The effect of irrigation service delivery and training in agronomy on crop choice in Tajikistan

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Selected Paper prepared for presentation at the 2019 Agricultural & Applied Economics Association Annual Meeting, Atlanta, GA, July 21 – July 23

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Abstract: The aim of this paper is to analyze the effect of irrigation delivery services and agricultural extension services on crop choice in southern Tajikistan. This analysis is motivated by the government's recent efforts to address the country's severe malnutrition problem by supporting changes in irrigation service delivery and agronomy to increase diversity in agricultural production and consumption, in an environment where the cultivation of cotton had, until recently, been mandatory. Water management in Tajikistan has largely been transferred to the community through the creation of water users' associations (WUAs), which were established between 2011 and 2013. While all WUAs received training to improve irrigation delivery services, some also received training in cultivating alternative crops and improving cultivation practices through agricultural extension services. Through specific empirical analysis conducted on a primary panel dataset of 1,855 farms in southern Tajikistan, we identify the extent to which improvements in irrigation services, and agronomy training through extension services affect decisions pertaining to cultivated areas of cotton and wheat (the traditional crops) and the cultivated area and number of (newer) high-value crops. We also examine the effect of water delivery and agricultural extension services on crop diversity and cropping intensity (how often land is used in a calendar year). We find that improvements in irrigation delivery services affect cultivated areas of cotton and wheat. Cultivation of high value crops is significantly influenced by agricultural extension services. While cropping intensity depends on water delivery services, crop diversity depends on extension services. From a policy perspective, these results highlight the importance of agricultural programs for stimulating agricultural value added in landscapes historically characterized by limited crop choice and a collapse of the agricultural sector.

Keywords: irrigation delivery; agricultural extension; water user associations; agricultural production; Tajikistan.

1. Introduction

Improvements in irrigation services and training in agronomy are important for enhancing agricultural production, especially in semi-arid parts of the world (Darko *et al.*, 2016). Irrigated lands account for around the major share of food production in Asia especially, and it is expected that half to two-thirds of future gains in global crop production will come from irrigated land (Kadiresan and Khanal, 2018). The experiences of the Green Revolution in Asia suggest that irrigation, when combined with inputs and improved crop varieties can enable year-round cultivation, expand cropping areas and improve agricultural productivity (Alaofè, Burney and Naylor, 2016). Improvements in irrigation and agricultural extension can often support the introduction of new crops (Jayne et al., 2010). Training in water management and agronomical practices, combined with peer-to-peer learning and community participation have been found to have a positive impact on agricultural production and food security (Bizikova, 2017).

In this article, we analyze whether improvements in irrigation service delivery and training in agronomy influence crop choices in Tajikistan. Through an empirical analysis, we aim to identify the effect on the acreage of cotton and wheat cultivation (the traditional crops); the acreage and number of high-value crops (alternatives to traditional crops); crop diversity on the farm; and the cropping intensity of the farm.

An examination of land use is motivated by the government's recent efforts to address the country's severe malnutrition problem by supporting changes in irrigation service delivery and agronomy, and by increasing awareness, to increase diversity in agricultural production and consumption (WFP, 2017; FAO, 2017), in an environment where the cultivation of cotton had, until rather recently, been mandated. The 2017 Global Hunger Index suggests that around 30% of the country's population in undernourished (WFP, 2017). In 2013, 26% of children under the age of five were stunted, while 10% suffered from wasting (Statistical Agency under the President of the Republic of Tajikistan (SA), Ministry of Health (MOH), and ICF International, 2013). The Tajik diet, which is poor in mineral-rich vegetables and fruits, has been identified as an important factor for persistent malnutrition (FAO, 2017). The Government has made efforts to tackle this problem, through programs such as 'Scaling Up Nutrition', which aim to improve diversity in agricultural production and consumption (FAO, 2017). However, agricultural markets continue to support the cultivation of cotton (Boboyorov, 2016). An understanding of how improvements in irrigation and training in alternative crops influences crop choice and land use would be important for designing and managing interventions to support the government's development goals.[1,2]

With support from the United States Agency for International Development (USAID), participatory irrigation management was introduced in 2006, and enabled by legislation defining water user associations (WUAs). WUAs were mandated to restore irrigation services by designing irrigation schedules, coordinating water use and collecting payments, in order to improve the timeliness of water delivery, the distribution of water, the quantity of water delivered, and the condition of canals; and consequently to expand cropping area. [3]

WUAs were created between 2010 and 2014, both by USAID and by the government in southern Tajikistan, and at present, around 400 WUAs are registered and functional. The USAID WUAs differ from other WUAs in that they provided longer trainings on irrigation service delivery and water governance along with training in improved agricultural practices through agricultural extension services. Other WUAs were provided shorter training in irrigation service delivery without any extension information (though information on changing and improving cultivation practices may have diffused from USAID WUAs to other WUAs).

Understanding how land use changes are influenced by improvements in irrigation service delivery and by training in agronomy can provide important evidence for policy and planning. This paper contributes to the literature by providing empirical evidence based on a study design

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[1] Understanding how perceptions and dietary choices can be influenced at the point of food consumption is also vital, but is beyond the scope of this paper.

[2] Tajikistan is characterized by migration of rural males, with 48% of rural households in Khatlon Province in southern Tajikistan having a male migrant. The World Bank estimates that around 55% of individuals in agriculture are now female. An understanding of how this feminization affects labor availability, that in turn influences crop choice would also be important for designing and managing future interventions that meet the government's development goals, but is also beyond the scope of this paper.

[3] It is worth noting that WUAs were introduced in Tajikistan to fill in the vacuum in irrigation service management that resulted from decollectivization of Soviet-era collective farms.

that controls for other factors that may influence crop acreage, crop type, diversity and intensity of land use. Propensity scores using historical agronomic and socioeconomic data were constructed for sub-districts served by USAID and non-USAID WUAs and then these subdistricts were selected for detailed examination in matched pairs, to control for observable factors in the past that may drive current production decisions, besides irrigation and extension services. Then, a representative sample of farms in southern Tajikistan within the selected subdistricts was selected through a stratified random sampling process. In addition, this examination of the effects of irrigation services and extension services is based on a panel dataset of farms, rather than relying on a cross-section. A total of 1,855 *dehkan* farms, with an equal number served by USAID WUAs and other WUAs were surveyed twice—once for the 2014 calendar year and again for the 2016 calendar year—to examine changes in the acreage and cropping behavior. The use of panel data allows for identification of more robust correlations between the irrigation, extension and decisions pertaining to cultivated areas, crop diversity and cropping intensity by controlling for unobserved time-invariant effects that may also affect agricultural decisions.

