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Impact of Water Users Associations on Water and Land Productivity, Equity and Food Security in Tajikistan

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Balasubramanya, S.; Price, J.; Horbulyk, T. 2018. Impact assessments without true baselines: assessing the relative effects of training on the performance of water user associations in Southern Tajikistan. *Water Economics and Policy* (online first). Available online at: https://doi.org/10.1142/S2382624X18500078

Title: Impact assessments without true baselines: assessing the relative effects of training on the performance of water user associations in Southern Tajikistan

Keywords: water user associations, performance, difference-in-difference, propensity scores, Tajikistan

Abstract: Conducting rigorous evaluations of whether the process of creating new institutions affects their performance of mandated duties presents several challenges. Not only is assignment to process often not random, but when the process of creating new institutions starts, outcomes and other performance-influencing covariates are not measurable because the yet-to-be created institutions are not functioning at baseline. This paper compares the performance of 74 'treated' water user associations in Tajikistan that were created using a longer training process with 67 'control' water user associations that were created using shorter training, to assess the impact of training on WUA performance of mandated duties. First, propensity scores were constructed to estimate the probabilities of being 'treated' by treatment status. These results guided the application of the difference-in-difference technique with right-hand side covariates in a context where field measures of outcomes and other performance-influencing covariates were made after the new institutions were created and functioning. The first measures were taken within 12-18 months of the new institutions being functional and the second measures were taken 24 months after the first. This choice of methods introduces a bias due to measurement error causing an underestimate of the treatment effects, while controlling for biases due to time-invariant and time-varying unobservables. An alternative method that only compared the differences in outcomes at a single point in time after the new institutions were created would have provided an inaccurate estimate of the effects of the intervention. This is a context where methods such as synthetic controls are impossible to employ due to the nature of the intervention, other macroeconomic structural changes, and severe data restrictions. The methodology employed here generates evidence that, while biased towards generating an underestimate of effect, can still be useful and informative for policy and management purposes, and for evaluating the impact of process on the functioning of new institutions in transition settings.

1. Introduction

Institutions for water management are rapidly transforming in Central Asia, as larger political and economic changes take place. Water user associations (WUAs) are now the legally mandated form of organization that provides irrigation services to agricultural land in Tajikistan (Republic of Tajikistan, 2006). Some of these WUAs were created using a longer and more gradual process than others. The

recent literature on institutional reform, which has focused on *process*, rather than *design* (Denyer Willis and Mota Prado, 2014) suggests that WUAs that have been created through a longer process may be more successful in performing their legally mandated functions than those created with a shorter process (Yap-Salinas, 1994 and Mukhtarov *et al.*, 2015).

Quantitative evidence on whether longer training affects performance is important for shaping government programs that are creating new and strengthening existing WUAs (e.g., the ongoing Tajikistan Second Public Employment for Sustainable Agriculture and Water Resource Management Project).[1] However, testing the effects of training on WUA performance in Tajikistan is complicated by the fact that the length of training was not randomly assigned. Observable characteristics of the geographies where WUAs were created; and unobservable characteristics of the same geographies that either are constant or are varying over time may have determined selection into longer and shorter training, consequently confounding the effects of training.

While well-established approaches for constructing an appropriate counterfactual in the absence of randomized assignment to an intervention are available, they require treatment and control units to exist in the pre-intervention period. Two more popular methods consist of synthetic controls (Abadie and Gardeazabal, 2003) and propensity scores (Rosenbaum and Rubin, 1985). Both methods rely on using pre-intervention data (either covariates and outcomes, or covariates alone) to select control units that look similar to the treatment units on observed characteristics. For example, Abadie *et al.* (2010) studied the effects of a tobacco control program in California by constructing a control group comprised of a weighted average of other US states that did not have any tobacco control programs using 19 years of pre-program data on covariates and outcomes. Rubin (2001) used propensity scores to design studies to estimate the causal effects of smoking and tobacco-company misconduct by matching smokers and never-smokers on pre-intervention covariates that were not affected by the intervention.

When treatment and control units do not exist during the pre-intervention period, experimental economics (especially laboratory experiments) could be used to construct counterfactuals; however, these methods are generally used to study strategic behavior in response to exogenous or endogenous policy changes. For example, Tellez Foster *et al.* (2017) conducted laboratory experiments to examine groundwater pumping decisions under alternative energy subsidy scenarios. In their study, all

[1] Project documents may be found at : http://projects.worldbank.org/P133327/tajikistan-second-public-employment-sustainable-agriculture-water-resources-management-project?lang=en.

participants play a status-quo round first, after which 'treatment' participants were randomly assigned to play one of the alternative situations, and 'control' participants were randomly assigned to play another status-quo round.[2] Fischer *et al.*, 2003 constructed 'treatments' to examine altruistic behavior under differential resource growth rates in the presence/absence of intergenerational links in laboratory settings.

This paper examines whether WUAs created via longer training processes perform their legally mandated functions as well as, or better than, those created via training processes with a shorter duration. This occurs in a non-strategic setting and context where WUAs did not exist before training began. The paper considers the population of WUAs in 20 districts of Southern Tajikistan and employs a difference-in-difference (DID) technique with right-hand side covariates. Since WUAs did not exist in the pre-training period, the DID technique is used with *both* sets of data collected in two time periods *after* the WUAs were created. This modified DID approach departs from the standard approach where one set of observations would have been collected at the time when WUAs were created and the other later. Though the modified approach introduces a bias in the estimated effects of training (explained further in methods section), this approach is able to control for time-invariant selection effects. This would not have been possible if the standard approach were used in this context, since all measures of WUA performance at the time of WUA creation would have taken values of zero.[3] Including covariates that affect performance on the right-hand side may help control for unobservable effects that vary over time.

This choice of methods is guided by the context of the intervention in question. Synthetic controls and experimental methods could not be used here due to the non-existence of pre-training data on covariates and outcomes; and due to the non-strategic setting. WUAs created with longer and shorter training components were established in geographies with gravity irrigation schemes of similar characteristics that were not influenced by the treatment;[4] however, they were created in different river basins (see results section). This assignment of WUA program groups across different river basins likely

[2] Tellez Foster *et al.* (2016) also conducted field experiments and compared results between the lab and field settings.
[3] Since WUAs did not exist at the start of the intervention, they were not performing any mandated functions.
[4] These gravity irrigation schemes were constructed before 1991 in the Soviet era. Since the collapse of the Soviet Union, no expansion of gravity schemes has been undertaken. Tax revenues are not sufficient to cover the costs of such an expansion, and any expansions would require loans. Development banks such as the World Bank and the Asian Development Bank have been keen to increase the efficiency of existing surface water schemes before new schemes are constructed, or existing schemes are expanded.

lowered the costs of the WUA creation program for the government (which created WUAs using a shorter training period) and the United States Agency for International Development (which created WUAs using a longer training period); but needs to be controlled for when assessing impacts, in order to address selection effects.

This paper contributes to the literature in three key ways. First, there are many cases in natural resource management where units of treatment are created by a new program or intervention; consequently, units did not exist in the pre-intervention era. Such cases are often not considered as plausible candidates for quantitative assessments due to difficulty in controlling for selection effects and constructing a baseline. Consequently, many assessments of institutional transformations are qualitative (Theesfeld, 2004; Zhou, 2013;Mustafa *et al.*, 2016). Quantitatively assessing performance of new institutions in their early years can yield important evidence that contributes to adaptive management, but also supports construction and testing of theories of change for the future. The modified DID technique with right hand side covariates used in this paper can be used to estimate impacts (albeit with an underestimate of effects) when treatment and control units do not exist before the intervention begins.

A second contribution of the paper is to explore the size and direction of the resulting bias in performance estimates that is associated with the (requisite) delay in collecting the first set of data. Since both treatment and control units did not exist in the pre-training era, most outcomes of interest take values of zero at the start of the intervention. With the modified DID technique, the resulting estimate is biased. However, it is less likely to be confounded by time-invariant selection effects than a simpler estimate that only examines the difference in the performance of the treatment and control groups at one point in time after the intervention is completed.

A third contribution of this paper is the choice of performance indicators it implements. Rather than using standards of performance such as efficiency and equity that may be more suitable while assessing established institutions, the paper uses indicators to reflect the functions that the WUA law (Republic of Tajikistan, 2006) requires WUAs to perform. This approach draws from Nagrah *et al.* (2016) who examine the correlation between farmers performing mandated tasks, and scheme characteristics and management perceptions. An examination of mandated functions in the case of new institutions can yield important information for adaptive management with longer term effects.

The results suggest that WUAs created using longer duration training processes perform mandated functions better than WUAs that were created using shorter training processes. Perhaps the most significant empirical result is that WUAs created using longer training recovered membership fees from 19% more of their members; and they were also 10% more likely to hold board meetings for planning activities before the start of the irrigation season. These results contribute to the literature on institutional design by providing new evidence on the relationship between length of training and performance of mandated functions. From a policy perspective, longer training can increase the functionality of new WUAs that are being created in Tajikistan.

A limitation of this paper is that it is not possible to test formally whether the outcomes for WUAs created with longer and shorter training would have followed the same trend in the pre-training period. WUAs did not exist before the training began, and consequently were not functional. The modified difference-in-difference technique followed in this paper to control for time-invariant unobservables; and the use of covariates that affect performance on the right-hand side to control for time-varying unobservables, is employed in a context where many other standard methods of controlling for selection effects are unsuitable. The empirical methods used here are easy to apply during the early years following creation of new institutions. They provide timely data-driven information on the way institutions are functioning, especially in contexts where it is not possible to separate the intervention from the units of intervention.

The remainder of the paper is organized as follows. Section 2 provides a context for examining WUAs in Tajikistan. Section 3 presents a conceptual framework and reviews literature concerning related aspects of WUA performance globally and in Central Asia. Section 4 describes the methodology, while Section 5 presents the summary statistics and results of the quantitative assessment. Section 6 aggregates the results and discusses them in relation to the existing literature and the broader context of evaluation of water institutions.

2. Context

Land-locked Tajikistan lies in the semi-arid region in Central Asia. Over 70% of its population lives in rural areas (United Nations, 2015), with almost one-third living below the national poverty line (World Bank, 2015). Agriculture—especially cotton cultivation—remains the main source of gross domestic product. Around 95% of crop production takes place on irrigated land (FAO, 2012). Cotton and wheat cultivation is predominant in Southern Tajikistan; in the Soviet era, this was Central Asia's main cotton-producing

hub (FAO, 2012). Tributaries of the Amu Darya River flow into the fertile Khatlon Province in the southwest, home to the majority of the country's population.

The introduction of WUAs in Tajikistan is best considered in the context of distinct periods that characterize the country's history. During the Soviet era, large collective institutions dominated the political and economic scene. An extensive system of irrigation canals was constructed as part of the Soviet economic plan to provide water to collective farms (cooperative and state enterprises; O'Hara, 2000). When the Soviet Union collapsed in 1991, 'Tajikistan did not have chance to become a state before it descended into political violence and civil war' (Matveeva, 2009). The Civil War (1992-1997) undermined public services and infrastructure, especially irrigation services.

After the civil war, collective farms were decollectivized into *dehkan* (private) farms. The district irrigation departments—called the *vodkhozes*—which were responsible for providing irrigation services to the Soviet collectives were not able to cope with the challenge of providing water to the thousands of private farms. A lack of Soviet subsidies and the departure of Russian irrigation specialists compromised clarity on jurisdiction and roles, budgets for maintenance and operations, and the availability of technical skills (Gunchinmaa and Yakubov, 2009; Shahriari, 2009). As one response, the government enacted the *WUA Law* (Republic of Tajikistan, 2006) and named WUAs as the institution that would henceforth be responsible for delivering irrigation services to the *dehkan* farms. International assistance to create these new institutions was also requested. Consequently, WUAs were piloted in the late 2000s by several international organizations, and a countrywide program to create new WUAs gained momentum in 2011-12.

In Southern Tajikistan, WUAs were created in 2012 and 2013.[5] The WUA boards and their members were provided training from international agencies and the national government in water and financial management and in conflict resolution. However, one key difference among these new WUAs is the duration of time over which they were trained when they were created (USAID, 2014; ADB, 2012). Specifically, WUAs created through a longer training process were sponsored by USAID, while those created through a shorter training process were sponsored by other international agencies. On average, USAID WUAs were created with 1.89 years of training, whereas non-USAID WUAs were created with

[5] All WUAs were officially registered by the agency creating them, about one to two years before the community-level process of creating them began. Consequently, the registered age of the WUA may be greater than the number of years of its physical existence.

0.73 years of training (Balasubramanya *et al.*, 2016: 44).[6] The content of the training provided to both groups of WUAs was similar, in part because USAID-designed WUA training materials were used by the government as well.

3. Conceptual framework

3.1. Review of performance assessment literature

Irrigation systems provide a prime example of common pool resources (CPRs). The constituent users of irrigation systems—water and infrastructure—have the defining characteristics of being difficult to exclude, and are subject to competition among themselves when seeking to access the subtractable resources (Hamidov *et al.*, 2015). Rivalry among water users may be due to inadequate water supply, issues of water distribution or timing of water delivery. Given the distinct features of CPRs, scholars have theorized about which forms of institutional design are most likely to enable community-level institutions to perform their legally mandated functions successfully (Kazbekov *et al.*, 2009).

In her seminal work, Ostrom (1990) offers a blueprint of eight core design principles that would enable CPR institutions to exist independently among local users, without being privatized or managed by central government. While acknowledging this body of literature (including Meinzen-Dick *et al.*, 2002), assessing the extent to which different groups of WUAs fit Ostrom's CPR institutional design principles would be beyond the scope of this paper.[7] Such analysis would likely require techniques such as ethnographic observation, which involve considerable time. New WUAs may have to be closely observed over several years to gauge if the core design principles are correlated with successful performance.

New institutions for resource management in quasi-democratic and liberalizing political economies often faces a number of challenges (Skaperdas, 2001). New bodies may not be perceived as legitimate, and low social capital may hamper cooperation and trust (Sehring, 2007; Hamidov *et al.*, 2015). For example, in Tajikistan, government officials have underlined the difficulty in introducing monetary mechanisms, such as water-related fees, because of a so-called 'Soviet mentality' that expects and may

[6] Before WUAs were created, irrigation water for farms was supplied by the state irrigation departments; the latter cannot serve as an appropriate control group to examine WUA performance of mandated duties because the role of supplying irrigation water to the new *dehkan* farms has been changed and legally handed over to WUAs. There are more than 300 WUAs across Tajikistan.

[7] In Tajikistan, all WUAs may align with a number of Ostrom's design principles. For example, user participation in decision-making, monitoring by elected members and accessible conflict resolution mechanisms are key design features of WUAs, especially those created by USAID (USAID, 2014).

encourage non-payment for services including water (Sehring, 2007; Matveeva, 2009). New bodies such as WUAs may find it difficult to perform their legally mandated functions.

Barcellini *et al.* (2015) stress that the duration of the process for creating participatory institutions warrants investigation because it can influence performance of mandated functions by young institutions. This focus on process partially stems from the idea that rapidly applying a universal 'blueprint' design may not fully appreciate the important contextual nuances of community water management (Smith, 2008; Mukhtarov *et al.*, 2015; Thiel *et al.*, 2015; Ricks, 2016). Longer training periods may foster productive relationships and improved functioning, leading to stronger collective action and more serviceable institutions (Nagrah *et al.*, 2016). Empirical studies have also demonstrated the importance of training on WUA performance. Batt and Merkley (2010) attributed the shortcomings of WUA performance in Egypt to inadequate training. This echoes Mukhtarov *et al.*'s 2015 case studies in Turkey and Azerbaijan, where WUAs were deemed unsuccessful in performing their functions due to inadequate preparation for taking over irrigation management responsibilities. In Uzbekistan, Wegerich (2000) and Hornidge *et al.* (2013) reviewed the limited or unclear duration of training provided, which they correlated to unreliable water delivery and poor WUA performance. By contrast, Yap-Salinas (1994: 126) concluded that 'the longer the project, the greater the chance of success,' after an eight-year WUA project in the Dominican Republic. Also, Johnson and Stoutjesdijk (2008) drew attention to WUAs in Kyrgyzstan, which after receiving training over four years were able to improve performance of mandated functions, improving water delivery and fee collection.

3.2. Hypotheses

Short-term analysis of the performance of community based irrigation management organizations is usually assessed by considering mandated functions (Yakubov, 2011). For example, collection of irrigation and/or membership fees and dispute arbitration functions of WUAs have been examined in Jordan, China and Turkey (see Çakmak *et al.*, 2004; Huang *et al.*, 2010;Mustafa *et al.*, 2016). Nagrah *et al.* (2016) consider performance indicators such as maintenance of irrigation watercourses, dispute resolution, collection of water charges and success of monthly meetings when explaining functioning of water user groups in Pakistan.

Building upon this literature, this paper considers the following indicators, and introduces a number of hypotheses regarding the effects of longer training. A list of indicators is provided in Table 1.

a. Water delivery planning: WUAs in Southern Tajikistan are supposed to create water delivery schedules, preferably by irrigation season. The WUAs are also supposed to hold at least two board meetings every calendar year, where delivery schedules are finalized and other important decisions such as setting of membership fees and other water deliver-related challenges are discussed. WUAs with longer training are hypothesized to have a greater probability of having seasonal water delivery schedules and of holding two annual board meetings than those with shorter training.
b. Repair and maintenance of irrigation infrastructure: WUAs are supposed to conduct routine cleaning and maintenance of secondary canals (distributaries) and tertiary canals (watercourses) at the start of each irrigation season (there are two cultivation seasons every calendar year). It is expected that WUAs with longer training are more likely to conduct two pre-irrigation season rounds of maintenance annually.
c. Collecting irrigation service fees and transferring them to the government: The WUA is mandated to collect irrigation service fees from all members seasonally; and transfer all irrigation fees to the government. Longer training is likely to increase the share of members from whom irrigation fees are recovered, and the share of collected irrigation fees that is transferred.
d. Collecting WUA membership fees: WUAs are authorized to collect annual membership fees from all members to finance day-to-day operations. Longer training is likely to increase the share of members from whom the WUA recovers membership fees.
e. Arbitrating disputes: WUAs are authorized to arbitrate disputes between members, and it is expected that WUAs with longer training have a higher probability of being the body that settles disputes.

4. Methodology

The difference-in-difference (DID) technique calculates the effect of an intervention by comparing the average change over time in the outcome variable for the treatment group, to the average change over time for the control group, in effect controlling for differences in the starting points and common time-trend effects in one or more measure of outcome between the two groups.

4.1. The DID estimator treatment and control units exist in the pre-intervention period

Consider the (standard) case where outcomes are measured at the start of the intervention. To describe the estimator mathematically, standard notation that uses two time-periods (where time is regarded as a discrete variable) is used.

Let the policy maker be interested in understanding the effects of the intervention two years after it was implemented (short-term effects).[8] Let t refer to the number of years since the intervention, where $t \in \{0, 2\}$. Let T_t be a categorical variable that denotes the two years, with $T_2 = 1$ if $t = 2$ and $T_0 = 0$ if $t = 0$.

Let d refer to treatment state, where $d \in \{0,1\}$, where '0' indicates the non-treated/control state, and '1' indicates the treated state. In this paper, the treatment is the longer duration of training for some WUAs. Let D_i be a categorical variable that denotes the treatment status of WUA$_i$, with $D_i = 1$ if $d = 1$ and $D_i = 0$ if $d = 0$.

Let i denote a specific WUA, where: $i \in \{1, 2, 3, \dots, k\}$ when $D_i = 1$; and $i \in \{k+1, k+2, \dots, k+m\}$ when $D_i = 0$; that is, there are k treatment WUAs and m control WUAs.

Consider the following equation: $Y_{it} = \mu + \gamma D_i + \theta T_t + \beta(D_i * T_t) + \vartheta_{it}$ (1) [9]

where Y_{it} refers to a specific outcome variable for WUA i at time t; and β reports the causal effect of the treatment, which controls for pre-existing differences in outcomes at the baseline.[10] Following the standard approach (Woolridge, 2002) to describe the difference-in-difference estimator $\hat{\beta}$:

$$\hat{\beta} = \{E(Y|D = 1, T = 1) - E(Y|D = 0, T = 1)\} - \{E(Y|D = 1, T = 0) - E(Y|D = 0, T = 0)\}. \quad (2)$$

Therefore: $\hat{\beta} = \left(\frac{1}{k}\sum_{i=1}^{k} Y_{i2} - \frac{1}{m}\sum_{i=k+1}^{k+m} Y_{i2}\right) - \left(\frac{1}{k}\sum_{i=1}^{k} Y_{i0} - \frac{1}{m}\sum_{i=k+1}^{k+m} Y_{i0}\right)$. (3)

Alternatively:

[8] In development practice, short-term effects are generally studied two years after the intervention was completed. This is a commonly observed norm, and is not necessarily supported by any theoretical model.

[9] The error structure is assumed to follow: $E(\vartheta_{it}|\, D = 1, T = 1) = E(\vartheta_{it}\,|D = 0, T = 1) = E(\vartheta_{it}\,|D = 1, T = 0) = E(\vartheta_{it}\,|D = 0, T = 0) = 0$. This is because the identifying assumption is that, by explicitly accounting for , the errors are uncorrelated with D and T .

[10] The difference-in-difference technique eliminates μ and γ because it involves using the difference$(Y_{i2} - Y_{i0})\ \forall\ i$. The coefficient θ controls for any year-related effects.

$$\hat{\beta} = \frac{1}{k}\left(\sum_{i=1}^{k} Y_{i2} - \sum_{i=1}^{k} Y_{i0}\right) - \frac{1}{m}\left(\sum_{i=k+1}^{k+m} Y_{i2} - \sum_{i=k+1}^{k+m} Y_{i0}\right). \quad (4)$$

The DID technique controls for time-invariant unobservables (μ), such as any WUA-specific, area-specific, or agency-specific fixed effects that are constant over time but may drive differences in level of performance.

4.2. The DID estimator when treatment and control units did not exist in the pre-intervention period

To demonstrate the DID technique when outcomes for treatment and control groups take values of zero at the start of the intervention, time is now defined as a continuous variable t_r, where $t_r \in (0, \infty)$.

Let $A(t)$ represents outcomes for the treatment unit, which vary with time, t. Let $C(t)$ represent outcomes for the control unit, which also vary with time. Due to the nature of the outcome, both $A(t) \geq 0$ and $C(t) \geq 0$.

Let the difference in magnitude of outcomes between the treatment and control units at any time t_r be defined as $\delta_r = A(t_r) - C(t_r)\ \forall\ t_r \in (0, \infty)$.

Let the intervention be implemented at t_0 for the treatment unit. Since treatment and control units did not exist at the start of the intervention, $A(t_0) = C(t_0) = 0$. Therefore, $A(t_0) - C(t_0) = \delta_0 = 0$. (5)

Let the policy maker be interested in measuring subsequent performance at time t_e, where $t_0 < t_e$. For the purposes of a clearer demonstration, one unit of observation from the treatment group and one unit of observation from the control group are considered.

(a) First, consider the case where the treatment unit performs better than the control unit after t_0; presented in Figure 1.

The standard DID estimator would measure changes in outcomes for the treatment and control group between t_e and t_0. That is: $DID = (A(t_e) - C(t_e)) - \big(A(t_0) - C(t_0)\big) = \delta_e - 0 = \delta_e$. (6)

Since treatment and control units did not exist before t_0, and $A(t) \geq 0$, $C(t) \geq 0$, and $A(t_0) = C(t_0) = 0$, it is not clear if the standard DID technique would eliminate the time-invariant unobservables represented by μ in equation (1).

Suppose now that the first measures of outcomes are made at $t_1 > t_0$. In this case the 'modified' DID estimator is: $DID' = \big(A(t_e) - C(t_e)\big) - \big(A(t_1) - C(t_1)\big) = \delta_e - \delta_1$. (7)

Then $DID - DID' = \delta_e - (\delta_e - \delta_1) = \delta_1 > 0$. (8)

This implies that $DID > DID'$; that is, the modified DID underestimates a positive effect of the intervention.

Generalizing, let the first measurement of outcomes be made at t_n such that $t_0 < t_n < t_e$. Then, $\delta_n = A(t_n) - C(t_n)$. Then, the 'modified' estimator is

$DID^n = \big(A(t_e) - C(t_e)\big) - \big(A(t_n) - C(t_n)\big) = \delta_e - \delta_n$. (9)

Let the error $\varepsilon(t) = DID - DID^n = \delta_e - (\delta_e - \delta_n) = \delta_n > 0$. (10)

Since $A(t)$ and $C(t)$ are diverging, this implies that $DID > DID^n$. (11)

As $t_n \rightarrow t_0$, $\delta_n \rightarrow 0$. Therefore $\varepsilon(t) \rightarrow 0$ as $t_n \rightarrow t_0$.

In this case, if one wishes to assess the effects of the intervention at t_e with baseline outcomes measured after t_0, then measuring farther from t_0 would further underestimate the actual effect of the intervention.

(b) Now, consider the case where the control unit performs better than the treatment unit after t_0; presented in Figure 2.

The standard DID estimator is $DID = (A(t_e) - C(t_e)\,) - \big(A(t_0) - C(t_0)\big) = -\delta_e - 0 = -\delta_e$. (12)

As in case (a), since treatment and control units did not exist before t_0; $A(t) \geq 0$, $C(t) \geq 0$, and $A(t_0) = C(t_0) = 0$. Therefore, it is not clear if the standard DID technique would control for time-invariant unobservables that may be driving performance of the two groups.

Consider the 'modified' DID estimator: $DID' = \big(A(t_e) - C(t_e)\big) - \big(A(t_1) - C(t_1)\big) = -\delta_e - (-\delta_1) = -\delta_e + \delta_1$. (13)

Similar to case (a), and demonstrated in equation (8): $DID - DID' = -\delta_e - (-\delta_e + \delta_1) = -\delta_1 < 0$.

In this case, $DID < DID'$; that is the modified DID underestimates the magnitude of a negative effect of the intervention.

Generalizing, let the first measure of outcomes be made at t_n such that $t_0 < t_n < t_e$. Then, $\delta_n = A(t_n) - C(t_n)$.

$$DID^n = \big(A(t_e) - C(t_e)\big) - \big(A(t_n) - C(t_n)\big) = -\delta_e - (-\delta_n) = -\delta_e + \delta_n. \quad (14)$$

Similar to case (a) and as demonstrated in equation (10), $\varepsilon(t) = DID - DID^n = -\delta_n < 0$.

Since $A(t)$ and $C(t)$ are diverging, this implies that $DID < DID^n$. (15)

As $t_n \rightarrow t_0$, $\delta_n \rightarrow 0$. Therefore $\varepsilon(t) \rightarrow 0$ as $t_n \rightarrow t_0$, similar to the result found in case (a).

In this case, if one wishes to assess the effects of the intervention at t_e with baseline outcomes measured after t_0, measuring farther from t_0 would also underestimate more greatly the magnitude of the actual effect of the intervention.

(c) Adding across case (a) and (b)

The net effect of the intervention will be biased under the modified DID technique, with the direction of bias unknown, since the modified DID approach underestimates both positive and negative effects. In this context, if some WUAs experience a positive effect of longer training duration and others experience a negative effect, then summing across WUAs provides biased aggregate measure of program effect, where the direction of bias is not known. However, as $t_n \rightarrow t_0$, $\varepsilon(t) \rightarrow 0$. Therefore, measuring as close as possible to t_0 would minimize the bias, and would address time-invariant selection effects.

5. Data

There are four river systems within Tajikistan—Vakhsh, Kafarnihon, Pyandj (which are tributaries of the Amu Darya Basin) and the Syr Darya. Irrigated agriculture is practiced on only 4% of Tajikistan's land.[11] To design a study that was representative of WUA populations in gravity irrigation schemes, ten such schemes that supply water to 164 *jamoats*[12] in 20 districts were identified.[13] A census of WUAs was conducted in late 2014 in these 164 jamoats, and 150 legally registered and functioning WUAs were identified. The chairs or managers[14] from 141 of the 150 WUAs agreed to participate in the study. Of these, 74 WUAs were created with a training period of 22-24 months; and 67 WUAs that were created with a shorter training period of three months.

The chair/manager was requested to donate around 1.5 hours of their time twice to provide the survey team with data. The first round of data described the 2014 calendar year and was collected in early 2015. The second round of data described the 2016 calendar year and was collected in early 2017. Respondents were not compensated monetarily for their participation. Instead, manuals on better agronomic practices, such as the use of improved seeds and application of fertilizers, were provided to be shared with the larger community.

Questions in the 2014 survey were repeated in the 2016 survey; the difference being the year about which the respondent was asked to report. The performance indicators for which data were collected reflect the various functions that WUAs in Tajikistan are mandated to perform by the *Water User Association Law* (Republic of Tajikistan, 2006; Table 1).

