Chapter 10
Economics of Land Degradation in Central Asia

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Abstract Land degradation is a major development challenge in Central Asia, with negative implications on rural livelihoods and food security. We estimate the annual cost of land degradation in the region due to land use and cover change between 2001 and 2009 to be about 6 billion USD, most of which due to rangeland degradation (4.6 billion USD), followed by desertification (0.8 billion USD), deforestation (0.3 billion USD) and abandonment of croplands (0.1 billion USD). The costs of action against land degradation are found to be lower than the costs of

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inaction in Central Asia by 5 times over a 30-year horizon, meaning that each dollar spent on addressing land degradation is likely to have about 5 dollars of returns. This is a very strong economic justification favoring action versus inaction against land degradation. Specifically, the costs of action were found to equal about 53 billion USD over a 30-year horizon, whereas if nothing is done, the resulting losses may equal almost 288 billion USD during the same period. Better access to markets, extension services, secure land tenure, and livestock ownership among smallholder crop producers are found to be major drivers of SLM adoptions.

Keywords Central Asia · Rangeland degradation · SLM adoptions

Introduction

Central Asia—consisting of Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan (Fig. 10.1), is strongly affected by land degradation with negative consequences on crop and livestock productivity, agricultural incomes, and rural livelihoods (Pender et al. 2009). The major types of land degradation in the region are secondary salinization in the irrigated lands, soil erosion in the rainfed and mountainous areas, and loss of vegetation, desertification or detrimental change in the vegetation composition in the rangelands (Gupta et al. 2009).

The drivers of land degradation in the region are numerous, highly complex and interrelated (Pender et al. 2009). The major proximate causes include unsustainable

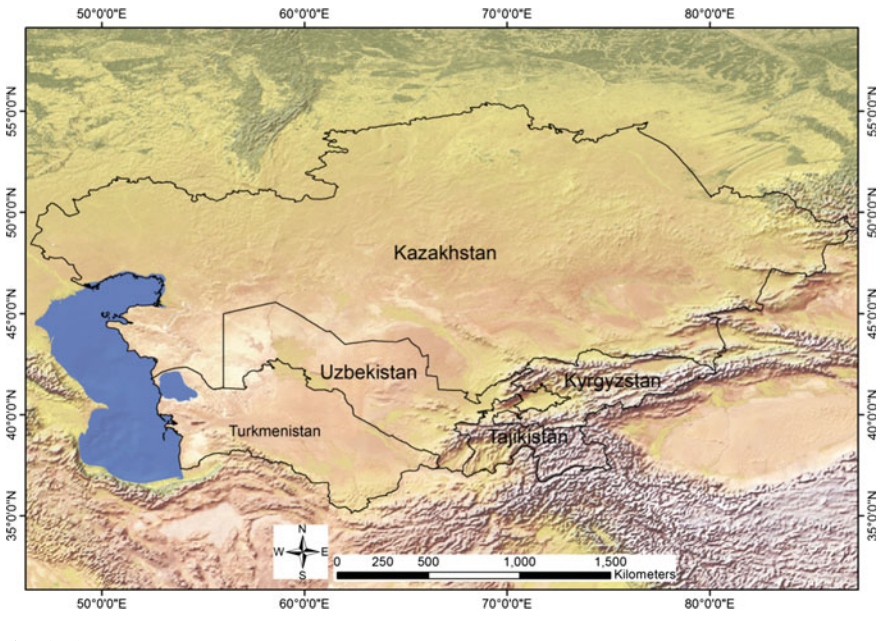

Fig. 10.1 Map of Central Asia. *Source* The authors

agricultural practices, the expansion of crop production to fragile and marginal areas, inadequate maintenance of irrigation and drainage networks, and overgrazing near settlements (Pender et al. 2009; Gupta et al. 2009; Kienzler et al. 2012). However, the underlying drivers of land degradation in the region are likely to be more important in terms of triggering these land degradation trends. The former Soviet policies of cotton and grain self-sufficiency had led to massive expansion of irrigated cotton and rainfed wheat production to marginal areas. Subsequently, there was a lack of resources and incentives to maintain those irrigation and drainage networks and adequately operate the expanded rainfed areas under the conditions of market economy (Gupta et al. 2009). The dismantling of former collective farms into much smaller and fragmented farmer plots has also created a mismatch with the irrigation system planned and operated for large-scale centralized farming and the needs of the new smallholder farmers. This had resulted in an institutional vacuum on sharing the responsibilities for the maintenance of the irrigation and drainage networks (Kazbekov et al. 2007). At the same time, the lack of irrigation water pricing effectively means subsidizing excessive water use by agricultural producers (Pender et al. 2009). A considerable share of previously cultivated rainfed lands, mainly in northern Kazakhstan, has now been abandoned (Propastin et al. 2008). Insufficient development of input and output markets resulted in higher input costs and post-harvest losses of produce. Other key underlying drivers of land degradation in the region are indicated to include land tenure insecurity, breakdown of collective action institutions regulating and facilitating access to common pool rangeland resources (CACILM 2006a, b, c, d, e; Pender et al. 2009; Gupta et al. 2009). The combination of these factors has led to lack of incentives for land users to adopt sustainable land management practices (Pender et al. 2009).

The national governments, research and development organizations, farmer associations and civil society are all well aware of this critical problem of land degradation and have been undertaking various efforts to address it, especially in terms of investments into de-silting and better maintaining drainage and irrigation systems, as well as promoting more sustainable agricultural practices (Pender et al. 2009; Kienzler et al. 2012). These efforts are highly needed and commendable, but could not yet completely address land degradation in the region because they are mainly targeting its proximate causes. On the other hand, there is a need for more efforts directed at addressing the underlying drivers of land degradation. This study aims to draw attention to the economic costs of land degradation in Central Asia and highlight the underlying drivers of land degradation in the region. For achieving these objectives, it seeks to answer the following four research questions:

1. What is the extent of land degradation in Central Asia?
2. What are the major underlying drivers of land degradation in the region?
3. What are the costs of land degradation?
4. How do the costs of inaction against land degradation compare with the costs of actions to address it?

In answering these research questions, the study intends to make the following contributions. Firstly, the latest knowledge on the extent of land degradation in the region is reviewed and discussed. Secondly, using data from nationally representative agricultural household surveys, the study identifies the underlying drivers of land degradation in Central Asia. Being based on actual data, this analysis is a step forward in the current knowledge of the drivers of land degradation in the region, which so far predominantly relied on qualitative analyses and expert opinions. Thirdly, we estimate the total economic costs of land degradation, including the losses in the value of indirect ecosystem services (such as carbon sequestration). Previous studies on the region, in general, have considered the costs of land degradation only associated with reductions in crop yields (see Pender et al. 2009 for a review). Moreover, the extent of adoption of sustainable land management (SLM) practices is identified, together with the drivers and constraints to these SLM adoptions.

Literature Review on Land Degradation in Central Asia

Extent of Land Degradation

Despite the recognized severity of land degradation in Central Asia, there is a lack of published studies identifying the extent of land degradation in the region using observed data at national or regional scales (Ji 2008). Most of the existing studies on the extent of land degradation in Central Asia are based on qualitative expert estimates (Gupta et al. 2009). On the other hand, there are a growing number of localized case studies based on detailed soil surveys or remote sensing data (O'Hara 1997; Buhlmann 2006; Dubovyk et al. 2013; Akramhanov et al. 2011; Akramhanov and Vlek 2012).