In spite of this contribution, one limitation of the paper is that the results of the analysis cannot be interpreted as causal estimates of the impacts of irrigation services and extension services. This is because of the absence of data on production choices before the interventions began.

This article is organized as follows. In the second section, details of the context of the agriculture sector in Tajikistan and the WUA interventions are provided. The third section provides a conceptual framework that motivates the analysis in the paper. Section 4 provides a description of the econometric methods, while Section 5 provides a description of sampling strategy and the data collected. Section 6 provides results from descriptive and econometric analysis. Finally, the policy implications of the key findings are discussed in Section 7.

2. Background

After the steady and intense agricultural growth during the Soviet period up to 1980, the agriculture sector stagnated in the 1980s. The post-independence transition phase from 1991 to 1997 was characterized by a decline of 55% in the gross agricultural output. Land reforms, which began in 1992, dissolved the Soviet-era collectives that specialized in the production of cotton, first into smaller collectives and then further into individual or family farms, called *dehkan* farms. Despite these land reforms, agricultural production remained depressed, due to the lack of irrigation services that could manage the needs of thousands of smaller farms (Gunchinmaa & Yakubov, 2010). The introduction of water user associations in 2006, and the completion of land reforms by 2008, brought agricultural production in 2008 back to its level at the time of independence (Lerman & Sedik, 2008).[4] In 2016, agriculture provided around 50% of the employment and contributed to around 25% of the country's gross domestic product (ADB, 2016).

Currently, there are three main types of agricultural land in Tajikistan—*dehkan* farms, household plots and agricultural enterprises. A typical *dehkan* farm is around 3-5 ha in size; and is usually farmed by around 3 households. [5] Farm members are referred to as *sahimdors*, or shareholders. While land continues to remains state property, shareholders have the right to cultivate *dehkan* farms and to transfer their allotted farms through inheritance (Abbott, 2016) or by leasing (Klümper et al., 2018). In 2011, *dehkan* farms managed 65% of arable land, and produced 20% of the gross agricultural output (GAO) (Lerman and Wolfgramm, 2011). In the same year, in contrast, household plots (small parcels of land adjacent to the homestead) managed 20% of arable land and produced 65% of the GAO (Lerman and Wolfgramm, 2011). The remaining 15% was under agricultural enterprises, which replaced the Soviet era collectives and produced less than 10% of the GAO.

2.1. Land use under different crops

While the crop policy that mandated the cultivation of cotton has been relaxed, cotton continues to remain an important crop (van Atta, 2009). In 2011, 24% of agricultural land was under cotton cultivation, which marginally fell to 19% in 2015 (Table 1). The Government of

[4] Early analysis of the effects of land reforms on productivity suggest that the distribution of benefits have been unequal among rural households (Robinson et al., 2008).
[5] A household is defined as a set of individuals who live in the same dwelling and share food cooked in the same kitchen.

Tajikistan regulates cotton prices; middlemen purchase cotton harvests from farms; and cotton fiber is an important source of foreign exchange (e.g it accounted for 15% of the total export revenue in 2014). The well-regulated structure of the cotton market and the relations between farmers and cotton purchasers that provide inputs and loans towards cotton cultivation contribute to the prevalence of cotton cultivation (Boboyorov, 2012; Boboyorov, 2016; Hofman, 2017) .

Bread, mostly made from wheat flour, is the staple food in Tajikistan and the main source of nutrition, as it provides 52% of the daily calorific intake in Tajikistan (Muminjanov *et al.*, 2016). The area under wheat cultivation has more than doubled since independence in 1991. In 2011, around 27% of agricultural land was cultivated with winter wheat, which increased marginally to 30% in 2013, and again marginally fell to 28% in 2015 (Table 1). Spring wheat was cultivated on 10% of agricultural land in 2011, and marginally declined to 7% in 2015 (Table 1). Tajikistan is the leading consumer of wheat per capita in the world (Husenov *et al*. 2015), with an average consumption of 166.3 kilograms (kg) per person per year in 2009. Since domestic production is insufficient, around 40% of the wheat consumed in Tajikistan is imported from Russia (Muminjanov *et al.*, 2016). These dietary customs combined with fluctuating prices of imported wheat provide strong incentives for farmers to choose to cultivate wheat for self- consumption.

This pattern of cotton and wheat cultivation is rather predominant, and is colloquially termed a 'cotton for cash, wheat for food' model. The cotton harvest is sold for cash, while a significant share of the wheat harvest is retained for self-consumption.

Vegetables have occupied a minor share of land. In 2011, around 6% of agricultural land was allocated to vegetables, which marginally increased to 7% in 2015 (Table 1). Similarly, agricultural land under potatoes increased from 6% in 2011 to 7% in 2015 (Table 1).

2.2. The evolution of water user associations

While water delivery was centrally administered by state irrigation departments for collective farms in the Soviet Union, the creation of *dehkan* farms was accompanied by the introduction of decentralized and participatory management of water (Gunchinmaa & Yakubov, 2010).

Tajikistan passed the 'Law on Water User Associations in November 2006 (with support from USAID), under which WUAs were recognized as the primary organization responsible for delivering water to dehkan farms. The principal functions of WUAs, as mandated by the law, are the operation of local water infrastructure, design and implementation of an irrigation schedule to deliver water to farms, repair and maintenance of irrigation canals, collection of fees (membership fees and water delivery service fees) and water-related conflict resolution (Sehring, 2009).

Training materials for establishing and supporting WUAs were developed under the Family Farming Program (FFP), launched by USAID in 2010, which was incorporated into the Feed the Future (FTF) initiative in 2011. USAID set up 70 WUAs in Khatlon Province in southern Tajikistan during 2011-2013. Local governments (with funding from other international organizations) also used USAID-developed training materials to establish WUAs in Khatlon during 2011-2013 (and across the country thereafter). As compared to other WUAs, members of USAID WUAs were provided longer duration of training in irrigation delivery and management.