In addition to these performance indicators, data on covariates that might affect performance of mandated functions were also collected for the 2014 and 2016 calendar years. Data collected included: the physical attributes of the WUA such as the type and magnitude of irrigation infrastructure; the area covered by gravity and lift irrigation infrastructure;[15] the service area under irrigation; the area of cotton, wheat and fodder cultivated; the number of members in the WUA; the size of the WUA board

[11] About 96% of the land area is covered by mountains, where irrigated agriculture is not practiced.
[12] A jamoat is an administrative area within a district (in other countries, the equivalent of a jamoat would be a sub-district). A collection of jamoats makes a district, and a collection of districts make a province. Tajikistan is divided into four provinces, and 400 jamoats.
[13] Considerable shares of area in other agricultural jamoats were irrigated by lift irrigation schemes, the operational costs of which are much higher than gravity schemes. This study covers almost every WUA in a gravity scheme that was legally registered and functioning in 2014.
[14] If these individuals were not available, then the WUA engineer or treasurer was asked to respond.
[15] Very small areas in only a couple WUAs were irrigated by lift irrigation. This was as expected because the study was designed to focus on gravity irrigation schemes.

and its gender composition; the number of disputes; and perceptions about the quality of the main, secondary (distributary) and tertiary (watercourse) canals. Measures of covariates pertaining to type and magnitude of irrigation infrastructure, and the area covered by gravity and lift irrigation infrastructure remained constant between the two surveys.[16] Measures of other covariates generally varied between the two surveys.

6. Results

Since assignment of WUAs to shorter versus longer training periods was not random, propensity scores were constructed by regressing each WUA's training status (1= longer training; 0=shorter training) on a set of covariates. These included: location of the WUA (head/middle/tail) on the canal; the number of main, secondary and tertiary canals within the WUA's command area; the share of the command area covered by gravity and lift irrigation infrastructure; the number of pumping stations within the command area; the number of drainage collectors within the command area; the number of irrigation wells within the command area; the number of years the WUA has been registered (but may not have existed on the ground); the district the WUA was located in; and the river that was the source of water for the irrigation system. These covariates were chosen because they are unlikely to have been influenced by the WUA program. Irrigation infrastructure was developed in the Soviet era, and has not expanded since 1990. This is reflected in the fact that in 1994, 720,000 hectares of land were irrigated, which marginally increased to 742,000 hectares in 2009 (FAO, 2012).[17]

Figure 3 presents results for the frequency distribution of the propensity scores associated with longer and shorter training, which were constructed using all covariates, except the district and the river. WUAs with longer and shorter training had overlapping distributions (indicating common statistical support). This implies that both groups of WUAs looked similar in terms of: location (head/middle/tail) on the canal; the number of main, secondary and tertiary canals within the command area; the share of the command area covered by gravity and lift irrigation infrastructure;[18] the number of pumping stations, drainage collectors and irrigation wells within the command area; and the number of years the WUA had been registered (but may not have existed on the ground). Propensity scores were then constructed

[16] No new irrigation infrastructure was developed nor was existing infrastructure expanded between the two surveys.
[17] The latest year for which official data are available is 2009.
[18] There is almost no use of groundwater, because aquifers are located in deep, hard rock layers, which increases pumping costs.

by including all of those attributes plus dummies for the districts in which the WUA was located (Figure 4). The extent of overlap between the frequency distributions is still considerable, but less than in Figure 3. Finally, when propensity scores were constructed by also including dummies for the river that was the source of water (Figure 5), the two frequency distributions had limited common support. Figures 3-5 suggest that while WUAs with longer and shorter training are not different in terms of their physical characteristics, they differ in terms of the river basins in which they were created. Since WUAs with longer and shorter training were created by USAID and the government respectively, program costs would have been lower with both agencies concentrating their efforts on specific river basins rather than each agency covering every river basin.

The following sections report the results from the modified DID technique with right-side covariates, listed in Table 2. There were minor changes between years in the share of irrigated area; the share of irrigated area under wheat, cotton and fodder production; and perceptions on the quality of the primary, secondary and tertiary canal. Covariates such as the number of registered members in the WUA, the size of the WUA board, and the number of disputes varied considerably between 2014 and 2016. Covariates such as the physical infrastructure, the share of command area served by gravity and lift irrigation, the district the WUA is located in, and the river that is the source of water did not vary between the two years. Only covariates whose measures varied between 2014 and 2016 are reported, because those whose measures did not vary between 2014 and 2016 (such as the physical infrastructure, river and district) are eliminated by the DID technique.

Tables 3 through 7 report the effects of having longer training duration on WUAs' performance of mandated duties, while including covariates (Table 2) that may also affect performance. In each table, the reported values express the modified DID estimate as a percentage difference, followed in parentheses by the standard error.

6.1. Water delivery

WUAS with longer training were 4% more likely to have a seasonal water delivery schedule in 2016, and were 9% more likely to have at least two board meetings in 2016, but these results are not statistically significant at the usual levels (Table 3). A 1% increase in area under cotton cultivation between 2014 and 2016 was associated with a 28% increase in the probability of having a seasonal water delivery schedule in 2016 ($p < 0.05$). This is consistent with the observation that cotton is a water-intensive crop that is cultivated in the dry season (summer). Also, a 1% increase in the area under wheat production between

2014 and 2016 was associated with a 27% decrease in the probability of having a seasonal irrigation schedule in 2016 ($p < 0.1$). This is consistent with the observation that wheat is a winter crop, which is mostly rainfed, with minimal supplemental irrigation. One additional member on the board between 2014 and 2016 increased the probability of having a seasonal water delivery schedule by 1% in 2016 ($p < 0.05$).

6.2. Routine cleaning and maintenance of irrigation infrastructure

WUAs with longer training were 6% more likely to conduct pre-irrigation seasonal maintenance of secondary canals in 2016, and 3% more likely to conduct the same for tertiary canals, but these results are not significantly different from zero at the usual levels (Table 4). A 1% increase in the area under fodder cultivation between the two years reduced the probability of conducting pre-irrigation seasonal maintenance of tertiary canals by 21% in 2016 ($p < 0.1$), consistent with the observation that fodder cultivation in Tajikistan is mostly rainfed.

6.3. Irrigation fee collection and transfers

WUAs with longer training had 9% more members paying their irrigation fees in 2016 than in 2014, as compared to WUAs with shorter training, although these results are not significant at the standard levels (Table 5). However, longer training has no effect on the change in the share of irrigation fees transferred to the government. WUAs with longer training also experienced an increase in indebtedness between 2014 and 2016 of TJS 27,691 (~$ 3,146),[19] which effect was not statistically significant from zero at the usual levels. A 1% increase in the cultivated area of wheat was associated with a reduction of debt of the magnitude of TJS 25,952 (~$ 3,377) reflecting the fact that wheat cultivation requires considerably less water. A 1% increase in area under fodder cultivation resulted in 53% increase in the share of members paying their irrigation fees ($p< 0.05$) consistent with the fact that since fodder cultivation is mostly rainfed, low (zero) water use results in low (zero) irrigation charges, which more farmers could afford to pay.

6.4. WUA membership fees collection

[19] All numbers adjusted for inflation, and converted at the exchange rate of 1 Tajikistan Somoni (TJS) ≈ 0.13 US$ in 2016-17.

WUAs with longer training were able to increase the share of members from whom they recovered membership fees by 19% between 2014 and 2016 ($p<0.01$; Table 6). In addition, a 1% increase in irrigated area between 2014 and 2016 was associated with a 37% increase in the share of members from whom the WUA was able to recover fees during the same period ($p<0.1$). Adding an additional WUA member reduced the share of members from whom the WUA would be able to recover fees ($p<0.01$), reflecting that having more members makes monitoring more difficult; however, the magnitude of this coefficient is very small (0.01%).

6.5. Dispute arbitration

WUAs with longer training were 6% less likely to be the arbitrator of disputes between 2014 and 2016 (Table 7); however this result is not significant ($p=0.46$). A 1% increase in the area under cotton cultivation increased the probability of the WUA arbitrating disputes from 2014 to 2016 by 28% ($p <0.1$), consistent with the higher demands on irrigation associated with cotton cultivation.

7. Discussion

Experimental methods such as randomized controlled trials in the field and laboratory experiments have the ability to control for selection effects and to provide unbiased estimates of effects of interventions, but have limitations related to the generalizability of results under different circumstances. When an appropriate control group is difficult to identify due to the scale of the intervention, synthetic controls can be used to construct a counterfactual, but they require the treatment unit and the potential control units to exist and be functioning for a considerable duration before the intervention commenced.

Assessment of the impact of large-scale development programs, such as those that create new institutions for community based resource management, is challenging for two reasons. First, the intervention often creates the units of interventions themselves. This means the units of intervention did not exist—and consequently their covariates or outcomes were not measurable—before the intervention, thus ruling out the application of methods such as synthetic controls. Second, assignment to treatment is not random, and because all covariates and outcomes took values of zero at the baseline, a standard difference-in-difference approach may not eliminate time-invariant unobservables.

In this paper, the difference-in-difference technique is employed in a context where measurements of outcomes and covariates were made in two time periods after the intervention was implemented,

because, at baseline, both took values of zero. This modified difference-in-difference technique with right hand size variables eliminates bias due to time-invariant unobservables, and controls the effect of time-varying unobservables, but introduces a measurement error. Despite this bias, the estimates provide empirical evidence on how the intervention influences the performance of new institutions in their early days, which could be highly valued for adaptive management. An alternative available estimate—the measured difference between outcomes in the later period—is likely to be less informative because it cannot control for selection effects that influence outcomes in each group.

A note of caution is warranted when using the modified difference-in-difference technique when the treatment and control units do not exist before the intervention. In this paper, the outcomes being examined—service delivery and financial functions—are typically slow to change, especially when institutions are new. In cases where the outcomes respond more rapidly to an intervention, the measurement bias may outweigh the reduction in bias achieved through the elimination of time-invariant unobservables. Practitioners using the modified DID technique would be advised to consider the nature of the outcomes under consideration.

In this paper, the results demonstrate that longer training enabled WUAs in Southern Tajikistan to perform their mandated functions better between 2014 and 2016. This was particularly the case for recovering membership fees from *dehkan* farm members, where WUAs with longer training increased their membership fee recovery by 19% in the two-year period. The existing literature on common-pool resources and institutional reform suggests that the length of the training process may be an important factor in determining institutional performance. The results in this paper add support to that claim, providing some evidence that additional training may allow WUAs to perform functions better. Follow-up measurement in subsequent years may present a more complete picture of the differences in this effect.

In countries such as Tajikistan where political and economic transitions are giving rise to new institutions, understanding performance in the short term can provide timely evidence for adaptive management. In this case, the results suggest that the government should focus on longer training if it expands its WUA program. Equally usefully, data-based comparisons such as those reported here, can indicate conditions where there are no radical differences in response to the program intervention that might necessitate immediate action. Where some analysts may be reluctant to conduct empirical analysis in the absence of well-established treatment and control groups, such as with the formation of

WUAs, quantitative methods of assessment can be applied in less-than-ideal conditions to generate evidence that can prove useful for policy purposes.

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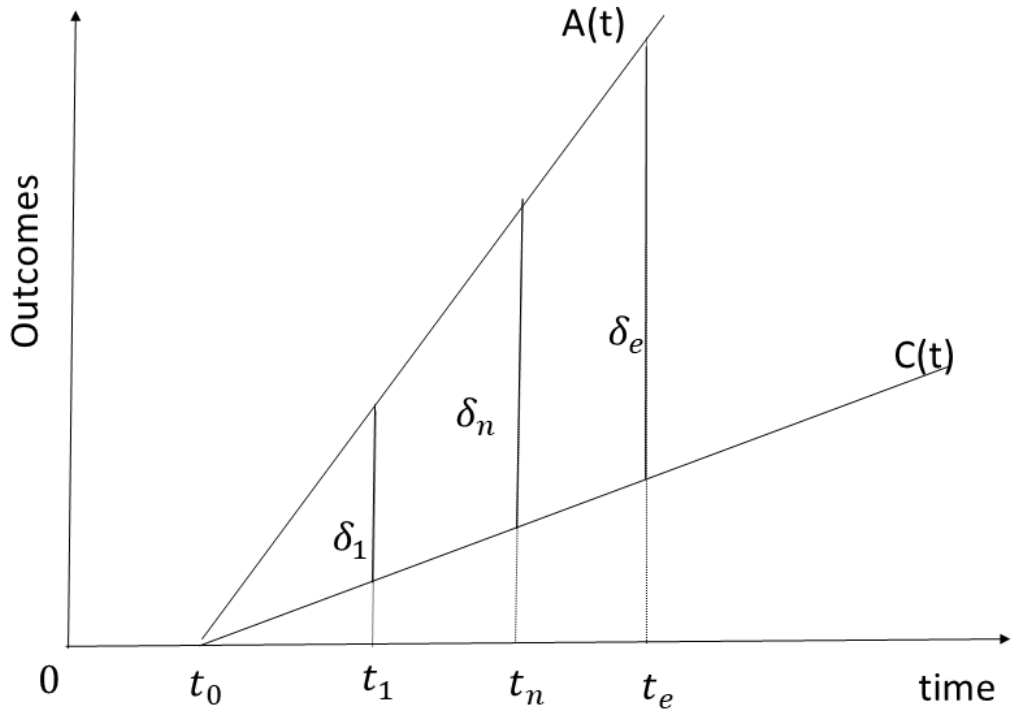

Figure 1: The standard and modified DID technique when the treatment unit performs better than the control unit

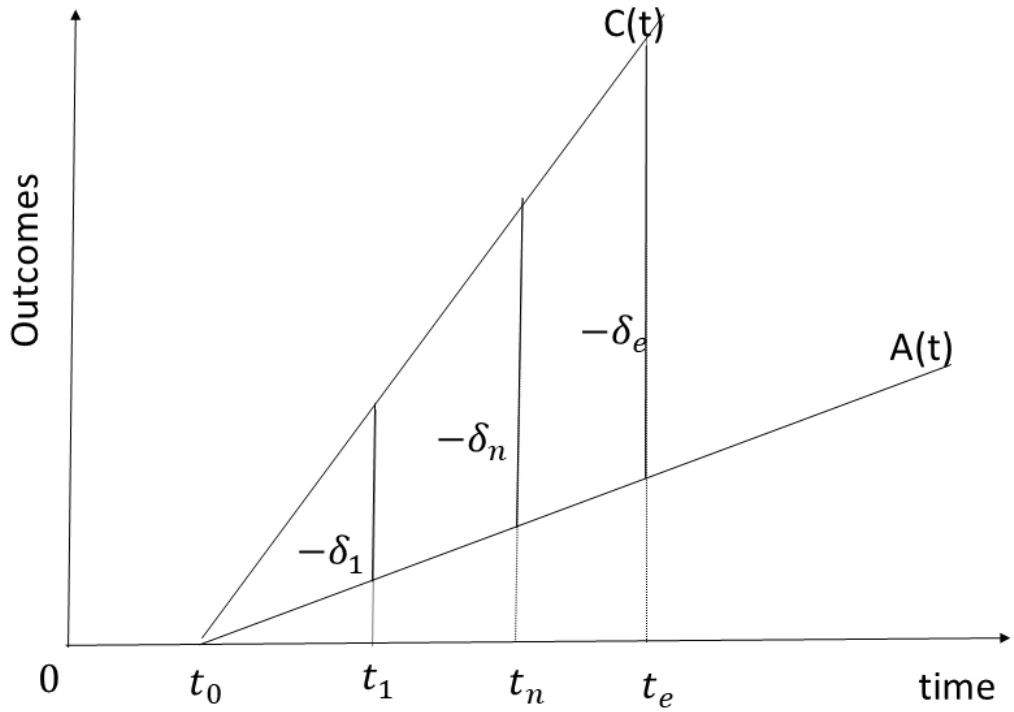

Figure 2: The standard and modified DID technique when the control unit performs better than the treatment unit

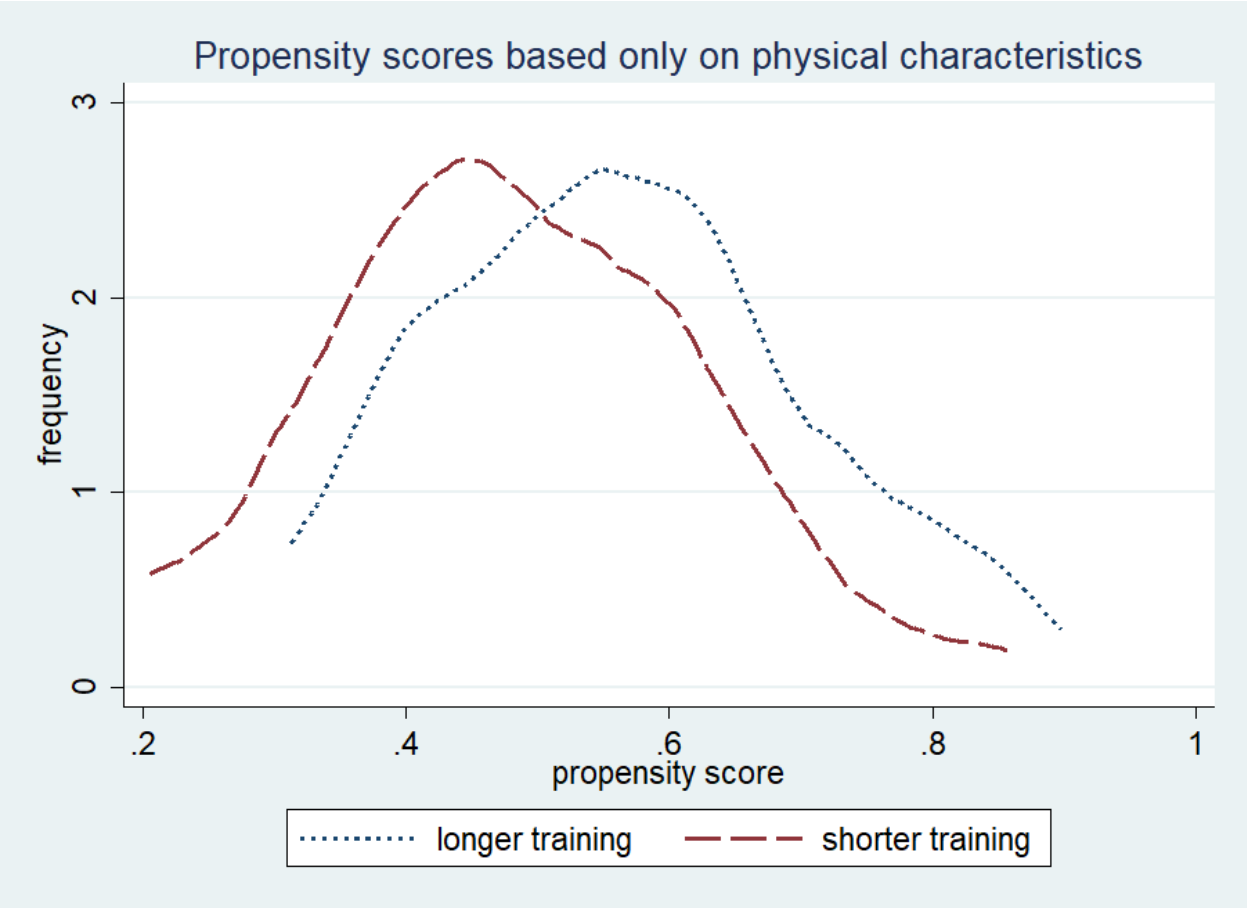

Figure 3: Propensity scores using time-invariant physical characteristics (excluding district and river)

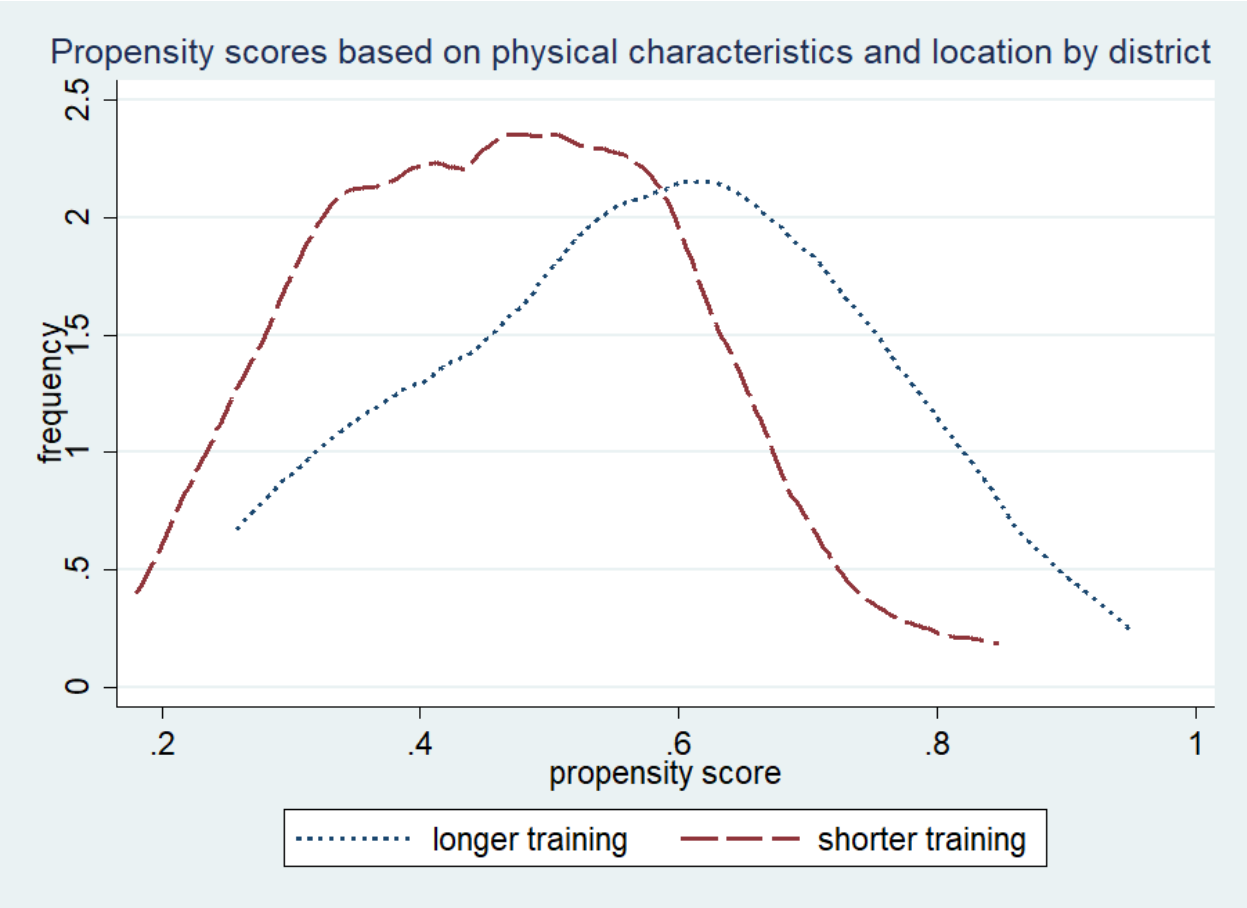

Figure 4: Propensity scores using time-invariant physical characteristics (including district)

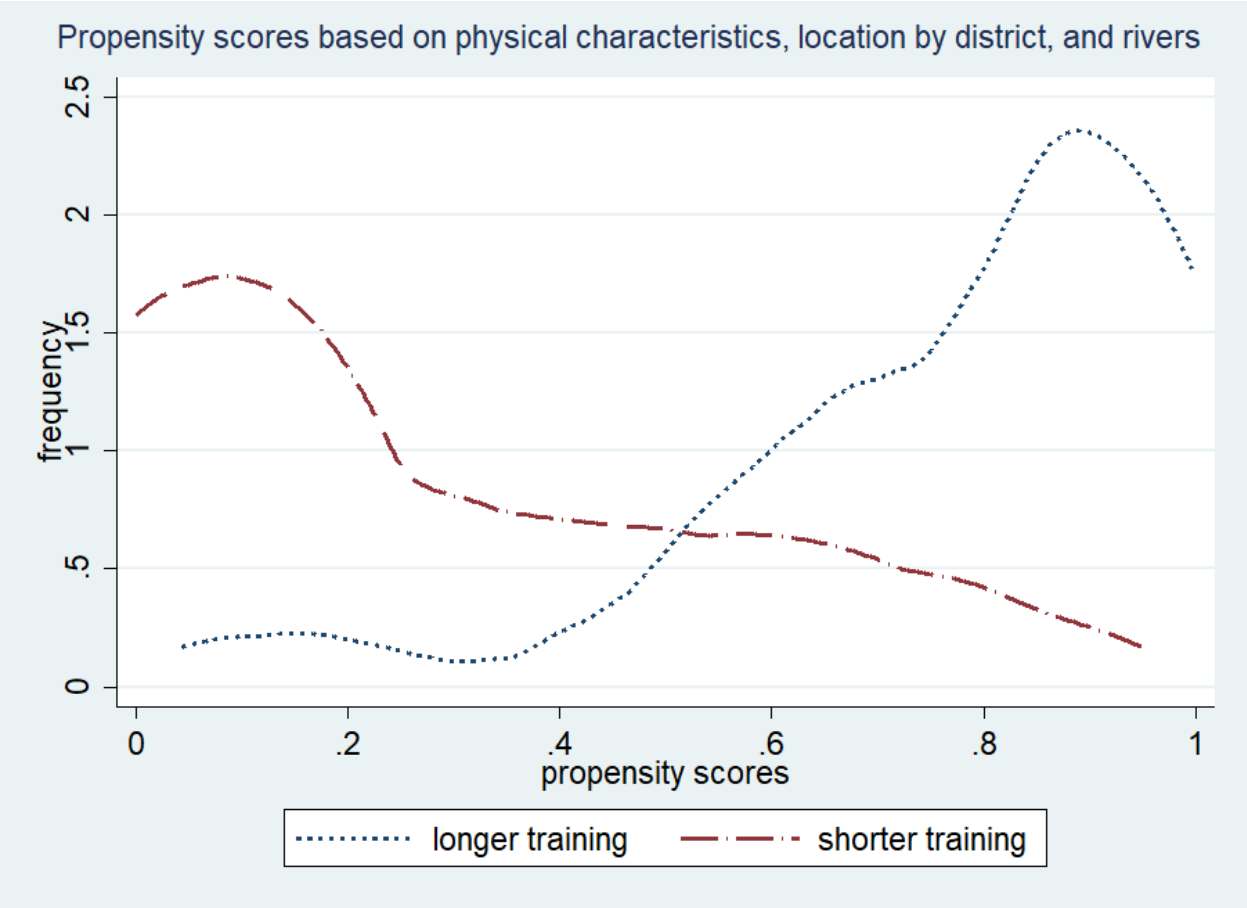

Figure 5: Propensity scores using time-invariant physical characteristics (including district and river)

Table 1: WUA performance indicators

Water delivery
WUAs had a delivery schedule
WUAs had at least two board meetings per year
Routine cleaning and maintenance of irrigation infrastructure
WUAs conducted two pre-irrigation maintenance sessions for secondary canals per year
WUAs conducted two pre-irrigation maintenance sessions for tertiary canals per year
Collect irrigation fees and transfer to government
Share of members paying irrigation service fees
Share of collected irrigation fees transferred to the government
Collect WUA membership fees
Share of members paying membership fees
WUA arbitrates disputes
Likelihood WUA arbitrates dispute between farmers

Source: Authors

Table 2: Summary statistics for covariates that could affect performance (included as right-hand-side variables in the DID)

	2014: survey 1				2016: survey 2			
Indicator (Y)	Treatment		Control		Treatment		Control	
	N	Mean (Std Dev)	N	Mean (Std Dev)	N	Mean (Std Dev)	N	Mean (Std Dev)
% WUA service area irrigated	73	0.96 (0.10)	67	0.92 (0.17)	73	0.94 (0.12)	67	0.94 (0.12)
% irrigated area producing wheat	73	0.23 (0.19)	58	0.28 (0.29)	73	0.23 (0.21)	58	0.25 (0.20)
% irrigated area producing fodder	73	0.07 (0.16)	58	0.07 (0.13)	73	0.08 (0.06)	58	0.10 (0.13)
% irrigated area producing cotton	73	0.47 (0.24)	58	0.42 (0.42)	73	0.49 (0.20)	58	0.34 (0.25)
# members in the WUA	74	240.62 (230.08)	67	285 (295.21)	74	687.41 (3424.94)	67	584.22 (1468.40)
# disputes	73	24.22 (31.53)	67	32.61 (44.67)	73	14.66 (22.06)	67	33.91 (68.76)
# board members	73	5.28 (1.18)	67	4.10 (2.08)	73	9.32 (7.22)	67	7.17 (6.65)
% of female board members	73	0.07 (.11)	67	0.08 (0.15)	73	0.09 (0.13)	67	0.09 (0.14)
Quality of main canal (1-5)	74	2.91 (0.58)	67	2.98 (0.67)	74	2.54 (0.92)	67	2.57 (0.96)
Quality of secondary canal (1-5)	74	3.08 (0.52)	67	2.87 (0.72)	74	3.03 (0.92)	67	2.69 (0.85)
Quality of tertiary canal (1-5)	74	3.09 (0.48)	67	2.79 (0.66)	74	3.12 (0.72)	67	2.81 (0.78)

Source: data collected by the authors

Table 3: Effects of longer training on water delivery

	WUA had a delivery schedule in 2014 and 2016	WUA had at least two board meetings in 2014 and 2016
Longer training	0.04(0.07)	0.09 (0.06)
% WUA service area irrigated	0.33 (0.21)	-0.22 (0.20)
% irrigated area producing wheat	-0.27 (0.13)*	-0.02 (0.12)
% irrigated area producing cotton	0.28 (0.13)**	0.15(0.12)
% irrigated area producing fodder	-0.00 (0.22)	-0.16 (0.20)
# members in WUA	0.00 (0.00)	-0.00 (0.00)
# disputes	-0.00 (0.00)	-0.00 (0.00)
# board members	0.01 (0.00)**	0.00 (0.00)
% of female board members	0.23 (0.20)	0.28 (0.189)
Quality of main canal (1-5)	-0.04 (0.03)	-0.02 (0.03)
Quality of secondary canal (1-5)	-0.03 (0.03)	0.00 (0.03)
Quality of tertiary canal (1-5)	0.01 (0.04)	0.04 (0.04)
Constant	0.78 (0.06)***	0.77 (0.05)***
N	131	131
R-squared	0.14	0.11
F-statistic	F(12,118)=1.59	F(12,118)=1.29
Prob > F	0.10*	0.29

The reported values express the modified DID estimate as a percentage difference, followed in parentheses by the standard error.

