of the expected changes, we limited our analysis to a time horizon of three years.

Monte-Carlo simulation is a stochastic technique that involves using random numbers and probability distributions to simulate different impacts of uncertain variables on the model outcomes (Liu *et al*., 2016). This method has become a popular approach to explore uncertainty in the context of biophysical and micro or macroeconomic research problems (Graveline *et al*., 2012). Several studies have used the method to assess the impacts of economic trend scenarios on farm income (März, 1990; Rauh *et al*., 2007; Krober *et al*., 2008; Kabura, 2007; Lauwers *et al*., 2010; Liu *et al*., 2016; Chung *et al*., 2016). The Monte-Carlo approach involves generating many different scenarios, by allowing extreme but realistic input values to be randomly selected. Important properties of the Monte-Carlo method are simultaneous consideration of threats and opportunities, and their respective probabilities of occurrence (Graveline *et al.*, 2012). We used this method to demonstrate how the various sources of uncertainty collectively affected the smallholders' farm incomes for mid-term horizon. The disadvantage of this method is that value allocation to each uncertainty variable is random and does not consider the interrelationship with other uncertainties. Thus, many modes in the simulation output use unrealistic or unlikely combinations of the uncertainty variables (Rezaie *et al.*, 2007).

We used the @Risk Monte-Carlo add-on for MS Excel v. 6.3.1 (Palisade Corporation, 2016) for our simulations. We determined a triangular probability distribution for each uncertain independent variable by collecting information on the expected minimum, maximum and most likely value (mode) for each input variable in our expert interviews. A uniform distribution, which gave all values within the range of minimum and maximum an equal chance of occurrence, was used if a mode value was not given. We conducted 1,000 simulation runs to determine the probability distribution and cumulative distribution functions for net farm profit and related output variables, such as revenues and expenses of each production method, assets and profit margin and on-farm income. The sensitivity of simulated outputs to variations in uncertain values was assessed by calculating the rank order correlation coefficient. In total, we conducted four separate simulations, i.e. one static and one dynamic scenario for each of the two farming systems (JM and JH).

4 Results

4.1 Socio-economic description of the prevalent farm-household systems

Livestock production was the most important economic activity and basic source of income in both systems (Table 1). No significant differences in terms of flock structure were observed. Fat-tailed sheep and local steppe cattle breeds suited to meat production predominated in both systems. A typical flock consisted of an almost equal number of sheep, horses and cattle. Flock size was generally low, with an average of 16.3 livestock units (LU) in both farming systems. All livestock, except dairy cows, were kept on the high mountain pastures during the summer months. Most farmers used the services of professional herders. Animals were generally kept if possible, on the pastures in order to reduce the amount of fodder required during winter. The average grazing period differed significantly and was 8.5 months in JM and 7.2 months in JH due to differences in environmental conditions. Animals generally suffered from a lack of fodder during winter, particularly so in JH. The productivity of both systems was low for milk and meat outputs with little variation between and inside the groups.

Although there was no statistically significant difference in terms of total income from livestock production in both

Table 1: *Basic mean socio-economic farm parameters for Jailoo-high (JH) and Jailoo-mid-level (JM) farming systems.*

	JH (n=109)	*JM* (n=126)
Altitude of village* (m a.s.l.)	2,200	1,700
Flock size (LU)	16.4	16.2
Flock composition (%)		
cattle	31	30
sheep/goat	35	34
horses	30	35
yak	3	1.4
Pasturing period* (month)	7.2	8.5
Total farm land area (ha)	8.4	4.9
Uncultivated area (ha)	2.5	0.2
Total actual cultivated area (ha)	5.9	4.7
Share of cultivated crops (%):		
meadow	47	17
legume fodder	27	38
potatoes	2	8.5
other crops (vegetables)	0.5	3.7
cereals (barley, wheat)	22.5	33
Market prices of whole herd†	7,130	8,468
Market price of produced crops†	2,782	4,702
Additional farm income†	493	543
Subtotal market price of products†	10,405	13,713
Expenses on livestock production†	4,976	6,101
Expenses on crop production†	999	1,501
Subtotal farm expenses†	5,975	7,602
Farm income†	4,430	6,111
Off-farm income*†	1,933	2,616
Family income†	6,363	8,727
Share of market sales (%)		
in total production	17.3	37.2
in livestock	35.7	33.2
in crop	17.3	37.2