Secondary salinization is the major land degradation problem in the irrigated areas in the region, covering an estimated 40–60 % of these irrigated areas (Qadir et al. 2009). The salinization is especially acute in the downstream areas: almost all irrigated areas in Turkmenistan, and the provinces of Uzbekistan and Kazakhstan bordering the Aralkum desert (the former Aral Sea) are affected with secondary salinization (CACILM 2006e; Pender et al. 2009). Farmers commonly try to address salinity by leaching the soil, but the use of increasingly saline irrigation water undermines the effectiveness of leaching, and adds to the problem of excessive water use (Pender et al. 2009).

The main land degradation problems in rainfed croplands of Central Asia are soil erosion and soil fertility depletion. Wind erosion is a major problem in the vast plains of Kazakhstan, while water erosion is a problem in foothill areas (Gupta et al. 2009). Loss of soil fertility is estimated to affect more than 11 million ha in the rainfed steppes of Kazakhstan, with losses of soil organic matter of as much as 40 % (Pender et al. 2009), although there may have been some recovery of carbon in these soils after abandonment from cultivation since early 1990s (De Beurs and Henebry 2004; Schiermeier 2013).

Rangelands are the largest land cover type in the region, occupying 65 % the total land area of Central Asia. Presently, there is a well-established knowledge of strong rangeland degradation close to population settlements (Alimaev 2003;

Gintzburger et al. 2005; Alimaev et al. 2006; Robinson et al. 2010), due to lack of herd mobility (Kerven 2003; Farrington 2005; Bekturova and Romanova 2007).

Mountainous ecosystems in Central Asia occupy about 10 % of the total territory and are ecologically very diverse. In terms of agricultural production, they have irrigated and rainfed crop production and extensive pastoral use of mountain rangelands. In spite of this, land degradation problems in mountainous areas have also their own characteristics. Specifically, soil erosion by water is a key problem in irrigated sloping areas, rather than salinity as in the irrigated areas located in the plains (Gupta et al. 2009).

Mapping Land Degradation Hotspots in Central Asia

Degradation of drylands manifests itself in reduced productive potential (Reynolds et al. 2007), indicated by a gradual loss of vegetation cover over time. Thus, negative vegetation trend over sufficiently long period of time is often related to land degradation. Bai et al. (2008) analyzed land degradation as a negative linear trend in the Normalized Difference Vegetation Index (NDVI) between 1981 and 2003, and found that land degradation ranges from 0.3 % of the territory in Turkmenistan to as much as 17.9 % of the territory in Kazakhstan. However, the NDVI trend can be an indirect indicator of soil degradation or soil improvement if the nutrient source for vegetation/crop growth is solely, or largely, from the soils (i.e., soil-based biomass productivity). In the agricultural areas with intensive application of mineral fertilizers (i.e. fertilizer-based crop productivity), NDVI trend principally cannot be a reliable indicator of soil fertility trend (Le et al. 2012). Moreover, the elevated levels of CO_2 and NO_x in the atmosphere (Reay et al. 2008; World Meteorological Organization 2012) can cause a divergence between Net Primary Productivity (NPP) trend and soil fertility change as the atmospheric fertilization effect has not been substantially mediated through the soil.

Le et al. (2014), in their mapping of land degradation hotspots around the world, account for atmospheric fertilization and delineate areas where chemical fertilizer application may be masking soil degradation processes. Thus, using the same definition of land degradation, Le et al. (2014), in addition, consider land degradation masked by atmospheric fertilization and application of chemical fertilizers. Le et al. (2014) find that relatively higher share of land in the Central Asian countries has been degrading between early 1980s and mid-2000s. The extent of land degradation in Central Asia, according to Le et al. (2014), ranges between 8 % (in Turkmenistan and Uzbekistan) and 60 % of the total area (in Kazakhstan) (Fig. 10.2). Cropland degradation is significant in all five countries, ranging from roughly one fifth of the total cropland in Kyrgyzstan, to 57 % in Kazakhstan. The land degradation hotspots are concentrated in the north of Kazakhstan, and stretch over Eastern Kazakhstan to the southern part of Central Asia, covering Kyrgyzstan, the north-west of Tajikistan and the southern parts of Uzbekistan and Turkmenistan.

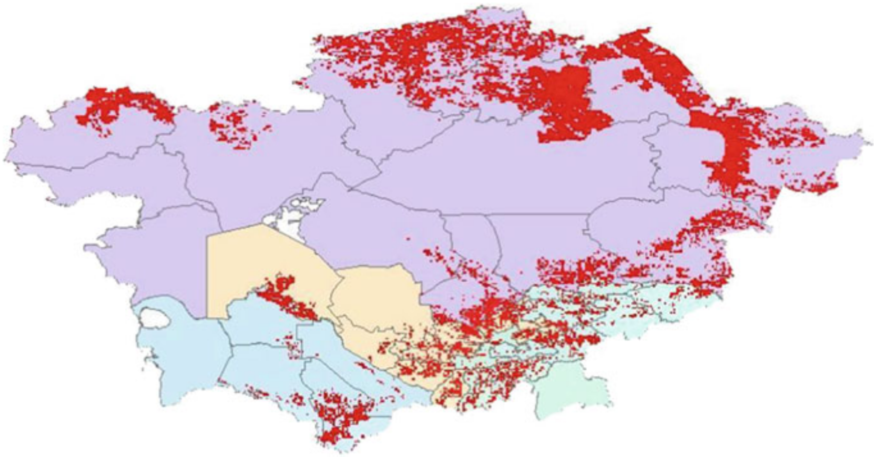

Fig. 10.2 Land degradation hotspots in Central Asia (in *red*), a negative change in NDVI between 1982 and 1984 and 2006. *Source* Adapted from Le et al. (2014)

Despite the advancement in the measurement of land degradation in Le et al. (2014), its definition as a long-term decline in the NDVI still entails some issues, since confounding factors changing over time, such as land use, influence the NDVI. Kazakhstan underwent a considerable transition in agricultural land use in the post-Soviet era, marked by a sharp decline in total rainfed grain area from 25 million ha in 1983 to 14 million ha in 2003, particularly in the country's northern part (De Beurs and Henebry 2004). Today, the area is largely covered by abandoned cropland returning to original land cover types prevalent before their conversion to cultivation (Schierhorn et al. 2013), mainly grassland. Although soil itself might have recovered some of its lost carbon due to abandonment (ibid.), cultivated land may elicit a higher NDVI value than abandoned land with sparser vegetation, leading to an overestimation of inherent soil degradation processes (Klein et al. 2012).

Drivers of Land Degradation in Central Asia

The drivers of land degradation in Central Asia are numerous and interrelated. Here, following the approach by Gupta et al. (2009), they are reviewed by the four major agro-ecological zones.

Irrigated areas. The main proximate causes of salinization are excessive irrigation through poorly constructed and maintained irrigation systems. Drainage systems add to the problem as they fail to drain off the excess water and salts, due to their inappropriate construction and maintenance (ADB 2007). In many upstream areas, drainage water is fed back into the rivers, increasing the salt levels in the rivers and irrigation canals downstream. Some underlying policy factors act through these proximate causes. Irrigated cotton production with inadequate drainage remains promoted (Gupta et al. 2009). Continued subsidies for irrigation create disincentives to economize on water (Pender et al. 2009). Input and output market institutions are underdeveloped or lacking. The interaction of poverty and low access to credit markets may prevent farmers from investing in costly, but in the long-term profitable, SLM technologies. Incomplete land reforms, resulting in continuing land tenure insecurity, are believed to be deterrents to SLM adoptions (Pender et al. 2009).