*** denotes that the difference is significant at 1%;

** denotes that the difference is significant at 5%;

* denotes that the difference is significant at 10%

Table 4: Effects of longer training on routine maintenance of irrigation infrastructure

	WUA conducted pre-season maintenance of secondary canals	WUA conducted pre-season maintenance of tertiary canals
Longer training	0.06 (0.04)	0.03 (0.04)
% WUA service area irrigated	-0.11 (0.15)	0.07 (0.12)
% irrigated area producing wheat	0.05 (0.09)	0.05 (0.08)
% irrigated area producing cotton	0.06 (0.09)	0.11 (0.08)
% irrigated area producing fodder	-0.20 (0.15)	-0.21 (0.12)*
# WUA members	-0.00 |(0.00)	0.00 (0.00)
# disputes	0.00 (0.00)	0.00 (0.00)
# board members	0.00 (0.00)	0.00 (0.00)
% of female board members	0.01 (0.14)	0.04 (0.12)
Quality of main canal (1-5)	-0.01 (0.02)	-0.01 (0.02)
Quality of secondary canal (1-5)	-0.00 (0.02)	0.00 (0.02)
Quality of tertiary canal (1-5)	0.03 (0.03)	-0.02(0.03)
Constant	0.05 (0.03)	0.03 (0.03)
N	131	131
R-squared	0.06	0.09
F-statistic	F(12,118)=0.60	F(12,118)=1.01
Prob > F	0.84	0.44

The reported values express the modified DID estimate as a percentage difference, followed in parentheses by the standard error.

* denotes that the difference is significant at 10%

Table 5: Effects of longer training on irrigation service fee recovery and transfer

	Share of members from whom irrigation service fee is recovered	Share of collected irrigation service fees transferred
Longer training	0.09 (0.07)	0.00 (0.11)
% WUA service area irrigated	0.21 (0.22)	-0.08 (0.33)
% irrigated area producing wheat	-0.18 (0.17)	0.33 (0.26)
% irrigated area producing cotton	0.08 (0.13)	-0.02 (0.18)
% irrigated area producing fodder	0.53 (0.22)**	-0.24 (0.34)
# WUA members	-0.00 (0.00)	0.00 (0.00)
# disputes	-0.00 (0.00)	-0.00 (0.00)
# board members	-0.00 (0.00)	-0.01 (0..01)
% of female board members	-0.07 (0.19)	0.24 (0.31)
Quality of main canal (1-5)	0.01 (0.03)	0.01 (0.05)
Quality of secondary canal (1-5)	-0.02 (0.04)	0.02 (0.06)
Quality of tertiary canal (1-5)	0.04 (0.04)	-0.04 (0.07)
Constant	0.08 (0.06)	0.94 (0.09)***
N	101	102
R-squared	0.13	0.05
F-statistic	F(12,88)=1.09	F(12,89)=0.38
Prob > F	0.38	0.97

The reported values express the modified DID estimate as a percentage difference, followed in parentheses by the standard error.

*** denotes that the difference is significant at 1%

** denotes that the difference is significant at 5%

Table 6: Effects of longer training on WUA membership fee recovery

	Share of *dehkan* farms from whom WUA membership fee is recovered
Longer training	0.19 (0.06)***
% WUA service area irrigated	0.37 (0.19)*
% irrigated area producing wheat	-0.14 (0.13)
% irrigated area producing cotton	0.07 (0.12)
% irrigated area producing fodder	0.21 (0.21)
# WUA members	-0.00 (0.00)***
# disputes	0.00 (0.00)
# board members	0.00 (0.00)
% of female board members	0.12 (0.18)
Quality of main canal (1-5)	-0.01(0.03)
Quality of secondary canal (1-5)	-0.06 (0.03)
Quality of tertiary canal (1-5)	0.02 (0.04)
Constant	-0.27 (0.05)***
N	115
R-squared	0.26
F-statistic	F(12,102)=2.77
Prob > F	0.00***

The reported values express the modified DID estimate as a percentage difference, followed in parentheses by the standard error.
*** denotes that the difference is significant at 1%;
* denotes that the difference is significant at 10%

Table 7: Effects of longer training on the likelihood of a dispute being arbitrated by the WUA

	WUAs settled disputes in 2014 and 2016
Longer training	-0.06 (0.08)
% WUA service area irrigated	0.24 (0.27)
% irrigated area producing wheat	-0.07 (0.17)
% irrigated area producing cotton	0.28 (0.16)*
% irrigated area producing fodder	-0.27 (0.27)
# WUA members	0.00 (0.00)
# disputes	0.00 (0.00)
# board members	-0.00 (0.01)
% of female board members	0.06 (0.25)
Quality of main canal (1-5)	0.00 (0.04)
Quality of secondary canal (1-5)	0.01 (0.05)
Quality of tertiary canal (1-5)	-0.00 (0.05)
Constant	0.35 (0.07)***
N	131
R-squared	0.05
F-statistic	F(12,118)=0.48
Prob > F	0.92

The reported values express the modified DID estimate as a percentage difference, followed in parentheses by the standard error.
*** denotes that the difference is significant at 1%;
* denotes that the difference is significant at 10%

Appendix 2

Balasubramanya, S. 2018. Farm participation in water user associations in Southern Tajikistan: effects of longer training and the role of gender. In review at *Agricultural Water Management.*

Title: Farm participation in water user associations in Southern Tajikistan: effects of longer training and the role of gender

Keywords: participation, training, gender, difference-in-difference, propensity scores, Tajikistan

Abstract: This paper examines whether longer training increases farm participation in community-managed water user associations, in a context where assignment to training duration was not randomized and none of these institutions existed before training began. We also examine whether participation is affected when farm managers migrate and leave farm operations to other workers, in a context where only managers have been directly trained, almost all managers are male, and females are increasingly operating farms. We collected microdata from 1,855 farms in Southern Tajikistan, where farm managers in 40 subdistricts received longer training, while those in the other 40 received shorter training. These 'treatment' and 'control' subdistricts were selected by constructing propensity scores and matching without replacement to address observable selection effects that may affect assignment to training duration. Farms were then selected from a census using a stratified random sampling process. A difference-in-difference technique with right-hand-side covariates is employed, where both sets of data were collected after training was completed. This choice of econometric methods controls against farm-level selection effects, but introduces a potential bias due to measurement error. Longer training has a causal effect on increasing participation in WUAs. Results also demonstrate that when male workers not directly trained operate farms, participation is not affected; however, participation is negatively affected when female workers operate farms. These results provide evidence for designing irrigation management programs to target female workers directly, in order to strengthen institutions whose success depends on active farm participation.

1. Introduction

In Tajikistan, water user associations (WUAs) are legally mandated to bring publicly provided irrigation water to the farm gate (Republic of Tajikistan, 2006). WUAs in Tajikistan serve *dehkan* (meaning private) farms, and legally, *dehkan* farms (not farmers) are eligible members of a WUA. These WUAs are participatory institutions; this implies that the participation and cooperation of representatives of member-farms is needed for WUAs to perform their mandated duty of water delivery successfully (Beresford, 2010). The *dehkan* farm is headed by a *manager*—a legally recognized position that is listed on the title of the *dehkan* farm. The farm title also lists the workers of the farm; these are individuals

with a legal claim to work on the farm, who also have a stake in the outputs of the farm. The farm manager and the listed workers typically belong to the same family, but not necessarily the same household.[1] The manager is the operator of the farm and represents the farm at the WUAs, when physically in residence.[2]

The WUA Law (Republic of Tajikistan, 2006) specifies the roles of the members. *Dehkan* farms are supposed to pay an irrigation service fee (toward the expense of water provision), which is levied seasonally; and a WUA membership fee (toward the expenses of WUA services provided), which is levied annually. They are also expected to contribute to (uncompensated) pre-irrigation season repair and maintenance of canals that is coordinated by the WUAs through the provision of labour of the workers of the farm (listed on the title) for the task. *Dehkan* farms are encouraged to sign a contract with the WUA at the start of the year. In the contract, water needs are stated for planning purposes. Representatives of member-farms are encouraged to attend WUA meetings. Participation can be assessed by examining these member-mandated functions in WUAs (Yakubov, 2011).

Some WUAs in Tajikistan were created using longer and more gradual training processes. Consequently the managers of the farms served by such WUAs received longer training on how to participate and cooperate with the WUA for more successful irrigation management. The institutional literature on farmer participation in community-based participatory management organizations suggests that longer training can increase the likelihood and extent of participation and cooperation, which is needed for such organizations to function successfully (Yap-Salinas, 1994; Kazbekov *et al.*, 2009; Mukhtarov *et al.*, 2015).

Estimating the impact of longer training using quantitative econometric methods can provide important information to target efforts to strengthen participation and functioning of new institutions.[3] However, conducting such evaluations in Tajikistan is challenging for at least two important reasons. First, assignment to longer training was not random, introducing potential selection bias. The second

[1] A family is defined as a set of individuals related through blood or through marriage. A household is defined as a set of individuals who consume food cooked in the same kitchen.
[2] When the manager is physically present, he is the operator for the farm. When the manager is not physically present, this could be because either they are deceased, or they have migrated to Dushanbe or overseas. In these cases, another member of the farm (listed on the title) became the operator. In cases of migration, the name of the manager is not legally changed on the title of the farm.
[3] While estimating the impact of longer training on water delivery is a worthy question, the lack of gauges at inlets and outlets to measure water flows in distributary canals and watercourses complicates addressing this question (for examples of such work, see Fernández-Pacheco *et al.*, 2015.

challenge pertains to the establishment of a baseline. *Dehkan* farms were created in the mid 2000s through the de-collectivization of the Soviet-era collectives. The government enacted the WUA Law in 2006 and mandated WUAs to be responsible for delivering water to farms. Even so, there was no participatory management irrigation organization in place until 2012. The process of creating the WUAs only began in 2012 through coordinated international assistance and government policy. At the start of the training, consequently, WUAs were not functioning, and there were no functional WUAs in which farms could participate. WUAs were established (and the managers of the farms were trained) in gravity schemes in Southern Tajikistan, the breadbasket of the country, by USAID and by the government, during 2012 and 2013. Managers of farms in WUAs created by USAID received 20-24 months of training, while those in WUAs created by the government received three to six months of training (Balasubramanya *et al.*, 2018).[4]

Training in participatory irrigation management in all WUAs—whether created using the longer or shorter process—has mostly been directed at managers of the farms. Since 98% of dehkan farm managers are male (FAO, 2018), this implies that training in participatory irrigation has mostly been provided to males. Migration of (mostly) males to either urban areas or overseas is rather common in Tajikistan. A study in 2013 estimated that 28% of households had at least one migrant, with migration greater in locations with rural and poorer households (Danzer *et al.*, 2013). Another study, with a study area matching that in this paper, estimated that in 2015, 48% of rural households in Southern Tajikistan had at least one migrant (Buisson *et al.*, 2016). A consequence of migration is that farm workers who were not directly trained in participatory irrigation are increasingly operating farms, with female farmers constituting an important share of non-trained individuals operating farms.

Whether training can increase participation in circumstances when individuals not directly trained are managing the farm would depend on the diffusion of information from those who were directly trained—the farm managers in this case—to those who were not trained but are now taking on the role of operating the farm. The literature on whether (and to whom) information diffuses from farmers directly trained (and produces associated behavior changes), suggests that the evidence is mixed and depends on farmer and farm characteristics of trained and other farmers (e.g. see Clausen *et al.*, 2004; Feder *et al.*, 2004).[5]

[4] Training was directed only at the managers of the farms, not at the listed members of the farm.
[5] This literature has focused on pest management, seed choice, and fertilizer application.

This paper examines whether longer training has a causal effect on increasing the probability of member-farm participation in WUAs in a context where no participatory organization existed before the training began. The paper considers a sample of 1,855 member-farms in 80 subdistricts[6] of Southern Tajikistan, where member-farm managers in 40 subdistricts received longer training (the treatment group) and those in the other 40 subdistricts received shorter training (the control group). These 80 subdistricts were selected from a population of subdistricts by constructing propensity scores and conducting a 1:1 matching without replacement to control against selection of observable confounders at the sub-district level (Rosenbaum and Rubin, 1985). Member-farms in these matched subdistricts were then selected from a census of member-farms through a stratified random sampling process to arrive at a representative sample of farms in Southern Tajikistan. Since there was no organization for member-farms to participate in before the end of the training , controlling against selection effects at the farm level entailed using a difference-in-difference (DID) technique with time-varying and time-invariant right-hand-side covariates, with data collected in two time-periods after the training of managers of member-farms was completed (Balasubramanya *et al.*, 2018).[7] This approach introduces a potential bias in the estimated effects of training due to measurement error, but controls against selection effects (as demonstrated in Balasubramanya *et al.*, 2018, and explained further in the methodology section of this paper).

The paper also considers whether participation is affected when the farm is operated by a person who was not trained, and whether any effect depends on the gender of that person. This is motivated by the observation that an increasing number of farms (~ 50% in this paper) are being operated by individuals who were not directly trained. To keep training costs low, most training programs train lead farmers (managers in this paper) (Anderson and Feder, 2007), who are often male (as is the case in this paper). However, diffusion of information to vulnerable individuals in the community (e.g., see Alesina and La Ferrara, 2000) and to females (e.g., see Kumar and Quisumbing, 2011; Beaman and Dillon, 2018) has often not been observed when lead male farmers are trained. In the context of Tajikistan, where almost everyone who was trained was male; where irrigation is regarded as “a man’s job” (Mukhamedova and Wegerich, 2018); and where those directly trained are decreasingly managing their farms, an

[6] In Tajikistan, a subdistrict is called a *jamoat.*

[7] This is in contrast to the standard DID approach, where one set of observations would have been collected at the time the training commenced, and the other after the training was completed.

understanding of how participation is affected when untrained males and females operate farms can provide information for targeted training.

The context of the participatory irrigation intervention renders the application of other methods of establishing causal effects impossible. Using a method of synthetic controls (Abadie and Gardeazabal, 2003) was not possible due to the non-existence of data on participation from before the starting of the training. Using experimental methods (Tellez Foster *et al.*, 2017) was not possible due to the non-strategic setting. Since data on subdistricts were available, they were used to select matched pairs of treatment and control clusters, in order to control for selection on observable confounders. This modified DID technique with the inclusion of time-varying right-hand-side covariates controls for selection on time-invariant and time-variant unobservable confounders.

This paper contributes to the literature in three ways. First, rather than using cross-sectional data (e.g., Nagrah *et al.*, 2016; Qiao *et al.*, 2009); or conducting qualitative analysis (e.g., Aydogdu *et al.*, 2015) to analyze participation, panel data are used. These data control for several types of selection effects and generate evidence needed for adaptive management and targeted investments in the early years of institutions whose success depends on member participation. The second contribution is to understand how participation, and thus the functioning of these participatory institutions, is likely to be affected as the gender composition of the agricultural workforce changes due to labor market adjustments. The third contribution is to contextualize the results presented in Balasubramanya *et al.* (2018) that examined the effects of longer training on WUAs' performance of mandated functions. That paper demonstrated that WUAs with longer training were able to recover membership fees from 19% more members, and were 10% more likely to hold meetings with members for planning purposes. The current paper uses a different primary dataset that was collected using a different study design that was specifically tailored for testing the effects of training duration and other determinants of farm participation such as gender.

The results in this paper demonstrate that *dehkan* farms whose managers received longer training are 8% more likely to pay their membership fees; 20% more likely to sign a water contract with the WUA, and 9% more likely to attend the WUA meetings. *Dehkan* farms whose managers received longer training contributed seven more person-days of labor towards routine pre-irrigation repair and maintenance of canals. Participation was not affected when the farm was operated by a male worker who was not directly trained. However, participation was negatively affected when the farm was

operated by a female, with such farms 9% less likely to pay their membership fees than farms operated by males, 11% less likely to sign a water contract, and 3% less likely to attend the WUA meetings.

A limitation of the paper is that it is not possible to test formally whether participation outcomes for farms with longer and shorter training would have changed in the absence of the intervention. This is because participatory organizations, with longer and shorter training, came into existence at the same time (2012), which coincides with the commencement of the intervention under consideration in this paper. Before 2012, no participatory water management institutions existed, and consequently, pre-2012 participation data do not exist. The choice of methods in the paper is based on the observation that standard methods to control for selection effects cannot be readily employed on this context.

The remainder of the paper is organized as follows. Section 2 provides a context for how participatory WUAs evolved in Tajikistan. Section 3 presents a conceptual framework and reviews literature concerning length of training and participation in WUAs globally and in Central Asia, along with literature on the diffusion of information from trained to other farmers. Section 4 describes the methodology, while Section 5 presents the study design and Section 6 contains details on data. Summary statistics and results are presented in Section 7. Section 8 aggregates the results and discusses them in relation to the existing literature and the evaluation of participatory institutions.

2. Evolution of participatory water user associations in Tajikistan

Within the former Soviet Union, Tajikistan was designated as Central Asia's main hub of cotton cultivation, which was practiced on collective farms (FAO, 2012). Only 4% of the land in Tajikistan is agricultural, with 95% of crop cultivation on irrigated land (FAO, 2012). Southern Tajikistan is the most populous part of the country, where cotton and wheat production are dominant.

WUAs were created in Tajikistan in response to the de-collectivization of the collective farms into *dehkan* (private) farms, which began in the mid-2000s. With the departure of Russian irrigation specialists and the lack of Soviet subsidies, irrigation departments—called *vodkhozes*—were not able to deal with the challenge of providing water to thousands of private farms (Gunchinmaa and Yakubov, 2009; Shahriari, 2009). The government enacted the WUA Law (Republic of Tajikistan, 2006) and named the WUA as the institution responsible for delivering water to the farms. International assistance for creating these organizations was requested. WUAs were piloted by several international organizations and a countrywide program to create new WUAs gained momentum in 2011. More than 300 WUAs are

now functional in Tajikistan, with the service area typically in the range of 1,400 ha to 1,600 ha (Balasubramanya *et al.*, 2016). All WUAs require their member-farms' participation and cooperation for irrigation service delivery.

Participatory governance and civic engagement are not new to Tajikistan (Cieslewska, 2010). For instance, even though state-directed institutions dominated the agriculture and water sectors during the Soviet era (O'Hara, 2000), traditional neighbourhood (*mahalla)* councils, which were elected by the households in the neighbourhood, played an important, though informal, role in addressing local problems (including water-related disputes) in the community. Such neighbourhood councils continue to play an important role today.

3. Conceptual framework

3.1. Participation in community-managed resource systems

Key among Ostrom's (1990) eight principles for managing subtractable common pool resources is the concept of participation, and the arrangements that facilitate such participation. Participation is viewed as a way of reconnecting disengaged citizens with the decision-making process in contexts of 'democratic deficit' (Pratchett, 1999: 619), as well as improving the quality of those decisions (Martin, 2009). Beyond mere participation, Gurung (1992: 32) states how it is important that users 'abide by the terms of agreement before, during, and after the implementation process of the participatory management program.' The collective management of common pool resources such as water critically depends on users continuously following the rules (Cleaver, 1999).

Among decentralized participatory institutions such as WUAs, external professionals may deploy an enabling logic, but the users in fact perform the service task for themselves (Bovaird *et al.*, 2015). For example, WUAs coordinate routine cleaning and repair of irrigation canals before the start of the irrigation season, but member-farms must contribute labour (of the workers of the farm) in order to improve irrigation service delivery for all member-farms. Accordingly, users may be viewed as being in partnership with their organizations, as they participate to co-produce services (Beresford, 2010).

3.2. Training members in participatory management

In the literature on institutional reform and service provision, it has become widely accepted that participation of users is required for institutions to be fully effective (Bovaird *et al.*, 2015). However,

when newly established, members of participatory institutions, such as managers of member-farms in the case of WUAs, may need training to comprehend how they need to participate and cooperate with the institution (Nagrah *et al.*, 2016).

Since these (new) water users may be constrained in participating and cooperating effectively due to a lack of knowledge (Hu *et al.*, 2014), the length of the training period provided can be an important variable determining user participation (Yap-Salinas, 1994). For example, Nagrah *et al.* (2016) note that without a sufficiently long period of training, 'farmers in Pakistan may not be ready or even interested in the task' of participating in a WUA and following its rules. In Turkey, Aydogdu *et al.* (2015) found that 'farmers lacked sufficient knowledge regarding WUAs' and needed more training to perform the WUA functions independently. In contrast, a 'high degree of understanding about water user associations' was found to be an important factor determining respondents' satisfaction based on surveys in Inner Mongolia (Qiao *et al.* 2009: 822).

Concerning post-Soviet states with a similar recent history to Tajikistan, service user satisfaction and willingness to pay among Armenian WUAs was compromised by insufficient, unreliable and untimely delivery of water, due in part to inadequate training of WUAs and their users (Alaverdyan and Houston, 2004: 11). In Kyrgyzstan, improved water delivery was brought about after a lengthy four-year period of training 'encouraged member participation' (Johnson and Stoutjesdijk, 2008: 311). By contrast, training time was limited or nonspecific in Uzbekistan, leading to poor rates of payment of fees and participation in WUA governance (Wegerich, 2000).

3.3. Diffusion of information from trained farmers to other farmers

Farmer-training programs are typically designed to improve performance by providing technical information to increase human capital (Anderson and Feder, 2004). Since farmers often rely on other farmers for information about agricultural practices (Rees *et al.*, 2000); such programs usually train head farmers or village heads, who in turn share that technical information with other farmers (Anderson and Feder, 2007). This also keep costs of programs low (Feder *et al.*, 2004).

The literature on whether information diffuses from directly trained farmers to other farmers and encourages changes in behaviors is mixed. For example, Feder *et al.* (2004) found that while Indonesian farmers directly trained in pest management reduced pesticide use, farmers not directly trained did not experience an improvement in either knowledge or a reduction in pesticide use. In contrast, in Uganda,

Clausen *et al.* (2017) found that farmers directly trained in pest management were also able to reduce the pesticide use of neighboring farmers.

These differences in diffusion of information, and associated changes in behaviors, are likely to depend on several factors. The complexity of the knowledge to be shared (e.g., Rola *et al.*, 2002), and the strength of interpersonal networks (e.g., Tripp *et al.*, 2005) are two such factors. Also important are the social status and gender of persons chosen for training (e.g., see Pemsl *et al.*, 2006; Beaman and Dillon, 2018); and idiosyncratic characteristics of farmers and their farms (e.g., Fuglie and Kascak, 2001).

Using low cost options to diffuse information, which often involves using pre-existing networks, may have unfortunate distributional consequences. For example, with respect to gender, Beaman and Dillon (2018) find that when the information on composting is spread using existing social networks in Mali (where networks are among lead male farmers) less influential farmers and female farmers, in particular, lose out on receiving valuable information.

3.4. Hypotheses

The paper considers member-mandated functions as specified in the WUA Law (Republic of Tajikistan, 2006) , and introduces a number of hypotheses regarding the effects of longer training on these indicators. A list of indicators is provided in Table 1.

a) Irrigation fees: Longer training is expected to increase the probability of a farm paying the seasonal irrigation fees.
b) WUA membership fees: Longer training is expected to increase the probability of a farm paying its annual membership fees
c) Participation in pre-irrigation cleaning of canals: Longer training is expected to increase the number of person-days of labor that the member-farm contributes towards cleaning.
d) Legal relations: Longer training is expected to increase the probability of a farm signing a contract with a WUA; and is expected to increase the probability of the manager or (listed) worker of a farm attending a WUA meeting.

Training in Tajikistan was imparted to managers (lead farmers), most of whom are male. Since the networks among male farmers are likely to be strong, we expect participation to not to be affected when non-trained males operate the farm, but to be lower when females operate the farm.

4. Methodology

Consider the following equation:

$$Y_{jt} = \mu + \gamma S_j + \theta t + \omega(S_j \times t) + \beta X_{jt} + \vartheta_{jt} \qquad (1),$$

where Y_{jt} refers to a participation indicator for farm j at time t. S_j is a categorical variable that denotes the treatment status of farm j, with $S_j = 1$ if the farm manager received longer training, and $S_j = 0$ if the manager received shorter training. The variable ω reports the causal effect of longer training on participation. X_{jt} refers to a set of farm-specific covariates at time t that might also influence Y_{jt}. ϑ_{jt} is the error term.[8]

The difference-in-difference (DID) technique identifies the causal effect of longer training by comparing the average *change* in participation over a time period for the treatment group to that for the control group, while controlling for differences at the starting points and common time trends. Typically, the DID technique would be executed by collecting data on participation and other covariates from farms, first at the start of the training (i.e., when $t = 0$), and again at some time $t > 0$ after training was completed, thus creating a panel dataset. Therefore, the standard DID technique assumes that both treatment and control groups were participating even before the training began (that is $Y_{jt} \neq 0$ when $t \leq 0$), allowing for a pre-training comparison of trends in outcomes between the two groups. Under this condition (called the standard condition), the DID technique eliminates time-invariant unobservable selection effects (μ in Equation 1)—such as any farm-specific, area-specific, or agency-specific fixed effects that are constant over time but may drive differences in level of participation—and provides an unbiased estimate of ω.

However, if participation indicators take values of zero in the pre-intervention period ($Y_{jt} = 0 \; \forall \; t \leq 0$), then there are no pre-intervention trends to compare. In the case of Tajikistan, there were no participatory institutions for farms to participate in, before training began in the area under study. If the DID technique were implemented by collecting the first set of data on participation and covariates at the start of the training (when $Y_{j0} = 0$ for all farms), and by collecting the next set of data at some time $t > 0$ for all farms (where $Y_{jt} \geq 0$ for all farms); then this would mathematically be equivalent to using

[8] The error structure is assumed to follow: $E\left(\vartheta_{jt} \middle| S_j, t\right) = 0 \; \forall \; S_j \; \forall t$). This is because the identifying assumption is that, by explicitly accounting for , , the errors are uncorrelated with S_t and t .

cross-sectional data, rather than panel data. Under this condition, the DID-technique would not be able to eliminate the time-invariant unobservable selection effects (μ), and would provide a biased estimate of ω.

Since the case of Tajikistan imposes the condition, where for all farms, $Y_{jt} = 0 \; \forall \; t \leq 0$; the difference-in-difference estimator is used in a modified setting, where *both* the first and the second sets of data are collected in time periods *after* the training was completed. This modification of standard practice eliminates bias in the estimation of ω due to time-invariant unobservable selection effects (μ), but introduces a potential bias due to measurement error. However, the magnitude of any bias due to measurement error is reduced to zero as the first set of data is collected closer to the time when training commenced (i.e. closer to $t = 0$). Therefore, collecting the first set of data as close as possible to $t = 0$ would minimize bias due to this measurement error, while also eliminating bias due to time-invariant unobservable selection effects (μ). A mathematical proof of the elimination of bias due to these unobservable selection effects (μ) and a minimization of the bias due to measurement error as the first set of data is collected closer to the time when training commences can be found in Balasubramanya *et al.* (2018).

Apart from time-invariant unobservable selection effects, there may be time-varying unobservable selection effects that also bias the estimation of ω. These are controlled for by including a host of farm-specific time-varying covariates (X_{jt}) on the right-hand-side of the modified DID equation, as demonstrated in Balasubramanya *et al.* (2018).

5. Study Design

5.1. Determining sample size, number of clusters and number of observations per cluster

A WUA usually provides water to member-farms in one or two subdistricts[9], enabling each subdistrict to be classified as either a treatment subdistrict (where farm managers received longer training) or a control subdistrict (where farm managers received shorter training). Power calculations were conducted to determine the number of treatment and control subdistricts, the number of observations within a

[9] It is unlikely that a dehkan farm is not a member of a WUA. WUAs have been created across all gravity schemes in Southern Tajikistan, and data collected from WUAs in a separate study demonstrate that all farms in the command area are member-farms (Balasubramanya *et al.*, 2016)

subdistrict, and the sample size. The minimum detectable effect (MDE) size was calculated using the formula:

$$\mathrm{MDE} = 2.487\ \sigma_y \sqrt{(1-R^2)\left[(1-\rho)\left(\frac{1}{a_t b_t}+\frac{1}{a_c b_c}\right)+\rho\left(\frac{1}{a_t}+\frac{1}{a_c}\right)\right]} \qquad (2)$$

In equation (2), a_c and a_t represent the number of control and treatment subdistricts; and b_c and b_t represent the number of member-farms per subdistrict. The variable σ_y is the standard deviation of the outcome variable; and the variable ρ refers to the intra-subdistrict correlation associated with that outcome variable. R^2 is the coefficient of determination. Outcome variables and their means, standard deviations (σ_y), and intra-subdistrict correlations (ρ) were taken from the Tajikistan Living Standards Measurement Survey (T-LSMS) (World Bank, 2003).[10] The coefficient of determination and the level of confidence were set at (conventional) rates of 0.8 and 0.95 respectively. Two outcome variables from the T-LSMS database were used as proxies for the range of indicators to be assessed. These were: proportion of farms that irrigated their agricultural plot; and proportion of farms that believed their plot received adequate water supply.