†In USD: average exchange rate in December 2013, $1.00 = 47.8 Kyrgyz som (KGS) (www.oanda.com); LU: livestock unit, corresponds to 1 cattle, 0.83 horses or 6 sheep/goats.
*Statistical significance, $p < 0.05$; Variables without asterisks were not tested for statistical significance.
Source: Survey data

farming systems, the structure of revenues and expenses differed slightly. JM farmers obtained higher revenues from livestock sales due to better market access and the fact that their animals were typically in better condition and obtained higher prices. This farming system also had higher average fodder cost per LU despite a longer pasturing period caused by using higher-quality fodder (hay and concentrates). These allowed farmers to better feed and more successfully sell their animals during winter when livestock prices were higher (cf. Steimann 2011; FAO 2016; Tilekeyev *et al.*, 2016). In contrast, most JH farmers were forced to sell their animals when they returned from mountain pastures in autumn at relatively low prices due to limited fodder availability during winter. Selling livestock in autumn was also motivated by immediate cash needs related, for example, to the beginning of the school year or social festivals.

There were statistically significant differences between both systems regarding average farm size (8.4 ha in JH, and 4.9 ha in JM) and amount of cultivated land (5.9 vs. 4.7 ha). Larger farm size in higher altitudes mainly reflected the lower land quality and lack of irrigation possibilities, which impeded agricultural production. Farmers in this system left a larger share of their land to fallow, cultivated only a limited number of crops, and crop production mainly served as source of winter feed for livestock. The largest part of the cultivated land (irrigated and non-irrigated) was used to grow grass, fodder legumes for hay making, and fodder cereals. In contrast, fodder legumes, potatoes, and sugar beets were the main crops in JM. In this system, crop yields were higher (although still generally low) because of more favourable climatic conditions and better irrigation infrastructure. Crops could also be marketed more easily due to more accessible markets. Vegetables were grown for family consumption, mainly in kitchen gardens. Additional farm income generated through sale of processed products (e.g. jam, yoghurt, cheese), through service provision using farm machinery (e.g. tractor) or herding services contributed between 7–10 % to total farm income on average without statistically significant differences between both farming systems. In contrast, there was a statistically significant difference regarding the farmers' access to off-farm income: while JH farmers obtained an average off-farm income of 1,933 USD, this value was 2,616 USD in the JM reflecting better non-agricultural employment opportunities, e.g. in the public sector. Given the primary focus of our work on farm production, off-farm income was not included in the simulation model.

The market orientation of both farming systems was low and subsistence production the predominant purpose. The share of market sales in total agricultural production was 35.2 % in JM and 26.5 % in JH, respectively. While sale of livestock was of comparable importance in both farming systems despite the low overall productivity of animal husbandry, crop production contributed significantly more to market sales in JM.

4.2 *Expected changes in prices, factor cost and respective adaptation strategies*

Table 2 presents the changes in costs, factor prices, and yields resulting from the various sources of uncertainty, and the farmers' adaptation strategies as revealed during expert interviews. Minimum, maximum and most likely impacts of these changes on the affecting variable were estimated by the experts. While most experts principally agreed on the direction of the likely changes for most variables, there was some noticeable variation in their assessment of the magnitude of change for some variables.

It was expected that prices for live animals would gradually increase to match the price levels in neighbouring EAEU countries, such as Kazakhstan and Russia. Cattle prices were estimated to increase by 7 % (range -1 % to +16 %), sheep prices by 10 % (+4 % to +21 %), and horse prices by 4 % (-9 % to +7 %) over three years. Milk prices were expected to increase by +10 % (4 % to 33 %). The price of hay was expected to increase by +14 % (-18 % to +38 %) due to an expected increase of livestock numbers leading to stronger demand for hay. The potato price was expected to increase by +15 % (0 % to 27 %) and sugar beet prices by 10 % (+3 % to 41 %) due to increasing local demand and export to Kazakhstan. Income from fruits and vegetables from kitchen gardens was expected to increase by between 85 and 150 USD per household reflecting better export opportunities, while the barley price was expected to slightly decline by -3 % (-19 to +6 %) because of intensified imports from Russia.

Prices of agricultural inputs were expected to increase slightly (diesel), moderately (herding services), or substantially (contractors, interest rate). It was expected that legume and cereal yields will slightly increase because of improved crop rotation. Simultaneously, it was expected that vegetable and sugar beet yields will slightly increase from current low levels due to wider use of fertiliser or pesticides.