Rainfed areas. Soil erosion and fertility depletion have been caused by expansion of rainfed wheat production with intensive tillage into marginal rangelands and cultivation on sloping lands with limited soil cover or use of soil and water conservation measures. Soil erosion is particularly severe during summer fallow periods in northern Kazakhstan, when intensive tillage is used to control weeds (Kienzler et al. 2012). Soil fertility depletion also results from insufficient inputs of fertilizers. Underlying these proximate causes are many factors such as lack of farmer awareness or training in the use of appropriate soil conservation practices and lack of access to credit (Gupta et al. 2009).

Rangelands. Rangeland degradation is mainly driven by overgrazing, cutting of shrubs, abandonment, and lack of maintenance of rangeland infrastructure (Pender et al. 2009). Difficult economic, institutional and land tenure conditions for mobile grazing are prevalent (ibid.). On the policy side, effective pasture management mechanisms are often absent and pasture leasing is not clearly regulated in most countries in the region. Institutional mandates are outdated or insufficiently defined (ibid.). In general, institutional mechanisms to sustainably manage rangelands are weak. On the farmers' side, there is a lack of economic and organizational capacity, particularly among individual household pastoralists. Furthermore, the awareness of rangeland degradation issues and approaches is limited (Pender et al. 2009; CACILM 2006a, b, c, d, e).

Mountainous areas. The major drivers of land degradation in mountainous areas in Central Asia are considered to be poverty and low market access; population pressure leading to cultivation of sloping, easily erodible lands without use of sustainable soil conservation technologies, poor extension and institutional limitations (Gupta et al. 2009; Pender et al. 2009).

Past Assessments of the Costs of Land Degradation

There are various estimates of the costs of land degradation in Central Asia. The studies range from the effects of land degradation on certain crops to the effects of land degradation at regional and national scales. To illustrate, the crop specific costs of land degradation were calculated for Uzbekistan by Nkonya et al. (2011) and Djanibekov et al. (2012b). Authors concluded that cultivation of major crops such as cotton and wheat on degraded soils result in profit losses for farmers. At the national scale, according to a World Bank assessment, the annual costs associated with land degradation in Uzbekistan amount to as much as 1 billion USD (Sutton et al. 2007). The costs of desertification in Kazakhstan are estimated to be about 6.2 billion USD (Saigal 2003, citing the National Action Program to Combat Desertification). At the regional scale, one of the widely cited estimates is that land degradation causes annual production losses worth as much as 2 billion USD in Central Asia (World Bank 1998, based on the USAID report). Suzuki (2003), based on the National Action Programs to Combat Desertification and other sources, indicates that desertification costs amount to about 3 % of the total income of Central Asian countries. Based on the ADB (2007) key indicators for the Central Asian countries for 2003, these desertification costs were equivalent to about 1.6 billion USD annually. Hence, the past research related to the national and regional analyses of land degradation underscore the high costs of land degradation in Central Asia. However, these previous studies did not consider the lost value of non-provisional ecosystem services due to land degradation.

Conceptual Framework

This study aims to achieve a more comprehensive estimate of the costs of land degradation in Central Asia by incorporating the value of both direct and indirect ecosystem services. For this purpose, the study is guided by the Total Economic Value (TEV) conceptual framework (Nkonya et al. 2013), presented in detail in Chap. 6 of this volume. The Total Economic Value (TEV) framework seeks to account for the losses of all ecosystem services due to land degradation. TEV framework considers land resources as a natural capital (Daily et al. 2011), yielding a stream of benefits in the form of terrestrial ecosystem goods and services. These ecosystem goods and services include provisional ones, such as food, feed and fiber, but also supporting, regulating and cultural ecosystem services, such as carbon sequestration, soil formation and water purification (Nkonya et al. 2013). The value of provisional ecosystem services and goods are captured by market prices. However, most supporting, regulating and cultural ecosystem services are not traded in the markets and do not have market prices, thus making it much more difficult to valuate them (ibid.). There are several methods of valuation of ecosystem services such as: market price method for those ecosystem services which have a market price (food, fiber, biomass); productivity and hedonic pricing methods which trace the contribution of ecosystem services to the market price of a marketed good (such as locational environmental attributes of land or real estate); travel costs method which infers about the value of ecosystem services in a specific site by asking people's willingness to pay (WTP) to visit that site; replacement cost method which measures the value of an ecosystem service by calculating the costs of substituting it; contingent valuation method which directly asks people about their willingness to pay for non-market ecosystem services; and benefit transfer approach that estimates the values for ecosystem services in one location based on the already existing studies using the above methods in some other location with similar characteristics (cf. Nkonya et al. 2011 for a review). This study, as explained in detail in the methodological section, applies the benefit transfer approach to the valuation of ecosystem services in Central Asia.

The Economics of Land Degradation (ELD) conceptual framework (Chap. 6) also guides the present analysis of the drivers of land degradation in Central Asia. The drivers of land degradation are classified into two categories: proximate and underlying drivers. The proximate drivers include unsustainable land management practices and biophysical factors, such as precipitation, length of growing periods, agro-ecological zones; on the other hand, underlying drivers consist of socio-economic and institutional factors such as poverty, land tenure security, access to credit and extension, and others. The proximate and underlying drivers of land degradation interact with each other to result in different levels of land degradation. As indicated in Chap. 7, the role of proximate drivers in affecting land degradation is well understood and there is a broad consensus in the literature about their causal mechanisms. For example, cultivating steep slopes without soil conservation measures is broadly agreed to lead to land degradation. However, the causal mechanisms of most underlying drivers are still debated (Nkonya et al. 2013), these causal mechanisms may have highly context specific characteristics (Chap. 7). For example, some studies find that poverty may lead to land degradation (Way 2006) due to lack of households' assets to invest into sustainable land management, on the other hand, some other studies find that the poor agricultural households, being more dependent on land for their livelihoods, are inherently more motivated to manage their land sustainably (Nkonya et al. 2008), for example, by applying labor intensive sustainable land management practices. Such opposing findings are prevalent in the literature on the role of most other underlying drivers (Nkonya et al. 2013). The present study studies the impacts of both underlying and proximate factors on land degradation in Central Asia. Among the proximate drivers, the study looks into the effects of annual mean precipitation, agro-ecological zones, length of growing period, temperature and precipitation variability, as well as the frequency of weather shocks. Among the underlying drivers: household characteristics; gender, age and education of the household head, distance to markets, land tenure, farm size, access to extension, and others are investigated for their impact on land degradation. The full list of the studied underlying drivers is given in the data section. The theoretical bases for their identified causal relationships with land degradation are discussed further in detail in the Results section.