While members of all WUAs received training on irrigation delivery and management, members of USAID WUAs also received formal training on agricultural technologies, and benefitted from peer-to-peer learning through gatherings. Tajikistan lacks formal agricultural extension services (Mandler, 2010). Information on improved cultivation practices and inputs for cotton and wheat (the traditional crops) was provided to members. In addition, demonstration plots for cultivating high value crops such as fruits and vegetables were undertaken, and farmers in USAID WUAs were trained in cultivating fruits and vegetables at larger scales . In WUAs set up by the government, such information and trainings were not provided; however farms served by non-USAID WUAs may have acquired such information through diffusion of information and through WUA exchange visits, which were organized by USAID and the government (Shtaltovna, 2016).

3. Conceptual framework

3.1. Empirical literature

Improvements in irrigation infrastructure and management may improve water availability that enables expansion of cropped areas. Such improvements could also increase the cultivation period, allowing crops of different maturation periods to be cultivated on the farm, thus increasing the number of crops cultivated and their acreage (Zimmerer, 2014; McCord et al., 2015). In semi-arid areas, irrigation enables the production of fruits and vegetables, that rainfed system alone may not have supported (Naylor *et al.* 2011).

Increases in cultivation of number and acreage of (new) high-value crops could take place without decreases in the area under traditional crops on the farm. For example, Pradhan and Ranjan (2016) demonstrated that improvements in irrigation services, which increased water availability, also increased the cultivation of dry season rice in Bangladesh (the traditional crop) along with other high-value seasonal crops. The incentives to increase variety of crops could arise either due to supply-side factors such as improving land quality ; or due to demand-side factors such as responding to new consumption needs that generate income generating opportunities (e.g. see Bobojonov and Lamers, 2008 in Uzbekistan).

Agricultural extension can play an important role in affecting and expanding crop choice especially in contexts where knowledge about cultivation of alternative crops may be limited (Calub et al., 2005; Oladele, 2005). For instance, extension services were found to play an important role in helping farmers in Thailand diversify crop cultivation, when national policy moved away from promoting cultivation of rice (Kasem and Thapa, 2011). Similarly, in Kenya, exposure to extension officers was found to increase the variety of crops cultivated especially for smallholder farmers (McCord et al., 2015).

3.2. Hypotheses

Cotton is a highly water-dependent cash crop; and improvements in irrigation infrastructure and irrigation management may encourage expansions of cultivated areas.[6] Wheat, which is less water dependent, may also expand in cropping areas if more water is available for

[6] The productivity of cotton may fall due to the impacts of climate change in the Central Asian region (Mannig et al., 2013; Bobojonov & Aw-Hassan, 2014). This may have implications for area under cotton cultivation, and consequently irrigation management, but this is beyond the scope of this paper.

irrigation and if better cultivation practices are introduced (Wang et al., 2009; Wang et al., 2018).[7] In the context of Tajikistan, improvements in water delivery services could expand cultivated areas of wheat and cotton on the farm (Birthal *et al.*, 2015; Kasem and Thapa, 2011). The areas under fruits and vegetables, that are also water intensive, may expand with irrigation service improvements. Additionally, the cropping intensity (defined as the number of times a plot on a farm is used in a calendar year) could also increase with irrigation service improvements.

In the Soviet Era, Tajikistan specialized in cultivating cotton and wheat, relying on other republics for other commodities under the USSR's central economic planning system (Pomfret 2008). With the mandatory cultivation of cotton relaxed, engagement with agricultural extension services have the potential to expand the variety of crops cultivated and the area under high-value crops (Winters et al., 2006). An increase in the variety of crops cultivated could reduce environmental damages generated due to historical cotton mono-cropping by reducing: nutrient loss in soils (Hooper and Vitousek, 1997; Reich et al., 2001); soil salinity; and risks from pests and climate change (Winters et al., 2006).

The hypotheses tested in the paper consist of the following:

- Improvements in water delivery increase the farm-level cultivated areas of cotton, wheat, and other crops, the number of crops cultivated on the farms, the crop diversity of the farm, and the cropping intensity.
- Provision of agricultural extension services increase the number of high-value crops cultivated on the farm, the area under high-value crops on the farm, the crop diversity of the farm, and the cropping intensity.

Due to the history of mono-cropping, we don't expect increases in cultivated area of high-value crops to occur with the reduction in cultivated areas of cotton. Rather, we expect the

[7] The productivity of wheat cultivation in Central Asia may improve due to climate change, providing cropping practices are also adapted (Sommer et al., 2013). This could provide incentives for expanding cropping areas, and consequently may have implications for irrigation management; but this is beyond the scope of this paper.

improvements in irrigation services and the provision of extension services to increase land areas under traditional and high-value crops.

4. Empirical model

Anchored on the conceptual framework, we analyze the determinants, at the farm level, of the following: cultivated areas of cotton, wheat, and other crops; number of crops cultivated (excluding cotton and wheat); crop diversity; and cropping intensity. Specifically, we examine the extent to which water delivery services and agricultural extension services influence crop production decisions on the farm.

The empirical model estimated is the following:

$$D_{ijt} = \beta_1 FC_{ijt} + \beta_2 MC_{ijt} + \delta_{\mathrm{D1}} WD_{ijt} + \delta_{\mathrm{D2}} AE_{ijt} + \eta_{ijt} \qquad (1)$$

D_{ijt} represents the following (in different regressions) measured at the farm level:

- cultivated area of cotton, cultivated area of wheat and cultivated area of other crops on farm i in subdistrict j in time t, each measured in hectares;
- the number of high-value crops cultivated (beyond wheat and cotton) on farm i in subdistrict j in time t ;
- the cropping intensity of farm i in subdistrict j in time t, which is calculated at the plot-level, as the gross cropped area divided by the net sown area, multiplied by 100. This indicates the number of times the plot was farmed in a calendar year.
- the Margalef's index of diversity for farm i in subdistrict j in time t. The Margalef' Index of Diversity (MID) has been chosen against other indicators as it is widely used in the literature on crop and variety diversification (Rehima et al., 2013). In this context MID is defined as the number of crops cultivated per hectare of land area, and is calculated as $MID = (N-1)/(\ln(A+1))$, where N refers to the number of crops cultivated, and A refers to the total area cultivated by the farm.

WD_{ijt} represents a vector of variables that contain water delivery characteristics for farm i in subdistrict j in time t. In an ideal world, the presence of meters and gauges would have enabled the inclusion of quantity of water delivered during peak irrigation time. In the absence of such meters and gauges, perceptions regarding fairness of water sharing, timeliness of irrigation services, quantity of water delivered, condition of the watercourse canal, and condition of the distributary canal are included, assuming that farmers' practices are correlated with their perceptions.

