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Impacts of innovative forestry land use on rural livelihood in a bimodal agricultural system in irrigated drylands

Utkur Djanibekov[a,*], Nodir Djanibekov[a,b], Asia Khamzina[a], Anik Bhaduri[c], John P.A. Lamers[a], Ernst Berg[d]

[a] Center for Development Research (ZEF), University of Bonn, Walter-Flex-Str. 3, 53113 Bonn, Germany
[b] Leibniz Institute of Agricultural Development in Central and Eastern Europe (IAMO), Theodor-Lieser-Str. 2, 06120 Halle (Saale), Germany
[c] Global Water System Project (GWSP), University of Bonn, Walter-Flex-Str. 3, 53113 Bonn, Germany
[d] Institute for Food and Resource Economics, University of Bonn, Meckenheimer Allee 174, 53115 Bonn, Germany

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ABSTRACT

The conversion of marginal croplands to tree plantations, as an option to address climate change, land degradation, and irrigation water scarcity, as well as to improve the welfare of local population requires prior analysis. This study analyzed the impacts of afforestation of marginal croplands, including potential benefits in the form of carbon sequestration rewards via the Clean Development Mechanism, on the livelihood of commercial farms and rural households by considering their interdependencies via wage-labor relations in irrigated agricultural regions of the lower reaches of the Amu Darya River, Central Asia. A dynamic nonlinear programming model was developed that jointly maximizes profit of farm and net incomes of rural households over a 15-year horizon under conditions of decreasing irrigation water availability and forestry plantations with a single seven-year rotation period. The results showed that the introduction of short-rotation plantation forestry in degraded irrigated croplands can help mitigate the repercussions of water shortages on rural livelihood, while sustaining energy needs, income, and food security. Although income and food consumption of rural households may decline from year two to six after afforestation, the subsequent increase in farm profit following the harvest of tree plantations would be transmitted to rural households through existing wage-labor payment arrangements. The incorporation of fuelwood into labor payment schemes would substitute the use of fossil fuels by rural households and thus substantially decrease their energy expenses and CO_2 emissions. Furthermore, given the low irrigation water demand of trees, afforestation would increase irrigation water availability for more productive croplands.

Introduction

Global warming is a major concern in arid and semi-arid areas (Solomon et al., 2007), as it will contribute to decrease of irrigation water availability, the spread of cropland degradation, and the diminishment of rural welfare (Holden and Shiferaw, 2004; Fischer et al., 2007; Solomon et al., 2007). Establishing tree plantations on degraded croplands in drylands bears the potential to mitigate such effects by improving land productivity and irrigation water use efficiency, sequestering carbon (C) and generating income (Djanibekov et al., 2012b; Khamzina et al., 2012). Under the Kyoto protocol for climate change mitigation, afforestation and reforestation efforts implemented within the Clean Development Mechanism (CDM A/R) framework were postulated as cheaper options than the other offset schemes for mitigating climate change impacts, while also having the potential for enhancing sustainable development (Boyd et al., 2007; Palm et al., 2009). Farm forestry was also recognized as an effective agricultural land use for making more food available to the hungry, reducing poverty, and improving environmental conditions (UNEP, 2011).

To be effective, economic and ecological aspects need to be considered simultaneously when aiming to introduce farm C sequestration activities through afforestation (Paul et al., 2013). Yet, published findings on the sustainable development objectives of C forestry are scarce and reach contrasting conclusions. Xu et al. (2007) and Shuifa et al. (2010) argued that such projects have the potential to alleviate poverty and increase job opportunities in China. In contrast, Glomsrød et al. (2011) reported that such projects have limited ability to reduce poverty in Tanzania, despite

* Corresponding author. Tel.: +49 228731852; fax: +49 228731869.
E-mail addresses: utkur@uni-bonn.de, utkurdjanibekov@yahoo.com (U. Djanibekov), djanibekov@iamo.de (N. Djanibekov), asia.khamzina@uni-bonn.de (A. Khamzina), abhaduri@uni-bonn.de (A. Bhaduri), jlamers@uni-bonn.de (J.P.A. Lamers), e.berg@ilr.uni-bonn.de (E. Berg).

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contributing to the mitigation of climate change. Reported findings in Central Asia indicated that the primary benefits from Certified Emission Reductions (CER = 1 ton of avoided CO_2 emissions) accrued from CDM afforestation on marginal irrigated croplands would be insufficient to attract farmers to this new land use (Djanibekov et al., 2012b).

Few studies have accounted for the potential of forest C offset projects for supplying multiple products that impact not only agricultural production and income, but also food and energy consumption of rural population. Kaul et al. (2010) stated that the integration of biofuel production within forest C offset projects could decrease household fossil energy expenditures and CO_2 emissions. Tree foliage as an inexpensive, protein-rich fodder might improve forage ration of livestock (Djumaeva et al., 2009; Lamers and Khamzina, 2010). Cost-benefit analyses in Uzbekistan showed that the integration of fruits and fuelwood production could substantially enhance the financial attractiveness of CDM afforestation (Djanibekov et al., 2012b). In addition, CDM afforestation on marginal irrigated croplands could increase irrigation water use efficiency in areas that are prone to water scarcity such as Central Asia (Djanibekov et al., 2012b).