A sensitivity analysis was subsequently carried out by varying the number of control and treatment subdistricts (respectively a_c and a_t), the number of member-farms per subdistrict (b_c and b_t) and the sample size. Results using the proportion of farms that irrigated their agricultural plot are reported in Figures 1-2. For a given sample size, the MDE is smaller as the number of clusters in the sample increases (Figure 2), and as the number of observations per cluster in the sample decreases (Figure 2). A study design of 40 treatment and 40 control subdistricts, with 25 farms per subdistrict, emerged suitable; the MDE for this study design is an increase of 10% in the proportion of households irrigating their plots; and an increase of 6% in the proportion of households that felt that their plots had adequate water. For the design of 40 treatment and 40 control clusters, the MDE falls as the sample size increases (i.e., the number of observations per cluster increases), but the change in the MDE is rather small (Figure 3).[11]

5.2. Selecting the clusters

[10] The T-LSMS (2003) was preferred to the T-LSMS from 2007 and 2009 due to a larger sample of rural households in the agricultural provinces.

[11] Results from using the proportion of households that believed their plot received adequate water supply are also similar.

Since assignment to longer training was not random, treatment and control subdistricts to be sampled in this assessment were selected by constructing propensity scores, and then using a 1:1 matching process without replacement to select matched pairs of treatment and control subdistricts. A pre-sampling survey of all subdistricts where irrigated cultivation of wheat and cotton was practiced (164 of the 406 subdistricts) was conducted. Of the164 subdistricts, 116 were in Khatlon Province, 21 in Sughd Province and 27 in DRS Province. Information on demographic attributes, agricultural practices, land use and farm attributes, and irrigation infrastructure was collected. Propensity scores were constructed to calculate the probability of each subdistrict being treated (i.e., where farm managers received longer training). A complete list of attributes that were used to construct the propensity scores and the model of treatment can be found in Table 2.[12]

Using the propensity scores, subdistricts with farms whose managers received longer training were matched (using a caliper size of 0.12) to subdistricts with farms whose managers received shorter training, without replacement to their nearest neighbor (1:1 match), to select 40 subdistricts of each type. The differences between the subdistrict attributes for unmatched and matched subdistricts is displayed in Table 3. When unmatched, treatment and control subdistricts displayed significant differences on a number of attributes; these differences did not emerge for the matched pairs.

5.3. Selecting *Dehkan* Farms

Records of the population of *dehkan* farms were not available in any government office at the national level. Therefore, a census of all *dehkan* farms in the 80 selected subdistricts was undertaken by the research team. Information on the name of the farm, and the name of the manager of the farm was collected. In addition, farms were categorized on two key variables: the type of canal from which the farm was irrigated (primary, secondary or tertiary); and the farm's location on that canal (head, middle, or tail). These two variables affect water availability at the farm level and may influence participation. For example, managers of farms located on the tail of a tertiary canal may be more inclined to attend WUA meetings because their access to water is deeply dependent on the actions of farmers at the head. On the other hand, these managers may be less likely to pay the irrigation fees if they perceive that they

[12] The propensity score also takes into account ethnic composition of subdistricts, the number of rural health centers and schools, and the number of agricultural markets in the subdistrict. It also takes into account whether land reforms have been completed, and the number of years of tenure of the current subdistrict leader. These could affect selection into treatment, and hence were accounted for while selecting the treated and control groups.

are unlikely to receive water anyway. A stratified random sampling method using these two characteristics was used to select 25 *dehkan* farms from each of the 80 selected subdistricts, totaling 2,000 farms. This process randomly selects the nine types of farms in proportion to their numbers in the population, producing a representative sample of farms in each subdistrict.

5.4. Clustering

The sample was selected by first selecting clusters (subdistricts) and then selecting farms within each cluster. Consequently, the econometric analysis of the data in the paper has been conducted by clustering results at the sub-district level, to account of the fact that two farms within the same cluster are likely to be more similar that two farms in different clusters.

6. Data

A panel data set was collected through surveys conducted with the 2,000 farms. The first survey was conducted in 2015 to collect information on the 2014 calendar year. The second survey was conducted in 2017 to collect information about the 2016 calendar year.

Respondent: Both surveys were targeted at the farm-managers, since they are the operators of the farms and had received the training. However, this was often not possible, due to overseas or rural-to-urban male migration. For the first survey, if the manager had not migrated and was in residence during 2014-2015, the manager was interviewed[13]. If the manager was not in residence during 2014-2015, the (listed) worker of the farm who had taken on the operations of the farm was interviewed. For the second survey, if the respondent of the first survey was still in residence, they were interviewed.[14] If the respondent of the first survey had migrated, then the person who had taken on the operations of the farm was interviewed. Interviews were scheduled in advance to check whether the person who had answered the first survey was available, and to coordinate with the new operator when needed. Data were also collected on the gender of the respondent (who was the operator of the farm for that calendar year).

[13] We did not find any case where the manager who was trained was in residence but was not the operator of the farm.

[14] We did not find any cases where the respondent of the first survey was still in residence and was not the prime operator of the farm.

Attrition between first and second survey: In the first survey, respondents from 1, 957 of the 2,000 member-farms agreed to participate in the study and were consequently interviewed. The second survey was answered by 1,855 of the 1,957 member-farms. Using data collected from the first survey, no statistically significant differences were observed between farms in the treatment and control group within the subsample of 102 member-farms that did not answer the second survey. The primary reason that these member-farms could not be surveyed again was because production on these dehkan farms had ceased after the first survey and before the implementation of the second survey most often due to male migration.

Final sample: Data pertaining to 1,855 member-farms are used in the analysis, with 933 farms whose managers received longer training (treatment group) and 922 farms whose managers received shorter training (control group).

Left-hand-side variables: Indicators pertaining to member-farm participation were constructed to reflect the roles as delineated in the WUA Law of 2006. Respondents were asked if the farm has paid its irrigation fees and its WUA membership dues for the calendar year. Respondents were also asked to report on the number of (listed) workers of the farm who had participated in canal cleaning and the number of days of labor each of those workers had contributed, in order to calculate person-days of labor that the farm had contributed towards repair and maintenance. Finally, respondents were asked if the farm had a signed a contract with the WUA for the calendar year, and if the farm had been represented at the WUA planning meetings in the calendar year. Data on these indicators were collected in both surveys.

Right-hand-side variables: Data on farm membership size and demographics, cotton acreage, and cultivation of other crops were collected. These data were also elicited in both surveys. Table 4 provides summary statistics for these key variables.

In 2014, a male who was not directly trained operated 30% of farms in the treatment group and 35% of farms in the control group. In 2016, males who were not directly trained operated 29% of farms in the treatment group and 31% of farms in the control group. Regarding the gender of the farm operator, females operated 10% of the treatment group farms and 11% of the control group farms in 2014. For 2016, these values changed to 16% and 19% for treatment group and control group respectively. The number of (listed) workers of the farm did not change significantly within and between groups across

years; they fell from ~ 7 workers to ~6 workers for the treatment group and from ~8 workers to ~7 workers for the control group.

The gender composition of the workers of the farm listed on the farm-title changed within and between groups; while 46% and 48% of listed farm-workers in the treatment and control groups during 2014 were female, 53% and 51% of listed farm-workers in the treatment and control groups during 2016 were female. Their difference-in-difference ((53-46) – (51-48)) is 4%, and is significant at 5%. The share of workers of the farm listed on the farm-title spending the majority of their working time on the farm increased within both groups but not between groups. While 79% of listed farm-workers in the treatment group and 72% of listed farm-workers in the control group worked a majority of their time on the farm during 2014, these increased later to 87% and 82% for the treatment and control groups, respectively. The number of households associated with the member-farms did not change, staying at around three households for both groups during both surveys. The area of land covered by the title of the member-farms also did not change much between the two surveys for both groups. This is because rental markets for land are not well-developed in Tajikistan.[15]

The cultivated area of the member-farms did not significantly change within and between the two groups over the two surveys. In 2014, the treatment group cultivated 4.19 ha per member-farm on average, and the control group cultivated 4.43 ha; these changed to 4.01 ha and 4.48 ha in 2016 for the treatment and control group respectively. Irrigated area of the member-farms also did not significantly change within and between the two groups. In 2014, the treated group irrigated 4.15 ha and the control group irrigated 1.05 ha on average; these changed to 3.95 ha and 4.18 ha in 2016. The share of member-farms cultivating cotton remained the same within each group; in 2014, 67% of treatment member-farms and 47% of control member-farms cultivated cotton, and in 2016, these changed to 70% of treatment member-farms and 49% of control member-farms. The area under cotton cultivation also remained the same between both within and between the groups. In 2014 the treatment member-farms cultivated 3.27 ha of cotton on average and the control member-farms cultivated 3.95 ha of cotton on average. In 2016, the treatment member-farms were cultivating 3.18 ha of cotton while the control member-farms were cultivating 3.81 ha of cotton, on average.

[15] In the first survey, the per-farm land rented was 0.14 ha for the treatment group and 0.13 ha for the control group. In the second survey, these numbers were 0.15 ha and 0.09 ha for the treatment and control group respectively.

The following variables were only measured during the first survey, because they either changed at the same rate over time for both groups, or were time-invariant. Treatment and control member-farms were of the similar age, with treatment member-farms ~4.83 years old (standard deviation (sd) = 0.32) in 2015 and control member-farms around 5.63 years old in 2015 (sd = 0.47). The average treatment member-farm was ~1.75 km away from the nearest road (sd = 0.27), while the average control member-farm was 2.03 km away (sd = 0.33). The age of the member-farm manager was similar for both groups, with managers around 48 years of age in 2015 (standard deviation of 0.43 and 0.48 for the treatment and control group respectively). The treatment group had a slightly higher share of member-farm managers who had completed secondary education, with 29% as compared to 24% for the control group. These variables were also included on the right-hand-side of the difference-in-difference estimating equations but the estimated coefficients are not reported in the paper because, being time-invariant, they are eliminated by the difference-in-difference technique during estimation.

7. Results

7.1. Causal effects of longer training on participation and cooperation

Member-farms whose managers were provided with longer training were 8% more likely to pay their membership fees than member-farms whose managers were provided with shorter training ($p < 0.10$) (Table 5). These member-farms contributed seven more person-days of labor per member-farm ($p < 0.01$) towards pre-irrigation season cleaning of canals, were 19% more likely to have signed a contract with their WUAs ($p < 0.01$) and 9% more likely to attend the WUA meetings ($p < 0.05$).

The coefficients of determination (R-squared) in these regressions are low, because these are not ordinary least squares regressions with cross-sectional data. Since these regressions are difference-in-differences (fixed effects) using panel data which is clustered at the subdistrict, the F-statistic is a more reliable indicator of explanatory power. These values are below 0.1 for the regressions where the effect of training is positive and significant at the usual levels.

7.2. Effect on participation when farm was operated by non-trained male worker

When the farm was operated by a male workers who had not been directly trained, that farm contributed two fewer man-days of labor than when the farm was operated by the manager who had been directly trained ($p < 0.1$; Table 5). However, the likelihood of a farm paying its irrigation fees, WUA

membership fees, signing a contract with the WUA and being represented at WUA planning meetings was not affected when the farm was operated by a non-trained male worker (Table 5).

7.3. Effect on participation when farm was operated by female worker

The gender of the operator of the farm was significant in determining participation. As seen in Table 5, a farm operated by a female worker was 9% less likely to pay its membership fees ($p<0.01$); 11% less likely to sign a contract ($p<0.05$); and 3% less likely to attend WUA meetings ($p<0.1$).

8. Discussion

In countries such as Tajikistan, formal participatory institutions are being newly developed after the state-control era of the Soviet Union. At the same time, larger macroeconomic and labor-market forces are changing the gender-based roles in agriculture. Understanding the role of training in enhancing participation in WUAs, and examining diffusion of information on participation from trained farmers to other male and female workers is important to provide evidence for program design and policymaking.

Quantitative assessment of participation in newly created community management institutions is challenging because control groups and baselines are often difficult to identify. Selection into participatory organizations is not random, complicating the isolation of causal effects from observable and unobservable confounders. Further, when participatory institutions are created for the first time, all participation variables take values of zero at baseline because the intervention also created the notion of membership, further complicating the elimination of unobservable confounders.

In this paper, quasi-experimental methods are used to construct a control group by calculating propensity scores at the cluster level, and then selecting matched pairs of treatment and control clusters without replacement, to control against bias due to selection effects at the cluster level. The first measure of participation is made after the newly created organizations started functioning, so that participation could be measured and did not have to take a default value of zero. Using the difference-in-difference technique with right-hand side indicators where both sets of data are collected after intervention began introduces a potential bias due to measurement error, but controls against bias due to selection effects at the farm-level. Despite the measurement bias, the estimates provide empirical evidence for the effects of longer training on participation and the diffusion of information from trained managers to non-trained workers in a context where almost all trained managers were male.

In this paper, the results demonstrate that farms that had longer training had a higher probability of paying their membership fees, signing a water contract, and attending WUA meetings. Information on participation likely diffused from trained male managers to untrained male workers, but not from trained male managers to female workers. This is demonstrated by the absence of a significant effect on participation when farms were operated by male workers who were not directly trained, and by the presence of a significantly lower effect on participation when farms were operated by female workers.

Such evidence is useful for programming purposes. Since longer training produces greater participation, supplemental or refresher-training modules can be designed to provide targeted training in areas where shorter training was provided. If more female workers are likely to operate farms, then investing in the human capital of female workers by directly training them in participatory management may be needed, rather than relying on traditional methods of training (male) lead farmers and expecting diffusion to other farmers across gender lines. In addition, in the current context where most migrants are males, the functioning of young participatory organizations such as WUAs may be enhanced if knowledge is housed with female workers. These trainees are economically less mobile, and have to continue farming to feed their families even while males are absent.

Despite the possibility of bias in results from delaying the inception of data collection, evidence that is less than first-best can still be useful for adaptive sectoral development when institutions are young.

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Figure 6: Relationship between Minimum Detectable Effect and number of clusters for a given sample size

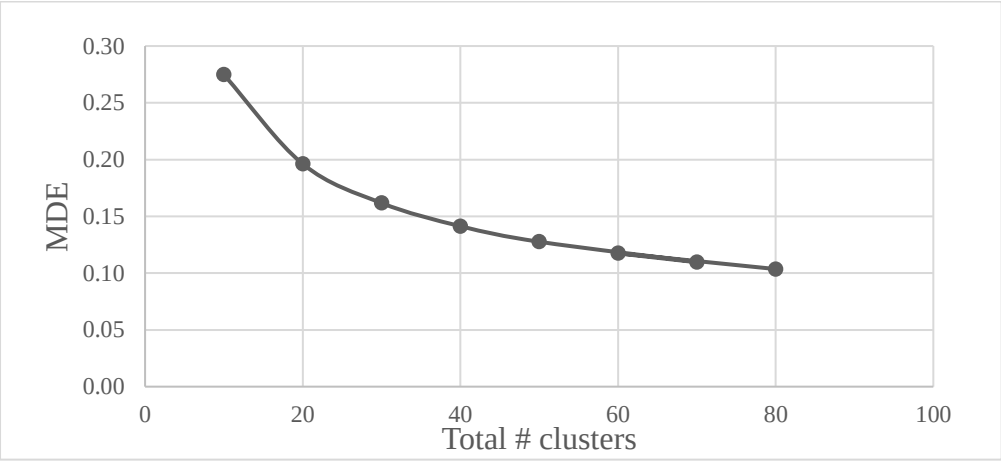

Figure 7: Relationship between MDE and number of observations per cluster for a given sample size

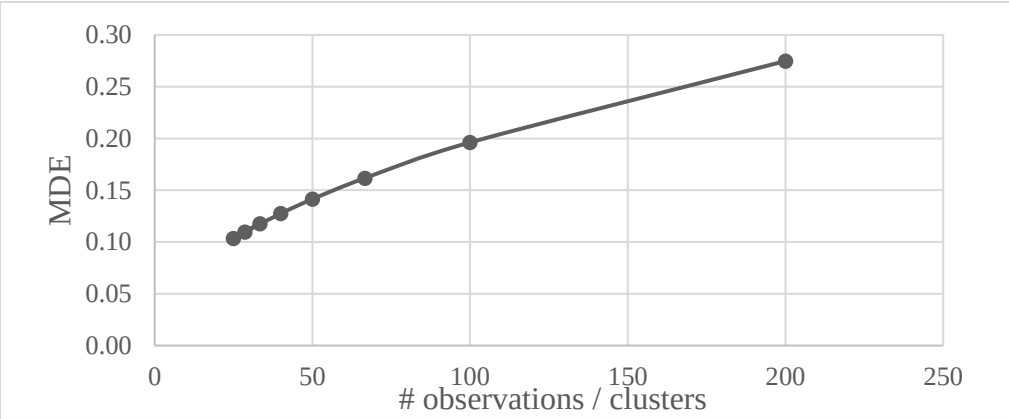

Figure 8: Relationship between MDE and sample size (n>=2,000)

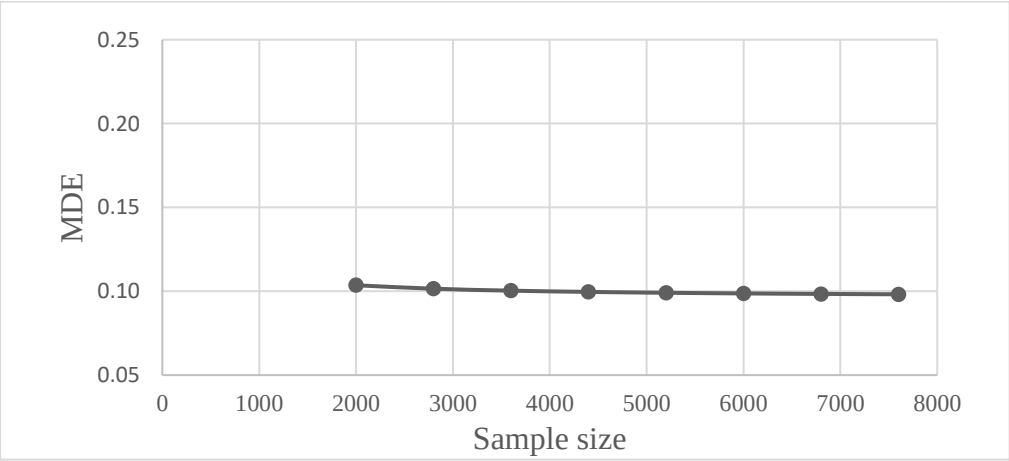

Table 1: Participation and satisfaction indicators

Irrigation Fees
Fees were paid for both irrigation seasons in the year
Farm owed arrears in irrigation fees in the calendar year
WUA membership fees
Membership fees were paid for the calendar year
Participation in pre-irrigation cleaning of canals
# of days donated by farm towards cleaning
# of people from the farm who participated
Legal relations
Farm signed a contract with the WUA
Farm member(s) attended WUA meetings

Table 2: Constructing propensity scores

	Logit Treatment *Subdistrict*
Population of the subdistrict in 2014	0.00 (0.00)
Number of villages	0.033 (0.05)
Total area of the subdistrict	0.00 (0.00)***
Majority of population Tajik (dummy)	-0.69 (0.54)
Number of secondary schools in subdistrict	0.07 (0.08)
Number of rural health centers in the subdistrict	-0.54 (0.19)***
Number of agricultural markets in the subdistrict	0.40 (0.29)
Chairman born in the subdistrict (dummy)	0.16 (0.64)
Number of years of election of the chairman	-0.07 (0.07)
Elevation of the subdistrict (m ASL)	0.00(0.00)
Sandy soil (dummy)	0.00 (0.55)
Deep groundwater level (dummy)	-0.81 (0.52)
Land reform completed (dummy)	2.54 (0.69)***
Cotton main crop of the subdistrict (dummy)	2.84 (0.66)***
Subdistrict irrigated by gravity system (dummy)	0.61 (0.67)
Constant	-3.89 (1.49)***
Pseudo R^2	0.402
Sample size	164

Table 3: Differences between treatment and control group for unmatched and matched sample

	Treatment - Control	
	Unmatched	Matched
	Mean (Std Dev)	Mean (Std Dev)
Population of the subdistrict in 2014	797.18 (1446.5)	-845.48 (2000.07)
Number of villages	-1.34 (1.08)	-0.775 (1.45)
Total area of the subdistrict	2770.21 (2888.16)	1537.04 (3992.63)
Majority of population Tajik (dummy)	-0.13 (0.07)*	-0.1 (0.09)
Number of secondary schools in subdistrict	0.51 (0.69)	-0.125 (0.98)
Number of rural health centers in the subdistrict	-1.03 (0.33)***	-0.125 (0.28)
Number of agricultural markets in the subdistrict	0.09 (0.15)	-0.125 (0.22)
Chairman born in the subdistrict (dummy)	0.05 (0.07)	-0.1 (0.09)
Number of years of election of the chairman	0.12 (0.62)	0.4 (0.81)
Elevation of the subdistrict	-178.22 (56.08)***	-56.48 (70.73)
Sandy soil (dummy)	0.04 (0.07)	-0.025 (0.1)
Deep groundwater level (dummy)	-0.23 (0.08)***	-0.11 (0.11)
Land reform completed (dummy)	0.34 (0.08)***	0.125 (0.09)
Cotton main crop of the subdistrict (dummy)	0.48 (0.08)***	0.17 (0.11)
Subdistrict irrigated by gravity system (dummy)	0.06 (0.07)	-0.025 (0.09)
Number of observations	164	80

Table 4: Summary statistics for first and second survey data

	First Survey 2014				Second Survey 2016				
	Treatment		Control		Treatment		Control		Difference-in Difference
	N	Mean (Std Err)	N	Mean (Std Err)	N	Mean (Std Err)	N	Mean (Std Err)	Mean (Std Err)
Farm operated by non-trained male	933	0.30 (0.02)	922	0.35 (0.02)	933	0.29 (0.02)	922	0.31 (0.02)	-0.02 (0.02)
Farm operated by female	933	0.10 (0.02)	922	0.11 (0.01)	933	0.16 (0.02)	922	0.19 (0.02)	0.00 (0.02)
Number of members	928	6.71 (0.47)	908	7.84 (0.70)	928	6.07 (0.39)	908	6.96 (0.46)	0.24 (0.60)
Share of members that were female	910	0.46 (0.01)	875	0.48 (0.01)	910	0.53 (0.01)	875	0.51 (0.01)	0.04 (0.01)**
Share of members spend majority of time	911	0.79 (0.02)	833	0.72 (0.02)	911	0.87 (0.01)	883	0.82 (0.02)	-0.03 (0.03)
Number of households	931	3.18 (0.26)	911	3.20 (0.31)	931	3.06 (0.27)	911	3.17 (0.22)	-0.09 (0.29)
Area with official title (ha)	933	5.15 (0.44)	921	5.33 (0.71)	933	4.53 (0.29)	911	5.38 (0.90)	-0.65 (0.54)
Cultivated area (ha)	932	4.19 (0.25)	918	4.43 (0.54)	932	4.01 (0.26)	918	4.48 (0.55)	-0.23 (0.29)
Irrigated area (ha)	933	4.15 (0.24)	917	4.05 (0.51)	933	3.95 (0.25)	917	4.18 (0.47)	-0.32 (0.29)
% farms cultivating cotton	929	0.67 (0.03)	919	0.47 (0.06)	929	0.70 (0.03)	919	0.49 (0.05)	0.01 (0.02)
Area under cotton cultivation (ha)	545	3.27 (0.29)	382	3.95 (0.73)	545	3.18 (0.29)	382	3.81 (0.84)	0.05 (0.27)

Table 5: Effect of longer training on farmer participation

	Irrigation fees paid	Membership fees paid	# man-days labor	Farm signed a water contract	Farm attended WUA meetings
Longer training	-0.06(0.05)	0.08 (0.05)*	7.10 (2.40)***	0.20 (0.05)***	0.09 (0.04)**
Farm operated by non-trained male	-0.02 (0.04)	-0.02 (0.02)	-2.43 (1.85)*	-0.02 (0.03)	-0.01(0.02)
Farm operated by female	0.03 (0.05)	-0.09 (0.03)***	3.21 (1.94)	-0.11 (0.04)**	-0.03 (0.01)*
Number of members	-0.00 (0.00)	-0.00 (0.00)	-0.09 (0.11)	0.00 (0.00)**	0.00 (0.00)
Share of members that were female	-0.05 (0.05)	-0.01 (0.03)	2.88 (2.29)	-0.00 (0.05)	0.01 (0.03)
Share of members that work permanently	-0.03 (0.03)	-0.00 (0.03)	-2.96 (2.47)	0.01 (0.05)	-0.03 (0.03)
Number of households	0.01 (0.00)*	0.00 (0.000	0.03 (0.28)	-0.00 (0.00)	-0.00 (0.00)
Area with official title	0.00 (0.00)	0.00 (0.00)*	0.03 (0.08)	0.00 (0.00)	-0.00 (0.00)
Cultivated area	0.01(0.01)	0.00 (0.00)	0.52 (1.03)	0.01 (0.01)*	0.01 (0.01)
Irrigated area	-0.02(0.01)**	-0.00 (0.00)	-0.39 (0.92)	0.01 (0.01)*	-0.01 (0.00)*
Area under cotton cultivation	-0.00 (0.01)	-0.00 (0.00)	-0.20 (0.37)	-0.00 (0.00)	0.00 (0.00)
Number of observations	1753	1753	1561	1753	1753
F-statistic	F (20, 60) = 1.21	F(20, 60)= 0.98	F(20, 60)=2.34	F(20,60)=3.48	F(20,60)=1.51
Prob > F	0.28	0.57	0.01	0.00	0.09
R-squared	0.02	0.04	0.02	0.09	0.03

Appendix 3

Buisson, M.C.; Balasubramanya, S. 2018. The effect of irrigation service delivery and training in agronomy on crop choice in Tajikistan. In review at *Land Use Policy.*

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

Keywords: irrigation delivery, agricultural extension, water user associations, agricultural production, Tajikistan

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) between 2011 and 2013. While all WUAs received training to improve irrigation delivery services, some also received training in cropping alternatives 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.

1. Introduction

In this article, we analyze the effect of irrigation service delivery and training in agronomy on crop choice made on Tajik *dehkan* farms. 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, 2018), in an environment where the cultivation of cotton had, until rather recently, been mandated. The 2017 Global Hunger Index suggests that ~30% of the country's population in undernourished (WFP, 2017). In 2013, around 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, 2018). 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, 2018). However, agricultural markets continue to support the cultivation of cotton even today (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.[35,36]

When the Soviet Union disintegrated, the government of Tajikistan introduced land reforms in the early 1990s to confer cultivation rights on households by decollectivizing the Soviet collective farms that specialized in cotton cultivation. However, large stretches of agricultural land were left fallow during the 1990s and early 2000s due to the lack of irrigation services that could manage the needs of thousands of smaller farms, rather than one large collective farm (Gunchinma & Yakubov, 2010). With support from

[35] 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.

[36] 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.

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. 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 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. 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 1,956 *dehkan* farms, with a 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. Finally, a representative sample of farms in southern Tajikistan within the selected subdistricts was selected through a stratified random sampling process.

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 effects or impacts of USAID WUA intervention, which combined water management with extension services. This is because of the absence of data on production choices before the interventions began.

The results suggest that decisions pertaining to cultivated areas of cotton and wheat, and the cropping intensity of the farm are dependent on water delivery services, while decisions pertaining to the cultivated areas of high-value crops and crop diversity are dependent on agricultural extension services. From a policy perspective, the results provide evidence for designing programs that coordinate water and agricultural extension interventions for stimulating the agricultural sector.

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 5 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

In Tajikistan, agriculture is the main sector of the economy, providing around 50% of the employment and contributing around 25% of the country's gross domestic product (ADB, 2016). 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. A typical *dehkan* farm is around 3-5 ha in size; and is usually farmed by around 3 households[37]. By 2008, the reforms undertaken after the civil war brought agricultural production back to its level at the time of independence (Lerman & Sedik, 2008). Land continues to remains state property, but farmers have the right to cultivate *dehkan* farms and to transfer their allotted farms through inheritance (Abbott, 2016).

As compared to the pre-independence system, these land reforms reduced control by the government on production choices. Yet, cotton fiber continues to be the country's second highest export earner, accounting for 15% of the total export revenues in 2014. The Government of Tajikistan continues to regulate cotton prices, and all cotton harvests are purchased by a few companies that export to the global market. At the country level, areas under cotton cultivation declined in the 1990s and 2000s, but production has remained stable after 2008, suggesting an increase in yields (Government of Tajikistan,

[37] A household is defined as a set of individuals who live in the same dwelling and share food cooked in the same kitchen.