AE_{ijt} is a vector capturing the agricultural extension services received by farm i in subdistrict j in time t. While such training was imparted to farms that are served by USAID WUAs, such information may have spread to other areas, with farmers in other areas visiting demonstration plots in USAID WUAs. Therefore, an indicator variable that denotes whether farm members were directly trained and the frequency of interaction with other members of an agricultural or water group is included in this vector.

δ_{D1} and δ_{D2} are the coefficients of interest to be estimated.

η_{ijt} is an error term which is assumed to have the following structure:

$$\eta_{ijt} = \vartheta_{it} + \alpha_j + \tau_t \qquad (2)$$

η_{ijt} is the term of error which is structured to have a time component (τ_t), a subdistrict component (α_j)and a farm component (ϑ_{it}).

Other variables that also affect production decisions are included. FC_{ijt} refers to a vector of the characteristics of farm i in subdistrict j in time t, with the area of the farm, the distance to the road and the age of the farm included in this vector.[8] MC_{ijt} represents a vector with the characteristics of the shareholders of farm i in subdistrict j in time t, which include the number of farm shareholders, the proportion of female shareholders, and the age, education and sex of the manager of the farm (who is the farm head).

In equation (1) the variables related to the selling price of the commodity, the consumer price of the product and the input prices have been voluntary omitted, because prices of cotton and wheat do not vary much across different locations. For non-regulated crops, the domestic price

[8] Farmers were not able to influence or decide the area of their farm when de-collectivization occurred. Also, land acquisition through rental or purchase is not common. Therefore, the area of the farm is not likely to be endogenous.

of high-value crops is influenced by world prices, which implies that prices are unknown in advance and unlikely to be used to make cultivation decisions (Bobokhonov *et al.*, 2017).

The empirical model equation (1) is estimated using a random-effects Tobit model (Greene, 2006; Tobin, 1958) when the determinants of cultivated areas of cotton, wheat and high-value crops; and the Margalef's index of diversity are examined, to take into account truncated values. A generalized least squares random-effects estimator is used when determinants of the number of high-value crops cultivated, and the cropping intensity are examined. In all cases, standard errors are clustered at subdistrict level to allow for intragroup correlation of the standard errors.

5. Study design and data

Tajikistan is divided into four provinces: Sughd, Khatlon, the autonomous province of Gorno-Badakhshan, and the Region of Republican Subordination. Each province is divided into several districts (58 districts in total) , which are subdivided into subdistricts (367 subdistricts) and then villages. This study is based in subdistricts of southern Tajikistan that are irrigated by gravity schemes. While farms in some subdistricts are served by USAID WUAs, farms in other subdistricts are served by WUAs established by the government. A pre-sampling survey was conducted in all subdistricts served by WUAs in gravity schemes in Tajikistan in 2014. Data from 164 subdistricts in Khatlon (116), Sughd (21) and Districts of Republican Subordination (27) provinces were collected. Information on land use and agricultural practices; irrigation infrastructure and schemes; the presence and characteristics of WUAs; and demographic characteristics was collected from the administrative office of each of the subdistricts. Based on this data, propensity scores were constructed to calculate the probability of each subdistrict being treated by USAID WUAs. Using the propensity scores, subdistricts served by USAID WUAs were matched (using a caliper of 0.12) to those that are served by government WUAs, without replacement to their nearest neighbor, to select 80 subdistricts—40 served by USAID and 40 served by government WUAs (Figure 1) [9]. Matching was conducted to control for selection bias

[9] Details pertaining to the propensity score matching, and the list of attributes used for the same can be found in Balasubramanya *et al*. (2016).

due to observable characteristics, since assignment of farms to USAID and non-USAID WUAs was not random. The propensity score matching improves the comparability of farms served by USAID and government WUAs.

Next, *dehkan* farms were selected within each sampled subdistrict. In the absence of consolidated lists of irrigated farms at the local or national level, a census of farms was conducted by the study team, to collect information on the name of the farm, name of the manager of the farm, type of canal serving the farm (primary, secondary, tertiary), and the farm's location along the canal (head, middle or tail). These characteristics together make up nine types of farms (three canal types by three canal locations). A stratified random sampling method was used to select 25 *dehkan* farms from each of the selected subdistricts. This sampling method randomly selects the nine types of farms in proportion to their numbers in the population, and allows for a spatially representative sample and for robust econometric identification of correlations between water delivery and agricultural extension interventions, and crop choice. Power calculations, taking into account intra-subdistrict correlation and non-response rates, conducted before the sample was selected, were undertaken to determine the appropriate sample size, the number of USAID and non-USAID subdistricts (clusters), and the number of farms per USAID and non-USAID subdistrict.

Panel data were collected from this sample. The person leading operation on the farm was interviewed a first time in 2015 and a second time in 2017. The 2015 survey collected information for the 2014 calendar year, while the 2017 survey collected information for the 2016 calendar year. The 2015 survey was answered by 1,956 farms. The 2017 survey was answered by 1,855 farms. Information on number and cultivated areas of crops, farm characteristics, and characteristics of the shareholders of the farm; perceptions regarding improvements in water delivery and the condition of infrastructure, training received from extension services, and frequency of interactions with an agricultural or water community group were collected in both surveys. Table 2 contains summary statistics pertaining to these variables, for farms located in subdistricts served by USAID WUAs, and farms located in subdistricts not served by USAID WUAs. Variables pertaining to farm characteristics and shareholder characteristics were not significantly difference between the two groups of farms, indicating that similar farms comprised both group. These variables are used during the econometric analysis in section 7 to control for other factors that may affect choices pertaining to cultivated areas, number of crops cultivated, crop diversity, and cropping intensity, and to improve specification fit. The variables pertaining to perceptions around water delivery were modestly higher in the USAID group (as was expected); and those pertaining to agricultural extension were significantly higher, with farms in the USAID group more often reporting receipt of training and peer-to-peer interactions (again, as expected).

6. Results

6.1. Descriptive statistics

The average farm area was 4.40 ha (standard deviation (s.d) of 8.70) in 2014, and 4.24 ha (s.d 8.15) in 2016. In 2014, farms had on average 7.4 members (s.d 11.10), which slightly fell to 6.55 in 2016 (s.d 9.77). Around 47% of farm members were female in 2014; this increased to 52% in 2016. In 2015, women headed 13% of farms, which increased to 38% in 2016.