Furthermore, introducing forest C offset projects on marginal farmlands may change rural economy relationships. In transitional, post-socialist economies such as Central and Eastern Europe and Central Asia, agricultural production is organized in a bimodal agricultural system (Kostov and Lingard, 2002; Lerman et al., 2004). On the one hand bimodal agricultural system is comprised of large commercial farms with external economies of scale occurring through advantages in accessing inputs, credits, and markets. These farms consume a negligible share, if any, of their own output and supply little, if any, of their own labor (Taylor and Adelman, 2003). On the other hand, there are a large number of smallholders whose incomes are limited to sales of their surplus crops and employment on large-scale commercial farms. Land use policies are typically oriented to benefit large-scale commercial farms, except in the case of countries with agricultural sectors dominated by smallholders, such as China and South Asia, where such policies are more focused on providing support for smallholders (Binswanger and Deininger, 1997). However, introducing new land use policies in a bimodal agricultural system will impact rural population, e.g., by altering employment structure on commercial farms and consequently agricultural contract relationships between commercial farms and smallholders. Shively (2001) showed that farmers tend to hire labor through mixed wage and rent contracts. In farm employment, a significant redistribution of wage occurs in kind, which, as an effective mean of supporting food security of subsistence smallholders (Slesnick, 1996), can happen via transfers of various tree products. Thus, in the context of a bimodal agricultural system, implementing agricultural policies and/or new land uses such as CDM afforestation will affect the commercial farms directly and the smallholders indirectly through their agricultural contract relationships.

In this respect, the allocation of commercial farms' degraded croplands to CDM afforestation will alter various activities that determine farmer-smallholder interdependencies. In contrast to previous studies that focused on financial viability and the economy-wide impacts of forest C offset projects (e.g., Boyd et al., 2007; Xu et al., 2007; Zhou et al., 2007; Palm et al., 2009; Olschewski and Benítez, 2010; Shuifa et al., 2010; Glomsrød et al., 2011; Djanibekov et al., 2012b; Paul et al., 2013), an explicit consideration of agricultural contracts between commercial farms and smallholders would help to address the changes in rural economic relationships and the analysis of multidimensional impacts on rural livelihood. Since C forestry activities can provide other products in addition to C payments (e.g., fuelwood, foliage as livestock fodder, fruits) the agricultural contract relationships between rural actors can reveal information about their dependencies on land uses and the resulting products, as well as the direct and spillover effects of land use change. Therefore, the objectives of this study conducted in irrigated drylands of Uzbekistan were (i) to investigate the role of interdependencies among commercial farms and semi-subsistence smallholders in the transfer of CDM afforestation benefits, and (ii) to analyze the impacts and spillover effects of land use change to CDM afforestation on agricultural production, income, consumption, and employment of rural households under conditions of decreasing irrigation water supplies.

Methods

Study area

The study area is the Khorezm region and three southern districts of the Autonomous Republic of Karakalpakstan, namely Beruniy, Turtkul and Ellikkala located in the Amu Darya River lowlands in Uzbekistan, Central Asia (Fig. 1). These locations have an arid climate with average annual precipitation of 100 mm. Precipitation occurs predominantly during the autumn and winter. Therefore, crop cultivation is only feasible through irrigation. Regional water availability and its distribution within the irrigated areas are among the main factors that influence crop yields (Dubovyk et al., 2012a). Nearly two million people reside in the study area, about 70% of which are in rural areas.

Agriculture accounts for about 35% of region's GDP. The study area includes around 410,000 ha of arable land, of which 88% are leased by 7200 commercial farms (as of 2009), while the remainder mainly belongs to semi-subsistence smallholders. The commercial farms and semi-subsistence smallholders/rural households (*dekhqans* in Uzbek) are distinguished according to the operated land size, income level, availability of assets and labor, agricultural activities, and requirements for the fulfillment of the state cotton and wheat procurement policies (Djanibekov et al., 2012a). The smallholders are mainly engaged in gardening and raising livestock on their plots that have an average size of 0.2 ha. They also depend on income from employment on commercial farms, sales of surplus products from their own plots, and non-agricultural activities. Land use patterns of commercial farms and rural households are also determined by the availability of resources such as surface irrigation water, the ratio between input use and output, and the prices of agricultural products (Djanibekov, 2008; Djanibekov et al., 2012a). Production decisions are primarily based on the policy instruments such as cotton and winter wheat procurement for commercial farms, and on food diets for rural households (Djanibekov, 2008; Veldwisch and Bock, 2011).

The major crops cultivated in the study area are cotton and winter wheat (hereafter referred to as wheat), which cover about 40% and 25% of the arable land respectively. Production of both crops falls under the state procurement policy (Djanibekov et al., 2010). According to this policy, commercial farms that specialize in cotton and grain production have to allocate about 50% of their cropland to cotton and comply with output targets that are pre-set based on the soil-fertility of their lands. The state purchases entire cotton harvests at lower rates than potential border prices (Djanibekov et al., 2010) and half of wheat harvests at prices below local market prices (Djanibekov et al., 2012b).

Nearly 20–30% of regional croplands have low production potential for annual crops (MAWR, 2010) and are generally located on commercial farms and cultivated with cotton or wheat. Despite convincing arguments for afforestation of marginal croplands in Uzbekistan (Djanibekov et al., 2012b; Khamzina et al., 2012), current legislation does not permit such a land use change (Kan et al., 2008; Djanibekov et al., 2012a). Moreover, ongoing farmland