The impact of land degradation on agricultural profits and poverty in Central Asia

A. Mirzabaev[1]; A. Strokov[2]; P. Krasilnikov[3]

1: University of Bonn, Center for Development Research (ZEF), Germany, 2: Russian Presidential Academy of National Economy and Public Administration (RANEPA), , Russian Federation, 3: Moscow State University, Eurasian Center for food Security (ECFS),

Corresponding author email: almir@uni-bonn.de

Abstract:

Land degradation is a critical challenge to sustainable development in Central Asia. The study found that land degradation over the previous three decades may have been responsible for about 27% losses in agricultural profits in the region during the 2009-2010 cropping season compared with the case without land degradation. Middle- and richer tercile of agricultural households lost a higher share of their farm profits due to land degradation, 30% and 34%, respectively. There was not a significant impact of land degradation on the farm profits of the poorest tercile. The poor agricultural households have a stronger dependence on land for their livelihoods, hence; have a stronger incentive to take a better care of land. The results corroborated this: the poor households applied, on average, 25% more sustainable land management practices than the richest group, and almost twice more than the middle group. The poor have higher incentives to manage their land sustainably if institutional and economic settings allow them to do so. Among such institutional factors, the study found that increasing crop diversification, securing land tenure and providing a better access to markets significantly contributed to higher farm profits among poor agricultural households in Central Asia.

Acknowledgment: We thank the German Federal Ministry for Economic Cooperation and Development, and Center for Development Research (ZEF), University of Bonn, for the support in the development of the methodological framework in this paper. The analysis and literature review in the paper were supported by Russian Science Foundation, project № 14-38-00023. We are highly grateful to the International Center for Agricultural Research in the Dry Areas (ICARDA) for the survey data and the Asian Development Bank (ADB) for funding the survey.

JEL Codes: Q15, Q56

#654

The impact of land degradation on agricultural profits and poverty in Central Asia

Abstract

Land degradation is a critical challenge to sustainable development in Central Asia. This study found that land degradation may have been responsible for about 27% losses in agricultural profits in the region during the 2009-2010 cropping season compared with the case without land degradation. Such losses in agricultural profits are highly negative for poverty reduction in Central Asia. However, contrary to widespread beliefs that land degradation affects the poorest the most, we find that medium and richer groups of agricultural households lost a higher share of their farm profits due to land degradation, 30% and 34%, respectively. We could not find any significant impact of land degradation on the farm profits of the poor. The poor agricultural households have a stronger dependence on land for their livelihoods, hence; have a stronger incentive to take a better care of land. Our results corroborate this: the poor households applied, on average, 25% more sustainable land management practices than the richest group, and almost twice more than the medium group. Poverty does not need to inexorably lead to land degradation and to subsequent viscous cycles exacerbating poverty. The poor have higher incentives to manage their land sustainably if institutional and economic settings allow them to do so. Among such institutional factors, we find that increasing crop diversification, securing land tenure and providing a better access to markets significantly contribute to higher farm profits among poor agricultural households in Central Asia.

Key words: land degradation, economic impacts, poverty, household survey, Central Asia

Introduction

Land degradation is a barrier for sustainable development and poverty reduction in Central Asia (Nkonya et al. 2016). Since agriculture remains an important source of employment in the region (Mirzabaev 2013), lower crop yields and livestock productivity because of land degradation are likely to result in lower incomes for agricultural households (Pender et al. 2009). This may, in turn, also hinder the ongoing efforts to reduce poverty and eradicate malnutrition, especially in the rural areas in the region.

The reasons for land degradation in the region are many and multifaceted (see Gupta et al. 2009 for a review). Mirzabaev et al. (2016) found that lack of access to markets and to extension, and insecure land tenure are the key causes of land degradation in Central Asia. Similarly, Aw-Hassan et al. (2016) point out that crop diversification, off-farm employment and secure land tenure are key factors for stimulating sustainable land management (SLM) in Uzbekistan.

Land degradation is, in fact, not a recent phenomenon in the region. Rangeland degradation and soil erosion were already wide-spread in the past (Bekturova and Romanova 2007). Monoculture of cotton introduced in Central Asian republics during the Soviet epoch was the main reason of the extension of irrigated lands and consequent development of soil salinization (Sievers, 2003). However, the scales of land degradation increased dramatically with the substantial expansion of cropped areas into marginal zones, both under rainfed and irrigated agriculture (Gupta et al. 2009). With the collapse of the Soviet Union, and the subsequent transition period, land degradation issues increased further due to lack of funding for sustainable land management measures, such as, for example, proper maintenance of irrigation and drainage infrastructures. Presently, 11 million hectares are affected by soil erosion Kazakhstan (Pender et al. 2009). More than half of irrigated areas in the region are salinized (Qadir et al. 2009).

More recently, Le et al. (2016) assessed the extent of land degradation hotspots in the region (Figure 1). Cropland degradation was found to cover substantial areas, from 25% of croplands in Kyrgyzstan to 57% in Kazakhstan (ibid.). Le et al. (2016) use remotely sensed Normalized Difference Vegetation Index (NDVI), GIMMS NDVI 1982-2006 dataset, to identify these land degradation hotspots based on the declines in biomass-productivity between 1982-1984 (baseline) and 2004-2006 (endline). Their estimation also removes the potential biases emanating from rainfall dynamics, atmospheric and chemical fertilization, thus, isolating human-caused land degradation.