Using the dynamic scenario, we found that since 2013 approximately half of the interviewed farmers had adjusted their production systems and were planning to further do so in future. We found no significant differences between the two farming systems. Ninety percent of farmers aimed to further increase total livestock numbers by 1.2 to 3.5 LUs due to the expected further increase of animal prices (mainly cattle and sheep in JM, and horses and sheep in JH). Because of larger herds, these farmers were also planning to ex-

Table 2: *Expected changes of uncertain dependent variables*

	Affecting	*Unit*	*Impact* *minimum*	*most likely*	*maximum*
Static scenario (changes induced by various sources of uncertainty)					
Price of cattle/ calf	revenue	percentage	-1	+7	+16
Price of milk (cow)	revenue	percentage	+4	+10	+33
Price of sheep/ lamb	revenue	percentage	+4	+10	+21
Price of horse/ foal	revenue	percentage	-9	+4	+7
Price of hay	revenue	percentage	-18	+14	+38
Price of potato	revenue	percentage	0	+15	+27
Barley price	revenue	percentage	-19	-3	+6
Sugar beet price	revenue	percentage	+3	+10	+41
Income from kitchen garden	revenue	USD	85	-	150
Fuel price	cost	percentage	-8	+4	+18
Interest rate (net of inflation)	cost	percentage	+29	+33.5	+34
Service of herders	cost	USD/LU	+5.8	+6.8	+9.4
Service of contractors	cost	percentage	0	+20	+50
Yield of cereals	revenue	percentage	2.3	2.4	2.5
Yield of alfalfa	revenue	ton/ha†	6.5	6.9	7.5
Yield of sainfoin	revenue	ton/ha†	3.0	3.3	3.7
Dynamic scenario (farmers' adaptation strategies)					
Jailoo-mid-level					
Increase in number of dairy cows	-	LU‡	1	-	2
Increase in number of sheep	-	LU‡	0.2	0.6	1
Increase in size of legume fodder	-	percentage	0.39	0.42	0.46
Jailoo-high					
Increase in number of sheep	-	LU‡	0.4	1.0	1.5
Increase in number of horses	-	LU‡	1	-	2
Increase in size of legume fodder	-	percentage	0.27	0.31	0.32

† dry matter, metric tons
‡ one livestock unit (LU) corresponds to 1 cattle, 0.83 horses or 6 sheep/goat; '0' means no change in price
Source: Key informant/expert interviews

pand the area of legume fodder cultivation alfalfa (*Medicago sativa*) in JM and sainfoin (*Onobrychis viciifolia*) in JH by reducing the cultivation area of less profitable barley and wheat. A few resource-rich farmers also mentioned that they were planning to invest in agricultural machinery and to provide contracting services in response to the likely changes in farming systems.

4.3 *Impact of expected changes in prices and factor cost on net farm income (static scenario)*

Net farm income was selected as the target output, as it is the crucial parameter to assess the impact of any changes in the production system on the farming families. From the Monte-Carlo analysis a statistical probability distribution for the annual imputed net farm income for 2018 in both farming systems was derived, assuming the expected changes of prices and factor cost (Figure 2). The simulated 2018 net farm income ranged between 3,670 and 4,550 USD with a mean of 4,163 USD for farms in JH, and 5,500 and 7,080 USD with a mean of 6,302 USD for farms in JM. Compared to the 2013 net farm incomes of 4,430 USD and 6,111 USD, respectively, this represents a decrease of 5.9 % for farmers in JH and an increase of 3.1 % for JM. Only 3.8 % of the Monte-Carlo iterations for JH resulted in a net farm income larger than in 2013, whereas 75.4 % of the iterations exceeded the 2013 value for JM. The s-shaped cumulated distribution functions indicated a generally lower variation in the modelled net farm income in JH, while the output for JM showed a higher level of variation. Because we expected several independent variables to influence the net income from livestock production and farming in opposite directions, we conducted separate sensitivity analyses for the two