Cotton and wheat were the most commonly cultivated crops by farms. In the sample, 56.1% of farms cultivated cotton and 58.5% cultivated wheat in 2014 (Figure 2); this did not change much between 2014 and 2016, with 59.5% farms cultivating cotton and 63.7% farms cultivating wheat in 2016. There was an increase in the number of farmers cultivating tomatoes, onions, and potatoes in subdistricts not served by USAID WUAs between 2014 and 2016, while in locations served by USAID WUAs, the share of farmers cultivating melons and clover increased between the two years.

A significant share of the net cultivated area constituted cotton cultivation. In 2014, cotton was cultivated on an average of 3.5 ha, which was equivalent to 67.1% of the net cultivated area of the farm (Figure 3). The cultivated area of wheat was lower, at 1.6 ha on average in 2014, which was equivalent to 44% of the net cultivated area. The share of the net cultivated area for both cotton and wheat decreased in subdistricts served by both non-USAID as well as USAID WUAs . There was a decrease in the areas under cotton and wheat by 7.1% and 15.2%, respectively, between 2014 and 2016. Except for maize and clover, which require larger areas, the cultivated areas of high-value crops did not exceed 1 ha, on average. Between 2014 and 2016, there was a small increase in the cultivated areas of tomatoes, onions, potatoes and melons in both types of subdistricts.

The number of crops cultivated by a *dehkan* farm, on average, was 2.9 in 2014 and this increased to 3.4 in 2016 (Table 3). The difference in the number of crops cultivated between the two years was significant at 1% but the difference-in-difference (change in the number of crops for the USAID group - change in the number of crops for the non-USAID group) was not significant. The Margalef's Index of Diversity (MID), was 1.67 for the average farm in 2014 and increased to 2.03 in 2016, with the difference between the two years significant at 1%.

The cropping intensity indicates the number of times the same plot on the farm was used during one agricultural year. In the full sample, cropping intensity was limited both for farms served by USAID WUAs and those served by non-USAID WUAs, and was centered around 100; generally, only one crop was cultivated per plot per year even if the cropping intensity significantly increased between 2014 and 2016. Wheat is usually sown in September/October and harvested in June/July; and cotton is sown in April and harvested from September to November (FAO, 2017). With these two traditional crops, the possibility of increasing cropping intensity on a plot is limited. A shift towards vegetables requiring a shorter cultivation duration may increase cropping intensity in the future.

6.2. Determinants of cultivated area, number of crops, crop diversity and cropping intensity

6.2.1. Cultivated areas

Table 4 presents the determinants of the cultivated areas of cotton, wheat and high-value crops. Water delivery services had a modest impact on the cultivated area of cotton, wheat and high-value crops. Farmers who perceived improvements in fairness in water sharing increased cultivated areas of cotton by 0.23 ha ($p < 0.1$); and farmers who perceived an improvement in the condition of the watercourse increase cultivated areas of high-value crops by 0.23 ha ($p < 0.05$). In contrast, farmers who perceived an improvement in the quantity of water delivered reduced cultivated areas of wheat by 0.49 ha ($p < 0.05$). Wheat is not a water-intensive crop, and any improvement in the quantity of water may provide an opportunity to cultivate high-value crop, which are more water intensive.

Receiving training did not have any impact on the cultivated areas of cotton, wheat, and high-value crops. However, additional interactions with an agricultural or water community group increased the cultivated area of high-value crops by 0.14 ha ($p < 0.05$).

These results suggest that cultivated areas of cotton and wheat depend on water delivery, while those of high-value crops depend on extension services and farmer-to farmer interactions.

6.2.2. Number of crops

Table 5, column 1 presents results pertaining to the determinants of the number of crops cultivated, other than cotton and wheat. Farmers who perceived an improvement in the physical state of the watercourse cultivated 0.16 additional crops ($p < 0.05$); while farmers who perceived an improvement in the condition of the distributary canal cultivated 0.12 additional crops ($p < 0.05$). Farmers who received formal training in cultivation of high-value crops (which was only provided to members of USAID established WUAs) cultivated 0.28 additional crops.

These results suggest that infrastructure maintenance and improvements, and formal training in cultivating high-value crops are important for increasing the number of crops cultivated.

6.2.3. Crop diversity

Table 5, column 2 contains results pertaining to the determinants of crop diversity. The condition of the watercourse canal was a significant determinant of the MID; farmers who perceived that the condition of the watercourse canal had improved had a MID of 0.13 more that those who thought that there were no such improvements ($p<0.05$). Receiving formal training in agricultural extension increased the MID by 0.29 ($p<0.01$)

6.2.4. Cropping intensity

Column 3 of Table 5 reports determinants of cropping intensity. A perceived improvement in the condition of the watercourse increased cropping intensity by 3.06%. Formal training in extension and the frequency of interaction with agricultural and water groups did not have any effect on cropping intensity.

6.3. Discussion

The results in this paper support the existing empirical literature on the effects of irrigation and agricultural extension on agricultural production decisions, which has found such programs to enhance cropping areas, crop diversity and year-round cultivation.

The two hypotheses tested are not rejected in the context of south Tajikistan. First, the improvements in water delivery significantly determined the cultivated areas of cotton, wheat and other crops, crop diversity and cropping intensity. These results are in line with the analysis of other authors in different international contexts, such as Mc Cord et al. (2015), Ranjan (2016), Birthal et al. (2015), and Kasem, and Thapa . However, while the effect of improved irrigation and water governance is positive on the cultivated areas of cotton and other crops, the effect is negative on wheat. Improvement in water delivery therefore have had a different impact on the two crops that are traditionally cultivated (cotton and wheat), which have different water needs and are cultivated for different purposes ('cotton for cash, wheat for food').

Second, the provision of agricultural extension services positively affected the areas cultivated with other crops, the number of other crops cultivated and the diversity index of the farm. This confirms the positive role of agricultural extension on diversification either through formal training (Kasem and Thapa, 2011; Calub et al., 2005) or through informal interactions (Winters, 2006). In our specific context, formal training determined the number of high value crops cultivated and the index of crop diversity, while informal interactions between the group members favored the areas cultivated with these new crops.