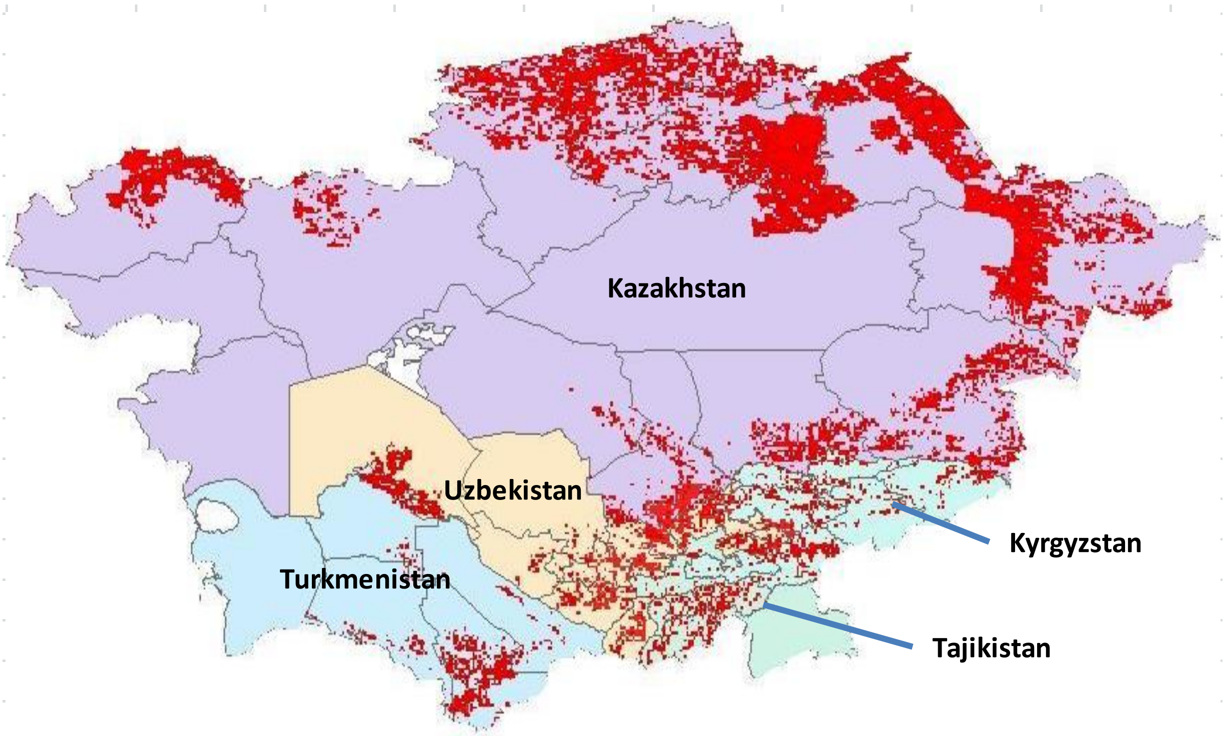

Figure 1. Land degradation hotspots in Central Asia (in red), a negative change in NDVI between 1982-84 and 2006.

Source: Mirzabaev et al (2016), adapting from Le et al. (2016).

Le et al. (2016) define land degradation as "the persistent reduction or loss of land ecosystem services, notably the primary production service". In this they follow previous definitions of land degradation, such as those indicating that land degradation leads to losses in ecosystem services and economic productivity of the land (UNCCD 1994), and that land degradation is commonly associated with the loss of productivity of soils due to the processes of physical, chemical, and biological deterioration (FAO, 2016). However, current views on land degradation are more complex and system-based. According to Meyer et al. (2016, in this issue): "Landscape degradation describes an irreversible or non-resilient system change to a landscape that affects the landscape system components (i.e., their geo-factors, land use and interlinkages), the natural and cultural capacities of the landscape in terms of structure, processes, and landscape functions (productive, ecological and social), or ecosystem services." According to this definition, the degradation of any component of a landscape, even the minor one, would lead to the imbalance in the internal structure of the system and thus to the loss of the capacity of the landscape to provide ecosystem services. The definitions of land degradation by Le et al. (2016) and Meyer et al. (2016) have both similarities and differences. The similarities are in way that both of these definitions view land(scape) degradation to be having significant negative impacts on landscape functions and ecosystem services with negative implications on human wellbeing. In contrast to Le et al. (2016), Meyer et al. (2016) emphasize landscape degradation as "an irreversible or non-resilient systems change". The latter approach is conceptually more nuanced and may better capture the complex systemic processes associated with land degradation, but would also require significant amount of data on landscape components, resilience thresholds and nonlinear processes that are currently not available for Central Asia. For this reason, we use the land degradation hotspots data generated by Le et al. (2016) for Central Asia in the analysis presented in this study.

In terms of lower ecosystem services, land degradation negatively affects the incomes of agricultural producers by reducing crop yields and by increasing input use. Some past global estimates of the effects of land degradation showed a decrease of about 12.7% in agricultural productivity due to land degradation (Oldeman 1998), with soil erosion negatively affecting crop yields (den Biggelaar et al. 2003, Pimentel et al. 1995). Barbier (1998) provides several examples of how soil conservation measures lead to the increase in the resource use in the future, whereas soil erosion increases the resource use rates in present. There is a lot of empirical evidence of interconnection between soil degradation and soil conservation measures and farm incomes. Kruseman and Bade (1998) and Pagiola (1996) describe farms in Africa when soil conservation measures led to declines in farmers' incomes, but after 7-10 years the farmers who applied SLM measures increased their income compared with the farmers who used traditional technologies. Djanibekov et al. (2012) showed positive impacts of afforestation on agricultural lands in Uzbekistan during a 7-year period. Their study showed that grain rotation and inputs optimization had a positive impact on farmers' incomes in Uzbekistan (Djanibekov et al. 2013). In Central America, Cocchi and Bravo-Ureta (2007) and Bravo-Ureta et al. (2006) find close and statistically significant relations between the application of soil conservation measures and the increase of farmers' incomes.

Despite a general awareness of the negative impact of land degradation on farmer incomes in Central Asia, there is lack of quantitative knowledge about the extent of these income losses. Moreover, the distributional impacts of land degradation among different categories of households have not been studied in the region. Globally as well, there is a strong lack of studies looking into the distributional effects of land degradation. This study aims to fill this gap.