Methods and Data Sources

Costs of Land Degradation

This study follows the methodology of estimating the costs of action versus inaction against land degradation described in detail in Chap. 6. First of all, the extent of land use and land cover changes (LUCC) between 2001 and 2009 in Central Asia is identified based on remotely sensed Moderate Resolution Imaging

Spectroradiometer (MODIS) satellite data (Friedl et al. 2010). The MODIS LUCC dataset distinguishes between eight types of biomes: forests, grassland, shrublands, woodlands, croplands, barren lands, urban areas and water bodies (Table 10.1). Following this, the values of ecosystem services of these biomes were estimated for Central Asia based on the benefit transfer approach using the Economics of Ecosystems and Biodiversity (TEEB) database (Van der Ploeg and de Groot 2010). We did not take into account urban areas due to lack of data on ecosystem services produced by urban areas. Moreover, the extent of urban areas in the overall territory of the region is extremely small. The TEEB database contains values of ecosystem services from over 300 case studies from across the world, including from Central Asia (cf. Chap. 6). These values are not only for direct use values, but also include indirect use values (i.e. not only provisional, but also supporting ecosystem services: nutrient cycling, soil formation; regulating: climate regulation, water purification; and cultural: aesthetic and recreational). The benefit transfer approach was employed using data both from the region and from other Asian countries, rather than other regions of the world to limit potential inaccuracies. Moreover, the values of provisional services of croplands are available from statistical databases in Central Asia and hence actual province specific values were used. Furthermore, we also conducted a local contingent valuation of ecosystem services in Uzbekistan (Chap. 21). Interestingly, it was found that the cropland values from statistical sources are very similar to those collected through local contingent valuations (1139 USD/ha from statistical sources versus 1018 USD/ha from contingent valuation). In a similar manner, the values of ecosystem services for grasslands that we estimated for Central Asian countries based on other Asian countries are broadly similar with the results of the grassland ecosystem values obtained directly in Uzbekistan through local contingent valuation (2871 USD/ha vs. 3550 USD/ha, respectively). This difference is also understandable: the regional average values attached to grassland ecosystem services are likely be lower for Central Asia as a whole, compared to only Uzbekistan, since the values attached to rangelands in Kazakhstan are very likely be lower than in Uzbekistan due to relative abundance of rangelands in Kazakhstan. On the other hand, considering that Central Asia is a diverse region, accurate estimates may require doing such contingent valuations at least in several dozens of different locations in the region, which is beyond the

Table 10.1 Land use/cover classification in Central Asia in 2001, in million ha

Land classification	Cropland	Forest	Grassland	Shrublands	Urban	Water	Barren	Total
Kazakhstan	41.3	2.1	187.0	9.2	0.3	5.7	27.8	273.3
Kyrgyzstan	3.0	0.2	10.4	3.0	0.2	0.7	2.4	20.0
Tajikistan	1.7	0.0	4.5	2.0	0.1	0.1	5.8	14.2
Turkmenistan	1.2	0.0	3.5	15.3	0.2	2.2	26.5	49.0
Uzbekistan	5.3	0.0	8.3	7.2	1.0	1.6	21.3	44.7
Total	52.5	2.3	213.0	36.7	1.8	10.4	83.7	400.4

Source Calculated using MODIS data

scope of the present study, but can be a promising topic for future studies. In such a context, using benefit transfer approach, gives first illustrative estimates of the full costs of land degradation in Central Asia. The broad accuracy of these estimates presented here is corroborated by the "ground-truthing" of the ecosystem values through local contingent valuations in Uzbekistan.

To calculate the costs of land degradation due to land use and cover change (LUCC) between 2001 and 2009, the values of ecosystem services provided by these seven biomes[1] (Obtained through benefit transfer approach described above for all except for croplands. For croplands, the province-specific values of provisional ecosystem goods were obtained from statistical databases) were multiplied by the extent of the biome in 2001 and 2009. This multiplication gives the total value of ecosystem services provided by these biomes in 2001 and 2009. Following this, changes in the area from a higher value biome to a lower value biome were used to calculate the total costs of land degradation during this period. Finally, to have the average annual change during this period, the obtained costs of land degradation were divided by eight.

In calculating the costs of action to address land degradation, three types of costs are considered: re-establishment costs from the degraded lower value biome to a higher value biome, maintenance costs and opportunity costs of the lower value biome. More formal and detailed presentation of the calculation process is given in Chap. 6.

Drivers of Sustainable Land Management

Land degradation usually occurs due to lack of use of sustainable land management practices. Those factors preventing households from adopting SLM practices also serve as drivers of land degradation, i.e. identifying the determinants of SLM adoption methodologically would also allow for identifying the drivers of land degradation. The following econometric model is applied to nationally representative agricultural household survey data from the Central Asian countries:

$$\mathbf{A} = \boldsymbol{\beta}_0 + \boldsymbol{\beta}_1 x_1 + \boldsymbol{\beta}_2 x_2 + \boldsymbol{\beta}_3 x_3 + \boldsymbol{\beta}_4 x_4 + \boldsymbol{\beta}_5 z_i + \varepsilon_i \tag{10.1}$$

where,

A Adoption of SLM technologies

x_1 a vector of biophysical factors (e.g. climate conditions, agro-ecological zones, etc.);

[1]Forests, woodlands, shrublands, grasslands, croplands, barren land, water bodies. Urban areas were excluded from the analysis as there are no data on the ecosystem services provided by them. Moreover, their area is very limited in the overall territory of the region. The following values were attached to each ha of these biomes: forests—5264 USD/ha, grasslands—2871 USD/ha, shrublands and woodlands—1588 USD/ha, barren lands—160 USD/ha, water bodies—8498 USD/ha, croplands—varies depending on the location, from 138 USD/ha to 4535 USD/ha.

x_2 a vector of policy-related and institutional factors (e.g. market access, land tenure, etc.);
x_3 a vector of variables representing access to rural services (e.g. access to extension);
x_4 vector of variables representing rural household level capital endowment, level of education, household size, dependency ratio, etc.;
z_i vector of country fixed effects

The dependent variable, A, is the number of sustainable land management technologies adopted by agricultural households in the region, as compiled through the agricultural household surveys, described below. In the survey, the households were asked to indicate the SLM technologies they use. They were given an open-ended list of about 30 SLM technologies[2] to choose from. Having this dependent variable allows to see not only the impact on the adoption of SLM (yes or no categories), but also the effect on the number of adopted SLM technologies.

Data

The MODIS satellite dataset is used to identify the shifts in the land use and land cover change (LUCC) in the region between 2001 and 2009 (Friedl et al. 2010). The MODIS dataset is groundtruthed and quality controlled (ibid.), with overall accuracy of land use classification at 75 % (ibid.).

The dataset used for the analysis of the drivers of land degradation comes from nationally representative agricultural household surveys carried out during 2009–2010 in Central Asia, except Turkmenistan.[3] 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 sample size varied between 380 and 385 respondents between the countries. To compensate for any missing or failed cases, the sample size for each country was determined to be 400 respondents, i.e. 1600 respondents in total.

[2]Bench terraces, stone bunds, mulching/surface cover, trash line, log line, grass strips, hedge rows (shrubs), minimum tillage, infiltration ditches, ridge and furrow, fallowing, improved fallowing, composting, farm yard manure application, green manure application, fertilizer (inorganic straight), fertilizer (inorganic compound), agroforestry, cover crops, crop rotation, enclosure of the land, restriction on livestock numbers (destocking), removal of unwanted bush, periodic resting of the rangeland, cattle routing, common watering points, supplementary fodder production, intercropping.

[3]The surveys were conducted by the International Center for Agricultural Research in the Dry Areas (ICARDA) and national partners under the Asian Development Bank (ADB)-funded project on climate change in the region. We are grateful to ADB for funding the surveys and to ICARDA for allowing the use of these datasets.

Uzbekistan and Kazakhstan (countries bigger in size) were first divided into major agro-ecological zones—west, south, center and east for Uzbekistan, north, center, west, south and east for Kazakhstan. Then in each zone, one province was randomly selected. In the case of Tajikistan and Kyrgyzstan (countries smaller in size) all provinces were selected for further sampling of villages in each of them. The number of respondents was allocated to each province depending on the share of the agro-ecological zone (or province, in the cases of Tajikistan and Kyrgyzstan) in the value of the national agricultural production. Following this, the total list of villages was obtained for each province selected. The villages in each province were numbered, and the corresponding numbers for the selected villages were randomly drawn using the Excel software function "RAND" (35 villages in Kazakhstan, 22 in Kyrgyzstan, 25 in Tajikistan, 25 in Uzbekistan) (Mirzabaev 2013). The number of respondents per village was evenly distributed within each province. At the village level, the list of all agricultural producers, including household producers, were obtained from the local administrations; agricultural producers were numbered, and then from this numbered list, respondents were randomly selected. Due to civil unrest during 2010 in southern Kyrgyzstan, it was impossible to include the three provinces in the south of Kyrgyzstan in the sampling. Similarly, Gorno-Badahshan autonomous province of Tajikistan was also excluded from sampling due to its very small share in agricultural production and population, as well as extremely high surveying costs due to its location in high altitude areas with difficult access (Mirzabaev 2013). In summary, in spite of these geographical gaps, the selected samples are expected to be well representative of the key areas in the region in terms of their share in the overall agricultural production and population (Fig. 10.3).