2007). At the farm level, cotton is still the most commonly cultivated cash crop, in part because cultivating cotton provides inputs such as stalks for heating and crop residue for fodder. The well-regulated structure of the cotton market; relations between farmers and cotton purchasers that provide inputs and loans towards cotton cultivation; and community norms 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). Around 40% of the wheat consumed in Tajikistan is imported from Russia (Muminjanov *et al.*, 2016). 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. These dietary customs combined with fluctuating prices of imported wheat provide strong incentives for farmers to choose to cultivate wheat for self-consumption. The area under wheat cultivation has more than doubled since independence in 1991. This pattern of cotton and wheat cultivation is rather predominant, and is colloquially termed a 'cotton for cash, wheat for food' model. The entire cotton harvest is sold for cash, while a significant share of the wheat harvest is retained for self-consumption.

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 (Gunchinma & Yakubov, 2010). Tajikistan passed the 'Law on WUAs' 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, USAID WUAs were provided longer training in irrigation delivery and management.

Beyond the primary training related to water delivery, and in the absence of formal agricultural extension services in the country, USAID-established WUAS were also imparted training on agricultural

technologies both formally through training and informally through farmer gatherings. Information on improved cultivation practices and inputs for cotton and wheat (the traditional crops) was provided. 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 (such commodities largely made their way into Tajikistan from other republics under the central planning economic system). 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.

3. Conceptual framework

Cotton and wheat production, the traditional crops in the irrigated agricultural areas, of Tajikistan faces several risks. The productivity of wheat and cotton is likely to fall due to the impacts of climate change in the Central Asian region (Mannig *et al.*, 2013; Bobojonov & Aw-Hassan, 2014; Sommer *et al.*, 2013).[38] Cotton is a highly water-dependent cash crop; deterioration of irrigation infrastructure and irrigation management decreases the quantities of water available, and the periods during which water is available for cultivation, thus affecting farmers' choices of cultivated area. The production of wheat, which is less dependent on water, depends on the types of cultivation practices (Wang et al., 2009; Wang et al., 2018); which could be influenced through the provision of extension services. In the context of Tajikistan, improvements in water delivery services and introduction of better technologies to cultivate cotton and wheat may increase agricultural production by expanding cultivated areas or improving yields (Birthal *et al.*, 2015; Kasem and Thapa, 2011).

Improvements in irrigation infrastructure and management may improve water availability and 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 addition, 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). 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; Bobojanov et al., 2013). With the mandatory cultivation of cotton relaxed, engagement with

[38] Risk management mechanisms such as forward markets and crop insurance are hitherto limited in their availability in Tajikistan.

agricultural extension services may likely expand the variety of crops cultivated (Winters, 2006). Extension services have been found to play an important role 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).

Increases in cultivation of number and acreage of other crops in Tajikistan may take place along with increases or decreases in the area under cotton and wheat cultivation 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 seasonal crops. In the context of Tajikistan, an increase in the variety of crops cultivated can reduce environmental damages generated due to historical mono-cropping of cotton by reducing: nutrient loss in soils (Hooper and Vitousek, 1997; Reich et al., 2001); soil salinity (Bobojonov et al., 2013); and risks from pests and climate change (Winters et al., 2006). The incentives to increase variety of crops are likely to arise more from the perspective of improving quality of recently decollectivized land that farmers now bear user rights to, and to cultivate consumption crops that were historically imported. Income generating incentives that encourage expansion of the number of crops cultivated may also gain importance as the (nascent) agricultural processing sector and markets develop (Bobojonov and Lamers, 2008).

4. Econometric methods

In this section, 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:

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

D_{ijt} represents the following (in different regressions): cultivated areas of cotton, of wheat and of other crops on farm i in subdistrict[39] j in time t; 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; the Margalef's index of diversity for farm i in subdistrict j in time t.

[39] Tajikistan is divided into 4 provinces. Each province is divided into districts. Each district is divided into subdistricts. WUAs typically provide water to *dehkan* farms in 1-2 subdistricts.

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.[40] 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 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 when the determinants of cultivated areas of cotton, wheat and high-value crops; and the Margalef's index of

[40] 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.

diversity[41] 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[42] are examine. In all cases, standard errors are clustered at *jamoat* level to allow for intragroup correlation of the standard errors.

5. Study design and data

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. A complete list of attributes used to construct these propensity scores can be found in Table 1. 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. Matching was conducted to control for selection bias 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 (a sample size of 2,000 farms in all). This sampling method randomly selects the nine types

[41] The Margalef's Index of Diversity (MID), commonly used for measuring biodiversity, is defined in this context as the number of crops cultivated per hectare of land area, and is calculated as:
MID=(N-1)/(ln(A+1)), where N is the number of crops cultivated and A is the total area cultivated by the farm.

[42] Cropping intensity of a plot on the farm was calculated as the gross cropped area divided by the net sown area, multiplied by 100 per plot. This indicates the number of times the same plot on the farm was used during one agricultural year.

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 a summary of these variables, which are also used during the econometric analysis in section 7 to control for other factors that affect choices pertaining to cultivated areas, number of crops cultivated, crop diversity, and cropping intensity.

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 an average of ~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, 13% of farms were headed by women, this increased to 38% in 2018.

Cotton and wheat are the most commonly cultivated crops by farms. In the sample, 56.1% of farms cultivated cotton and 58.5% cultivated wheat in 2014 (Figure 1). This scenario did not change much between 2014 and 2016, with 59.5% farms cultivating cotton and 63.7% farms cultivating wheat in 2016. High-value crops were not cultivated by more than 15% of the farms in 2014. There was an increase in the number of farmers cultivating tomatoes, onions, potatoes, melons and clover between 2014 and 2016. Potatoes were cultivated by 10.9% of the farms in 2014 and increased to 17.7% in 2016 ($p < 0.01$). A significant share of the net cultivated area constituted cotton cultivation. In 2014, cotton was cultivated on 3.5 ha, which was equivalent to 67.1% of the net cultivated area of the farm (Figure 2). The cultivated area of wheat was lower, at 1.6 ha in 2014, which was equivalent to 44% of the net cultivated

area. 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. There was a decrease in the areas under cotton and wheat by 7.1% and 15.2%, respectively, between 2014 and 2016.

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 between the two years is significant at 1%. The Margalef's Index of Diversity (MID), commonly used for measuring biodiversity and defined in this context as the number of crops cultivated per hectare of land area, was calculated as:

$$MID = \frac{N-1}{\ln(A+1)} \qquad (3)$$

where N is the number of crops cultivated and A is the total area cultivated by the farm. On average, this indicator was 1.67 in 2014 and increased to 2.03 in 2016, with the difference significant at 1%. Finally, the cropping intensity of a plot on the farm was calculated as the gross cropped area divided by the net sown area, multiplied by 100 per plot. This indicates the number of times the same plot on the farm was used during one agricultural year. In the sample, cropping intensity was limited, centered around 100, and generally, only one crop was cultivated per plot per year even if the cropping intensity significantly increased from 2014 to 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 could 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 thought that fairness in water sharing had improved 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 exchanges.

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 again a significant determinant of the MID; farmers who perceived that the condition of the watercourse canal had improved had a MDI of 0.13 more that those who thought that there were no such improvements ($p<0.05$). The MDI has also higher by 0.29 ($p<0.01$) when a shareholder had received formal training in agricultural extension.

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.

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 result in this paper suggest that improvements in irrigation delivery services affect the cultivated areas of cotton and wheat, as well as

that of high-value crops. Irrigation services also determine the number of high-value crops cultivated and the cropping intensity. Formal training in agricultural extension significantly influences crop diversity.

From a policy perspective, this analysis highlights the role of a multifactorial approach in increasing cultivated areas, the number of crops cultivated, crop diversity, and cropping intensity. In a landscape where agricultural production was historically characterized by limited crop selection and where production in the agricultural sector had collapsed, better coordination between water management and agricultural extension programs may stimulate the agricultural sector. Moving forward, developing national agricultural extension services, along with expanding agricultural markets that supply quality inputs for cultivating fruits and vegetables will be important for easing supply-side constraints on diversification in production.

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Table 1: Constructing propensity scores

	Logit Treatment *Subdistrict*
Population of the subdistrict in 2014	0.00 (0.00)
Number of villages	0.033 (0.05)
Total area of the subdistrict	0.00 (0.00)***
Majority of population Tajik (dummy)	-0.69 (0.54)
Number of secondary schools in subdistrict	0.07 (0.08)
Number of rural health centers in the subdistrict	-0.54 (0.19)***
Number of agricultural markets in the subdistrict	0.40 (0.29)
Chairman born in the subdistrict (dummy)	0.16 (0.64)
Number of years of election of the chairman	-0.07 (0.07)
Elevation of the subdistrict (m ASL)	0.00(0.00)
Sandy soil (dummy)	0.00 (0.55)
Deep groundwater level (dummy)	-0.81 (0.52)
Land reform completed (dummy)	2.54 (0.69)***
Cotton main crop of the subdistrict (dummy)	2.84 (0.66)***
Subdistrict irrigated by gravity system (dummy)	0.61 (0.67)
Constant	-3.89 (1.49)***
Pseudo R^2	0.402
Sample size	164

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

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

Table 2: Variables for which data was collected for the 2014 and 2016 cropping year

		2014			2014		
		#	Mean	Std. Dev	#	Mean	Std. Dev
DEPENDANT VARIABLES	Cultivated area of cotton (ha)	1956	1.95	5.10	1956	1.82	5.53
	Cultivated area of wheat (ha)	1956	0.96	2.32	1956	0.89	2.04
	Cultivated area of high-value crops (ha)	1956	1.22	4.22	1956	1.45	3.95
	Number of high-value crops (#)	1956	1.79	1.59	1848	2.10	1.74
	Margalef's index	1917	1.67	1.71	1845	2.03	1.87
	Cropping intensity	1902	96.90	34.75	1825	107.87	39.47
FARM CHARACTERISTICS	Area of the farm (ha)	1950	4.40	8.70	1854	4.24	8.15
	Distance of farm to road (kms.)	1914	1.43	2.19	1914	1.43	2.19
	Age of farm (years since farm allotted) (#)	1899	6.26	4.87	1899	8.26	4.87
SHAREHOLDER CHARACTERISTICS	Number of shareholders (#)	1936	7.42	11.10	1853	6.55	9.77
	Proportion of female shareholders	1882	0.47	0.25	1848	0.52	0.24
	Age of the manager of the farm (#)	1854	49.39	12.81	1854	50.39	12.81
	Education of farm manager(categorical)	1855	3.89	1.23	1855	3.89	1.23
	Female farm manager (dummy)	1956	0.13	0.33	1956	0.38	0.48
WATER DELIVERY	Perception of fairness of water sharing (categorical)	1327	2.90	0.59	1848	2.81	0.59
	Perceived timeliness of water distribution improved (dummy)	1956	0.42	0.49	1956	0.42	0.49
	Perceived quantity of water received improved(dummy)	1956	0.43	0.49	1956	0.43	0.49
	Perceived condition of water course canal (categorical)	1893	2.45	0.85	1822	2.58	0.80
	Perceived condition of distributary canal (categorical)	1876	2.39	0.84	1812	2.48	0.81
AGR EXTENSION SERVICES	Shareholder received training in extension (dummy)	1899	0.29	0.45	1855	0.38	0.48
	Frequency interaction with agriculture/water group (categorical)	1937	0.91	1.42	1956	1.19	1.19

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

	2014		2016		Difference (2016 – 2014)
	Mean	Standard Deviation	Mean	Standard Deviation	
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

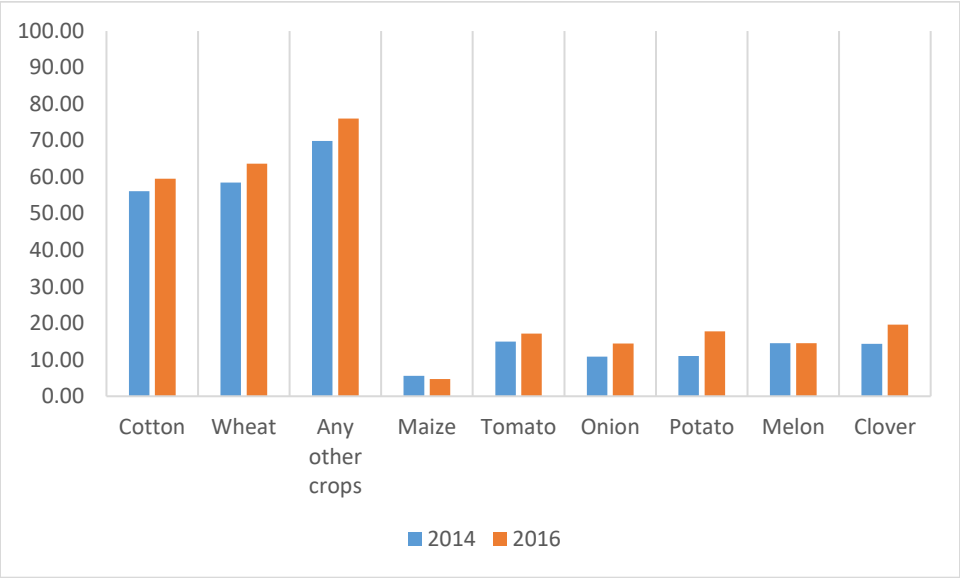
Notes: Robust standard errors are included in parentheses. ***implies p<0.01, ** implies p<0.05, and * implies p<0.1. In addition to the variables included in this table, the following variables were also included: a constant, dummies variables for the type of canal serving the farm (primary, secondary, 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

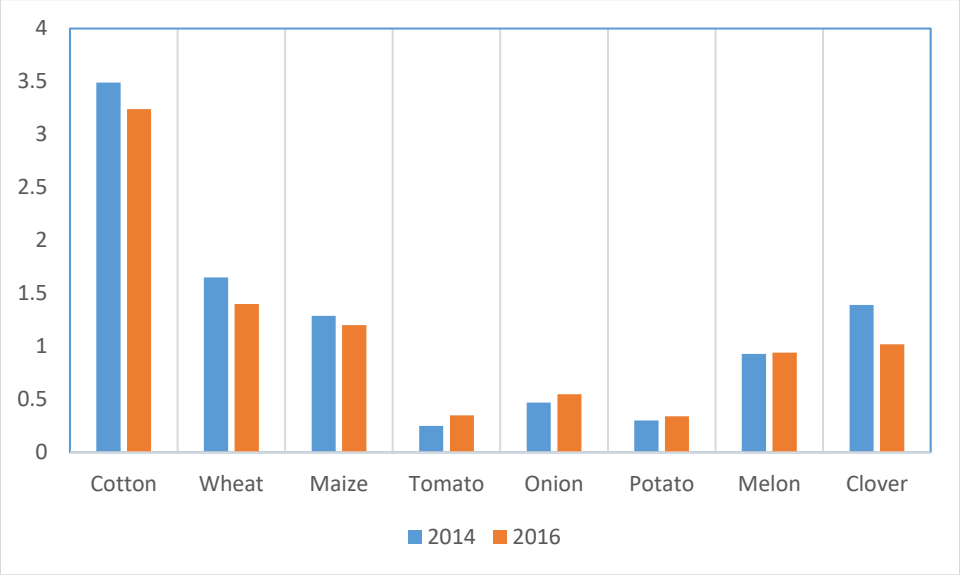
Notes: Robust standard errors are included in parentheses. ***implies p<0.01, ** implies p<0.05, and * implies p<0.1. In addition to the variables included in this table, the following variables were also included: a constant, dummies variables for the type of canal serving the farm (primary, secondary, 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 9: Share of farms cultivating different crops



Source: Authors' calculation based on survey data collected

Figure 10: Cultivated area of different crops (ha)



Source: Authors' calculation based on survey data collected

Appendix 4

Price, J.; Balasubramanya, S. 2018. The role of the *mahalla* in local water dispute resolution in Tajikistan. Revise and resubmit at *Central Asian Survey.*

Title: The role of the *mahalla* in local water dispute resolution in Tajikistan

Keywords: dispute resolution, *mahalla*, water user associations, Tajikistan

Abstract: This article examines how *mahalla* committees interact with newly introduced water user associations (WUAs) in Tajikistan, following institutional reforms after the disintegration of the Soviet Union and the civil war. The study adopts a qualitative approach using data from elite interviews in Dushanbe, and a case study in Khatlon Province. While not well-recognised in formal legislation, the *mahalla* committee is found here to play a significant role in local water governance and dispute resolution in practice. Since they regulate water for 'kitchen gardens', *mahalla* leaders often coordinate with WUA leaders to resolve prevailing disputes between water users from different plot types. In some cases, however, *mahalla* leaders dominate new water-related institutions and services. These findings are particularly significant due to the increase in kitchen gardens in the context of increased male out-migration to Russia, and might suggest a need for revisiting the status of the *mahalla* in policy.

1. Introduction

Within the theory and practice of institutional reform, there has been a growing interest in the importance of pre-existing forms of governance (World Bank, 2017). In developing countries, these forms can often be informal – not legally recognised – but still wield significant and persistent power. Local water governance and dispute resolution in Tajikistan presents one such case. Newly introduced water user associations (WUAs)[1] are mandated by law to provide irrigation services, including a dispute resolution mechanism, but water disputes prevail and are also found to be resolved by alternative means

[1] WUAs have been introduced in Tajikistan since the earlier 2000s, as part of water sector reforms after the disintegration of the Soviet Union in 1991 and the ensuing civil war.

unidentified in recent studies (Balasubramanya, Price and Horbulyk, 2018). This presents an empirical puzzle.

Local governance in Tajikistan and wider Central Asia historically has been characterised by the existence of *mahalla* committees, which have endured pre-Soviet, Soviet and civil war eras (Sievers, 2002). The *mahalla* committee can be defined as 'elected representatives of community members', including a leader, 'who mediate to stabilise contested political and economic relations' (Asian Development Bank (ADB), 2011: 1; Mandler, 2010: 7). The word '*mahalla*' translates as 'neighbourhood', or the unit of the village in rural contexts. *Mahalla* committees are known traditionally to be an important institution in community affairs, from water allocation to resolving general conflict. This article therefore seeks to answer: what is the role of the *mahalla* committee in local water dispute resolution in Tajikistan, and how does the *mahalla* committee interact with WUAs?

Mahalla committees are often over-looked among policy interventions and donor programmes, as well as in the literature (United States Agency for International Development (USAID), 2013; Republic of Tajikistan, 2009). As suggested by Freizer (2004), 'there is room for greater cooperation and division of competencies between *jamoats*[2], *mahallas,* higher government authorities, local NGOs and international donor agencies'.

Tajikistan has considerable potential for, and experience with, water disputes at both local and transboundary levels. Localised conflict has punctuated the contested border regions in the Ferghana Valley in the north of the country (Bichsel, 2009), while the densely populated cotton-growing Khatlon Province experiences disagreements over in-demand land and water resources. This research therefore addresses a salient issue, identifying the *de facto* collection of governance arrangements – formal and informal.

[2] A *jamoat* is an administrative unit within a district. In other countries, the equivalent of a *jamoat* is a sub-district. In Tajikistan, a collection of *jamoats* makes up a district.

The article employs qualitative methods to investigate governance forms and phenomena that are not easily visible from quantitative or formal legal analysis. It advances the proposition that 'policy making and policy implementation do not occur in a vacuum. Rather, they take place in complex political and social settings, in which individuals and groups with unequal power interact within changing rules as they pursue conflicting interests' (World Bank, 2017: 283). The article examines Tajikistan as one such setting, using data from interviews conducted in Dushanbe and rural Khatlon in 2017 to form the basis of the analysis. This is supplemented by consulting formal legal documents, against which to contrast *de facto* governance dynamics. Interviews were conducted at multiple levels of governance, to uncover the causal mechanisms of disputes and better define resolution processes in practice. There is a lack of up-to-date accounts of the role and influence of *mahalla* committees in general in Tajikistan, but particularly regarding how *mahalla* committees relate to institutions and institutional reforms introduced following the disintegration of the Soviet Union and the civil war in the 1990s. This article addresses this broader gap in the literature, as well as the specifics of water dispute resolution in practice.

The research finds that the *mahalla* committee does indeed play a significant role in local water governance in Tajikistan. The *mahalla* leader regulates water for household 'kitchen gardens', while WUAs govern matters concerning private *dehkan* farms. There are many disputes between different water users from different plot types, due to kitchen garden water users diverting canal irrigation water to their plots (before the water reaches *dehkan* farms). In these instances, the *mahalla* leader often coordinates with the WUA leader to resolve the dispute. The form of dispute outlined also relates to fee payment disputes between *dehkan* farms and WUAs, since water users from *dehkan* farms resent paying fees when kitchen garden water users are perceived as not paying for water-related services in the same way. Although effective coordination between the *mahalla* committee and the WUA exists, there are also cases of *mahalla* leaders seeking to dominate new water-related services.

Section 2 provides a context for examining water disputes and their resolution in Tajikistan. Section 3 reviews the literature; first constructing a conceptual framework, then comparing empirical cases where these concepts apply. Section 4 outlines the methodology, while Section 5 proceeds with the analysis of qualitative data. Finally, Section 6 aggregates the results and discusses them in relation to the existing literature and the context, before Section 7 offers policy implications and avenues for future research.

2. Context

The *mahalla* committee as an institution can be traced back to medieval Central Asia, but is neither temporally static nor spatially uniform. Originally, the *mahalla* was a central unit of socio-political organisation based around kinship ties and the geographic area, and it often superseded other potentially more divisive features such as religion, language or class (Sievers, 2002). The *mahalla* committee provided services for its residents and a framework for general 'social securing functions' (Poos, 2011: 5), outside of the structures of the state. More recently, during the Soviet period, *mahalla* committees were subverted but not entirely abolished[3].

In post-war Tajikistan, Mandler (2010: 2) advises that 'it is not the state that controls local affairs'. This is especially the case in rural communities, where local networks and kinship ties shape daily life. The *mahalla* committee remains a mediator of these affairs. It is known to play a role in general relations between neighbours and within families (Freizer, 2004). Less clear, is the specific role that it plays in local water governance, in relation to WUAs.

Several authors maintain how, in some villages, the *mahalla* committee may be more trusted as a reliable form of governance than the state and development agencies (Boboyorov, 2013; Sehring, 2009).

[3] The reasons for this are subject to debate, but are suggested to be either due to risks of revolt or that the *mahalla* committee could complement Soviet societal goals, if moderated (Sievers, 2002).

Boboyorov (2013: 26) goes as far as to assert that 'people do not trust the state and development institutions due to the short-term, unstable and unpredictable protection they offer in Tajikistan. Instead, *mahalla* serves to transform these institutions into long-term reciprocal networks which then reduce political and economic uncertainties and threats'. For example, formal courts may be distrusted or deemed ineffective by citizens. To give a sense of the potential local power held by *mahalla* committees, Noori (2006: 538) explains that 'neither state courts nor the local government are authorised to intervene in disputes involving residents, unless one of the parties obtains written permission from his or her *mahalla* committee documenting the committee's intervention or attempt at reconciliation.'

In the agricultural communities in southern Tajikistan, the *mahalla* committee often consists of an elected *mahalla* leader, village elders, respected Islamic clerics, and other locally powerful individuals (Boboyorov, 2013; Cieslewska, 2010). These figures form a committee and typically meet in a designated *chaikhana* (teahouse) to discuss and mediate affairs. They base their activities and decisions on traditional unwritten rules. Sievers (2002) notes how social harmony is often emphasised over absolute justice as a goal of dispute resolution. Some scholars and Western policymakers view this as one of the negative aspects of *mahalla* committees, alongside perceptions that they are defined by patriarchal or unequal power structures (Cieslewska, 2010). As such, the *mahalla* committee is viewed as a negative institution by some actors, and as a positive one by others.

Tajikistan is home to a predominantly agrarian population, many of whom inhabit the densely populated arable land in cotton-growing Khatlon in the south-west (Abdullaev and Barnes, 2001). There is a strong agricultural tradition, advanced by the Soviet Union which designated the southern part of the Tajik Soviet Socialist Republic as Central Asia's main cotton producing hub. Since the disintegration of the Soviet Union in 1991, cotton cultivation – which requires substantial water – remains the main source of Gross Domestic Product in Tajikistan (Food and Agriculture Organization of the United Nations, 2012).

However, while agricultural activities have continued, the land tenure underpinning them has shifted significantly. Collective farms from the Soviet Union were broken down into private *dehkan* farms, with their irrigation services provided by community-based participatory WUAs, as part of a logic of increased decentralisation and democratisation. Notably, WUA membership is for *dehkan* farms and other entrepreneurial entities (Republic of Tajikistan, 2006). Recently, land use has been influenced by an increase in male out-migration to Russia for labour. As a result, women are increasingly left to cultivate crops at home on 'kitchen gardens', which are small plots attached to houses (or in the vicinity of a residence) used to grow crops for subsistence. The increase in male migration has thus led to a greater prominence of kitchen gardens. Kitchen gardens cannot become members of WUAs by law, since they are not considered entrepreneurial entities (Republic of Tajikistan, 2006).

3. Literature review

Conceptual framework

While one may associate the term 'governance' with official organs of the state, practitioners and scholars have recently acknowledged that governance may be provided by a variety of actors (Skarbek, 2011; Denyer Willis, 2014; World Bank, 2017). For example, Skarbek (2011: 702) underlines that 'centralised governments and competing, overlapping, governance organizations can both provide governance institutions that resolve disputes, secure property rights, and limit negative externalities'. A broad conception of governance is thus: 'the process through which state and non-state actors interact to design and implement policies within a given set of formal and informal rules that shape and are shaped by power' (World Bank, 2017: 3).

In light of this definition, there is a distinction between 'formal' and 'informal' governance (i.e. official governance provided for, or regulated, by the state, and governance provided by non-state actors). The *mahalla* council is an example of a mode of informal governance. Especially in contexts of political

and economic transition, some scholars reflect on the reality of 'hybrid arrangements' of formal and informal governance (Meagher, De Herdt and Titeca, 2014; Koehler, 2004). Rather than newly created institutions discretely replacing old ones, the reality on the ground is often that a *bricolage* of institutions interact, and contest or coordinate in a more disorderly fashion (Sehring, 2009). In particular, this may be the case when the institutions are externally devised (as is the case with WUAs). As a result, one can view institutions in terms of their 'form versus function' (World Bank, 2017: 5). Different forms of institution (formal or informal) may carry out the same functions in practice (or may be capable of doing so); or may combine to carry out a function. Some scholars argue further that governance functions must be accompanied by specific accountabilities and oversight in order to be complete or effective (Jepson, 2005).

Water dispute resolution is an example of a governance function (Joffé, 2015); it may be provided by a wide range of institutions - the state, non-governmental organisations (NGOs), foreign governments, development agencies, or traditional informal institutions. If a function such as dispute resolution is provided by a traditional institution, then the power dynamics and historical continuity associated with the institution mean that it may remain the outlet of preference for citizens, and may be firmly established as the provider of the governance function due its influence in local politics. These considerations arise during and after institutional reform, where carefully-designed policies can seem optimal in principle, but may meet a complex political environment on the ground. In such cases, interaction and compromise may be unavoidable (Knaus and Stewart, 2011).

Empirical cases

Globally, there are numerous cases of informal modes of governance playing an important role in local water dispute resolution, where one can examine the institutional interactions born from modern policy interventions. Joffé (2015) outlines water governance mechanisms in North Africa, highlighting the durable nature of traditional water allocation and dispute resolution practices within the Berber

population. He demonstrates how these practices have, in fact, informed recent democratic developments in the region, rather than colliding with formal and newer forms of governance. Stewart (2004) provides an account of the patterns of local governance in Afghanistan, observing the local power held by informal village-level structures. By contrast, he describes the challenges arising when external powers (such as foreign governments and development agencies) sought to establish formal democratic and decentralised institutions, and how these collided with traditional informal institutions when there was insufficient recognition of their pre-existence.

In Central Asia, Sehring (2009) notes that path dependencies[4] can limit the effectiveness of institutional reform. She explains how 'rules and organisations established formally by the state and or international donor organisations are undermined by informal institutions. Yet informal institutions are not only an obstacle to reform, but can also support it'. Related to this, Koehler (2004) describes how, in practice, such hybrid arrangements combine to impact the occurrence and processing of conflict in Central Asia.

Stevens (2005: 282) reflects on interactions between *mahalla* committees and modern NGOs in Uzbekistan, citing the '*Mahalla* Initiative Program' – 'one of the earliest attempts at incorporating the *mahalla* into donor programming'. He concludes that there is significant complementarity between NGOs and *mahalla* committees, and cautions that, without accommodation, *mahalla* leaders may 'seek to consolidate their constituencies and may be best placed to take advantage of political liberalisation' (Stevens, 2005: 293). In Kyrgyzstan, WUAs were introduced in the 1990s - slightly earlier than in Tajikistan. Farmers were still found to turn towards traditional institutions in the case of conflict, but, again, Sehring (2005) indicates how these institutions 'can support WUAs'. These findings from elsewhere in the region frame the potential issues surrounding the role of the *mahalla* committee in Tajikistan that are examined in this empirical enquiry.