Theoretical framework

The analysis in this study is guided by the application of the so-called Ricardian method to studying the impacts of land degradation on agricultural profits. The Ricardian approach was first suggested by Mendelsohn, Nordhaus and Shaw in mid 1990s (Mendelsohn *et al*. 1994) for assessing the impacts of climate change on agriculture in the USA. The Ricardian approach makes use of cross-sectional data to capture the influence of climatic, land quality, as well as other economic and other factors on land values or net farm income. The monetary value of land is assumed to reflect the productivity of the land. The Ricardian method was since then widely applied in many settings for analyzing the impacts of climate change on agriculture (Aurbacher et al. 2010, Benhin 2008, Seo *et al*. 2009).

The Ricardian method is theoretically traced to hedonic models (Grilliches 1971, Rosen 1974). Hedonic models take their theoretical underpinnings from an approach to consumer demand theory proposed by Lancaster (1966), where a demand for a particular product can be attributed into demands for individual qualities or characteristics constituting that product. Hedonic models have been widely used in housing market analysis (Can 1992). Hedonic models characterize housing values to be made of a bundle of attributes, so that house price = f (a_1, a_2, ..a_n), where $a_1 \dots a_n$ are various characteristics of the house, such as number of rooms, availability of parking lot, etc. Marginal price of each attribute, then, can be estimated separately within a multivariate regression framework (ibid.). Applying this thinking to our case, the model considers land quality to be one of the attributes making up the agricultural profitability from this land. Thus, marginal impact of degraded land on land values or agricultural profits from that land can be estimated in monetary terms. The original Ricardian approach suggested by Mendelsohn et al. (1994) has been further modified to better account for the particularities of developing countries without functional land markets, hence, without the possibility of using land values as the dependent variable in the reduced form regressions. Instead of land values, net revenues per hectare were used as dependent variable (Kurukulasuriya and Ajwad 2007). This approach is applied in this study for Central Asian countries, where land values are replaced with net farm profits. A production function of the farm can be denoted as a function of inputs such as land quality, climate variables (temperature, precipitation), etc, such that:

$$\pi = \sum(P * Q(I, C, E)) - Pr * I \qquad (1)$$

π – net profit

P – vector of output prices

Q – vector of crop outputs

I - vector of purchased inputs

C- vector of climate variables

E – vector of farm endowments such as **land quality**, machinery, market access, etc

Pr – vector of input prices

The farmer seeks to maximize net revenues given the characteristics of the farm and market prices. The impact of land degradation is measured as:

$$\Delta U = \pi(L_0) - \pi(L_1) \qquad (2)$$

where,

Δ U – change in the farming profits

π (L_0) – net profits without land degradation

π (L_1) – net profits after land degradation

Methods and data

Empirical framework

In the empirical analysis, the reduced form of regression of the model given in (1) is estimated using ordinary least squares (OLS) regression. The model is given as:

$$\pi = \alpha L + \beta H + \phi C + \eta A + \delta I + \mu G + \epsilon \qquad (3)$$

where,

π = net profits

L= variable showing if land is degraded or not [1]

H = a vector of household characteristics

C = a vector of climate variables (temperature and precipitation, their variability)

A=vector of agro-ecological characteristics (length of growing period, etc)

I = a vector of institutional variables (access to extension, land tenure, etc)

ϵ = the error term

[1] The land degradation indicator is derived from Le et al. (2016), who use remotely sensed Normalized Difference Vegetation Index (NDVI), GIMMS NDVI 1982-2006 dataset, to identify land degradation hotspots. The land degradation is defined as "as the persistent reduction or loss of land ecosystem services, notably the primary production service". Statistically significant decline of more than 10% in the NDVI values between the baseline of 1982-84 and endline of 2004-06, after correcting for the masking effects of rainfall and atmospheric fertilization, is considered to represent land degradation.

The country fixed effects G are also included in order to account for unobserved country-specific variables. α, β, ϕ, η, δ, and μ are vectors of corresponding parameters.

In addition to identifying the average effects of land degradation on agricultural profits, this study also seeks to evaluate the distributional effects of land degradation. To identify these distributional effects, we run the model specified above separately for households of different asset categories. As assets are accumulated over a longer period of time and are less liquid, they are likely to be a better indicator of households' economic status (Carter and Barret 2006), since monthly or annual expenditures may be more volatile. Moreover, households can use various consumption smoothing mechanisms in the short run (for example, by borrowing), hence categorizations based on household assets may be more accurate than those based on household expenditures. We classify households into three categories using the total value of all their assets, including the value of their real estate, personal cars, farm equipment and tools. The bottom 25% of the households are classified as "poor", those between the bottom 25% and top 25% as "medium", and those belonging to the top 25% by the value of their assets as "rich". On average in the sample, the households classified in the poor category have about 800 USD of assets, those in the medium category have about 12,400 USD of assets, and those in the rich category have about 60,000 USD of assets.

Data

The dataset used in this study comes from nationally representative agricultural household surveys carried out during 2009-2010 in Central Asia, except Turkmenistan. The multi-stage survey sampling was conducted in a way to ensure representativeness of the sample with the overall population of agricultural producers across different agro-ecologies in each country (Mirzabaev 2013). The confidence interval of 95% was used to calculate the sample size. The calculated sample size varied between 380 and 385 respondents between the countries. To compensate for any missing or failed cases, the surveyed sample size for each country was determined to be 400 respondents, i.e. 1600 respondents in total (Figure 2).