Fig. 10.3 Location of surveyed households across agro-ecological zones in Central Asia. *Source* Mirzabaev (2013)

Results

Land Use and Land Cover Dynamics in the Region

Central Asia has been experiencing dynamic land use and land cover changes (LUCC) over the last decade. Tables 10.1 and 10.2 present these changes over the period of 2001 and 2009, using the data from MODIS satellite datasets. These changes can be summarized into four sources: (1) abandonment of massive areas formerly under rainfed crop production in Kazakhstan, (2) continued desiccation of the Aral Sea, (3) conversion of a sizable share of barren lands into other land uses, mainly shrublands and grasslands, (4) increases in the forested area across the region, but especially in Kazakhstan.

The results show considerable reductions in the cropped area and similarly big increases in grasslands, both mainly in Kazakhstan. This is related to the discontinuation of rainfed crop production in vast areas in northern Kazakhstan, where abandoned croplands shifted back to their natural state of grasslands (Schierhorn et al. 2013). These grasslands were brought under cultivation in 1950s through the so-called "Virgin Lands" program to achieve grain self-sufficiency for the former Soviet Union (De Beurs and Henebry 2004).

However, the crop yields were low and unstable, and after the dissolution of the Soviet Union and institution of market-based mechanisms, crop production in many of those areas has become unprofitable. Similar shifts from croplands to grasslands and shrublands have been observed in other countries of the region, though in much smaller scales. At the same time, Turkmenistan and Uzbekistan had net gains in cropped areas over the last decade by converting grasslands and shrublands into croplands. The second major change is the decrease in the area of barren lands by 19.6 million, mainly shifting to grassland and shrublands: in Kazakhstan mostly to grasslands, whereas in more arid desertic areas of Uzbekistan and Turkmenistan to shrublands. The reasons behind this shift are not fully clear. In the case of desert biomes, Liobimtseva (2007) associates this "greening" to elevated levels of atmospheric fertilization, increasing the photosynthetic rate among desert mosses and higher forms of vegetation. The role of human management, if any, in this shift

Table 10.2 Land use/cover change in Central Asia in 2009 relative to 2001, in million ha

Land classification	Cropland	Forest	Grassland	Shrublands	Urban	Water	Barren
Kazakhstan	−10.0	1.5	19.0	1.4	0	−0.4	−12.3
Kyrgyzstan	−0.8	0.4	1.7	−0.9	0	0.0	−0.4
Tajikistan	−0.4	0.2	−0.5	0.2	0	0.0	0.5
Turkmenistan	0.6	0.0	−1.1	2.7	0	0.0	−2.3
Uzbekistan	0.4	0.1	0.4	4.3	0	−0.4	−5.1
Total	−10.3	2.2	20.0	7.6	0.0	−0.8	−19.6

Source Calculated using MODIS data

is not yet studied. The third major change includes doubling of forested areas, although from a very low base of 2.3 million to 4.5 million ha, mainly through shifts from woodlands and grasslands to forests in Kazakhstan (Almaty and Eastern Kazakhstan provinces). The fourth major land use change is associated with the continued desiccation of the water bodies, principally, the Aral Sea, where about 0.4 million ha in Kazakhstan and Uzbekistan each have shifted from being under water to barren land since 2001. Although the magnitude of this shift is dwarfed in terms of area by other major land use changes in the region, however, the socio-economic, environmental and symbolic importance of this land use change is, arguably, the most widely felt and studied in the region.

Economic Impacts of Land Degradation

Costs of Land Degradation

The results show that the total annual costs of land degradation in Central Asia due to land use change only (i.e. without the costs of land degradation due to lower soil and land productivity within the same land use), are about 5.85 billion USD between 2001 and 2009 (Table 10.3).

Most of these costs, about 4.6 billion USD are related with shifts from grasslands to lower value shrublands and barren lands: in total, about 14 million ha grasslands have shifted to shrublands and barren lands in the region between 2001 and 2009, highlighting the massive problem of rangeland degradation. Another 0.75 billion USD were due to shifts from shrublands to barren lands, especially in the parts of the region near the Aral Sea, highlighting the growing problem of desertification. Deforestation has led to about 0.32 billion USD in losses, whereas the abandonment of croplands has resulted in about 110 million USD of losses, annually. The latter figure does not comprise the losses in crop yields in those croplands that continue to

Table 10.3 The costs of land degradation in Central Asia through land use and cover change

Country	Annual cost of land degradation in 2009, in billion USD	Annual cost of land degradation per capita, in USD	GDP in 2009, current billion USD	The cost of land degradation as a share of GDP (%)
Kazakhstan	3.06	1782	115	3
Kyrgyzstan	0.55	822	5	11
Tajikistan	0.50	609	5	10
Turkmenistan	0.87	1083	20	4
Uzbekistan	0.83	237	33	3
Total	5.85	769	178	3

Source The authors' calculations using MODIS and TEEB datasets be cultivated but with lower economic returns due to land degradation. Presently, there are no comprehensive and reliable databases to estimate the costs of land degradation due to lower productivity of degraded croplands in all Central Asia. The estimates presented in Chap. 6 indicate at about 330 million USD of annual losses for three crops—wheat, rice and maize, with most of the costs coming through loss of soil carbon storage potential due to land degradation, rather than actual losses due to lower yields under land degrading agricultural practices. Hence, the estimates of 5.85 billion USD of annual costs due to LUCC and potentially another 0.33 billion from lower crop productivity and loss of carbon sequestration in degraded croplands from growing wheat, maize and rice, are conservative estimates of land degradation costs. The actual costs are likely to be higher. Similarly, the cost figures for other land uses are also underestimated as they do not include losses in productivity without land use change (for example, grasslands providing lower vegetation for livestock grazing, etc.). Finally, calculated land degradation costs per capita also vary among countries: the highest in Kazakhstan (about 1800 USD annually) and lowest in Uzbekistan (about 250 USD annually).