[4] i.e. current practices based on historical preference

4. Methodology

The research adopts a qualitative approach using data from interviews, and from a case study of a village in southern Tajikistan to provide supportive evidence. Combined with elite interviews of broader geographic scope, the case study allows for a deeper analysis to uncover and define the causal mechanisms of disputes, and the detail of their resolution in practice. Interviews were conducted, ranging from the highest relevant central government authorities, through local government, and the WUA leader, *mahalla* leader and water users in the case study village (see Table 1). Consulting all levels allows for comparison of issues and themes to determine whether different actors are highlighting the same points. The case study selection was derived from quantitative results in a previous study on WUAs in Tajikistan (Balasubramanya, Price and Horbulyk, 2018.). The WUA jurisdiction with the greatest number of water disputes in that study's sample, and where disputes were not always resolved by the WUA alone, was selected (a village in Vakhsh District, Khatlon Province – 'Obishirin 2016' WUA).

A purposive sampling method was used in the selection of formal pre-arranged interviews, while a snowballing sample method allowed for informal discussions with water users in the case study village (Table 1). Interviews were semi-structured, with mostly open-ended questions. A voice recorder was used to record interviews (if endorsed by the interviewee), and anonymity was guaranteed for government officials. Interviews were later analysed using framework analysis (Ritchie and Lewis, 2003). Finally, after conducting the interviews, further information regarding the legal status of the *mahalla* was collected.

Findings from a single case study cannot claim to provide generalisable results that are representative of the region or country at large. In addition, fieldwork time was limited to ten days, meaning it was not possible to interview a very large number of stakeholders, or spend an extended period of time observing in great detail water governance and dispute resolution practice in the case study village. Nevertheless, the fieldwork still produced rich and nuanced perspectives from key actors at all

levels. It uncovered some of the mechanisms of dispute resolution that are not always visible through quantitative survey data or formal legal analysis.

Table 1: Interviews conducted during fieldwork in Tajikistan, August 2017

1.	Tax Administration Authority interviewee
2.	Ministry of Land Reclamation and Water Resources interviewee
3.	Local government (district) interviewee
4.	WUA leader (case study village, Vakhsh)
5.	*Mahalla* leader (case study village, Vakhsh)
6.	Water users (case study village, Vakhsh)

5. Analysis

The mahalla, de jure

The *mahalla* is almost completely absent in Tajik legislation today, and had no clear legal status and definition during the Soviet period. After the collapse of Soviet Union in 1991, Tajikistan launched a series of public administration reforms, which defined the main public authorities. New laws were articulated and established accordingly. Part of this re-structuring involved the designation of WUAs as irrigation water providers, as stipulated in the WUA Law (Republic of Tajikistan, 2006). WUAs are mandated to perform functions including the 'provision of fair, effective and timely allocation of water resources', 'collection of payments for water supply services'; and 'solving disputes' (Kabilov, 2017).

In 2008, a new law on 'self-governance organisations' was enforced (Republic of Tajikistan, 2009). This formalised the generic concept of self-governance organisations, which may be established by members of local communities. *Mahalla* committees can only register officially as this type of organisation. Any group of local people may register a broad variety of organisations as self-governance organisations, which means that there are no clear formal jurisdictions or authorities for *mahalla* committees *per se*. As a result, *mahallas* do not have an explicit legal status. Although some legal documents indirectly refer to the *mahalla*, there are no separate regulations defining them and their

responsibilities. Indeed, the leader of the *mahalla* committee in the case study village, Vakhsh District, was unsure of his exact status in Tajik legislation. He was of the conviction that the activities of the *mahalla* committees are somehow related to the government and public affairs, but was not aware of any explicit written statements about the *mahalla* in Tajik law.

The mahalla, de facto

The role of the mahalla committee in local water governance

Most interviewees voluntarily shared information on the *de facto* role of the *mahalla* committee, including officials from government. They outlined the role of the *mahalla* committee in water governance across Tajikistan, describing how the *mahalla* leader typically regulates water for drinking and for kitchen gardens. The interviewee from the Ministry of Land Reclamation and Water Resources expressed that, currently, in many districts outside of Dushanbe, 'the *mahalla* committee plays an important role in solving this or that problem or improving the quality of life'. He described the form and functions of the institution, stating that the *mahalla* committee has a leader that is elected by people living there, and performs tasks such as 'creating schedules for using water' as a regulatory mechanism, and ensuring uniform use and cleanliness.

The *mahalla* leader in the case study village described a role in which he is in charge of water management for drinking water and for kitchen gardens for the people living within his *mahalla* (informal) jurisdiction. For drinking water, he is responsible for keeping the water clean. When there is a shortage of water, he creates the schedule for both drinking water and kitchen garden water supplies. The water for kitchen gardens comes primarily from taps which were fitted in the Soviet period. When kitchen garden water users have a problem, they visit the *mahalla* leader for support or advice, and the *mahalla* committee assembles to discuss these various community issues. For straightforward disputes, the

mahalla leader works as a mediator, bringing people together and 'kindly presenting both sides of an argument to each party' to stabilise community relations (*mahalla* leader, case study village).

Water users in the case study village recognised the importance of both the *mahalla* leader and the WUA leader. The users viewed the leaders' roles as complementary, seeing the *mahalla* leader as a coordinator, while the WUA leader implements more technical plans. Residents in the area seem comfortable approaching either leader, and do so depending on the issue in question. In some villages, the *mahalla* leader may be viewed as being more important than the WUA leader. Notably, the local government interviewee gave the strongest expression of the *mahalla* leader's local power in water governance which will be elaborated upon further.

The role of the mahalla committee in water dispute resolution

Because of the *mahalla* committee's local influence and importance – due to its role in regulating kitchen gardens and stabilising community relations - when a dispute arises, the *mahalla* leader often plays a direct role in dispute resolution. It was observed by the interviewee from the Tax Administration Authority that *mahalla* leaders' decisions may carry a lot of weight in communities and are often honoured in practice. One prevalent form of dispute concerns kitchen gardens and *dehkan* farms, and was detailed by both the local government interviewee and the *mahalla* leader in the case study village. When the taps for kitchen gardens are not functioning or there are water shortages, kitchen garden farmers seek alternative sources of irrigation water. In many villages, farmers from kitchen gardens set their pipes in canals and irrigate their plots. These water users divert water from canals that are administered by the WUA and are thus formally for use by *dehkan* farms. Especially when water is scarcer, this may mean that insufficient irrigation water reaches some of the *dehkan* farms, and they, too, do not receive enough water for cultivation. This problem is the cause of 'huge disputes', as formal *dehkan* water users visit the WUA leader and complain that kitchen gardens are taking their water. The *dehkan* farmers ask: 'Why is there a way for others to receive water for free?' (local government interviewee).

The *mahalla* leader is often central to the resolution of this form of dispute, due to his involvement with kitchen garden water users. The *mahalla* leader in the case study village explained how he is called upon by the WUA leader to resolve such disputes and the two leaders must coordinate together. The *mahalla* leader and the WUA leader thus meet with the parties concerned to resolve the dispute jointly in a conciliatory fashion. This form of dispute also compounds another form of dispute, whereby *dehkan* farm water users are reluctant to pay WUA fees for irrigation services. In part, this dispute is driven by lingering Soviet attitudes of non-payment for services deemed communal, and a lack of clarity in the law regarding what precisely is being paid for[5]. However, there is also a degree of resentment and reluctance to pay fees when *dehkan* farm water users observe kitchen garden water users receiving water for free.

Further mahalla committee-WUA interactions

The interactions examined, between the *mahalla* committee and the WUA appear inevitable in many settings in Tajikistan, such as the case study village in Vakhsh, Khatlon. In addition to dispute resolution, the *mahalla* leader in in the case study defined other more general interactions with the WUA leader. The *mahalla* leader is sometimes called upon by the WUA leader to provide assistance, and information shared in the interview suggested that water management-related responsibilities are well divided between these two important community figures. The *mahalla* leader must also interact and coordinate with other stakeholders involved in local governance. He negotiates with *mahalla* committees from neighbouring areas when necessary (and may be required to resolve disputes jointly with them in a similar manner as with the WUA leader). The *mahalla* leader must also interact with local government to gain permission for allocating drinking water to homes. This is despite the fact that the *mahalla* committee is not a formally recognised institution in the law. However, information from interviews shows that, in practice, the

[5] In the Water Code (Republic of Tajikistan, 2000), water itself is free; water users only pay for water-related services such as water delivery or related electricity fees. However, due to miscommunication of the laws, there is some confusion, such that some water users believe that they are paying for the water resources.

mahalla committee is accepted by other official local actors as playing an important role in local governance. District state authorities are known to authorise informally the *mahalla* committee as the institution to mediate and resolve some disputes.

According to the interviewee from the Tax Administration Authority, who offered an overview of *mahalla*-WUA interactions nationally, the *mahalla* committee does not always work closely with the WUA in every case. This can be the cause of some tensions. Since the WUA 's mandate is to serve *dehkan* farms alone, the WUA's conduct may not align with the *mahalla* leader's activities in regulating water for kitchen gardens. The local government interviewee shared stories of resource and service misappropriation in his district and elsewhere. In some cases, foreign governments and NGOs have built pumps and/or established WUAs in villages, but after the project was concluded, the *mahalla* leader dominated and regulated the water-related services according to his own policy; anyone who wanted water then had to consult the *mahalla* leader. The interviewee reported that this 'happens in many places' when projects are not established with a long-term vision. These findings suggest that the scope and dominance of the *mahalla* committee can vary in different contexts; its role may be more pervasive in some than others, and can depend on personalities and other circumstances.

6. Discussion

Analysis of *de facto* water governance and disputes in Tajikistan in this study indicates that the *mahalla* committee does indeed play a significant role, despite being absent in Tajik legislation. Involved in a range of water-related community affairs, the *mahalla* leader regulates water for household kitchen garden water users. This reality was found to have implications for water dispute resolution involving kitchen gardens and *dehkan* farms. Interviewees expressed that there are frequent disputes between different water users from different plot types, due to kitchen garden water users diverting canal irrigation water - formally for use by *dehkan* farm water users. In these instances, in the article's case study, the *mahalla*

leader coordinates with the WUA leader to resolve the dispute. The form of dispute outlined also relates to fee payment disputes between *dehkan* farms and WUAs, since water users from *dehkan* farms resent paying fees when they observe kitchen gardens obtaining water for free. Although coordination between the *mahalla* committee and the WUA was found to exist in the case study village in Vakhsh, Khatlon (and elsewhere), there are also cases of *mahalla* leader dominance. This demonstrates the potential local power held by *mahalla* leaders, and that they may involve themselves in certain activities without accountability or oversight.

Overall, these mixed findings showed both coordination and dominance as possible outcomes of interactions between the *mahalla* committee and a WUA. Two scenarios were observed: that either newly established WUAs function cooperatively alongside pre-existing *mahalla* committees (i.e. coordination), or that the *mahalla* committee asserts its local influence or dominates a newly established WUA (i.e. dominance). From this particular research, it does not appear that WUAs discretely replace pre-existing forms of local governance in Tajikistan.

The role of the *mahalla* in local disputes and their resolution in Tajikistan is therefore one of influence, regulation, coordination and mediation. It also has the potential to be one of misappropriation and dominance of local water governance. In practice, the *mahalla* committee appears to undertake specific tasks related to water governance. These tasks are recognised by officials in government, even if they are not formally recognised in the law. From this research, the main emphasis of *mahalla* committees' governance seems to be stabilising community relations to maintain social order.

Similar to Boboyorov (2013) and Noori's (2006) discussions, this research finds that some water users continue to recognise and turn to a traditional, informal institution (the *mahalla* committee) in Tajikistan. In addition, the findings are particularly significant in the context of the changes in the movement of labour and the associated increase in importance of kitchen gardens. In turn, this has implications for the role of the *mahalla* committee and its involvement in dispute resolution.

Findings here demonstrate continuity with, but also add to, existing concepts and accounts in the literature. The World Bank (2017: 3) definition of governance seems highly relevant in this case of rural Tajikistan. In villages, a function of governance – water dispute resolution - is provided by formal modes of governance (WUAs), but also informal modes of governance (the *mahalla*). The case study offers one example of 'hybrid arrangements' of governance. Here, different institutions interact to produce functions in a complex socio-political setting. This research resonates with Stewart (2004) and Sehring's (2009) analysis, highlighting the potential for traditional practices and informal institutions to undermine institutional reform in the region. In the accounts of *mahalla* leader dominance and misappropriation, there is evidence of *mahallas* seeking to 'consolidate their constituencies' as Stevens (2005: 293) warned. However, as Sehring (2009) suggests, such institutions may also coordinate with and support new policy endeavours, as was more the case in the village in Vakhsh, Khatlon. In resolving disputes and stabilising political and economic relations, the *mahalla* may play a significant role governing water resources and influencing community cohesion. Whether this influence is always positive or negative in terms of governance outcomes such as justice or equality is not conclusive from this research.

7. Policy implications and future research

This research has three implications for policy in Tajikistan, and may also provide broader lessons. Firstly, since the findings indicate that the *mahalla* committee is active in local water governance *de facto*, and is recognised by local citizens, there may be a need for greater formal recognition in the law, and when developing, implementing and monitoring institutional reforms. Secondly, the findings suggest that encouraging coordination between the *mahalla* committee and the WUA (particularly the leaders) may result in more functional governance and the stabilisation of disputes. It appears important to recognise the realities on the ground, and the role of *mahalla* committees, since failure to do so may facilitate dominance and misappropriation. Finally, the potential for misappropriation of newly introduced water-

related services underlines the importance of long-term monitoring and evaluation of institutional reform projects.

Mahalla committees fulfil certain roles without formal accountability or oversight. However, it was beyond the scope of the article to assess the effectiveness or desirability of the *mahalla* committee's role in water governance, and to trace what happens after water disputes are resolved in the manner documented in this article. There was no opportunity to examine scenarios of non-compliance or the possible sanctions that a *mahalla* committee might impose. Further research into water disputes and institutional interactions addressing these issues could build on the findings from this research, and, in so doing, develop a greater understanding of the scope of the *mahalla* committee in Tajikistan.

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Appendix 5

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Title: Local water management in Tajikistan: legal framework

Keywords: Tajikistan, WUA, water law, water management, contract

Abstract: *Water management plays an important role in the economy of Central Asian states. With the transition into post-Soviet era, the States implemented several phases of agricultural reforms. The establishment of the Water User Associations (WUAs) in Tajikistan started in the 1990s following the implementation of the first phase of Land Reforms in 1998-2000. Main purposes of creating such WUAs, often initiated and supported by international donors, is to operate, maintain and use on-farm irrigation system with the purpose of on-time, adequate and reliable water supply to its water users. No reforms take place in a vacuum. Effective legislative framework is needed to support new initiatives and institutional settings. While a WUA being a separate legal entity, it has certain obligations both provided in law and in the contracts they sign. These obligations then transformed into liabilities when non-performance or mal-performance occur. Therefore, it is important to know what the law says about the chain of water management and the relationships involved, where WUA stands as an intermediate institution between State water organizations and farmers, the ultimate water users. This paper will look into these legal settings and endeavours to explain the complex nature of local water management in Tajikistan from the perspective of the law.*

1. Introduction

Tajikistan is a civil law country with laws being codified in the codes and legal-normative acts, and the judicial decisions as legal precedent, unlike in common law countries, are not the sources of law. Since its independence in 1991, Tajikistan has undertaken an effort to build its legal system entirely anew and towards the end of 1990s has seen most of the laws and other normative acts being adopted by independent Tajikistan.

However, it should be noted that many laws in Tajikistan, especially the ones that are believed to play important role in the legal system and in the economic development, have been developed with the assistance of foreign legal experts. Therefore, in the context of water, the presumption is that when it comes to the players in the local level, no clarity exists on the prescription of the law regarding the rights and obligations of WUAs and farmers, who are the ultimate water users. The law which regulates WUA, its status in the society, and its relationship with other water players in the chain of water management is *the Law on Water Users Associations* (hereinafter, the WUA Law) adopted in 2006. Although WUA creation began in the country several years' prior adoption of the law, the WUA Law was expected to fill the gap in the law. It is supposed to provide, alongside other laws such as Civil Code of the Republic of Tajikistan, a legal framework for the establishment and operation of WUAs throughout the country.

This paper will explore the relevant provisions in the law that define the relationships among the stakeholders in the chain of water management in Tajikistan with the view that it will contribute to fill the knowledge gap in this important sector of the economy. After all, effectiveness and long-lasting

positive impact of any reform depends on the laws, the clarity of the rights and obligations, and the legal awareness of the subjects of that reform. When things go wrong you better know your point of redress.

Introduction section is followed by a general background text on the relationship among different types of legal regulatory acts and those subject to discussions in this paper. Then, relevant provisions are discussed in terms of institutional framework: main actors involved, definitions and who has what competence in the chain of water management, including WUAs, their operations, finances and etc. Remaining sections will cover dispute resolution, issues of water quality and a small discussion on gender as covered in the law, with a brief conclusion ending the paper.

Disclaimer should be made at this stage that this is a purely legal paper, which looks into the law and gives a picture of what the law says. Direct references are made to the relevant provisions of the law with some analysis from the author on implications for practice. Real picture on the ground can be substantially different, provided this is a general tendency in post-soviet world: laws are adopted for the sake of adoption but not altering the practice.

2. General Background

According to the Constitution, Tajikistan is a state based on the rule of law[1]. The legal system in Tajikistan is based on the hierarchy of legal norms, which are also divided based on the area of regulation. This hierarchy is provided by *the Law of the Republic of Tajikistan on Legal and Normative Acts*, a principal document which sets up the relationship of different legal acts (laws, by-laws, decrees and regulations and etc.).

Article 7 provides the following system of laws:

- Constitution of the Republic of Tajikistan;
- Laws of the Republic of Tajikistan, adopted through referenda;
- International legal acts (treaties), recognised by Tajikistan;
- Constitutional laws;
- Codes, Laws (legislative acts adopted by the Parliament);
- Joint resolutions of the Majlisi milli (upper house) and Majlisi namoyandagon (lower house) of Majlisi Oli (*Supreme Council*, the Parliament);
- Resolutions of the Majlisi milli and Majlisi namoyandagon of Majlisi Oli (the Parliament) of the Republic of Tajikistan;
- Orders of the President of the Republic of Tajikistan;
- Decrees of the Government of the Republic of Tajikistan;
- Directives of the ministries and state committees (of the Government);

For the purpose of this paper following legal mechanisms will be subject to analysis:

[1] Article 1, the Constitution of the Republic Tajikistan, adopted on 6 November 1994.

1. The Constitution of the Republic of Tajikistan – Article 13 provides that 'the land, its resources, *water*, airspace, fauna and flora, and other natural resources are exclusively the property of the State, and the State guarantees their effective use';
2. The Water Code of the Republic of Tajikistan, adopted in 2000 with the latest amendment being made in 2012. *A code* is 'a unified and ordered law through which a particular area of public relations is in full, directly and systematically regulated'.[2] It has to be borne in mind that the text of the Code is approved and adopted by a separate law of the Parliament. In other words, the Parliaments adopts the law to approve the Code. And because of this fact, it is suggested that the normative status of the Code is equal to any other laws (legislative acts), similarly adopted by the Parliament, such as the next instrument;
3. The Law on Water Users Associations (the WUA Law) of the Republic of Tajikistan, adopted in 2006. *Law* (in a narrower sense) is 'a normative legal act adopted by the legislative authority in accordance with the established procedures, which regulates the most important public relations'[3];
4. The Law on Environmental Protection of the Republic of Tajikistan, adopted in 1994. The document is relevant when it comes to issues of environmental protection of water resources and water quality issues;
5. Decree No. 281 of the Government of the Republic of Tajikistan on approval of the Regulations on the procedure of charging consumers of public irrigation systems for water supply services, adopted in 1996. Decree (or Resolution), in this context, is defined as 'a normative legal act of the Government of the Republic of Tajikistan, adopted in the form of *Decree* of the Government of the Republic of Tajikistan'.[4]
6. Decree No. 39 of the Government of the Republic of Tajikistan on approval of the Regulation on the delineation of the powers of specially authorized state bodies for regulating the use and protection of water resources, adopted in 2002. The document established clearly defined responsibilities on the relevant ministries and State committees in the sphere of water management and protection.

The above mentioned instruments are provided in hierarchal order. As mentioned, the normative statuses of the Water Code and the WUA Law are equal and referring to the Article 3 of the Water Code, both are constituent parts of the water legislation of the Republic of Tajikistan.[5]

What if conflict of laws? The Constitution is the supreme law in the country and no national law may contradict its provisions. However, Article 10 of the Constitution provides that in case of a conflict between the laws and the recognized international legal treaties, the international mechanism shall prevail.

Article 70 (1) of the Law on Legal-Normative Acts provides that if there is conflict between two different instruments applicable on one particular issue, the privilege is given either to (1) the

[2] Article 17 of the Law of the Republic of Tajikistan on Normative Legal Acts, adopted in 2009 with the latest update being made in 2011.
[3] Article 18, *Ibid*.
[4] Article 21.2, *Ibid*.
[5] Article 3 reads as follow: "Water legislation of RT is based on the Constitution of RT and consists of the present Code, laws, and legal-normative acts of the RT and the international acts recognized by the RT".

instrument that is adopted later than the one it is in conflict with or if (2) the instrument is considered to be more specifically tailored to deal with the situation or question under consideration (*lex specialis*).

3. Institutional Framework

3.1. Main Actors and Definitions

The primary source of water legislation in Tajikistan is the Constitution and the Water Code of the Republic of Tajikistan. The Constitution guarantees that the water is the exclusive property of the State[6], while the Water Code elaborates that principle setting detailed guidance for all kind of sectors dealing with water.

Article 1 of the Code in its provision 1 provides that the Code aims for 'strengthening of the lawfulness and protecting the rights of individuals and legal entities in the field of water relations'. The next section of this paper shall discuss *the water relations* as performed by various actors, bodies responsible for water management and use in the local level – namely (i) local executive bodies, (ii) water management organizations (*vodkhozes* or basin authorities), (iii) water user associations (WUAs) and (iv) water users (individual farming entities). The complex nature of the water relations played by the above mentioned actors shall make up the institutional framework for the local level water management in Tajikistan.

For the purpose of clarity and intellectual curiosity, it is important that legal definitions for certain terminology and concepts are brought at this stage of the study. The Code in its Article 2 defines following terms, some of which will be referred throughout this study:

- *General water use* – water use without use of water infrastructure or engineering tools;
- *Special water use* – water use with the means of water infrastructure and engineering tools;
- *Primary water users* – natural and legal entities, who are provided with water bodies for use;
- *Secondary water users* – natural and legal entities, who are given permission by the primary water users to use water bodies on a contractual basis and with the authorisation of the State regulatory bodies in the field of use and protection of water resources;
- *Water User Association* – non-commercial organization, established by legal entities who have the right to agricultural land use and commercial organizations;
- *Basin Water Management Organization (BISA)* – Water management organization serving water users within a river or main canal basin[7].

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[6] Article 13 of the Constitution of the RT provides that 'the land, its resources, water, airspace, fauna and flora, and other natural resources are exclusively the property of the State, and the State guarantees their effective use'. Article 5 of the Water Code reiterates this provision.

[7] BISAs are created to replace provincial water management organizations called "OblVodkhozes", while RayVodkhozes refer to previous district water authorities. Newly created organizations are gradually being replaced as the local executive branches of the Agency for Land Reclamation and Irrigation, central executive authority in the area of land reclamation and irrigation.

3.2. The Scope of Competence of the Various Actors

Due to the fact that the focus area of this study is the local level actors in the water management hierarchy, the study will concentrate primarily on the relationship between various actors at local level as provided by the relevant laws. Reflections are the result of legal opinion based on the statutory law as it stands but where necessary reflections are also drawn on the implications of the law for practice.

The principles and the hierarchy of the water management is provided in Article 9 of the Water Code which states that:

'*The State management in the field of use and protection of water resources is based on the combination of basin and border and administrative-territorial management principles and implemented by the Government of the Republic of Tajikistan, the executive authorities, local authorities, as well as by the authorized State agencies on water management and protection*'.

The sequence of *implementers* in the provision can be interpreted as the intention of the legislators in terms of setting up the *institutional hierarchy* in water relations, which provides for the following order in the local water management context:

1. The executive authorities (provincial);
2. Local authorities (district);
3. Authorised state water management agencies (*vodkhozes* and/or basin authorities);

Thus to the full picture of water relations on the ground we can conclude that *beneficiaries* would be:

4. WUAs (as primary water users); and
5. Individual water users (as secondary water users).

3.3. Competence of the Local Executive Branches of the State (Khukumats)

Article 7 of the Water Code defines jurisdictional scope of the local state authorities within their respective territories. It includes but not limited to:

- *Determining main direction of water management and protection in the territory of their respective jurisdiction*. In practice it may mean that local executive authority dictates or should dictate the trend of water management in their respective territories.
- *Guaranteeing lawfulness and legal order in the field of regulating water management and protection*. The practical implication of this provision is that, in case of breach of law and established norms, a party at loss may bring a claim against a party at fault to the attention of local executive branches of the state. In addition, this provision should be read together with Article 12 of the Water Code, which provides that State control on water use and protection shall be vested upon authorised state water management agencies (*vodkhozes* or basin authorities). The implication of the combined reading of these provisions might suggest that local executive bodies of the State should maintain more of role of a watchdog while authorised state water management agencies are the ones responsible to take an action. <u>However, it has to be noted,</u>

the claim mentioned above is an administrative claim and there is nothing in law that prohibits parties to sue each other for an alleged wrongdoing.

- *Registration and assessment of the state of water and water bodies, control of water use and protection, observance of the established water use limits*;
- *Carrying out activities for the conservation and improvement of the status of water bodies, prevention and liquidation of harmful effects, as well as water pollution, restore facilities damaged by accidents, floods, landslides and other natural disasters*. This has to be read together with other provisions of this Code and other relevant laws on rehabilitation and construction of works. It can be suggested that the responsibility of the local executive authorities in rehabilitating and restoring water infrastructure primarily covers overseeing overall status of water and water infrastructure in the territory it administers and that responsibility particularly becomes important in emergency situations;
- *Cooperation with the specially authorised state water management and protection agencies (vodkhozes);*

3.4. Competence of the State agencies on water management and protection (vodkhozes)

The State agencies on water management and protection on provincial and district level, namely *Vodkhozes* or/and Basin water management agencies, are in the position of entering into contractual relations with *the primary water users* for special water use, whereas primary water users can establish contractual relations with *the secondary water users* for this purpose (Article 25 of the Water Code). The following mechanisms define the contractual rights and obligations of the parties:

1. Contract itself
2. The Water Code
3. 2006 Law on Water Users Associations (WUA Law).

The rights of water users for the special water use can be restricted by the authority who vested those rights upon them, that is *Vodkhozes* upon primary water users and primary users upon secondary users (Article 44(4), Water Code). This provision is also reflected in Article 49, which provides for the circumstances when the right to water use can be terminated. This includes but not limited to expiration of the permission for a special water use or systematic violation of a water supply contract by a water user. *Vodkhozes* as water supply agencies maintain direct right to terminate water use right of a primary water user (e.g. WUA) and supervisory role in case of a primary water user terminates the right of a secondary water user (e.g. WUA terminating the right of its member) (Article 50). However, as stated above, water users maintain the right to challenge the legality of the decision on termination of their respective water use rights and bring it to the attention of a respective *Vodkhoz* and/or local executive body of the State.

Water users can establish a water user association (WUA). WUAs then become a *primary water user* for the purpose of acquiring special water use rights under Article 25 above, and its respective members are classified as *secondary users*. Water users have the right to demand from *Vodkhozes* to take necessary measures to prevent exhaustion and contamination of the water fund and providing water resources in appropriate quantity and quality (Article 43, Rights of Water Users). However, the latter should be read

in the light of obligations of the water users to make timely payment for water delivery services; maintaining irrigation and drainage systems in an appropriate functioning state and comply with established requirements and conditions of a water supply contract with *Vodkhozes* (Article 45).

3.5. Responsibility of Vodkhozes in relations to the Water Users

Article 48 of the Code defines the responsibilities of *Vodkhozes* and it includes but not limited to:

- *Providing appropriate maintenance of irrigation systems in order to deliver the necessary quantity of water to water users as indicated in water supply contracts*. The implication of this provision for practice would be that the law as such does not define what irrigation systems are meant by this provision. However, as the delivery of water takes place at the point of water distribution – the WUA gate e.g. – it can be suggested that it is up to that point of irrigation system that Vodkhoz has to undertake maintenance work;
- *Preparing drains, water catchment-discharge systems, water ways, and water supply*
- *Supplying water to water users according to norms and at fixed times*[8];
- *With the agreement of water users, installing water level indicators at the point of water distribution in order to identify the quantity of delivered water in accordance with a water supply contract*. Implications for practice would be that it is the responsibility of Vodkhozes to install water measurement units at a WUA water in-take gates.

The above mentioned responsibilities are positive obligations held in relation to the water users and if breached becomes liability serving as a ground for claim by the water users.

3.6. Competence of Water Users

According to Article 27 of the Water Code, 'natural and legal persons, no matter of the form of ownership, whose activities are based in the territory of the Republic of Tajikistan and on the laws of the Republic of Tajikistan can become a water user'. Water users of general water use benefits from the use free of charge, while water users benefiting from special water use shall make payment for the use of water and the delivery service (Article 35, Water Code). Any analysis on the competence of the water users should also be undertaken in the light of the responsibilities of the players in the higher hierarchy of water relations, as those responsibilities are translated into the rights for water users.