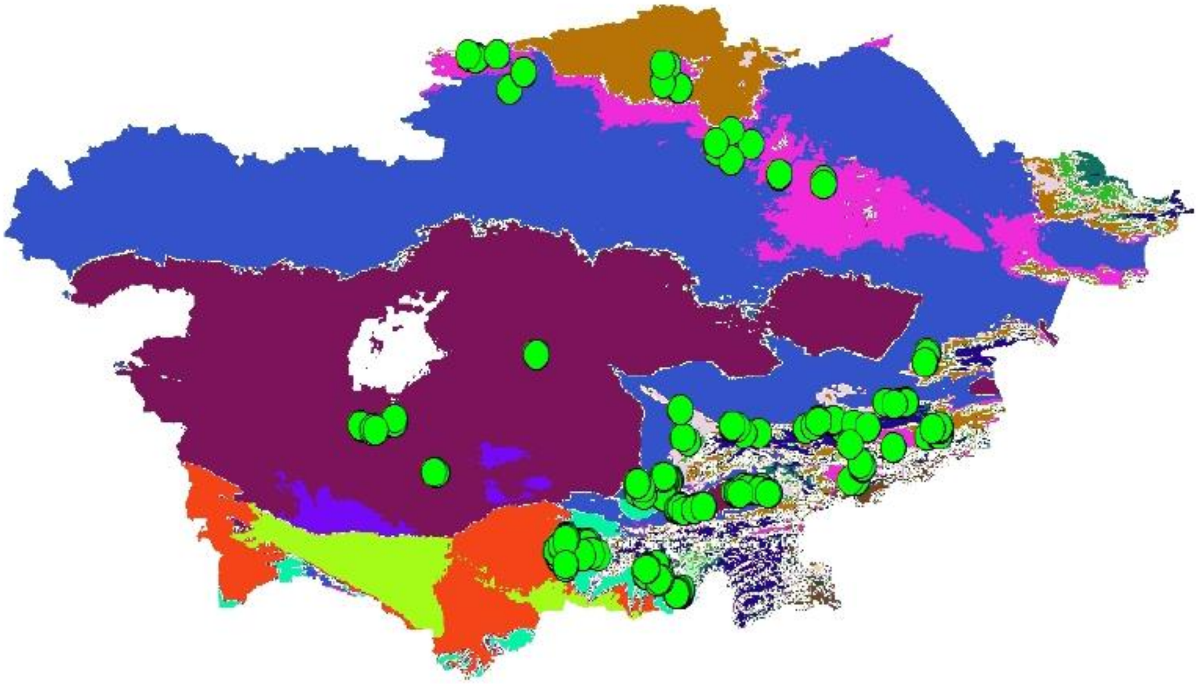

Figure 2. Location of surveyed households across agro-ecological zones in Central Asia. Source: Mirzabaev (2013)

Variable selection

Most of the variables used in the analysis come from the above described household survey. In addition, several spatial variables were incorporated at household level using household geographic position system (GPS) coordinates from other sources and warrant more explanation. This concerns specifically our land degradation indicator and climate variables.

Land Degradation variable

As indicated earlier, land degradation variable used in the analysis is a categorical one (0- no land degradation, 1-there is land degradation). It is derived from the work of Le et al. (2016), who use remotely sensed Normalized Difference Vegetation Index (NDVI), GIMMS NDVI 1982-2006 dataset, to identify land degradation hotspots. Le et al. (2016) use 1982-1984 as baseline, and 2004-2006 as end-line. Their estimation removes the potential biases emanating from rainfall dynamics, atmospheric and chemical fertilization, thus, the variable stands for the anthropogenic land degradation between 1982 and 2006. Le et al. (2016) define land degradation as "the persistent reduction or loss of land ecosystem services, notably the primary production service". Statistically significant decline of more than 10% in the NDVI values between the baseline of 1982-84 and endline of 2004-06, after correcting for the masking effects of rainfall and atmospheric fertilization, is considered to represent land degradation. This land degradation mapping was also validated through local evaluations, including in Uzbekistan, and has shown a high level of accuracy (Anderson and Johnson 2016). An important added advantage of this variable is since land degradation has occurred before the time of the survey, there is no endogeneity problem in our estimation. One caveat in using this variable in the estimation is that it is of very course resolution (8x8 km^2), and not at household level. However, since our surveyed households are very much spread out across the region, this variable is likely to show regional average impacts of land degradation on agricultural profits in a relatively accurate way.

Climatic characteristics

The climate variables have been compiled from about 400 weather stations across Central Asia. The data come from national meteorological agencies, Williams and Konovalov (2008), NASA´s Global Summary of the Day, and other sources. Climate variables from individual weather stations were spatially projected to the digital map of Central Asia using spatial interpolation technique of inverse weighted distance. Following this, corresponding weather variables were extracted for each household using the GPS location of the household.

Results

Some major characteristics of the surveyed households are presented in Table 1. Most characteristics are similar across the countries in the region, except for the value of total assets, where the farming households in Kazakhstan are richer than those in other countries. Similarly, average farm sizes are significantly higher in Kazakhstan. Crop diversification levels come out to be higher in Uzbekistan then in the rest of the region. The farmers in Tajikistan and Uzbekistan have also substantially better access to extension services than in Kyrgyzstan and Kazakhstan. The average household size is about 6-8 people across the surveyed households, with the dependence ratios also being similar at about 0.7. Although there are a lot of similarities between the countries in the region, there are also some marked differences as demonstrated in Table 1. The applied estimation approach seeks as much as possible to explicitly account for these differences in the model. However, there may be myriad of other country-specific unobserved differences, for example, related to divergences in agricultural policies in the countries. To implicitly account for these factors, we use country-fixed effects in our estimation, using a categorical variable made up of 4 categories, with Kazakhstan representing the base (0), then Kyrgyzstan having the value 1, Tajikistan 2, and Uzbekistan 3.

Table 2 shows the impact of the selected variables, including land degradation, on the agricultural profits of surveyed households in 2009-2010 cropping season. These results show that land degradation may have been responsible for about 26.6% losses in agricultural profitability in the region. The results also show that access to extension may increase agricultural profitability, on average, by 33% among the surveyed households. Private land tenure was also found to be associated with 24% higher profitability. Smaller farms were found to be more profitable than larger farms in the region.