However, along with land degradation, there is also land improvement happening in the region through land use change. In fact, the annual monetary amount of land improvement is around 13 billion USD, exceeding land degradation through land use change (Table 10.4). This amount also does not include potential improvements in soil fertility due to application of SLM practices, when land use does not change. The major contributors to this land improvement is the transition of low productive croplands in northern Kazakhstan to grasslands, including the improved provision of ecosystem services (about 10 billion USD): a seemingly very contradictory finding given that many land degradation mapping exercises, including both by Bai et al. (2008) and Le et al. (2014) indicate massive land degradation in the area. However, there is nothing surprising if we take into account that this area of abandoned cropland is returning to original land cover types prevalent before their conversion to cultivation (Schierhorn et al. 2013): although soil itself might have recovered some of its lost carbon due to abandonment (ibid.), and is providing higher levels of ecosystem services in terms of carbon sequestration, nutrient cycling, etc., i.e. may have higher Total Economic Values, the

Table 10.4 Total economic value (TEV) of land ecosystems and GDP in Central Asia, in billion USD, constant for 2007

Country	TEV 2001	TEV 2009	GDP in 2009	Value of ecosystems per capita, in USD	GDP/TEV (%)
Kazakhstan	577	639	115	55,169	18
Kyrgyzstan	40	45	5	14,620	11
Tajikistan	20	19	5	6261	27
Turkmenistan	40	42	20	13,795	48
Uzbekistan	44	53	33	3 481	63
Total	720	797	178	22,935	20

Source The authors' calculations using MODIS and TEEB datasets cultivated land may elicit a higher NDVI value than abandoned land with sparser vegetation, leading to mapping this area as degraded. From the economic perspective, these areas in northern Kazakhstan had very low crop productivity and extremely low profitability, in fact, periodically even leading to economic losses during often recurring drought years. However, especially during good rainfall years and extensive operation, they would also generate tangible local benefits in terms of provisional goods (grain). As grasslands, they may have larger global benefits (generating higher levels of supporting and regulating ecosystem services) than as croplands, however, these global benefits are not internalized locally. Other major sources of land improvement include afforestation on additional 2.2 million ha (about 1.4 billion USD) and conversion of shrublands to grasslands and croplands (1.6 billion USD).

The total economic value of ecosystem goods and services is estimated to equal about 800 billion USD in the region, exceeding the conventional GDP by 5 times. The relative value of ecosystems per capita depends on the territory, land use/cover characteristics and population. In this regard, Kazakhstan with its huge territory, most of it under higher valued grasslands, and relatively smaller population has the highest per capita value of ecosystems in the region. In contrast, Uzbekistan with the biggest population in the region and almost half of its territory consisting of barren deserts, has the lowest per capita monetary value of ecosystems. From another perspective, if in Kyrgyzstan: the share of GDP in the Total Economic Value is just 11 %, this number is 48 % in Turkmenistan and 63 % in Uzbekistan, implying that population pressure on ecosystems is much higher in Uzbekistan and Turkmenistan.

Cost of Action to Address Land Degradation

The results of the analysis of the costs of action are given in Table 10.5. The results show that the costs of action against land degradation are lower than the costs of inaction in Central Asia by more than 5 times over a 30-year horizon, meaning that each dollar spent on addressing land degradation is likely to have about 5 dollars of returns. This is a strong economic justification favoring action versus inaction. Thus, the costs of action were found to equal about 53 billion USD over a 30-year horizon, whereas if nothing is done, the resulting losses may equal almost 288 billion USD during the same period. Almost 98 % of the costs of action are made up of the opportunity costs of action, for example, the value of new shrublands in areas where the original grasslands are being restored, whereas the actual implementation costs were found to be relatively smaller.

The costs of actions, however, do not include the potential transaction costs of implementing SLM-oriented reforms at the national level, or of transaction costs of adopting SLM technologies at the landusers level, as presently, there are no data available on these transaction costs.

Table 10.5 Costs of action versus inaction in Central Asia

Country	Annual TEV cost of land degradation in 2009, in billion USD	Annual provisional cost of land degradation in 2009, in billion USD	Cost of action (6 years), in billion USD	Cost of action (30 years), in billion USD	Of which, the opportunity cost of action, in billion USD	Cost of inaction (6 years), in billion USD	Cost of inaction (30 years), in billion USD	Ratio of cost of inaction/action
Kazakhstan	24	11	22	22	21	102	138	6
Kyrgyzstan	4	2	6	6	6	22	29	5
Tajikistan	4	2	4	4	4	17	24	6
Turkmenistan	7	3	10	10	9	35	48	5
Uzbekistan	7	3	11	11	11	36	49	5
Central Asia	47	20	53	53	51	213	288	6

Drivers of Land Degradation

Data Descriptives

Table 10.6 reports descriptive statistics for the variables of interest for the analysis of SLM adoption for each country. In the analysis, to ensure that results are not driven by a small amount of large outliers, log transformations have been applied where appropriate. Table 10.6 reports all the variables in their level form for more convenient understanding and comparisons.

The distribution of the number of SLM technologies adopted by the respondents is quite dispersed, ranging from 0 to 15 (Fig. 10.4). About 39 % of the surveyed agricultural households in the region did not use any SLM technology, while the remaining 61 % used at least one SLM technology. Among the most frequent used SLM technologies are the integrated soil fertility management by applying varying levels of fertilizers and manure, as well as more efficient irrigation techniques such as drip irrigation, or the use of portable chutes for irrigation, especially in sloping areas.

Moreover, if the use of SLM practices is taken by country, the conditional variance of the distribution is higher in all cases than conditional mean (Fig. 10.5). The number of adopted SLM technologies varies among the countries of the region, with higher number of adoptions among the surveyed agricultural households in

Table 10.6 Data descriptives

Variables	Kazakhstan	Kyrgyzstan	Tajikistan	Uzbekistan
Number of SLM technologies used	2.8	0.2	4.4	4.9
Household size	6	6	8	6
Dependency ratio	0.7	0.7	0.7	0.8
Average age of household head	51	50	52	47
Length of growing periods	97	102	131	92
Number of crops grown	0.99	1.03	2.12	3.21
Annual precipitation	402	448	486	289
Mean annual temperature	7.0	5.7	14.4	14.4
Frequency of weather shocks	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	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 min)	133	150	59	75
Value of total assets (in USD)	83,123	20,727	7407	34,939

Source The survey

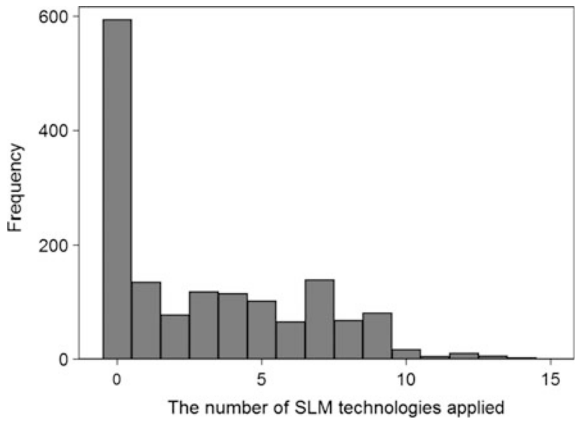

Fig. 10.4 The distribution of the number of SLM technologies used among households in Central Asia. *Source* The survey

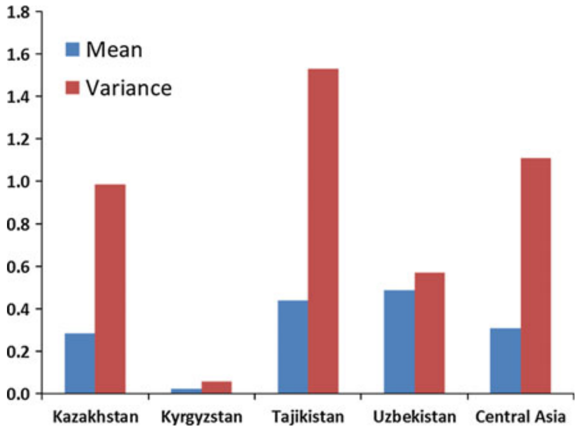

Fig. 10.5 The mean and variance of the number of SLM technologies used. *Source* The survey

Tajikistan and Uzbekistan. On the other hand, the variance of the number of adopted technologies is higher in Tajikistan and Kazakhstan, meaning that in these two countries there are bigger differences among households in the number of the SLM technologies they adopt.