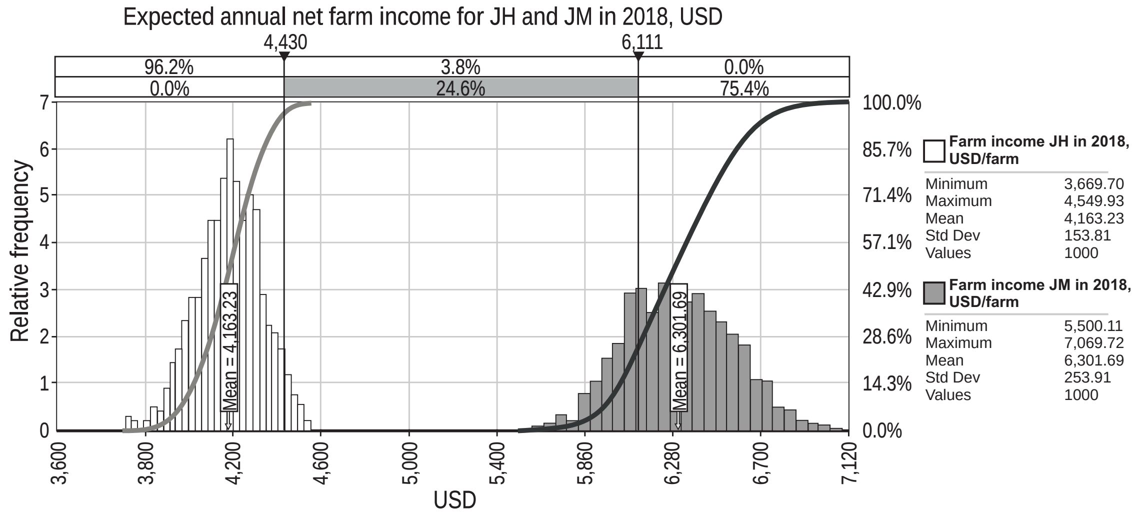

Fig. 2: *Probability distribution and distribution function of annual net farm income in 2018 for Jailoo-high (JH) and Jailoo-mid-level (JM) (static scenario). Source: Survey data.*

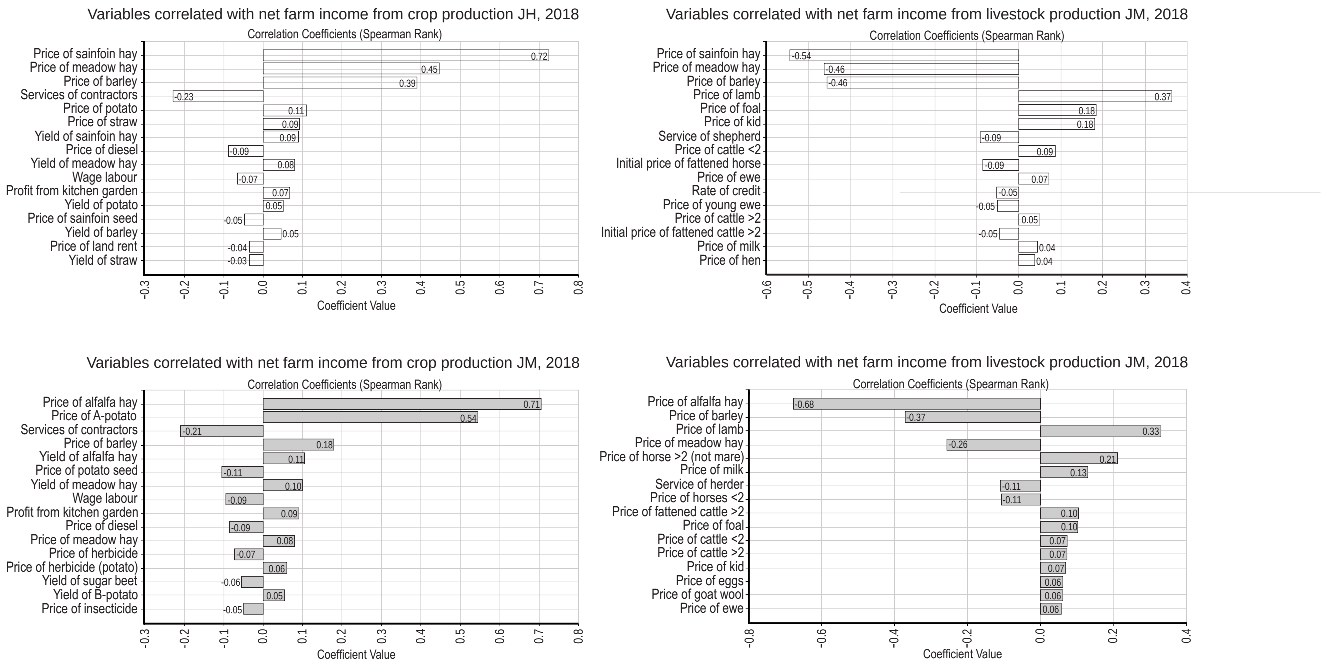

Fig. 3: *Factors affecting 2018 net farm income for Jailoo-high (JH) and Jailoo-mid-level (JM) (static scenario). Source: Survey data.*

main farm enterprises (Figure 3). The expected changes in the prices of sainfoin and meadow hay as well as barley had the strongest influence in JH. These variables had a strong to moderately strong positive influence on income from crop production and, simultaneously, a moderately strong negative influence on income from livestock production. The expected increase of hay price (14 %; Table 2) increased the income from crop production, but simultaneously decreased the profitability of livestock production. The expected decrease of the barley price (3 %; Table 2) had the opposite, but a comparatively smaller effect. The expected increase in sheep/lamb prices had a moderately strong positive effect on income from livestock production. Other variables were weakly or very weakly correlated with the expected profits in JH. Overall, these factors collectively decreased both the expected income from crop production (-16 %) and the income from livestock production (-1.4 %), resulting in a net decrease in total farm income of 5.9 %.