Table 1. Data descriptives

Variables	Kazakhstan	Kyrgyzstan	Tajikistan	Uzbekistan
Household size, persons	6	6	8	6
Dependency ratio	0.7	0.7	0.7	0.8
Average age of household head, years	51	50	52	47
Length of growing days	97	102	131	92
Number of crops grown	0.99	1.03	2.12	3.21
Annual precipitation, in mm	402	448	486	289
Mean annual temperature, °C	7.0	5.7	14.4	14.4
Frequency of weather shocks during the last 5 years	2.7	0.4	1.1	1.4
Land tenure (0-not private, 1-private)	0.63	0.90	0.73	0.60
Farm size in ha	194	5	4	28
Access to extension (0-no, 1-yes)	0.1	0.2	0.7	0.7
Value of livestock (in USD)	5255	8998	869	6796
Distance to markets (in minutes)	133	150	59	75
Value of total assets (in USD)	83123	20727	7407	34939

Source: the survey

The results also indicate that crop diversification is likely to increase agricultural profits by about 19%. Among the weather variables, those farmers located in warmer parts of the region were found to be more profitable. However, higher variability of temperatures was negatively related with agricultural profitability.

The fact that past land degradation is presently causing the losses of almost of a third of net agricultural profits in the region may be highly negative for poverty reduction in Central Asia. To keep in mind, this is not agricultural revenues, but the net profits excluding variable and fixed costs. Land degradation leads to both more input use (i.e. higher costs of production) and lower crop yields. In terms of distributional effects, our results show that the effect of land degradation on the agricultural profits of the poorest 25% of households is not statistically significant, whereas the households in the medium and rich asset categories lost 30% and 34% of the net profits in 2009-2010 cropping season due to past land degradation (Table 3).

Table 2. The estimation results on the impacts of land degradation on agricultural profits

VARIABLES	Coefficient	Confidence interval
Land degradation (no-0, yes-1)	**-0.266*** **	**-0.439 - -0.0936**
Household size	0.0223	-0.00724 - 0.0519
Education of household head, base-primary		
Middle school	-0.0175	-0.509 - 0.474
High school	0.0595	-0.439 - 0.558
College	-0.0147	-0.509 - 0.480
University degree	0.0813	-0.412 - 0.575
PhD	1.653	-0.964 - 4.271
Country, base-Kazakhstan		
Kyrgyzstan	0.239	-0.169 - 0.647
Tajikistan	-1.346***	-1.838 - -0.854
Uzbekistan	-1.014***	-1.447 - -0.580
Gender of household head (0-female, 1- male)	0.205	-0.0406 - 0.451
Age of household head	-0.00261	-0.00974 - 0.00452
Agro-ecological zone, (base-arid)		
Semiarid	-0.452**	-0.898 - -0.00716
Sub-humid	-0.158	-0.676 - 0.360
Humid	0.488	-0.133 - 1.110
Length of growing days	0.00159	-0.00608 - 0.00926
Number of crops grown	0.188***	0.112 - 0.264
Annual precipitation, in mm	-9.77e-05	-0.00120 - 0.00100
Mean annual temperature, °C	0.0473***	0.0157 - 0.0789
Precipitation variability	0.00104	-0.00103 - 0.00311
Temperature variability	-0.207***	-0.335 - -0.0798
Frequency of weather shocks	-0.000448	-0.0266 - 0.0257
Farm size (logs)	-0.181***	-0.264 - -0.0980
Private land tenure (0-no, 1-yes)	0.243*	-0.0456 - 0.531
Interaction of land tenure and farm size	-0.0419	-0.151 - 0.0672
Access to extension (0-no, 1-yes)	0.330***	0.126 - 0.534
Value of owned livestock	5.15e-06***	2.34e-06 - 7.95e-06
Distance from markets (log)	-0.0414	-0.139 - 0.0564
Constant	7.064***	5.983 - 8.145
Note: *** p<0.01, ** p<0.05, * p<0.1, R-squared 0.206		

Table 3. The estimation results on the impacts of land degradation on agricultural profits by households of different asset categories.

VARIABLES	Asset Categories		
	Poor	Medium	Rich
Land degradation (no-0, yes-1)	**0.00791**	**-0.300*** **	**-0.342***
Household size	0.0120	0.0240	0.0198
Education of household head, base-primary			
Middle school	-0.0537	-0.0272	0.277
High school	0.285	0.122	0.245
College	-0.0817	0.102	0.193
University degree	0.121	-0.0860	0.405
PhD	2.468		
Country, base-Kazakhstan			
Kyrgyzstan	1.003	0.0688	-0.700
Tajikistan	-0.838	-1.114***	-0.971
Uzbekistan	-2.165***	-0.623**	-0.738*
Gender of household head (0-female, 1- male)	-0.113	0.317**	0.214
Age of household head	-0.00787	-0.00260	-0.00139
Agro-ecological zone, (base-arid)			
Semiarid	-0.168	-0.105	-0.427
Sub-humid	-0.00460	0.520	-0.206
Humid	-1.628*	1.240***	0.834
Length of growing days	-0.0246*	0.00284	0.0122
Number of crops grown	0.259***	0.264***	0.0765
Annual precipitation, in mm	0.000261	0.000381	-0.000456
Mean annual temperature, °C	-0.320*	-0.127	-0.266
Precipitation variability	0.00568**	-0.000726	-0.000433
Temperature variability	0.168**	0.0448**	-0.00568
Frequency of weather shocks	0.0561*	0.00192	-0.109***
Farm size (logs)	-0.248**	-0.209***	-0.396***
Private land tenure (0-no, 1-yes)	0.540*	0.158	-0.292
Interaction of land tenure and farm size	-0.0788	-0.0875	0.304***
Access to extension (0-no, 1-yes)	0.133	0.0975	0.814***
Value of owned livestock	0.000155	4.70e-05***	3.34e-06**
Distance from markets (log)	-0.281**	-0.0179	0.0811
Constant	8.166***	6.023***	7.426***
Note: *** p<0.01, ** p<0.05, * p<0.1			