Furthermore, the dependent variable on the number of SLM technologies used is a count variable. Such a nature of the dependent variable requires the application of negative binomial regression, which is a generalization of Poisson regression for count dependent variables with dispersed distribution (Hilbe 2011). Figure 10.6 gives the information on the spatial distribution of adoption of SLM technologies in land degradation hotspots (for hotspots of land degradation see Fig. 10.2 and Chap. 4). Based on this overlay, it seems that higher SLM adoption rates are more closely associated with areas with more land degradation hotspots, i.e. SLM technologies are applied more in areas with higher land degradation.

The results of the regression on the determinants of the number of SLM technologies used by households are given in Table 10.7. The overall test of model fit

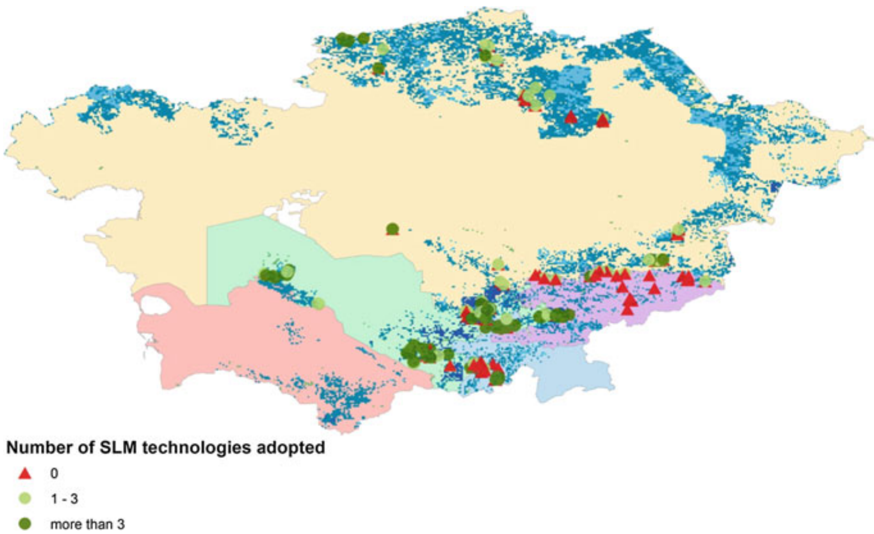

Fig. 10.6 Spatial distribution of SLM adoption. *Note* The hotspots of land degradation are given *blue colors*, for more spatial information on land degradation see Fig. 10.2. *Source* The survey

Table 10.7 Drivers of sustainable land management in Central Asia

Variables	Coefficient	(95 % confidence interval)	
Distance to markets (log)	−0.0565**	−0.11	−0.01
Household size	−0.0149**	−0.03	0.00
Dependency ratio	−0.0619**	−0.11	−0.01
Education (base—Primary education only)			
Middle school	0.0452	−0.15	0.24
High school	−0.00,909	−0.21	0.20
College	0.0421	−0.16	0.24
University degree	0.0691	−0.13	0.27
Ph.D.	0.598*	−0.08	1.28
Country			
Kyrgyzstan	−2.642***	−2.94	−2.34
Tajikistan	−0.0634	−0.34	0.22
Uzbekistan	0.102	−0.10	0.30
Gender (base—Female)	−0.0737	−0.18	0.03
Age	0.00281	0.00	0.01
Agroecological zone (base—Arid)			
Semiarid	−0.770***	−0.97	−0.57
Sub-humid	−1.060***	−1.35	−0.77

(continued)

Table 10.7 (continued)

Variables	Coefficient	(95 % confidence interval)	
Humid	−1.269***	−1.92	−0.62
Length of the growing period	0.00900***	0.00	0.01
Number of crops grown	0.00198	−0.03	0.03
Annual precipitation	0.000404	0.00	0.00
Mean annual temperature	0.0106	−0.01	0.03
Variance of temperature	−0.137***	−0.20	−0.08
Variance of precipitation	−0.00308***	0.00	0.00
Frequency of weather shocks	0.0217***	0.01	0.03
Farm size (log)	0.0110	−0.03	0.05
Private land ownership	−0.0624	−0.20	0.08
Interaction of private land ownership and farm size	−0.0573**	−0.10	−0.01
Access to extension	0.115**	0.02	0.21
Knowledge of SLM technologies	0.0895***	0.08	0.10
Source of SLM knowledge: other farmers	0.0771***	0.07	0.09
Source of SLM knowledge: farmers' association	−0.0796***	−0.09	−0.07
Source of SLM knowledge: media	0.0650***	0.03	0.10
Value of livestock (log)	−1.54e−05**	0.00	0.00
Interaction of crop producer and value of livestock	2.21e−05***	0.00	0.00
Value of total assets	−2.10e−07	0.00	0.00
Constant	0.590**	0.04	1.14
Observations	1519		

*** means statistically significant p-values <0.01, ** p-values < 0.05, * p-values <0.1

shows that the model is statistically significant at 1 % (LR $chi^2(34) = 1681.75$, Prob > $chi^2 = 0.0000$, and Pseudo $R^2 = 0.2460$). The likelihood ratio test comparing this negative binomial model to the Poisson model is statistically significant at 1 %, suggesting that the negative binomial model fits the data better than the Poisson model.

The regression results point at several variables which have statistically significant relationship with the number of SLM technologies adopted by households. For example, one percent increase in the distance to markets could decrease the log count of the number of SLM technologies adopted by 0.0565. Similarly, one unit increase in household size could decrease the log count of the number of SLM technologies adopted by 0.0149.

In this manner, the results of the model show that the key underlying factors positively associated with SLM adoptions in Central Asia are better market access, access to extension, learning about SLM from other farmers, private land tenure among smallholder farmers, livestock ownership among crop producers, lower household sizes and lower dependency ratios.

The distance to markets variable shows the time it takes for the household to reach the nearest urban market with at least 50,000 residents (Nelson 2008). The results show that the households with better market access are likely to adopt higher number of SLM practices, as the better market access is likely to provide with more incentives for increased production and productivity, making the opportunity cost of foregone benefits due to land degradation much higher. Similarly, access to extension is found to increase the number of SLM adoptions, by increasing farmers' knowledge about SLM practices and their awareness about the benefits of SLM. The more number of SLM technologies farmers know, the more SLM technologies they adopt. What is interesting, farmers adopt more SLM practices when they learn about them from their peers—other farmers: this is probably due to the fact that farmers trust more the successful experiences of other farmers. On the contrary, when the source of knowledge are the farmers' association, a more institutionalized, and often state-operated organizations, there is a statistically significant negative association with the number of SLM technologies used, highlighting the need for increasing the relevance and demand orientation of the farmer training courses conducted by the farmers' associations.

These estimates cannot tell much about the impact of private land tenure on SLM adoptions in general, however, the results show that among smallholder farmers having private land tenure has positive influence on SLM adoptions (the interaction of private land tenure and farm size). This may be due to the fact that smaller sizes combined with the incentives coming from private land tenure may allow for more flexibility in farming operations. Specifically, smaller scale farmers are usually specialized in the production of vegetables and fruits in the region, which are considered to be as higher value cash crops, compared to grains. Moreover, in Uzbekistan, small household farms are also exempt from growing two State-mandated crops (where the State regulates both the production process and the marketing of the produce): cotton and wheat, and can sell the vegetables and fruits they produce directly in the market. More detailed information on the institutional aspects of agriculture and of agricultural reforms in the Central Asian countries can be found in Pomfret (2008), Petrick et al. (2013), and OECD (2013).