The expected increase in the price of alfalfa and potatoes by 14 % and 15 % (Table 2), respectively, had a strong to moderately strong positive influence on income from crop production and, simultaneously, the price of alfalfa had a strong negative influence on income from livestock production in JM. In addition, and similarly to JH, the expected increase in sheep/lamb prices by 10 % (Table 2) had a weak positive, and the expected decrease of the barley price by 3 % (Table 2) and the expected increase in meadow hay prices by 14 % (Table 2) had a weak negative association with income from livestock production. The influence of other variables on incomes from crop and livestock production in JM was weak or very weak. Overall, these factors collectively increased expected income from crop production by 7.1 %, and simultaneously decreased the income from livestock production by 1.6 %, resulting in the net increase of total farm income by 3.1 % in this farming system.

These findings illustrate the constraints under which farmers in the study region operated. Because of limited fodder availability and low overall livestock productivity in JH, increasing prices and market opportunities for livestock did not translate in improved farm income. Rather, the expected price increase for sainfoin and meadow hay (14 %) and expected decreases for barley price (3 %) have substantially increased average fodder cost, and hence, cost of livestock production (Table 2). Simultaneously, farmers could not benefit from the improved prices and market opportunities for sainfoin and meadow hay, as these crops were mainly used on their own farms and not marketed in order to alleviate the severe fodder shortage during winter. The decline in barley price, which constituted one of the few crops for which the excess produce was regularly sold by farmers in JH, has further reduced their cash earnings. In addition, increasing costs for contractors and fuel prices have contributed to reducing overall farm income in JH.

While the agronomic and socio-economic frame conditions were slightly more favourable in JM, our results indicate that farmers in this system were faced with similar challenges. Increasing fodder cost decreased the profitability of livestock production despite increasing animal prices, and increasing input costs and the use of fodder on farmers lands reduced the benefits farmers derived from increasing fodder prices. However, overall farm incomes increased slightly because these farmers produced a greater variety of crops (e.g., potatoes, sugar beets), more productive crops (e.g., alfalfa vs. sainfoin), and a larger share of their production was marketed for income generation compared to farmers in JH. For example, in contrast to JH, farmers in JM usually sold a portion of their alfalfa hay, representing an important source of cash income.

In summary, the expected changes of factor cost, and prices lead to only marginal and non-significant changes in the income from livestock production in both farming systems. Simultaneously, they significantly decrease the income from crop production for JH, while increasing the cropping income for JM. These model results indicate the necessity for farmers, particularly in JH, to respond to these expected changes by adapting and modifying their land use and production methods.

4.4 *Impact of expected changes in prices and factor cost and the respective adaptation strategies on net farm income (dynamic scenario)*

Assuming that farmers respond to the expected changes of prices and factor cost by adjusting their farm operations and management decisions, the simulated 2018 net farm income ranged between 4,036 and 5,521 USD with a mean of 4,704 USD for farms in JH, and 5,975 and 7,956 USD with a mean of 6,781 USD for farms in JM (Figure 4). Compared to the 2013 net farm incomes this represents an increase of 6.2 % for farmers in JH, and an increase of 10.9 % for JM. The probability of obtaining modelling results above the 2013 net farm income was 88.2 % for JH and 99.3 % for JM. Again, we observed a slightly lower variation in the modelled net farm income in JH compared to JM.

The sensitivity analyses (Figure 5) revealed that prices of sainfoin and meadow hay had the strongest influence on income from crop and livestock production in JH. These variables had a strong to moderately strong positive influence on income from crop production and, simultaneously, a moderately strong negative influence on income from livestock production. The expected change of barley prices had a weak positive correlation with cropping income, and a moderately strong negative correlation with income from livestock production. The expected increase in sheep/lamb prices had a moderately strong positive effect on income from livestock production. The farmers' most important response to the expected price changes was the intended expansion of cropping areas, in particular for sainfoin, which had a weak positive influence on incomes derived from cropping. Further adaptation strategies, such as increasing the number of livestock, had only weak, yet positive effects on income from livestock rearing. Other variables showed only weak or very weak correlations with the expected profits in JH. Overall, these factors collectively decreased the expected income from crop production by 3.6 %, and simultaneously increased the income from livestock production by 13.4 %, resulting in the net increase of total farm income by 6.2 %.