There have been many studies in the past indicating that land degradation has negative impacts on rural poverty (Barbier 2000, Grepperud 1997, Nkonya et al 2008). Moreover, poverty was also indicated to lead to land degradation, and further to a vicious cycle of land degradation-poverty-land degradation (Way 2006, Cleaver and Schreiber 1994, Scherr 2000). However, there have been also studies showing that the poor can successfully address land degradation if market conditions allow for that (de Janvry et al. 1991, Nkonya et al (2008b). Based on the results above, we find no evidence that past land degradation had negative impacts on the agricultural profits of the poorest agricultural households in Central Asia, moreover, it seems that past land degradation had a significant and substantial negative effects on the agricultural profitability of the richer group of households during 2009-2010 cropping season. The discussion below elaborates on these findings.

Discussion

The results of the analysis are surprising given that many previous studies indicate that the poor are likely to be affected more by land degradation because of their stronger dependence on land resources for the livelihoods (Nachtergaele et al. 2010). Moreover, their coping capacity against land degradation is lower than among the richer households, so they may adopt fewer sustainable land management practices to address the impacts of land degradation. On the other hand, exactly because the poor are more dependent on land resources, they are likely to take a better care of land than the richer households, by adopting more sustainable land management practices. We test each of these assumptions above to find out the explanations for our findings.

Do poor depend more on agriculture for the livelihoods?

To answer this question, we compare the share of agricultural profits in the total food consumption of poor, medium and rich households. If exact data on incomes were available, it would be a straightforward task to compare agricultural profits with total household net income and identify the extent of each households' dependence on agriculture. However, survey-based measures of income were found to be much less reliable than the survey data on the actual spending of the households (Deaton 1997). Here, the food expenses are taken as they represent major share of household expenditures for most of the surveyed households. The results are revealing (Table 4).

Table 4. Comparisons of agricultural profits, total sales and food expenses of households of different asset categories

Variables	Poor	Medium	Rich
Annual food expenses, USD	1 649	2 022	2 496
Net agricultural profits, USD	2 014	1 589	2 186
Total agricultural sales, USD	3 054	5 127	25 380
Share of food expenses in net agricultural profits, %	82%	127%	114%
Net profits compared to gross revenues, %	66%	31%	9%

The poor households' food expenses are funded entirely from their agricultural profits, and they are also using their agricultural profits to cover at least some of their non-food expenses. On the other hand, medium and rich households' food expenses are bigger than their agricultural profits, hence, also covered by non-farm income. Moreover, although their food expenses are 19% lower than those of the medium group, and 35% lower than those of the rich group, the profitability margins among the poor are twice higher than among the medium group, and more than 7 times higher than among the rich group. These results corroborate that the poor are more dependent on agriculture for the livelihoods and they are doing their best to eke out as much as they can from their agricultural assets.

But how the poor are able to achieve this? Are they are adopting more sustainable land management practices?

This seems exactly what is happening, the poorest households are adopting, on average, 25% more SLM practices than the rich group, and almost twice more than the medium group (Figure 3). This corroborates the earlier findings in the literature that the poor can manage their land sustainably when the institutional conditions allow for this. Among the key variables that were positively related to higher agricultural profits among the poor were land tenure security, higher crop diversification and better access to markers.

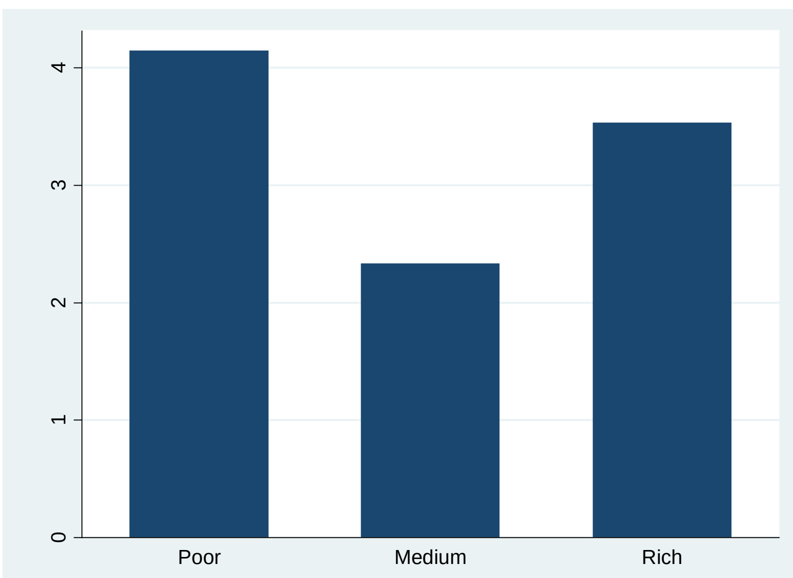

Figure 3. Adoption of SLM practices by different categories of households

Note: The variable on the adoption of sustainable land management (SLM) practices comes from the agricultural household survey, where the surveyed households were asked to indicate the SLM practices they use. They were given an open-ended list of about 30 SLM practices, including such as manure application, mulching, minimum tillage, crop rotation, cover crops, etc.