This paper contributes to the literature from a methodological standpoint by: using a study design that controls for other factors that may influence land use choices; having a sample size that is large enough to detect small changes in production decisions; employing a sampling strategy that provides a stratified random sample that is representative of farms in southern Tajikistan; and using panel data. These design features allow for a more robust estimation of relationships between irrigation, extension and production decisions. This analysis also estimates the effect of water delivery services along with agricultural extension services; the empirical literature usually focus on one or the other.

7. Conclusion

The government of Tajikistan has adopted a policy of diversification in agricultural production and consumption to tackle the problem of malnourishment. This policy is being implemented by supporting improvements in irrigation delivery, encouraging cultivation of high-value crops, and by increasing awareness about the benefits of diversified production and diets. The results in this paper indicate that improvements in irrigation delivery services affected the cultivated areas of cotton and wheat, as well as that of high-value crops. Irrigation services also increased the number of high-value crops cultivated and the cropping intensity. Formal training in agricultural extension significantly increased crop diversity.

The increase in cropping areas of a traditional crop and (new) high-value crops, and an increase in crop diversity are often viewed as important factors on the pathway of improving food security for smallholders. Within that perspective, developing national agricultural extension services in Tajikistan that encourage diversification could play an important role in boosting production of fruits and vegetables. Enhancing the technical capabilities of WUAs through targeted training, and improving the capacities of district irrigation departments that oversee WUAs would help maintain irrigation service delivery. Such coordinated approaches are timely, because females, who have not received training in either participatory irrigation management, or in improved agronomical practices, are increasingly managing farms due to high rates of male migration. These changes in the gender composition of the agricultural workforce also provide opportunities for developing gender-inclusive and gender-sensitive agricultural and water management programs.

The returns to improvements in water management and extension services would likely be higher with a coordinated development of agricultural value chains. Markets that supply a range of quality inputs such as improved seeds and agro-chemicals would also help increase agricultural productivity and yields; such markets are currently at a nascent stage of development in Tajikistan. Development of processing, canning and packaging facilities, which currently are missing, can increase the value of agricultural production, further supporting the returns on irrigation and extension. In a landscape where agricultural production was historically characterized by limited crop selection and where production in the agricultural sector had collapsed, coordinated investments in irrigation, extension and value chains have the potential to relax supply-side constraints, change land use and stimulate the agricultural sector.

Acknowledgments:

This research is funded through a project titled 'Impact of Water Users Associations on Water and Land Productivity, Equity and Food Security in Tajikistan' funded by the United States Agency for International Development under USAID Grant Number AID-BFS-G-11-00002. The opinions expressed herein are those of the authors and do not necessarily reflect the views of the U.S. Agency for International Development. We would like to thank Ted Horbulyk for comments and suggestions; and Sohrob Aslamy and Katherine MacDonald for supervising data collection. Both authors contributed equally to this work. All errors are ours.

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Table 1: Allocation of agricultural land in 2011-2015

	2011	2012	2013	2014	2015
	(in percent of total)				
Total crops	100	100	100	100	100
of which:					
Irrigated land	67	67	66	68	68
Winter crops	29	29	33	32	31
of which:					
Winter wheat	27	26	30	29	28
Barley	2	2	3	3	3
Spring crops	21	21	18	18	20
of which:					
Wheat	10	9	7	6	7
Barley	6	6	6	6	7
Maize	2	2	2	2	2
Rice	2	2	1	1	1
Others	2			2	2
Cotton	24	23	22	21	19
Flax	2	2	2	2	2
Potatoes	4	5	5	4	5
Vegetables	6	6	6	6	7
Fodder	10	11	11	13	12
Melons and gourds	2	2	2	2	3
Other industrial crops	2	2	2	2	2

Source: Tajikistan Statistics Department
Available at: https://www.stat.tj/en/tables-real-sector

Table 2: Variables for which data was collected for the 2014 and 2016 cropping years, for subdistricts served by USAID WUAs and subdistricts not served by USAID WUAs

		2014						2016					
		Subdistrict served by USAID WUAs			Subdistricts not served by USAID WUAs			Subdistrict served by USAID WUAs			Subdistricts not served by USAID WUAs		
		#	Mean	Std. Dev	#	Mean	Std. Dev	#	Mean	Std. Dev	#	Mean	Std. Dev
DEPENDANT VARIABLES	Cultivated area of cotton (ha)	1000	2.13	3.73	956	1.76	6.21	1000	1.95	3.93	956	1.69	6.81
	Cultivated area of wheat (ha)	1000	0.73	1.32	956	1.20	3.01	1000	0.70	1.18	956	1.09	2.64
	Cultivated area of high-value crops (ha)	1000	1.12	2.25	956	1.32	5.58	1000	1.25	3.04	956	1.65	4.71
	Number of high-value crops (#)	1000	1.76	1.44	956	1.82	1.73	929	1.81	1.45	919	2.38	1.96
	Margalef's index	986	1.62	1.53	931	1.72	1.88	929	1.81	1.58	916	2.25	2.10
	Cropping intensity	981	96.66	31.49	921	97.15	37.94	925	106.70	36.73	900	109.08	42.09
FARM CHARACTERISTICS	Area of the farm (ha)	998	4.31	6.02	952	4.50	10.83	933	4.00	5.82	921	4.48	9.96
	Distance of farm to road (kms.)	982	1.48	2.42	932	1.39	1.92	982	1.48	2.42	932	1.39	1.92
	Age of farm (years since farm allotted) (#)	989	5.90	4.60	910	6.65	5.12	989	7.90	4.60	910	8.65	5.12
SHAREHOLDER CHARACTERISTICS	Number of shareholders (#)	995	6.83	7.95	941	8.04	13.63	933	6.11	9.86	920	7.00	9.68
	Proportion of female shareholders	974	0.46	0.25	908	0.48	0.24	932	0.53	0.24	916	0.52	0.24
	Age of the manager of the farm (#)	933	49.24	12.44	921	49.53	13.18	933	50.24	12.44	921	50.53	13.18
	Education of farm manager(categorical)	933	3.78	1.18	922	3.99	1.27	933	3.78	1.18	922	3.99	1.27
	Female farm manager (dummy)	1000	0.11	0.31	956	0.15	0.36	1000	0.37	0.48	956	0.39	0.49