The expected increase in prices of alfalfa, potatoes, and sugar beets had a strong to moderately strong positive influence on income from crop production in JM. Simultaneously, the prices of alfalfa and barley had a strong negative and weak negative correlations, respectively, with income from livestock production. In addition, area expansion of al-

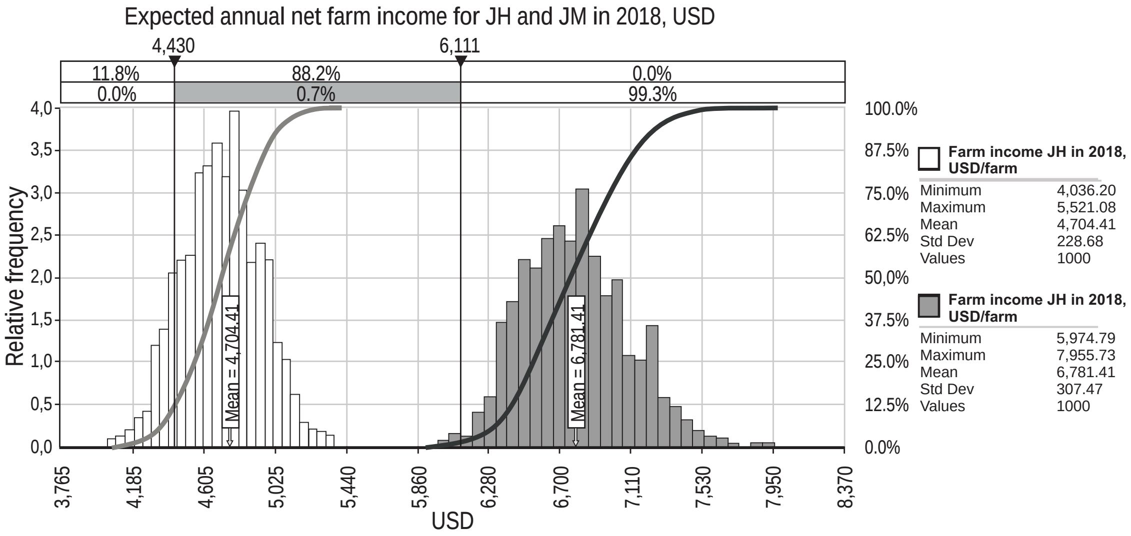

Fig. 4: *Probability distribution and distribution function of annual net farm income in 2018 for Jailoo-high (JH) and Jailoo-mid-level (JM) (dynamic scenario). Source: Survey data.*