Conclusions

The study finds that land degradation that had occurred over the previous three decades may be responsible for about 27% of losses in agricultural profits in the region during the 2009-2010 cropping season in Central Asia. Contrary to wide-spread understanding that land degradation affects the poorest the most, we find that richer households lost a much higher share of their profits to land degradation than the poor. This is due to the fact that the poor households have adopted more sustainable land management practices than their richer counterparts. Our findings tell a positive story. Poverty does not need to lead to land degradation. On the contrary, the poor have the incentives to manage their land sustainably if the institutional frameworks allow them to do so. Among such institutional variables, we find that increasing crop diversification, securing land tenure and providing better access to markets significantly contribute to higher farm profits among the poor agricultural households.

One limitation of this study is a potential "survivorship bias", making our estimates of the losses due to land degradation relatively more conservative. We are looking into the areas where land degradation has not trespassed the irreversibility points and thresholds beyond which no agricultural production is possible. There are some areas in the region where the severity of land degradation has led to their abandonment from crop production, consistent with Meyer et al. (2016) definition of landscape degradation. However, there are no suitable counterfactual socioeconomic and detailed biophysical data, including on potential restoration costs and opportunity costs of alternative uses of these abandoned lands. Hence, this is the area that we recommend for further research and data collection in the region.

References

Anderson, W, Johnson T. 2016. Evaluating Global Land Degradation Using Ground-Based Measurements and Remote Sensing. In Economics of Land Degradation and Improvement–A Global Assessment for Sustainable Development (pp. 85-116). Springer International Publishing, doi 10.1007/978-3-319-19168-3_5.

Auerbacher J., Lippert C., Krimly T. 2010. Assessing the impact of climate change on agriculture in Germany - a Ricardo analysis. In: Contributed paper at the IATRC Public Trade Policy Research and Analysis Symposium 'Climate Change in World Agriculture: Mitigation, Adaptation, Trade and Food Security' Universitaet Hohenheim, Stuttgart, Germany

Bekturova G, Romanova S. 2007. Traditional Land Management Knowledge in Central Asia: Resource Pack. Almaty: S-Print, p. 86.

Benhin JKA. 2008. South African crop farming and climate change: An economic assessment of impacts. *Global Environmental Change*, 18(4), 666-678. doi: http://dx.doi.org/10.1016/j.gloenvcha.2008.06.003

Barrett S.1991. Optimal soil conservation and the reform of agricultural pricing policies. *Journal of Development Economics* 36 p: 167-187. doi:10.1016/0304-3878(91)90031-P

Barbier EB.1998. The Economics of Soil Erosion: Theory, Methodology and Examples, in E.B. Barbier, (ed.), The Economics of Environment and Development: Selected Essays, Edward Elgar, London, pp. 281-307.

Barbier EB. 2000. The economic linkages between rural poverty and land degradation: some evidence from Africa. *Agriculture, ecosystems & environment*, 82(1), 355-370. doi:10.1016/S0167-8809(00)00237-1

den Biggelaar C., Lal R., Eswaran H., Breneman V., Reich, P. 2003. Crop yield losses to soil erosion at regional and global scales: Evidence from plot-level and GIS data. In: Keith Wiebe (ed.), Land Quality, Agricultural Productivity, and Food Security: Biophysical Processes and Economic Choices at Local, Regional, and Global Levels, pp. 262-279. Cheltenham, UK and Northampton, MA, USA: Edward Elgar.

Bravo-Ureta B., Solis D., Cocchi H., Quiroga R. 2006. The impact of soil conservation and output diversification on farm income in Central American hillside farming. *Agricultural Economics* 65 p: 267-276. doi: 10.1111/j.1574-0862.2006.00161.x

Can A. 1992. Specification and estimation of hedonic housing price models. Regional science and urban economics, 22(3), 453-474, doi:10.1016/0166-0462(92)90039-4

Carter MR., Barrett CB. 2006. The economics of poverty traps and persistent poverty: An asset-based approach. *The Journal of Development Studies*, 42(2), 178-199, doi:10.1080/00220380500405261

Cleaver KM., Schreiber GA. 1994. Reversing the spiral: The population, agriculture, and environment nexus in Sub-Saharan Africa. Washington, USA: The World Bank.

Cocchi H., Bravo-Ureta B. 2007. On-site costs and benefits of soil conservation among hillside farmers in El-Salvador. Working Paper: OVE/WP-04/07. November, 2007.

Deaton A. 1997. The analysis of household surveys: a microeconometric approach to development policy. World Bank Publications, Washington DC, USA.

De Janvry A., Fafchamps M., Sadoulet E. 1991. Peasant household behavior with missing markets: Some paradoxes explained. *The Economic Journal*, 101, 1400–1417. doi: 10.2307/2234892

Djanibekov U., Khamzina A., Djanibekov N., Lamers J. 2012. How attractive are short-term CDM forestations in arid regions? The case of irrigated croplands in Uzbekistan. Forest Policy and Economics 21: p. 108-117, doi:10.1016/j.forpol.2012.01.006

Djanibekov N., Sommer R., Djanibekov U. 2013. Evaluation of effects of cotton policy changes on land and water use in Uzbekistan: Application of a bio-economic farm model the level of water users association. *Agricultural Systems* 118: 1-13, doi:10.1016/j.agsy.2013.02.004

Food and Agricultural Organization of the United Nations (FAO), (2015). Status of the World's Soil Resources Report. FAO, Rome.

Griliches, Z. 1971. Hedonic Price Indexes of Automobiles: An Econometric Analysis of Quality Change," in Zvi Griliches (ed.), Price Indexes and Quality Change, Cambridge: Cambridge University Press

Grepperud S. 1997. Poverty, land degradation and climatic uncertainty. Oxford Economic Papers, 49(4), 586-608, doi: 10.1073/pnas.1220070110.

Gupta R., Kienzler K., Martius C., Mirzabaev A., Oweis T., de Pauw E., Qadir M., Shideed K., Sommer R., Thomas R., Sayre K., Carli C., Saparov A., Bekenov M., Sanginov S., Nepesov M., and Ikramov R.. 2009. Research Prospectus: A Vision for Sustainable Land Management Research in Central Asia. ICARDA Central Asia and Caucasus Program. Sustainable Agriculture in Central Asia and the Caucasus Series No.1. CGIAR-PFU, Tashkent, Uzbekistan. 84 pages.