WATER DELIVERY	Perception of fairness of water sharing (categorical)	656	2.97	0.54	671	2.83	0.62	929	2.86	0.52	919	2.76	0.65
	Perceived timeliness of water distribution improved (dummy)	1000	0.39	0.49	956	0.46	0.50	1000	0.39	0.49	956	0.46	0.50
	Perceived quantity of water received improved(dummy)	1000	0.38	0.49	956	0.47	0.50	1000	0.38	0.49	956	0.47	0.50
	Perceived condition of water course canal (categorical)	985	2.52	0.85	908	2.38	0.86	923	2.60	0.77	899	2.55	0.83
	Perceived condition of distributary canal (categorical)	968	2.49	0.82	908	2.29	0.84	918	2.55	0.78	894	2.41	0.84
AGR EXTENSION SERVICES	Shareholder received training in extension (dummy)	975	0.35	0.48	924	0.22	0.41	933	0.41	0.49	922	0.34	0.48
	Frequency interaction with agriculture/water group (categorical)	985	1.05	1.53	952	0.76	1.28	1000	1.46	1.18	956	0.92	1.14

Table 3: Number of crops, crop diversity and cropping intensity of the farm

	2014		2016		Difference
	Mean	Standard Deviation	Mean	Standard Deviation	(2016 – 2014)
Number of crops cultivated	2.93	1.59	3.37	1.74	7.984***
Margalef's Index of Diversity	1.67	1.71	2.03	1.87	6.239***
Cropping intensity	96.90	0.79	107.87	0.92	9.018***

Notes: Standard errors included in parentheses, next to the coefficients.

***implies p<0.01, ** implies p<0.05, and * implies p<0.1.

Table 4: Determinants of cultivated areas of cotton, wheat and high-value crops

	Area of cotton cultivated (tobit)	Area of wheat cultivated (tobit)	Area of high-value crops cultivated (tobit)
Area of the farm (ha)	0.51 (0.01)***	0.15(0.01)**	0.31 (0.01)***
Distance of farm to road (km)	-0.09 (0.06)*	0.05 (0.03)*	(-0.02 (0.04)
Age of the farm (#)	-0.02 (0.02)	0.03 (0.01)**	0.03 (0.02)**
# shareholders	0.07 (0.01)***	-0.01 (0.01)*	-0.03 (0.01)***
% female shareholders	1.37 (0.3)***	-0.07 (0.19)	-0.59 (0.27)**
Age of manager (#)	-0.01 (0.01)	0.00 (0.00)	0.00 (0.01)
Education of the manager (categorical)	-0.09 (0.09)	-0.02 (0.04)	0.08 (0.06)
Female manager (dummy)	0.04 (0.14)	-0.00 (0.09)	0.49 (0.13)***
Fairness in water distribution (categorical)	0.23 (0.12)*	-0.11 (0.08)	-0.12 (0.12)
Timeliness of water distribution improved (dummy)	0.03 (0.48)	0.28 (0.21)	0.18 (0.30)
Quantity of water received improved(dummy)	0.77 (0.48)	-0.49 (0.21)**	-0.08 (0.30)
Condition of watercourse (categorical)	-0.11 (0.11)	0.07 (0.07)	0.23 (0.10)**
Condition of dist. canal (categorical)	0.11 (0.11)	-0.11 (0.07)	0.10 (0.10)
Shareholder received training in extension (dummy)	0.09 (0.13)	0.02 (0.09)	-0.02 (0.13)
Frequency interaction with agriculture/water group (categorical)	-0.04 (0.05)	0.06 (0.03)	0.14 (0.05)***
Number of observations	2,874	2,874	2,874
Number of farms	1,730	1,730	1,730

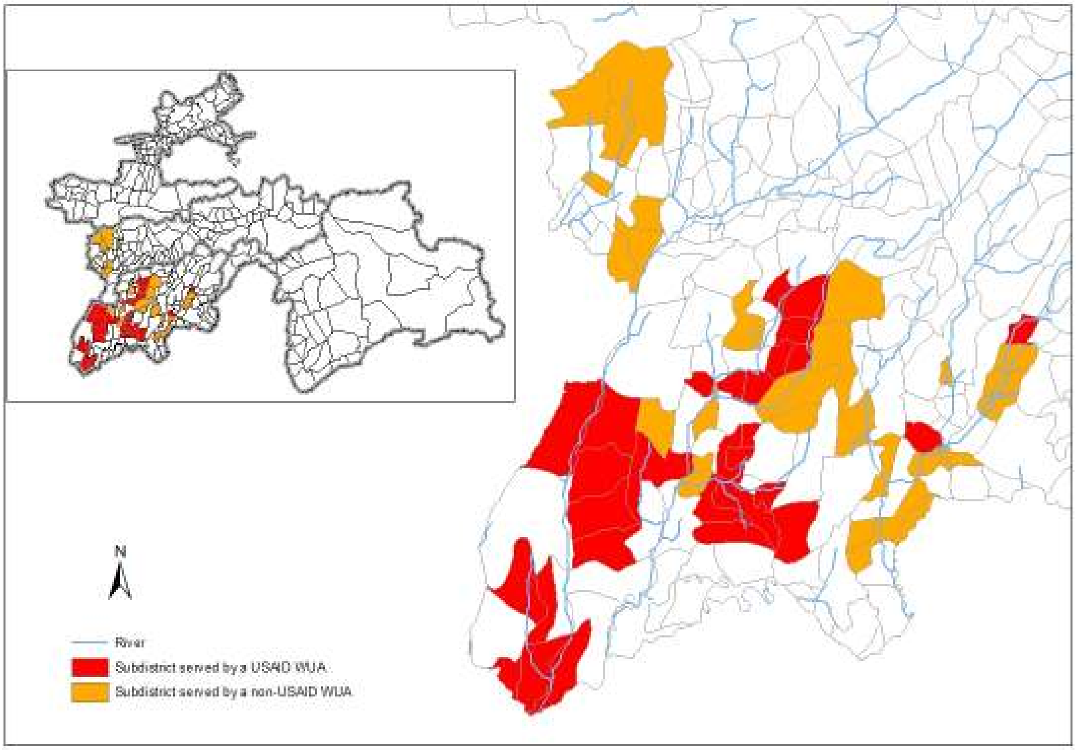
Notes: Robust standard errors are included in parentheses. ***implies $p<0.01$, ** implies $p<0.05$, and * implies $p<0.1$. In addition to the variables included in this table, the following variables were also included: a constant, dummies variables for the type of canal serving the farm (primary, secondary, tertiary); dummy variables for the location of the farm along the canal (head, middle, tail); and dummy variables for the rivers that were the source of water for the canals (Vakhsh, Pyanj, Kafirnigan, Sukhandarya).