Owning livestock is expected to provide with savings mechanism for flexible capital which can be invested into SLM technology adoptions. The findings here corroborate this point for crop producing farmers in the sample. Higher livestock ownership among crop producers is associated with larger number of technologies adopted. However, higher livestock values, in general, are negatively associated with the number of SLM technologies adopted. This is not very surprising given that the pastoralist households in the sample have naturally much higher values for livestock ownership, but they apply fewer SLM technologies (the presented list of SLM options includes pastoralists-oriented practices, such as rotational grazing, enclosures, etc.).

Most household characteristics, such as gender, education, and age of the household head, are not significant in the sample. However, household size and dependency ratio are inversely related to the number of SLM technology adoptions. In the case of dependency ratio, it could be due to higher risk aversion among households with higher dependency ratios, whereas the negative impact of larger household size on adoption is somewhat surprising since larger households could provide with more family labor making the adoption of labor intensive SLM technologies easier.

Among significant proximate drivers positively influencing SLM adoptions are being in more arid agro-ecological zones, longer growing period for crops, lower variance in annual precipitation and temperature, more experiences of past weather shocks. More arid agro—ecologies in Central Asia are associated with more intensive agricultural production through application of irrigation and the related higher productivity, making the value of agricultural lands in these areas much higher, thus increasing the opportunity costs of losses due to land degradation and providing with higher incentives for SLM adoptions. The same mechanism explains the significant positive coefficient of the length of growing periods. The higher variability of long-term (30 years) rainfall and precipitation has negative association with SLM adoption. Most agricultural technologies do not perform equally well, for example, under drought and flooding, or under frosts and heatwaves. Higher climate variability leads to inconsistent performance and returns from a given SLM technology, consequently reducing the likelihood of its being adopted. However, past own experiences of short-term weather shocks (as opposed to climate variability) are found to have positive relationship with SLM adoption, as farmers having more experiences of weather shocks may seek ways on how to minimize their impacts by trying out various SLM technologies.

Discussion

SLM technologies are usually innovative approaches that are aimed to reduce the pressure of conventional unsustainable practices. Yet, such technologies are also accompanied by high uncertainty in their economic and environmental performance. Land users may not adopt these options unless they observe their costs and benefits. Accordingly, the dissemination of information on SLM technologies is necessary to tackle the problems of land degradation. This was also confirmed in this study, where it was shown that access to extension plays a vital role in adopting SLM by rural households. Development of extension services may accelerate the process of SLM adoption. Observing the performance of technologies will lead to learning effect and will further boost the expansion of SLM technologies. However, even if sufficient information is available about the SLM practices the lack of private/secure land tenure can be one of the major barriers for investments into such practices in the region. In most of the Central Asian countries farmers have usufruct rights for land. When farmers are uncertain if they will be allowed to continue using this land in the future, as rational decision makers they would rather maximize their immediate returns, and avoid making any costly long-term investments, thus effectively “mining” the land. Therefore, transparent and objective implementation of inalienable user rights to land for a long and secure time horizon would be a vital option to promote longer term SLM investments by farmers. On the other hand, the experiences from the region show that private and even secure, land tenure do not automatically lead to wide-scale adoption of SLM technologies. Some, but not all, SLM technologies may require sizable upfront investments and take several years before these investments are recovered through increased returns (e.g., drip irrigation). There is a need for a wider package of measures to accompany land tenure security for it to be effective in terms of addressing land degradation. Most of the SLM practices require initial investments and generate full benefits only after some time. Thus, farmers, especially poorest, may not have sufficient funds to cover costs of SLM while considering that its benefits would be generated in long-term and especially when there are often high and immediate opportunity costs. Therefore, measures in the form of fiscal and credit incentives to farmers would be important to reduce the burden of high initial costs and provide financial incentives to invest into the SLM. The land tenure is often connected to the state procurement policies, mandating cultivation of certain crops. Failure to accomplish this policy often leads to the expropriation of farmland (Djanibekov et al. 2012a). Abolishing the State quota system, notably for cotton and wheat, is often considered to increase crop diversification and consequently agricultural production and rural livelihoods (e.g. Djanibekov et al. 2013).

The findings of this study show that the costs of actions to address land degradation are only a fraction of the costs of inaction. The question is then why the action undertaken so far was not sufficient to address land degradation if the economic returns from sustainable land management are so high. This analysis is conducted from the social perspectives taking into account both provisional and non-provisional ecosystem services lost due to land degradation (i.e. both private and global public goods). However, rational private landusers would usually include only the private costs of land degradation in their decision making framework because they cannot internalize the benefits from safeguarding or restoring the non-provisional ecosystem services of land (such as for example, climate regulation, nutrient cycling). Since many of these non-provisional ecosystem services of land are global public goods, even national Governments are less likely to incorporate the full value of the lost land ecosystem services into their calculations, since they as well cannot internalize fully the benefits of SLM within the country. Thus, a wider use of payment for ecosystem services (PES) approaches through international investments could potentially help in reducing this lack of incentives to invest into SLM. Finally, this analysis does not include all the potential costs of action to address land degradation. Specifically, transaction costs of implementing SLM-oriented reforms at the national level, or of transaction costs of adopting SLM technologies at the landusers level, are not included, as presently, there are no data available on these transaction costs. Moreover, even when the land users would decide to take action (often the losses of provisional services alone may be more than the costs of action, thus justifying it from private perspectives as well), they may be constrained by lack of information about available SLM options, lack of access to markets and credit, with often long-term nature of investments and high upfront costs, etc.—the conditions which are prevalent across the region, which were, among other factors, also shown in the drivers analysis above as constraining factors for SLM adoptions in Central Asia. Finally, even under ideal conditions for SLM investments, landusers may still decide not to invest in land if the opportunity costs of other investment options available to them are higher than the benefits from sustainable land management (e.g. investing in their children's education and health, with potential longer-term higher returns, rather than in SLM).

Conclusions

Central Asia has four major agro-ecological regions: irrigated, rainfed, rangeland and mountainous areas. The nature of land degradation problems in the region can be best illustrated along these four major agro-ecological regions. The major land use changes in the region over the last decade, which have triggered land degradation processes in the region, can be summarized into four sources: (1) abandonment of massive areas formerly under rainfed crop production in Kazakhstan, (2) continued desiccation of the Aral Sea, (3) conversion of a sizable share of barren lands into other land uses, mainly shrublands and grasslands, (4) increases in the forested area across the region, but especially in Kazakhstan. The main areas affected by land degradation is concentrated in the north of Kazakhstan, and stretches over Eastern Kazakhstan to the southern part of Central Asia, covering Kyrgyzstan, the north-west of Tajikistan and the southern parts of Uzbekistan and Turkmenistan.

The estimates show that the annual cost of land degradation in the region due to land use change is about 6 billion USD, most which due to rangeland degradation (4.6 billion USD), followed by desertification (0.8 billion USD), deforestation (0.3 billion USD) and abandonment of croplands (0.1 billion USD). The costs of action against land degradation are lower than the costs of inaction in Central Asia by more than 5 times over a 30-year horizon, meaning that each dollar spent on addressing land degradation is likely to have about 5 dollars of returns. This is a very strong economic justification favoring action vs. inaction against land degradation. Thus, the costs of action were found to equal about 53 billion USD over a 30-year horizon, whereas if nothing is done, the resulting losses may equal almost 288 billion USD during the same period.

The key underlying factors conducive to SLM adoptions in Central Asia are found to be better market access, access to extension, learning about SLM from other farmers, private land tenure among smallholder farmers, livestock ownership among crop producers, lower household sizes and lower dependency ratios. Among significant proximate drivers positively influencing SLM adoptions are being in more arid agro-ecological zones, longer growing period for crops, lower variance in annual precipitation and temperature, more experiences of past weather shocks.

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