Kruseman G., Bade J. 1998. Agrarian policies for sustainable land use: bio-economic modelling to assess the effectiveness of policy instruments. *Agricultural Systems*, 58(3), 465-481, doi:10.1016/S0308-521X(98)00041-9

Kurukulasuriya P., Ajwad M. 2007. Application of the Ricardian technique to estimate the impact of climate change on smallholder farming in Sri Lanka. *Climatic Change,* 81(1), 39-59, doi: 10.1007/s10584-005-9021-2

Lancaster KJ. 1966. A new approach to consumer theory. The Journal of Political Economy, 74(2), 132-157

Le QB., Nkonya E., Mirzabaev A. 2016. Biomass Productivity-Based Mapping of Global Land Degradation Hotspots. In: Nkonya E., Mirzabaev A., von Braun J. 2016. Economics of land degradation and improvement—A global assessment for sustainable development. Springer International Publishing. doi, 10(1007), 978-3.

McConell, KE. 1983. An Economic Model of Soil Conservation. American Journal of Agricultural Economics 65(1), 83-89, doi: 10.2307/1240340.

Mendelsohn R., Nordhaus W., Shaw D.1994. The Impact of Global Warming on Agriculture: A Ricardian Analysis. *The American Economic Review*, 84(4), 753-771.

Meyer B., Mezösi G., Kovács, F.2016. Landscape degradation at different spatial scales caused by aridification..

Mirzabaev A. 2013. Climate Volatility and Change in Central Asia: Economic Impacts and Adaptation. Doctoral thesis at Agricultural Faculty, University of Bonn. urn:nbn:de:hbz:5n-3238

Nachtergaele F., Petri M., Biancalani R., Van Lynden G., Van Velthuizen H. 2010. Global Land Degradation Information System (GLADIS). Beta Version. An Information Database for Land Degradation Assessment at Global Level. Land Degradation Assessment in Drylands Technical Report, (17), Rome, Italy.

Nkonya E., Pender J., Kaizzi K., Kato E., Mugarura S., Ssali H., Muwonge J. 2008a. Linkages between land management, land degradation, and poverty in Sub-Saharan Africa: The case of Uganda (Vol. 159). Intl Food Policy Res Inst., Washington DC, USA.

Nkonya E., Pender J., Kaizzi K., Kato E., Mugarura S., Ssali H., Muwonge J. 2008b. Linkages between land management, land degradation, and poverty in Sub-Saharan Africa: The case of Uganda. IFPRI Research Report 159. Washington D.C., USA.

Nkonya E, Gerber N, Baumgartner P, von Braun J, De Pinto A, Graw V, Kato E, Kloos J , Walter, T. 2011. The Economics of Land Degradation – Towards an Integrated Global Assessment. Peter Lang.

Nkonya E., Mirzabaev A., von Braun, J. 2016. Economics of land degradation and improvement—A global assessment for sustainable development. Springer International Publishing. doi, 10(1007), 978-3.

Oldeman LR. 1998. Soil Degradation: A Threat to Food Security? Report 98/01, International Soil Reference and Information Centre, Wageningen, Netherlands. 18 p.

Pagiola S. 1996. Price Policy and Returns to Soil Conservation in Semi-Arid Kenya. *Environmental and Resource Economics,* 8, 255-271.

Pender J., Mirzabaev A., Kato E. 2009. Economic Analysis of Sustainable Land Management Options in Central Asia. Final report for the ADB. IFPRI/ICARDA, 168 p., Washington, USA.

Pimentel D., Harvey C., Resosudarmo P., Sinclair K., Kurz D., McNair M., Crist S., Shpritz L., Fitton L., Saffouri R., Blair R. 1995. Environmental and Economic Costs of Soil Erosion and Conservation Benefits. Science, 267: 24.

Qadir M., Noble A., Qureshi A., Gupta R, Yuldashev T., Karimov A. 2009. Salt-induced land and water degradation in the Aral Sea basin: A challenge to sustainable agriculture in Central Asia. In Natural Resources Forum (Vol. 33, No. 2, pp. 134–149). New York: Blackwell Publishing Ltd., doi: 10.1111/j.1477-8947.2009.01217.x

Rosen, Sh. 1974. Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition. *Journal of Political Economy,* Vol. 82, Jan./Feb.

Seo S., Mendelsohn R., Dinar A., Hassan R., Kurukulasuriya P.2009. A Ricardian Analysis of the Distribution of Climate Change Impacts on Agriculture across Agro-Ecological Zones in Africa. *Environmental and Resource Economics* 43(3): 313-332, doi: 10.1007/s10640-009-9270-z

Scherr S. 2000. Downward spiral? Research evidence on the relationship between poverty and natural resource degradation. *Food Policy,* 25(4), 479–498, doi:10.1016/S0306-9192(00)00022-1.

Sievers E. 2003. The post-Soviet decline of Central Asia: sustainable development and comprehensive capital. London and New York: Routledge Curzon. 248 p.

UNCCD. 1994. United Nations Convention to Combat Desertification in Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa. Final text of the Convention. [http://www.unccd.int/convention/text/pdf/conv-eng.pdf]

Way SA. 2006. Examining the links between poverty and land degradation: From blaming the poor toward recognizing the rights of the poor. In P. Johnson, K. Mayrand, & M. Paquin (Eds.), Governing global desertification: Linking environmental degradation, poverty, and participation (pp. 27–41). Burlington, VT: Ashgate.

Williams M., Konovalov V. 2008. Central Asia Temperature and Precipitation Data, 1879-2003. Boulder, Colorado: USA National Snow and Ice Data Center. Digital media