Table 5: Determinants of number of crops, crop diversity and cropping intensity

	# of high-value crops cultivated (GLS)	Margalef's index of Crop Diversity (tobit)	Cropping intensity of plots on the farm (GLS)
Area of the farm	0.02 (0.01)**	-0.03 (0.01)***	-0.53 (0.190***
Distance to road	-0.03 (0.02)	-0.05 (0.02)***	0.01 (0.37)
Age of the farm	0.03 (0.01)***	-0.01 (0.01)	-0.17 (0.21)
# shareholders	0.00 (0.01)	-0.00 (0.00)	0.07 (0.08)
% female shareholders	-0.21 (0.14)	-0.29 (0.16)*	0.21 (3.27)
Age of manager	0.00 (0.00)	0.00 (0.000	-0.00 (0.07)
Education of the manager	0.00 (0.03)	-0.00 (0.03)	0.45 (0.65)
Female manager (dummy)	-0.08 (0.07)	0.07 (0.08)	4.12 (2.06)**
Fairness in water distribution (categorical)	0.08 (0.07)	0.04 (0.07)	0.48 (1.68)
Timeliness of water distribution improved (dummy)	0.06 (0.14)	0.12 (0.16)	1.15 (2.84)
Quantity of water received improved (dummy)	-0.04 (0.150	-0.04 (0.16)	-0.23 (2.83)
Condition of watercourse (categorical)	0.16 (0.06)**	0.13 (0.07)**	3.07 (1.38)**
Condition of dist. canal (categorical)	-0.12 (0.06)**	0.00 (0.06)	-1.58 (1.52)
Shareholder received formal training in extension	0.28 (0.09)***	0.29 (0.08)***	1.48 (1.84)
Frequency of interaction with agriculture/water group (categorical)	-0.02 (0.03)	-0.03 (0.03)	0.42 (0.71)
Observations	2,874	2,854	2,823
Number of farms	1,730	1,728	1,717

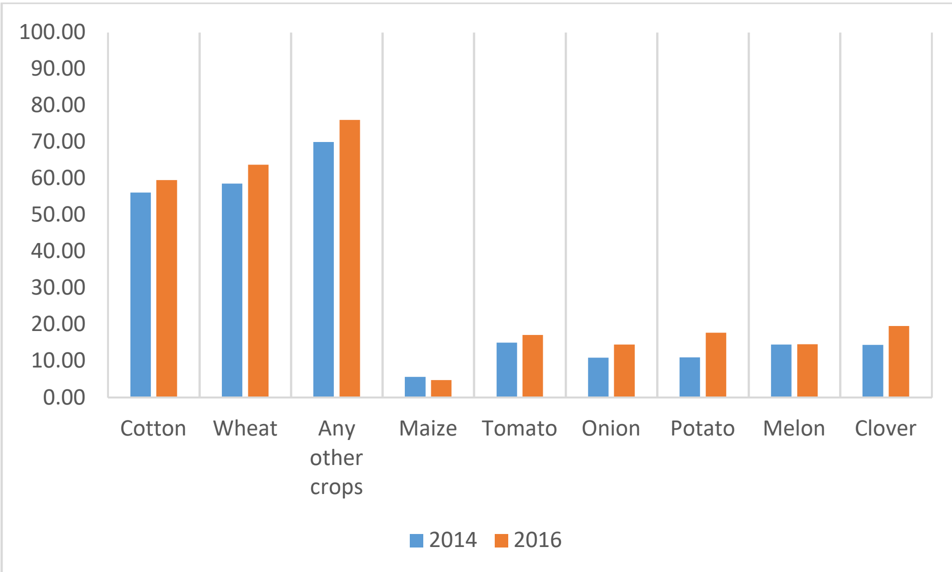
Notes: Robust standard errors are included in parentheses. ***implies p<0.01, ** implies p<0.05, and * implies p<0.1. In addition to the variables included in this table, the following variables were also included: a constant, dummies variables for the type of canal serving the farm (primary, secondary, tertiary); dummy variables for the location of the farm along the canal (head, middle, tail); and dummy variables for the rivers that were the source of water for the canals (Vakhsh, Pyanj, Kafirnigan, Sukhandarya).

Figure 1: Study area



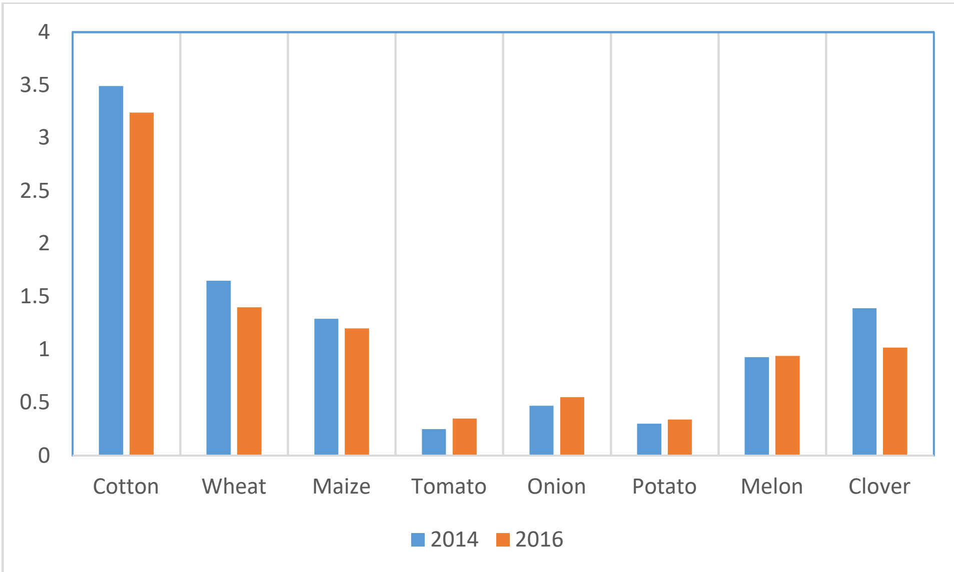
Source: Hydroinformatics Unit, IWMI

Figure 2: Share of farms cultivating different crops



Source: Authors' calculation based on survey data collected

Figure 3: Cultivated area of different crops (ha)



Source: Authors' calculation based on survey data collected