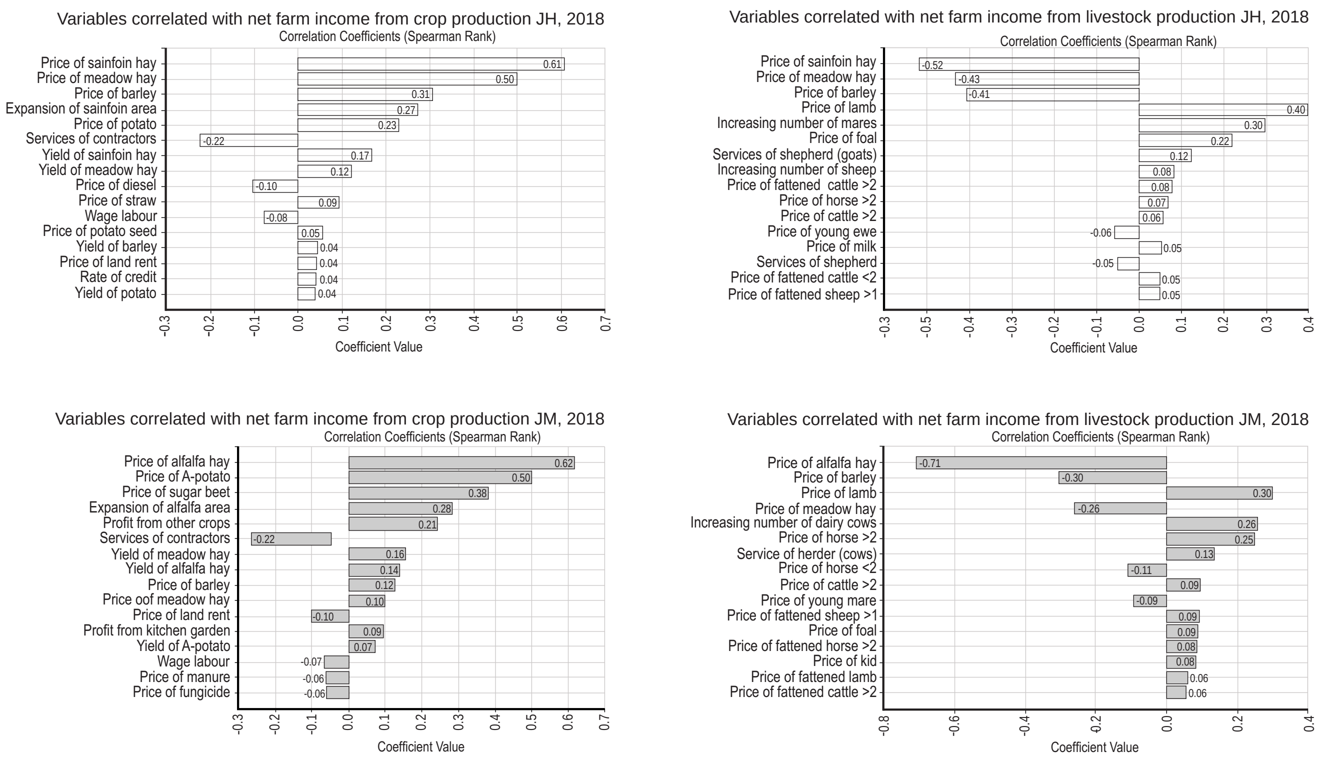

Fig. 5: *Factors affecting 2018 net farm income for Jailoo-high (JH) and Jailoo-mid-level (JM) (dynamic scenario). Source: Survey data.*

falfa in response to the anticipated changes of prices and factor cost, and the expected price change for sugar beets had a weak positive influence on cropping income. Moreover, the expected increase in meadow hay prices had a weak negative, and the expected increase in sheep/lamb prices and the planned increase of livestock numbers had a weak positive effect on income from livestock production. The influence of other variables on incomes from crop and livestock production in JM was weak. Overall, these factors collectively increased the expected income from crop production by 23 %, and simultaneously decreased the income from livestock production by 3.2 %, resulting in the net increase of total farm income by 10.9 % in this farming system.

In summary, our results show increasing net farm incomes for both farming systems resulting from increasing crop and livestock prices and adjustments in farm management and production methods. The effect of these changes differed in both farming systems. In JH, the increase of total net farm income was mainly driven by changes that affected the profitability of livestock production, while the increased net farm income in JM mainly resulted from the increased profitability of crop production. Processed products (e.g., cheese, mare milk) did not substantially contribute to farm income in either of the farming systems despite growing markets and increasing prices for these products.

5 Discussion

Smallholder farmers in mountain regions are faced with various uncertainties. In this paper, we investigated how the various bio-physical, economic, and political sources of uncertainty collectively affected their farm income for a mid-term horizon. We defined static and dynamic scenarios, the latter of which incorporated likely adjustments in land use and production methods.

While most farmers openly shared information on the level of farm operations, past and future adjustments, and the current costs, prices, and incomes with researchers during the farm survey and in-depth interviews, the accuracy of data was limited due to the general lack of farm records and the necessary reliance on recall. By limiting the study period to the year of data collection and through careful triangulation of data and sources we tried to minimize potential inaccuracies as much as possible. Experts were generally cooperative and provided thoughtful assessments of the likely impacts of the various sources of uncertainty. Due to practical limitations a Delphi panel setup was not feasible. However, through repeated and extensive probing of the individual expert's estimates, we obtained dependable appraisals of the magnitude of impact for the various uncertain factors.

The results of our study illustrate the uncertain factors that most affect farm incomes, which in turn help to improve farm revenues. For example, in order to benefit from increasing prices for livestock and agricultural products, farmers need to further adjust and modify their farm management, which can include the further expansion of cash crop cultivation in JM or an increase of herd sizes along with an expansion of fodder cultivation in JH. Schoch *et al.*, (2010) and Sabyrbekov (2019) found that increasing incomes led to production diversification, e.g. increase in livestock numbers. Given the substantial importance of livestock production in both farming systems and increasing pasture degradation in Kyrgyzstan (e.g., Robinson, 2016), an important consideration is to what extent herd size increases can be supported by pasture conditions without degrading pastures. A study in western Kyrgyzstan showed that increases in livestock numbers did not contribute to pasture degradation because herd owners, rather than herders, possessed long-term interests in maintaining pastures (Zhumanova *et al.*, 2016). Herders, in contrast, pursued short-term objectives and increased herd size despite deteriorating pasture conditions, thereby intensifying degradation. Because only between 8.2 % and 14.5 % of households derived income from herding services, we would like to suggest that the herd size increase that can be anticipated in response to market changes will not aggravate pasture degradation. Our results also imply that livestock production remains a major enterprise in both farming systems and that production methods are likely to remain low-input/low-output, particularly in JH. Simultaneously, increasing demand for animal fodder and cash crops can act as an incentive for some farmers to further diversify their operations and/or to specialize rather than to increase their own herds, thereby decreasing their dependence on subsistence production. This indicates the need to conduct agricultural extension outreach to advise and guide farmers in their attempt to specialize agricultural production. Other studies have reported similar findings in the region (Lerman & Sedik 2018, Sabyrbekov 2019). Furthermore, results clearly indicate that JM farmers benefit more from the expected changes of prices and factor costs than farmers in JH. This is not surprising given the existing differences between both areas regarding their remoteness, climatic conditions, and soil fertility. Farmers in high elevations are additionally disadvantaged by the general lack of road infrastructure and market access; poor irrigation facilities and livestock watering points; and the limited availability of extension and veterinary services. Therefore, farmers in JH can only make slight adjustments to their production methods due to their limited resources in terms of productive land, capital, or knowledge and information. Our findings can, thus, also be understood as a plea to policy-makers and development practitioners to intensify their efforts to promote rural development of mountain regions to alleviate the socio-economic disparities between the various parts of Kyrgyzstan. This finding also agrees with the widening gap reported between policy-makers and smallholder pastoralists (Kasymov *et al.*, 2016).