In the following sub-section, the competence of WUAs is discussed in the context of a water user (primary), while the next sub-section will look at WUA competence in terms of a water supplier (to individual members/farmers).

3.7. Responsibilities of the Water Users

Responsibilities of water users can be defined as contractual obligations and those provided in the Water Code and other normative acts, such as WUA Law. If looked from the perspective of *vodkhozes,* those responsibilities laid down in the Water Code are applicable both on WUAs and its members. However, the WUA Law makes the responsibilities of WUAs and individual water users clearly distinctive from each

[8] Subject to Article 44 of the Water Code as stated above

other. Therefore, assuming individual water-users are members of a WUA their responsibilities are held in relation to that WUA. Meanwhile, the responsibilities of the WUA are held in relation to the respective *vodkhoz* in the capacity of a water user and in relation to its members in the capacity of water supplier.

Responsibilities of the water users as provided in the Water Code include but not limited to (applicable both on individual water users and WUAs as collective water users)[9]:

- *Rational use of water, saving water resources, and rehabilitating and improving water quality*;
- *Making timely payment for water use and water use services*. Implication of this provision would be that individual water users shall make payment to WUAs and WUAs to vodkhozes;
- *Maintain the irrigation, drainage, wastewater treatment and other facilities in a repaired condition and improve their performance*. One can suggest that individual water users are responsible to maintain the infrastructure in their own territory, including tertiary canals and in some cases secondary canals, and WUAs are responsible for main (the part located in WUA's territory) and secondary canals. However, the provision itself provides no clarification in terms of territorial limits of this responsibility.
- *Comply with the established requirements and conditions of water supply contracts*;

Furthermore, the WUA Law places particular responsibilities to WUAs in its capacity as a water user. These responsibilities basically reiterate those mentioned above, namely making timely payment to vodkhozes for the water supply services and maintaining water infrastructure in a working condition, although the latter is more of a responsibility in the capacity of a water supplier (Article 11, WUA Law).

3.8. Competence of Water User Associations as a Water Supplier

The Water Code provides fundamental aims of establishing a WUA, which are:

(i) Maintenance and exploitation of inter-farm amelioration and irrigation systems, which are in collective and individual use;
(ii) Provision of fair, effective and timely allocation of water resources among farming entities;
(iii) Collection of payments for water supply services; and
(iv) Solving disputes among its members on matters related to water allocation (Article 43(2)).

The WUA Law reiterates the above mentioned aims in a more elaborative manner in Article 3 (aims and tasks of WUA) and in Article 11 (responsibilities of WUA). In addition, the Law gives right to WUA to enter into contractual relations with a respective *vodkhoz* and individual water users, members and non-members alike. Under the contract, WUA shall collect payment from its members and non-members and make payment to vodkhozes for the amount of delivered water.

In addition to the *aims*, there are also *principles* upon which WUAs shall function. Interestingly, from the list of principles, the first comes '*involvement of the WUA members in the management, repair and rehabilitation of the irrigation systems*' (Article 4). If the provision is read together with the first *aim*, which is on maintenance too, one can draw a conclusion that the law clearly places responsibility on WUAs to undertake necessary repair and reconstruction works and the WUA members are under a positive duty to avail themselves when their involvement is required. Accordingly, the role of the WUA are more of a

[9] Article 45, Water Code.

mobilizer of collective efforts. However, this statement may also be a misguiding because it is impossible to separate a member from WUA and vice-versa. WUA is association established by members, with collegial managerial body, composed also from the members. Then if WUA is responsible according law, then this responsibility is the equal subsidiary responsibility of each member of WUA.

Operation and functioning of the WUA shall be organized in the following manner/order (Article 21 and 22):

1. The amount of water to be delivered to each water user and the schedule under which the delivery takes place is provided in the water supply contract – amount and schedule can be referred as *the plan*.
2. Then, *this plan* is reflected in the internal timetable (plans) of the WUA.
3. Then, these plans are brought to the attention of water supply organization to seek their confirmation.
4. Then, the approval is sought from local executive bodies for these plans.

As the law stands, it is not quite clear how this works: whether contractual arrangements are made first and reflected within internal plans of WUA or contractual calculations are the reflection of the WUA internal plans. The whole process is referred as State regulation over the activities of WUAs.

4. Payment for Water Supply Services

The 2006 WUA Law defines two types of payment the members shall make to WUA (Article 2):

1. *Membership fee* – payment to be collected from the WUA members according to the decision of the general meeting (the highest management body) and to be utilized on management and maintenance of irrigation system and the functioning of the WUA.[10];
2. *Payment for the water supply services* – payment to be collected from the members and other water users in order to make payment to vodkhozes for the provision of water to the zone of WUA coverage.

The membership and thus the above mentioned payments give right to water users (members and non-members alike) to claim the water as stated in their contract and claim for damages from WUA in case of the breach of contract by WUA (Article 8).

In addition to collecting membership fees, there is nothing in law that prohibits WUA to obtain extra funding from various sources to maintain its activities. A WUA also has a right to acquire a property, property and non-property rights[11].

WUA can establish its own membership fee and any other fees (this may include punitive fees for non-compliers), which has to be incorporated in its Charter. The law provides that WUA has a right 'to demand fee for water supply services and any other established fees'[12]. Thus, the scope of *any other fees* can be wide enough, to the extent not prohibited in law.

[10] Article 19 of the Law asserts that the repair and reconstruction works to be covered from the WUA budget.
[11] Article 10, WUA Law
[12] *Ibid*

Furthermore, the law does not prohibit WUAs to build up a capital surplus.

Chapter 6 of the Water Code establishes that water supply for irrigation purposes is subject to payment, which has to be performed on contractual basis. The contractual relations between a water supplier and a user creates certain rights and obligations, which are specified in Chapter 7 of the Code. Making payment for water supply is one of the obligations of the water users, breach of which may result in partial or full termination of the water supply. The same Chapter also provides for implicit risk assignments in case of emergency or low water availability, where the user's right to a particular amount of water shall be limited in order to accommodate State interests and the interests of other water users. Drinking and domestic water uses shall be given priority in situations mentioned above.[13]

Detailed methods of charging for water supply is provided in the regulatory document *Decree No. 281 of the Government of the Republic of Tajikistan on approval of the Regulations on the Procedure of Charging Consumers of Public Irrigation Systems for Water Supply Services*, adopted in 1996.

Accordingly, Ministry of Melioration and Water Resources and other sub-organizations, such as *Vodkhozes* and Irrigation System Authorities are defined as *water supplier* and agricultural water consumers (and others) are defined as *water consumer*.

Article 1.2 provides that water supply is to be conducted on the basis of a contract between supplier and consumer, whereas Article 1.3 provides that non-legal water consumers/users can unite within an association that is a single water consumer who will be entitled to enter into a water supply contract with the Water supplier (the case with WUA).

Article 1.5 provides for dealing with emergency situations, according to which, 'both parties shall participate with their respective technical, material and other means to eliminate the consequences of emergency situation and each side bears the cost of the works undertaken in its own respective side'. The same principle applies when the provision is interpreted in the WUA context, that is to say expenses for accident's repair and liquidation of its consequences must be covered by respective institution, who owns this part of irrigation system. This provision if read together with the responsibilities of WUAs, once again clarifies that each side is responsible to bear its own cost in its respective territories.

Measurement unit for water is m^3 and for irrigated land is hectare (ha). The amount of water delivered to the consumer is measured with special gauges. Where there is no a gauge, delivered water is measured with instrumental measurement techniques and the processes is supervised by authorised persons from each side and duly recorded. On the basis of these records at the end of each month an act of receiving a water supply is made. The act serves as a document for payment collection (Article 2).

Article 3 and its provisions define the order of payment. Payment is calculated according to the tariff for each m^3 delivered to the consumer. Tariffs for water supply services are determined based on the total regulatory costs: for maintenance and repair of public irrigation and drainage systems and their structures, full restoration of depreciated assets, mandatory payments, the insurance fund to cover expenses during events such as extremely low availability of water or flooding, expansion of production, scientific, technological and social development of the Supplier. Salary costs of the staff of water supply

[13] Article 44, Water Code

organization are not mentioned in the provision, as the water supply organization is not a self-sustaining commercial entity and thus it is under the state budged.

40% advance payment is applicable for water supply services for irrigation purposes as provided in Article 3.7. Payment for water supply services is paid according to established tariff as long as water withdrawal remains within established agreed limits. Over the limit water withdrawal will be charged with multiplying factor equal to 1/2 and an unauthorized withdrawal will be charged three times more.

Within associations united as a single consumer (e.g. WUA), tariffs (how much water is requested) will be determined by consumers, subject to agreement by the Supplier.

5. Conflict Resolution

The hierarchy of the institutions with the capacity to resolve disputes related to water management is as follow:

1. The Government of the Republic of Tajikistan;
2. Local State Authorities;
3. Authorised Water Management Bodies; and
4. The Court.

WUA has a positive duty to resolve disputes among its members and non-members[14] through establishing an *ad hoc* commission comprising three people. Commission adopts an act with the decision and the act is given to an appropriate body of WUA for implementation[15].

Resolving inter-WUA disputes is the responsibility of the authorised water management body (*Vodkhoz*) who gave them the right for water use.[16] Any dispute can be brought to the attention of the Court if the above mentioned institutions are not able to settle dispute for the parties.

6. Water Management and Water Quality – Legal Framework

A special chapter of the Water Code deals with the water protection issues (Chapter 21 Water Protection). According to it, 'all waters (and water infrastructure) are subject to protection from pollution, clogging and depletion'. But some harm is permissible, as long as it does not undermine the natural capacity of water to self-rehabilitate.

The Law obliges all legal entities, whose activities have impact on the quality of water, 'to undertake technological, forest-ameliorative, agro-technical, hydro-technical, sanitary and other measures to provide protection against water pollution, clogging and depletion and facilitates improvement of water quality and water regime'[17]. These rules are one of a preventive character.

Two practical implications can be drawn from the above provision:

[14] Article 11, WUA Law (2006)
[15] Article
[16] Article 116, 117, Water Code
[17] Article 120, Water Code

1) all legal entities include water user associations, as well as WUA members alike with a legal entity status;
2) the law does not actually prohibit all the harm but it obliges entities causing harm to undertake measures to mitigate the harm and thus improve quality of the water. In other, words the rule is one of due diligence[18]. Thus, a conclusion would be an entity who is causing harm and *not* addressing it shall be considered as the one who is causing harm to the quality of water. This conclusion will be relevant for the purposes of remedy.

Water pollution and clogging is considered to be a violation of the law [19] and subject to damages in the amount and order established by law[20], However, payment in the form of remedy does not discharge the violator from undertaking the measures to mitigate and eliminate the harm[21].

Territorial planning of water protection measures is the responsibility of the local executive authorities, while implementing costs of water quality measures shall be borne by the State and the water users like.[22]

Water users (both legal and individuals) are obliged to undertake measures to warn and liquidate adverse impact on water caused by accidents and emergency situations. These measures are subject to coordination and agreement with the state water management agencies[23].

Coordination of urgent matters related to warning and liquidation of adverse impacts on water will be undertaken by a commission established by the Cabinet of Ministries and the state local authorities[24].

Overall control and monitoring the changing quality of water resources is the responsibility of the State Committee on Nature Protection[25].

6.1. Right to a Healthy Environment

The foundation of *the right to a healthy environment* is to be found in the Constitution of the Republic of Tajikistan. Article 36 provides that the State guarantees each citizen's right to a healthy environment. This right is further reiterated in the Law on Environmental Protection (1994), whose scope is extended to cover the surface as well as groundwater water resources[26]. The Law gives right to both individuals and public and non-governmental associations (this includes WUAs) to bring a complaint to the authorised state agencies in the field of environmental protection, who then may take an administrative and legal action against a party at fault[27].

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[18] Due diligence is an extremely important concept in environmental regulation and compliance. When properly done, it provides a defence to regulatory charges or, at least, can mitigate the amount of fines imposed.
[19] Article 142, Water Code
[20] Article 144, Water Code and Article 20 of the 1994 Law on Environmental Protection
[21] Article 20 (4), the 1994 Law on Environmental Protection
[22] Article 122, Water Code
[23] Article 129, Water Code
[24] Article 130, Water Code
[25] Decree No. 39 of the Government of the Republic of Tajikistan on approval of the Regulation on the delineation of the powers of specially authorized state bodies for regulating the use and protection of water resources, adopted in 2002
[26] Article 6, Law on Environmental Protection
[27] Article 9 on the *Competence of the Authorised State Agencies in the Field of Environmental Protection*

Individuals and public and non-governmental associations may also bring a direct legal claim to the court in case their right to a healthy environment is infringed[28]. This means WUAs fall within the latter category and thus having the right to act as a claimant in legal proceedings.

However, it has to be noted that if an environmental harm is caused due the fault of one of the members of the WUA, the respondent (defendant) shall be the member itself but not the WUA, because, according to the legislation, the WUA is not responsible for the activities of its members[29].

Remedies under the law includes *damages*, *specific performance* (that is rehabilitation and maintenance works and etc.) and *potential losses*[30]. The Water Code also provides that the right to use water may be taken away from the entity in case environmental balance is *substantially* violated[31]. It can comfortably be suggested that ecosystems and environmental flows can be included in this provision, meaning if the share of water of the environment is taken away from the environment this may mean that environmental balance is infringed. These rules mentioned above are of a remedial character**.**

7. Law, Gender and Equality

The Constitution of the Republic of Tajikistan recognizes international law as a component part of the national legal system, and Tajikistan is a Party to the Convention on the Elimination of All Forms of Discrimination Against Women (CEDAW) and to other fundamental human rights treaties. In 2014, the parliament ratified the Optional Protocol to CEDAW, which allows individual women in Tajikistan to submit complaints to the CEDAW Committee and gives them an additional remedy for violations of the convention. Important steps have also been taken to implement UN Security Council resolutions on women, peace, and security (1325 and 2122) with the drafting of a national action plan.

The Constitution guarantees equal rights on the basis of sex (Article 17), and principles of non-discrimination are enshrined in basic legislation, for example, the Family Code, the Labour Code, the Land Code, the Criminal Code, the Law on Education, and the Law on Public Health.

No laws that have been discussed above in the context of water management make reference to gender issues. But if read in the light of national and international mechanisms in the field of protection of women's right, the laws in the field of water management have equal application on both man and woman.

8. Concluding remarks

The paper has reviewed legislative framework in Tajikistan in order to understand the functioning of water user associations and whether the law supports smooth operation of local water management if interpreted and applied correctly. Reforms and transition become sustainable if they are supported by law and order. Effective functioning of the law and order depends to the extent people can rely on them.

[28] Article 12 and 13 respectively
[29] Article 11, WUA Law (2006)
[30] Article 77-81 on dispute settlement and remedies, Law on Environmental Protection
[31] Article 49 (2), Water Code

Reliance become stronger if people know what the law says in terms of their rights and obligations, making legal capacity building and raising awareness important component of any developmental endeavours.

The analysis shows that the frame is good enough to provide for fair and equitable water management system. However, due to the nature of the legal system of the country (this is true for almost entire post-soviet world), making sense out of the law is not easy as documents make endless reference to *existing legislation*. This becomes particularly erroneous for organizations when resources are limited. But then, even one takes an effort for detailed analysis there are still lack of clarity in the law, e.g. in terms of responsibilities of the stakeholders for rehabilitation works, water measuring and competences of Local Executive Branches of the Government and *Vodkhozes.*

Moreover, water is still a political phenomenon in Tajikistan and in neighbouring states. This makes power politics in resources management as an integral part of the system. But if we talk about *sustainability*, efforts should be made to abandon old habits and make the way for clear, effective and just laws to do the job for us.

Acknowledgement

This research is funded through a project titled 'Impact of Water User 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, awarded to the International Water Management Institute, Colombo. The author would like to thank Ted Horbulyk and Soumya Balasubramanya for comments on an earlier version of this paper.

Appendix 6

Wiberg, D. 2018. Remotely-sensed cropping and productivity differences between areas with water user associations and areas without. Technical note.

Title: Remotely-sensed cropping and productivity differences between areas with water user associations and areas without

Introduction and methodology

One of the major activities of USAID's Family Farming Program (FFP) was the creation of WUAs to improve timely, regular, and equitablee access to on-farm water for improving yields, crop diversity, and enhancing livelihoods. Since 2011, USAID set up WUAs in 12 districts in southern Khatlon Province, to improve on-farm water delivery, which could impact yields, crop choice and activities of agricultural workers.

To support the evaluation of the impact of these water user associations on productivity in cultivated areas, a remote sensing analysis was performed to assess difference in productivity between areas where WUAs have been established and those where they have not been established. This analysis focused on cotton and wheat cultivation and used satellite images during the growing seasons from April to Nov. and Dec. to April, respectively, for USAID project and non-project areas between 2010 and 2017. The year 2010 has been taken as a base year, since private farms did not exist before 2010. Agricultural land was still collectivized at that time, and farmers couldn't decide what to cultivate.

Landsat satellite images, having suitable temporal and spatial, 30 m, resolution were chosen to carry out the analysis. Landsat scenes with minimum cloud and snow cover, for an area of 2.3 million ha of land spread over 12 districts of southwest Khatlon province, between the years 2010 and 2017, were selected and downloaded. The downloaded scenes were acquired by Landsat 5, Landsat 7 ETM+ and Landsat 8 sensors.

For each year two sets of images were used for the analysis. One set for the cotton growing season, and the other for the wheat growing season. The study area covers multiple satellite scenes. Five satellite images are required to cover the study area for one season. Suitable cloud free images were not available for the years 2012 and 2013. Sixty images were required for the analysis of both the seasons in the remaining six years. The downloaded satellite images were pre-processed including layer stacking and resolution merge techniques for the data obtained from Landsat 7 and Landsat 8, taking advantage of presence of panchromatic band with higher resolution in both Landsat 7 & 8.

The selected satellite images were classified into 11 classes following the supervised classification technique, using the maximum likelihood algorithm. The signatures for various land use types were generated/gathered based on the ground truth data provided and high-resolution images from Google Earth. The classes the satellite images were classified into included Cotton, Wheat, Rice, Other Crops/Vegetables, Fallow land, Bare land/Shrub/Fodder, Fruit Orchards/tree cover, Urban/Built-up, Wetland, Water, and Snow with an extra category to indicate the area covered by Clouds.

Cotton and wheat coverage have been assessed during their growing seasons, August through October for Cotton, and November through March for Wheat. The satellite images for the months of September and October were preferred for the identification of cotton as during these months cotton crops start bearing flowers resulting in a unique reflection recorded by the satellite sensors and the specific spectral reflectance pattern of cotton is more distinct from other crops during this period. Similarly, the satellite images for month of March were preferred for the identification of wheat crops as most of the wheat fields were fully grown giving a strong vegetative reflection.

Results

Time series analysis

Analysis of the outputs do not indicate major changes between 2010 and 2017 in the overall area under cotton cultivation (Table 1, Fig. 1). However, wheat production appears to be increasing dramatically between 2014 and 2017 (Table 2, Fig 2).

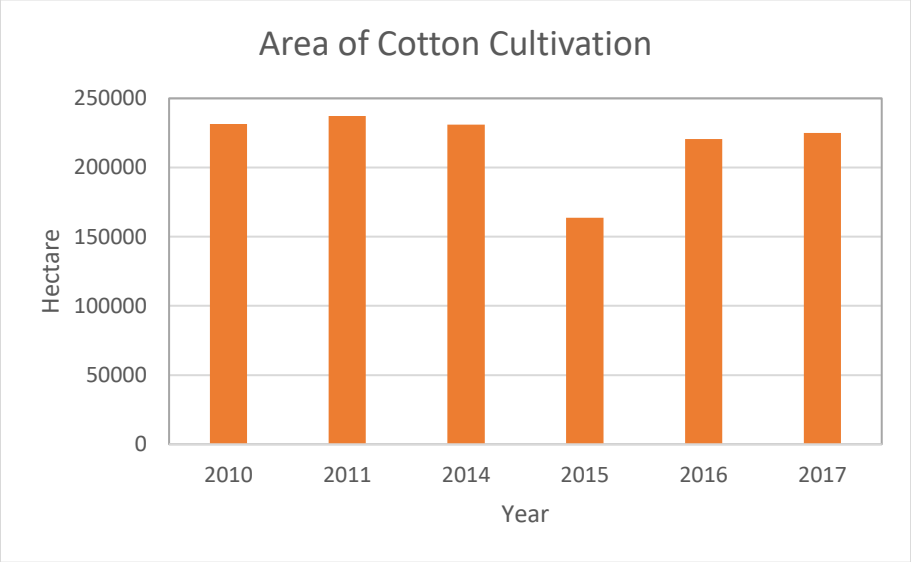


Fig. 1. Area under cotton cultivation in the study area

		Area in hectare during the cotton season of the year (ha)					
No.	**Land Cover**	**2010**	**2011**	**2014**	**2015**	**2016**	**2017**
1	Cotton	231591	237227	231062	163700	220707	224977
2	Rice	2964	1540	9859	3602	797	13412
3	Other Crops	17073	80653	52058	152628	89299	113691
4	Fallow land	474850	436171	460894	430172	421756	396524
5	Bare land/Shrub/ Fodder	1322510	1252510	1252850	1321930	1322780	1251200
6	Fruit orchards /Tree Cover	119266	119983	120356	120568	119920	120288
7	Built-up	69172	69184	72895	72975	72991	73679
8	Wetland	20768	20896	27124	4313	24995	20284
9	Water	49012	51321	39317	32806	42165	50725
10	Snow	10502	1381	2772	6121	2256	293
11	Clouds		46764	48574	8938	85	52691

Table 1: Area of different land use types during cotton cultivation season of the year in the entire study area

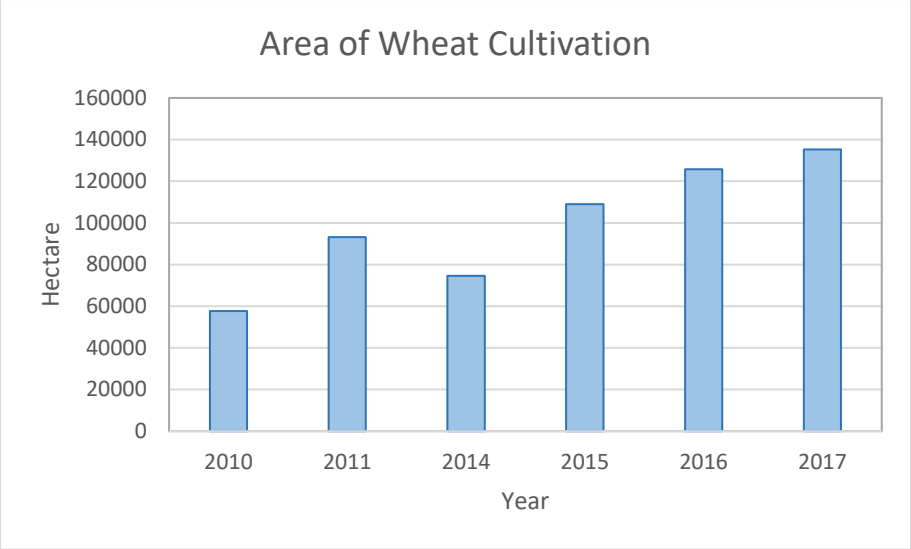


Fig 2. Area under wheat cultivation in the study area

		Area in hectare during the wheat season of the year (ha)					
No.	**Land Cover**	**2010**	**2011**	**2014**	**2015**	**2016**	**2017**
1	Wheat	57618	93145	74581	109051	125809	135310
2	Rice	14043	286.537	0	1108	3092	12351
3	Other Crops	119469	93020	58185	136207	139897	130991
4	Fallow land	548194	517224	549350	419103	449711	451212
5	Bare land/Shrub/ Fodder	1322560	1249850	1252710	1251370	1322740	1250910
6	Fruit orchards /Tree Cover	118083	119402	120248	117923	119994	116856
7	Built-up	68205	68711	72908	72103	72992	71715
8	Wetland	16701	5830	7611	15422	27157	18431
9	Water	52830	32330	43340	41389	41181	46896
10	Snow		82550	86472	143443	11642	83089
11	Clouds		55291	52355	10608	3533	

Table 2: Area of different land use types during wheat cultivation season of the year in the entire study area

Analysis of Water User Association areas

A comparison of areas where water user associations are (WUA) present and where those institutions are not present indicates significant differences. A comparison of different land cover types between WUA areas and remaining areas can be found in Table 3 & 4. The percentage of cotton and wheat cultivated areas within agriculture lands is higher where WUAs are present compared to other areas. (Fig 3 & 4). While extent of cotton cultivation has not changed much over time, the proportion of cotton cultivation in croplands in WUA areas is much higher than remaining areas. The proportion of wheat

cultivation in croplands in WUA areas are not only higher compared to the remaining areas, but these areas also show significant increases in wheat cultivation over time. The cultivated area of wheat where WUAs are not present is stagnant.

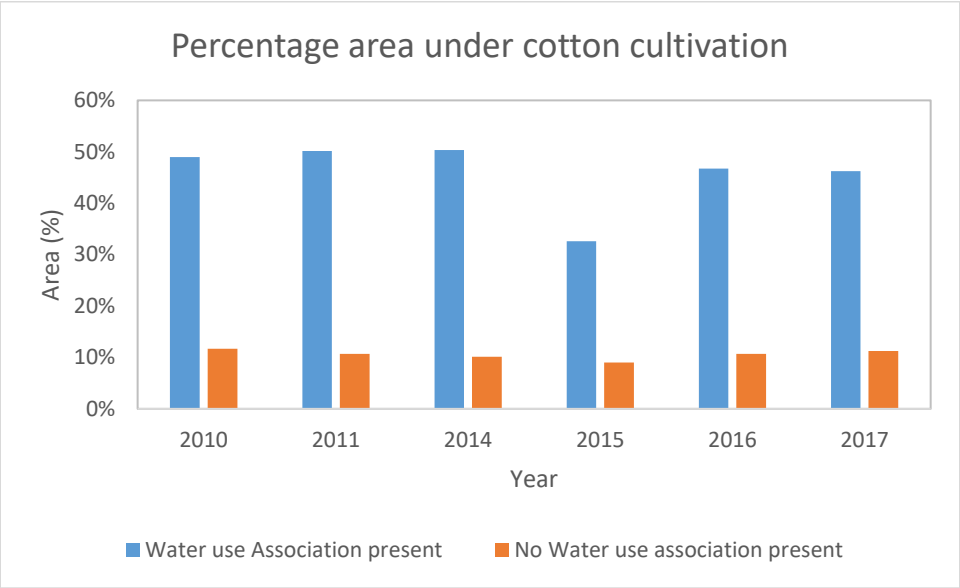


Figure 3. Comparison of percentage of cotton cultivated areas in agriculture lands, in areas where water user associations are present and the remaining areas.

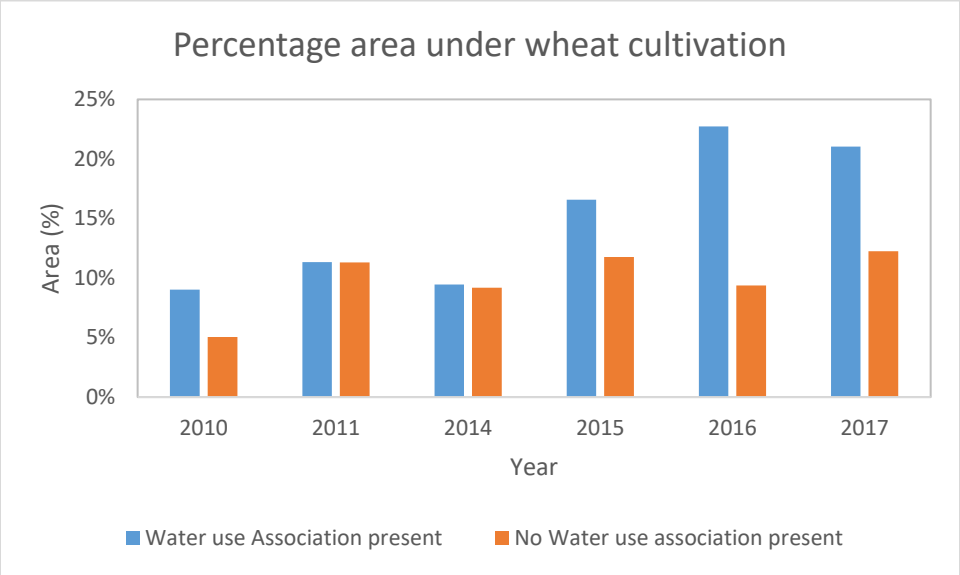


Figure 4. Comparison of percentage of wheat cultivated areas in agriculture lands, in areas where water user associations are present and the remaining areas.