The lessons regarding the required adjustments of farm management and production methods and the dissimilar benefits derived by farmers in the high-elevation versus middle-altitude systems, considering the uncertainties that affect rural areas, may prove beneficial for other countries in the region. As a practical contribution, our analyses can provide the following useful insight and guide policy making in Kyrgyzstan and beyond: the relatively small scale of farm operations and related inefficiencies suggest that significant improvement potential lies in consolidating the farming structure by helping smallholder farmers to cooperate in agricultural and livestock production, marketing, investments in infrastructure and technology and/or farm expansion to achieve more competitive scales. While the establishment of cooperatives and larger-scale private farms is difficult in the short term due to various historical, economic, and socio-political reasons, it remains an important strategy of agricultural policy-making in the future. Equally important are investments to ensure the quality and safety of agricultural products, particular livestock and meat products, to export these to other countries. Kyrgyz producers have difficulties to export agricultural products to EAEU markets due to numerous impediments and barriers. In 2007, for instance, Russia and Kazakhstan imposed a ban on Kyrgyz meat imports because of the occurrence of epizootic diseases, and the temporary import ban for potatoes to Kazakhstan due to detection of nematodes (*Globodera rostochiensis*) in 2016. Towards this objective, several structural improvements need to be implemented in the Kyrgyz livestock sector from farm to fork, which includes the provision of improved extension and veterinary services to farmers, more stringent veterinary and sanitary controls, upgrading of lab equipment and staff training, as well as improving the hygienic conditions in slaughtering and meat processing. Such improvements could foster the export potential of the sector to international markets, thereby increasing income for Kyrgyz farmers as noted by other researchers (Mogilevskii *et al.*, 2014, Tilekeyev *et al.*, 2016)

We are aware that our approach has the following shortcomings: (i) dependence on expert estimates in absence of ex-post data, as well as the size and composition of the expert panel, which we tried to address by assembling the best expertise available from leading national institutions in public administration, academia, and the livestock sector; (ii) restriction of our focus to a mid-term horizon, which was deemed to be the most acceptable compromise between foresight and accuracy of predictions, despite the fact that a long-term perspective would be more desirable; and (iii) use of average values as entry parameters for the simulation models in both farming systems. We believe that our study will inspire further research to help address some of these aspects.

6 Conclusions

Overall, our results indicate that various uncertainties in rural areas significantly affect the operations and economic performance of smallholder farms. Because of these combined uncertainties, continuous adjustments in the smallholders' land use and production methods are required to increase farm income. National agricultural and economic policies can improve farmers operational conditions by encouraging further professionalisation of the farming sector through education, infrastructure development, consolidation of the agrarian structures, and improved food quality and safety management. The adjustments farmers propose to their current farm management in response to price and factor cost changes will help facilitate and increase the movement of their largely subsistence-oriented system to a more market-oriented production system. This could be observed already in JM where farmers switched from fodder production to cultivation of potatoes, sugar beets, haricot beans, or green peas in response to foreign demand. For farmers, a moderate increase in livestock numbers and livestock marketing along with an expansion of fodder cultivation is suggested to increase the profitability of livestock production.

Acknowledgements

We are very grateful for the critical comments we received on our draft from the anonymous reviewers as well as from Patrick van Damme, which helped us to significantly improve our manuscript. We gratefully acknowledge the financial support of German Academic Exchange Service (DAAD) without which this research could not have been conducted.

Conflict of interest

Authors state no conflict of interests.

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