		Water User Association present						Water User Association not present					
No.	**Land Cover**	**2010**	**2011**	**2014**	**2015**	**2016**	**2017**	**2010**	**2011**	**2014**	**2015**	**2016**	**2017**
1	Cotton	174141	182649	178557	117777	167975	167956	57450	54578	52505	45923	52732	57021
2	Rice	698	192	6219	1975	46	4260	2266	1348	3640	1626	751	9152
3	Other Crops	10157	49850	27024	97200	53097	59151	6916	30803	25034	55428	36202	54540
4	Fallow land	129770	108973	90217	105657	94167	102905	345080	327198	370677	324515	327589	293619
5	Bare land/ Shrub/Fodder	17602	9636	17927	13689	15183	9080	1304908	1242874	1234923	1308241	1307597	1242120
6	Fruit orchards/ Tree Cover	40612	22620	52737	38481	44200	29159	78654	97363	67619	82087	75720	91129
7	Built-up	41241	40939	42178	41412	40043	42107	27931	28245	30716	31563	32948	31572
8	Wetland	3331	2467	3617	268	2522	2731	17438	18429	23507	4046	22473	17553
9	Water	2525	2732	1077	1808	2846	2685	46487	48589	38241	30998	39319	48040
10	Snow	0	16	518	0	0	0	10502	1365	2254	6121	2256	293
11	Clouds	0	0	8	1815	0	48	0	46764	48565	7123	85	52643

Table 3: Area of land cover types during the cotton growing season in locations where Water User Associations are present and where not present

		Water User Association present						Water User Association not present					
No.	**Land Cover**	**2010**	**2011**	**2014**	**2015**	**2016**	**2017**	**2010**	**2011**	**2014**	**2015**	**2016**	**2017**
1	Wheat	32499	40705	32890	58033	80339	75803	25118	52440	41691	51018	45470	59507
2	Rice	8245	186	0	104	2374	7610	5798	101	0	1004	718	4741
3	Other Crops	69965	53084	26220	62743	94239	64356	49504	39936	31965	73464	45658	66635
4	Fallow land	211853	225093	262618	207990	130567	177551	336341	292131	286732	211113	319144	273661
5	Bare land/ Shrub/Fodder	13677	18146	24313	21482	18832	13338	1308883	1231704	1228397	1229888	1303908	1237572
6	Fruit orchards/ Tree Cover	37914	40330	26623	21303	45942	35150	80169	79072	93625	96620	74052	81706
7	Built-up	40148	40406	41885	41794	40415	41419	28057	28305	31023	30309	32577	30296
8	Wetland	3051	727	329	1527	3772	2577	13650	5103	7283	13894	23385	15854
9	Water	2725	626	1752	3192	2594	2275	50104	31704	41588	38197	38587	44621
10	Snow	0	0	7	61	281	0	0	82550	86465	143382	11361	83088
11	Clouds	0	772	3443	1853	726	0	0	54519	48911	8756	2807	0

Table 4: Area of land cover types during the wheat growing season in locations where Water User Associations are present and where not present

Discussion

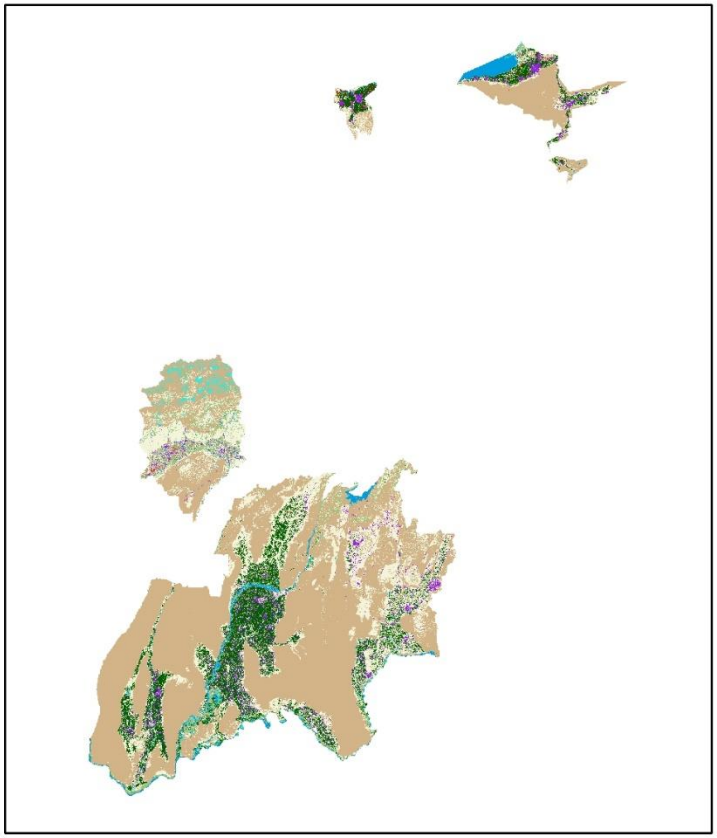
The results appear to indicate that the development of Water User Associations have benefited crop production. In the case of cotton, the cultivated area is much higher where WUAs are present. However, since the cultivated area was higher throughout the entire time period, it may simply be that land where WUAs are present is more suitable for cotton anyway. A stronger case can be made for wheat cultivation of the beneficial impact of WUAs, since wheat cultivated areas are both larger and growing where WUAs are present throughout the period, but not growing where WUAs are not present.

As already alluded to, the results presented here come with a few caveats. The results come from remotely-sensed images, and therefore provide only an indication of the area of land covered by the crops assessed. Image classification is also not perfect. Results can always benefit from further verification, both in terms of checking and verifying the methodology, and comparing to any ground data and statistical information that is available. Furthermore, production changes have multiple causes and influences. The remote sensing analysis presented here only provides an indication of changes in land use and land cover. It does not by itself establish the causality of the patterns presented.

By assessing only land cover, this was also only an initial step in the types of analysis that could be performed using remote sensing. Additional remote sensing analysis could further aid the assessment of the effectiveness of water user associations through estimations of water productivity on these lands, for example.

The classified land cover maps for each year are provided on the following pages.

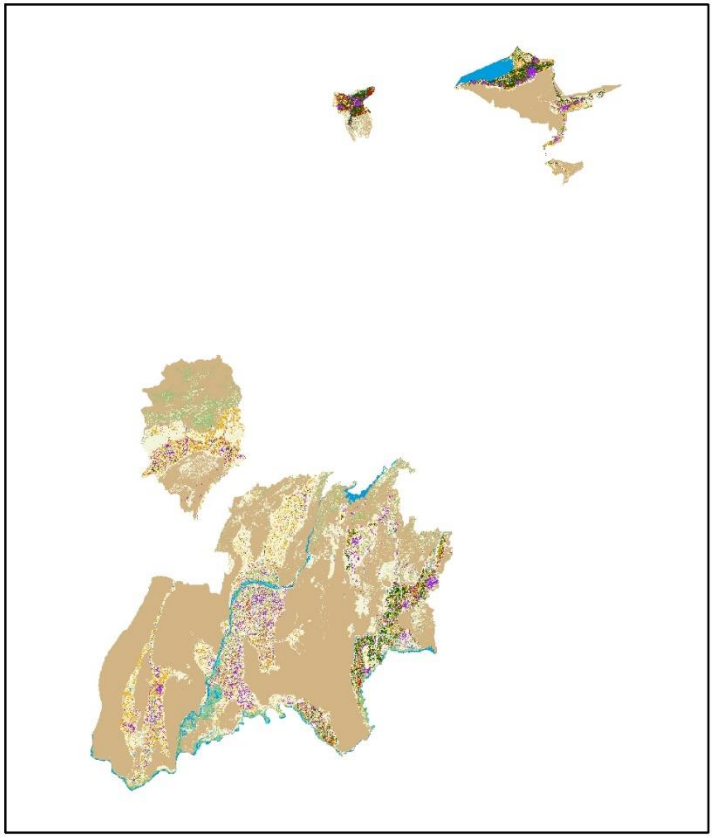
Cotton Season 2010



Land Use

- Wet_Land
- Water
- Snow
- Rice
- Other_Crops/Vegetable
- Fruits/Tree_Cover/Orchids
- Fallow_Land
- Cotton
- BuiltUp
- Bare_Land/Shrub/Fodder/Grass_Lan

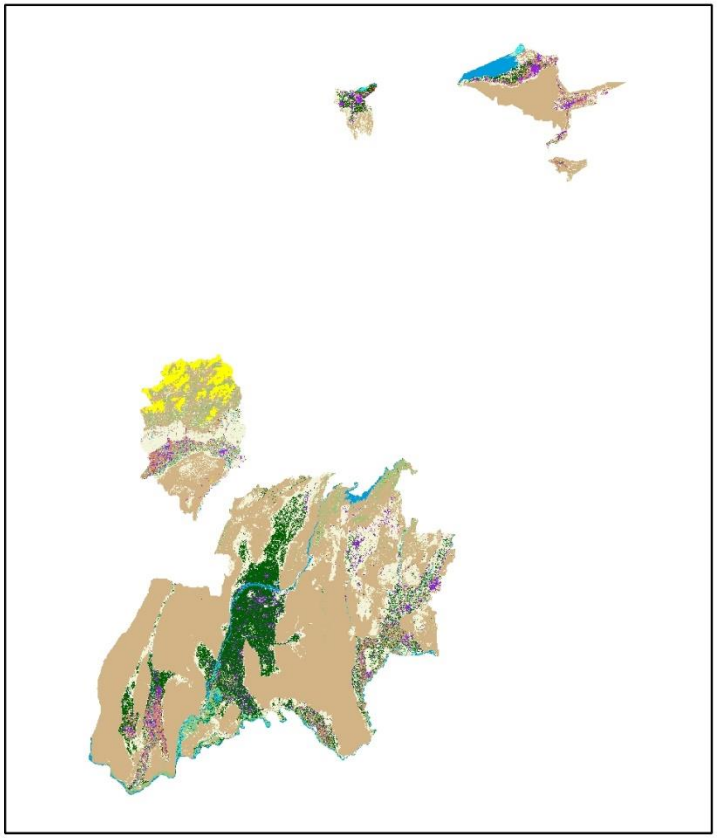
Wheat Season, 2010



Land Use

- Bareland/ Openspace/Shrub
- Built_up
- Fallow
- Fruits/Orchards/Treecover
- Other Crops
- Rice
- Water
- Wetland
- Wheat

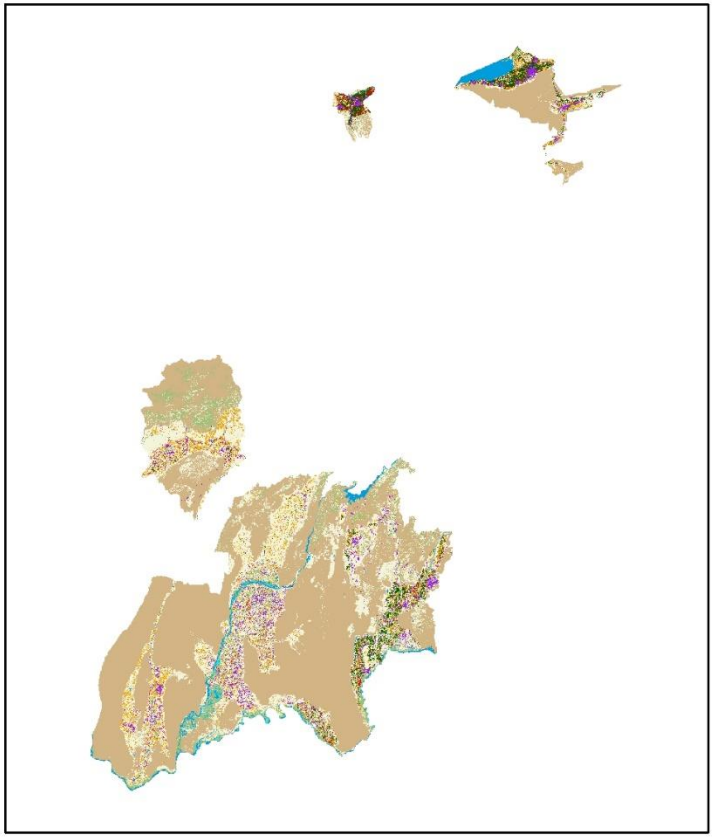
Cotton Season 2011



Land Use

- Wet_Land
- Water
- Snow
- Rice
- Other_Crops/Vegetable
- Fruits/Tree_Cover/Orchids
- Fallow_Land
- Cotton
- BuiltUp
- Bare_Land/Shrub/Fodder/Grass_Lan
- Clouds

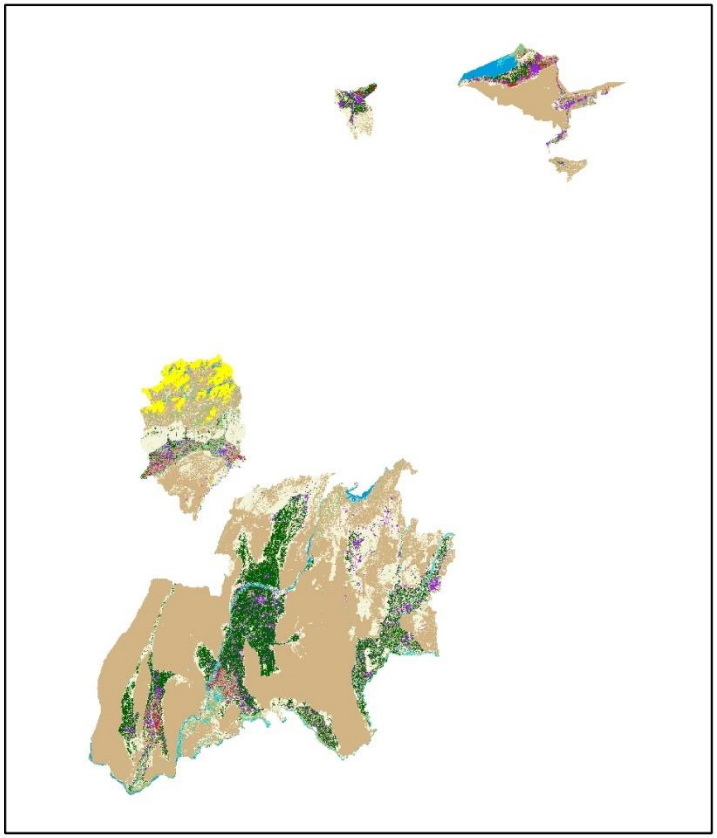
Wheat Season, 2011



Land Use

- Bareland/ Openspace/Shrub
- Built_up
- Fallow
- Fruits/Orchards/Treecover
- Other Crops
- Rice
- Water
- Wetland
- Wheat

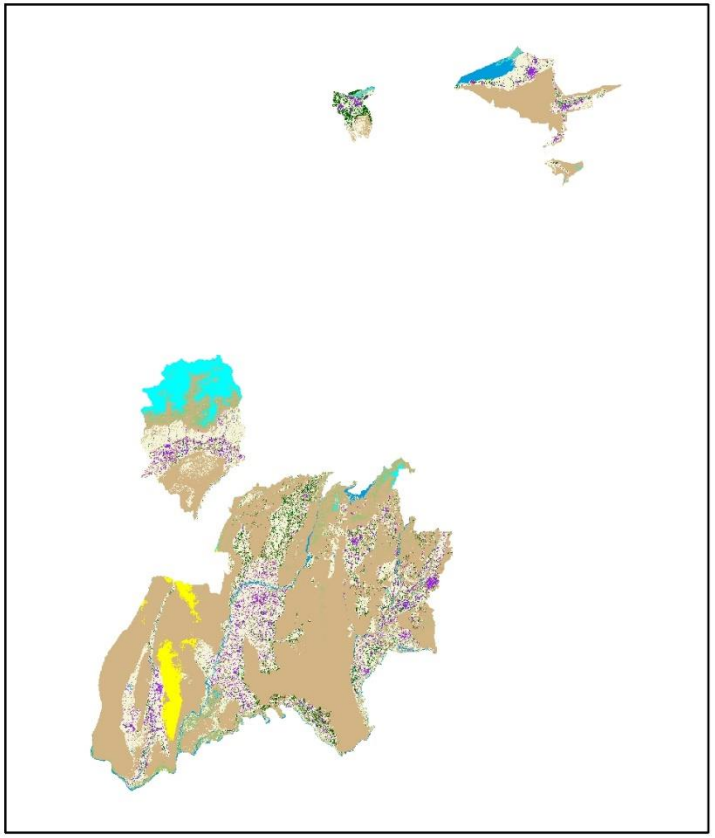
Cotton Season 2014



Land Use

- Wet_Land
- Water
- Snow
- Rice
- Other_Crops/Vegetable
- Fruits/Tree_Cover/Orchids
- Fallow_Land
- Cotton
- BuiltUp
- Bare_Land/Shrub/Fodder/Grass_Lan
- Clouds

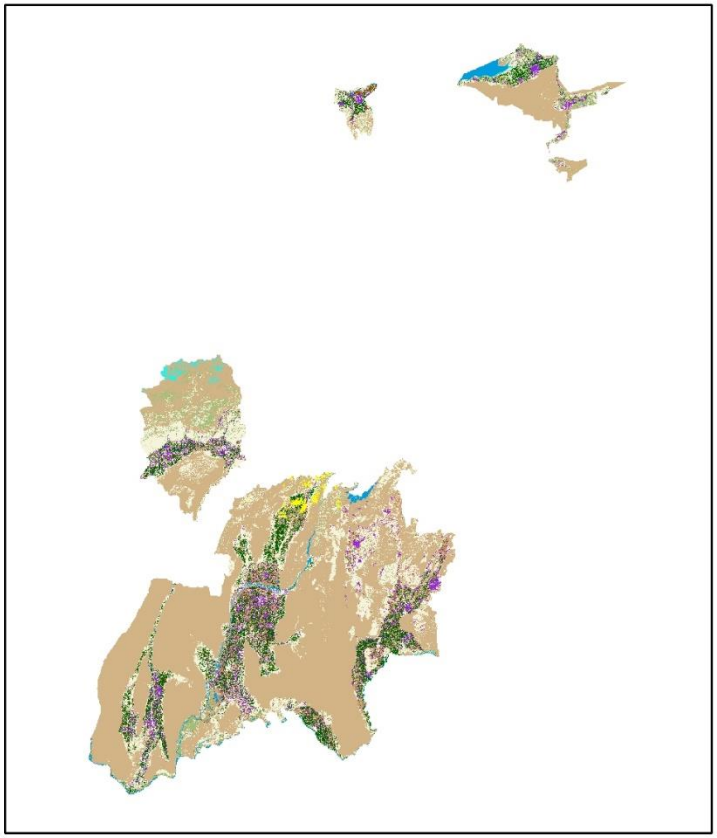
Wheat Season, 2014



Land Use

- Bareland/ Openspace/Shrub
- Built_up
- Fallow
- Fruits/Orchards/Treecover
- Other Crops
- Rice
- Water
- Wetland
- Wheat

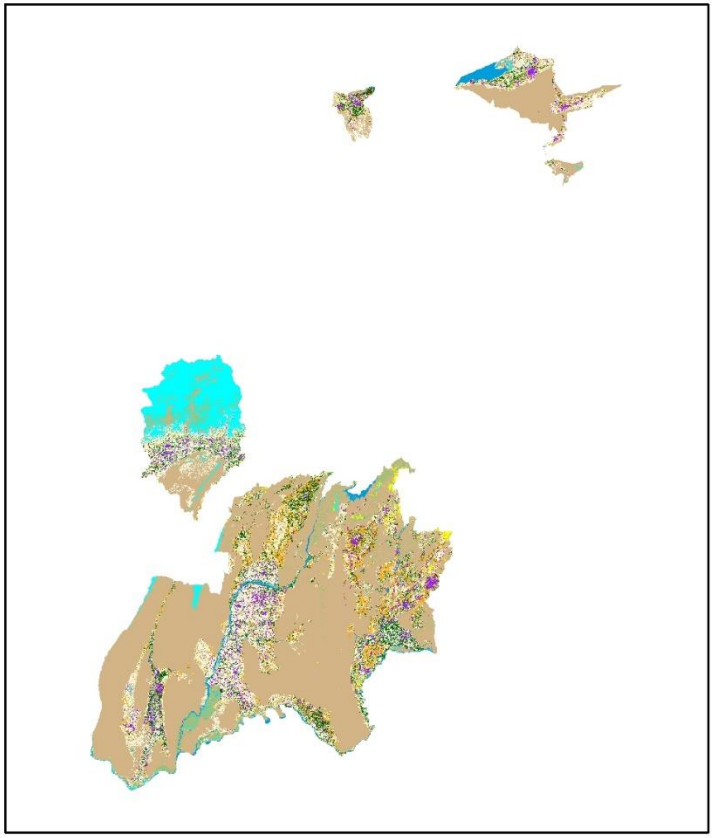
Cotton Season 2015



Land Use

- Wet_Land
- Water
- Snow
- Rice
- Other_Crops/Vegetable
- Fruits/Tree_Cover/Orchids
- Fallow_Land
- Cotton
- BuiltUp
- Bare_Land/Shrub/Fodder/Grass_Lan
- Clouds

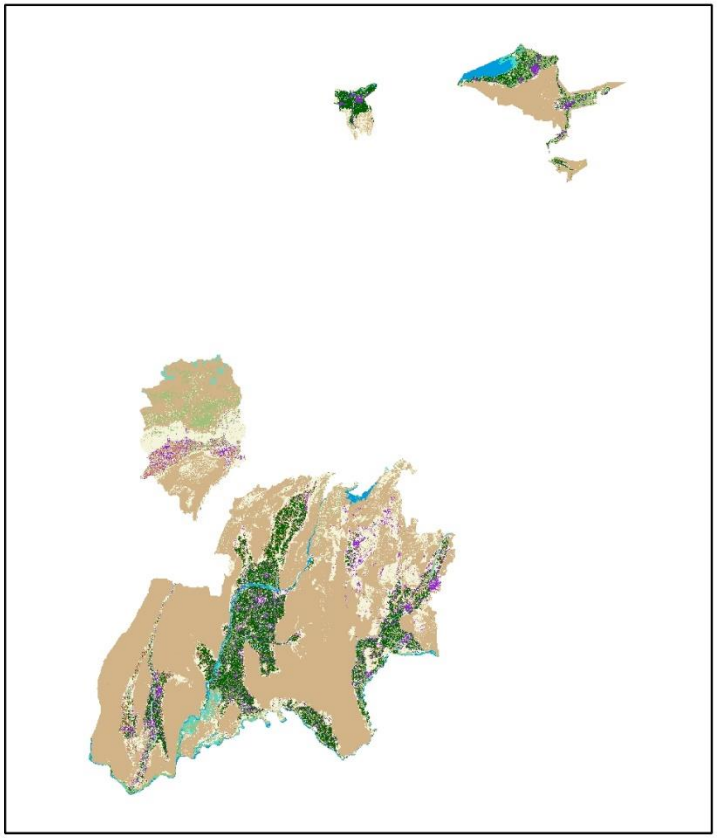
Wheat Season, 2015



Land Use

- Bareland/ Openspace/Shrub
- Built_up
- Fallow
- Fruits/Orchards/Treecover
- Other Crops
- Rice
- Water
- Wetland
- Wheat

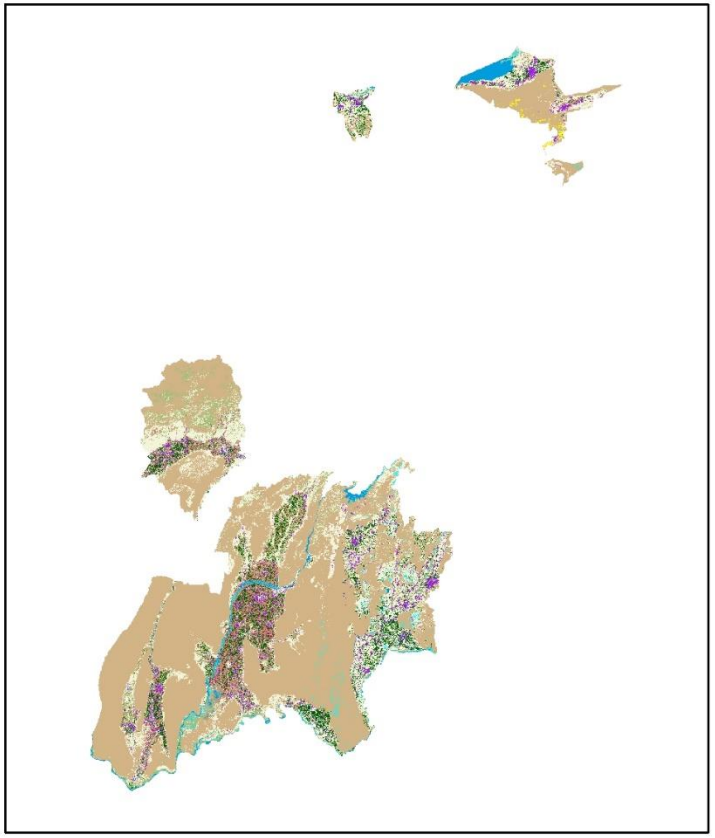
Cotton Season 2016



Land Use

- Wet_Land
- Water
- Snow
- Rice
- Other_Crops/Vegetable
- Fruits/Tree_Cover/Orchids
- Fallow_Land
- Cotton
- BuiltUp
- Bare_Land/Shrub/Fodder/Grass_Lan
- Clouds

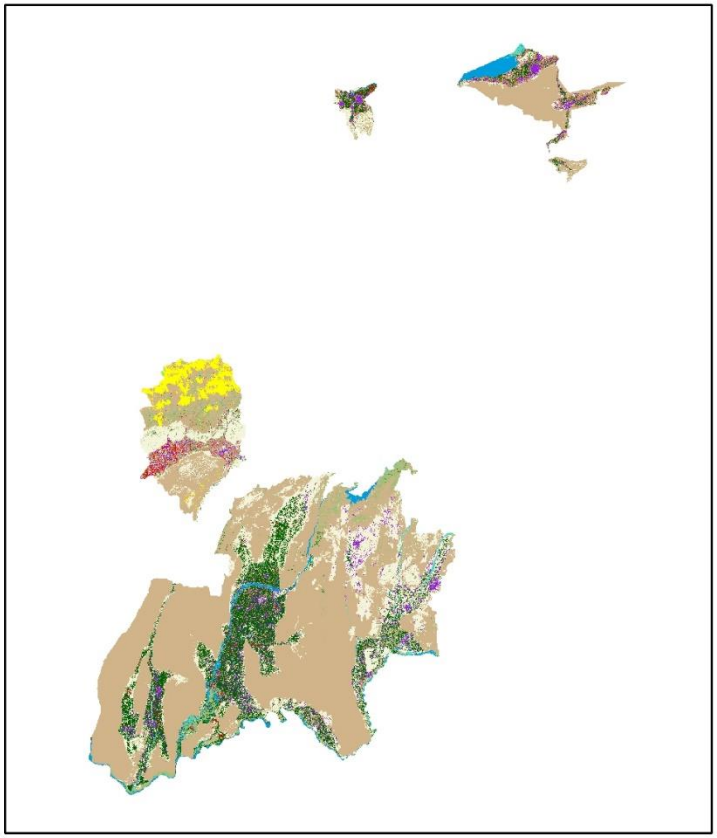
Wheat Season, 2016



Land Use

- Bareland/ Openspace/Shrub
- Built_up
- Fallow
- Fruits/Orchards/Treecover
- Other Crops
- Rice
- Water
- Wetland
- Wheat

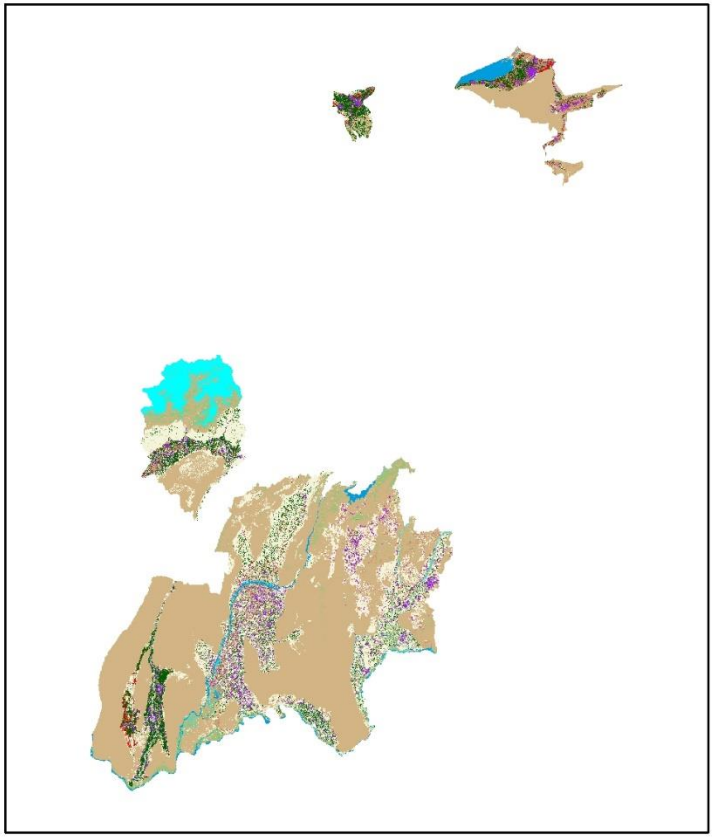
Cotton Season 2017



Land Use

- Wet_Land
- Water
- Snow
- Rice
- Other_Crops/Vegetable
- Fruits/Tree_Cover/Orchids
- Fallow_Land
- Cotton
- BuiltUp
- Bare_Land/Shrub/Fodder/Grass_Lan
- Clouds

Wheat Season, 2017



Land Use

- Bareland/ Openspace/Shrub
- Built_up
- Fallow
- Fruits/Orchards/Treecover
- Other Crops
- Rice
- Water
- Wetland
- Wheat