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Sharofiddinov Husniddin

*International Fund for saving the Aral Sea, Republic of Tajikistan*

Moinul Islam

*Research Institute for Future Design, Kochi University of Technology*

*School of Economics and Management, Kochi University of Technology*

Koji Kotani

*School of Economics and Management, Kochi University of Technology*

*Research Institute for Future Design, Kochi University of Technology*

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School of Economics and Management

Research Institute for Future Design

Kochi University of Technology

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# Does the reorganization of large agricultural farms decrease irrigation water availability? A case study of Tajikistan

Sharofiddinov Husniddin\* Moinul Islam<sup>†,‡</sup> Koji Kotani<sup>§,¶,\*,\*†</sup>

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## Abstract

Irrigation water unavailability has become one of the long term problems in Tajikistan. In the post-Soviet period, Tajikistan government started reforming agricultural land for the efficient management. The reallocation was initiated by administrative boundary changes to facilitate the growing number of farmers and ensure crop diversity. However, the modernization of the irrigation water infrastructure did not take place simultaneously. This study identifies agricultural land reform's impact on the irrigation water demand and supply of Sugd province of Tajikistan. We conduct the panel regression analysis by utilizing the data from 1996 to 2020 of the 13 states in Sugd province. We identify the impact of the number of water users, irrigation area type and water payment system on the irrigation water demand. Our results show that to deal with the changing demand of water in Tajikistan, irrigation systems need to modernize for gravity and pump irrigated areas. The payment system for irrigation water also deserves attention for the compatibility with the increasing irrigation water demand of Tajikistan. We also identify that irrigation water supply is impacted by the number of increasing water users. The possible solution to deal with the water supply shortage in Tajikistan is to eradicate system loss, introduce irrigation water rationing, improve water supply networks and update the Soviet period water pumps.

**Key Words:** Irrigation water; water users; pump irrigation; gravity irrigation; payment for water services; Tajikistan

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\*International Fund for saving the Aral Sea, Republic of Tajikistan

<sup>†</sup>Research Institute for Future Design, Kochi University of Technology

<sup>‡</sup>School of Economics and Management, Kochi University of Technology

<sup>§</sup>Research Institute for Future Design, Kochi University of Technology

<sup>¶</sup>School of Economics and Management, Kochi University of Technology

<sup>||</sup>Urban Institute, Kyushu University

<sup>\*\*</sup>College of Business, Rikkyo University

<sup>††</sup>Corresponding author, E-mail: kojikotani757@gmail.com

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# 1 Introduction

The agriculture sector is one of the leading sectors in the economy of Tajikistan, forming about 27% of gross domestic product (GDP), and employing about 70% of the working population. The agricultural sector is the largest water consumer in the country, which accounts for around 90% of water resources. The critical factor in the country's socio-economic development in agriculture contributing to the national development strategy for 2030 and the national development program for 2016 to 2020. Sustainable development of agricultural and irrigation sectors plays an essential role in economic growth, social development, food security, poverty reduction and prevention of migration through employment in the country.

After gaining independence and transitioning from a post-Soviet economy, Tajikistan's government started economic reforms. The first steps of agricultural reform began in 1995. In order to increase agricultural output, based on the rational use of natural resources in mountainous areas, such as land and water resources, by the president decree in 1995, agricultural land was distributed to farmers. After that, to develop high-income and profitable farm production and freedom of product prices, farmers' freedom to plant crops, and ensuring food security, in 1996 dated 25 June by president decree was enacted.

A series of state programs and strategies were developed for successful agricultural reform. Development of the agricultural sector was one of the programs in state economic programs such as poverty reduction strategy, state program on economic growth and state investment program. Accordingly, former collective and state farms were reorganized into large private farms. This process contributed to the development of a market economy by the free pricing of agricultural products and the choice for crop planting. On the other hand, a transition to the market based-on economy irrigation sector has been gradually transferred to the principle of self-sufficiency. Resolution of the government in Tajikistan implemented water supply payment in 1996.

Adoption of the water sector reform program of Tajikistan for the period 2016-2025, approved by the government of Tajikistan on December 30, 2015, aims to implement fundamental reforms in the land reclamation and irrigation sector of Tajikistan, considering the principles of integrated

water resources management (IWRM) and transition to the hydrographic management system. The government of Tajikistan also pays serious attention to the reform progress, especially in the land reclamation and irrigation sector. Thus, at a meeting under the Prime Minister of the Republic of Tajikistan “On reviewing the financial condition of the agency for land reclamation and irrigation, held on September 25, 2017, ALRI and other interested ministries and departments were instructed to develop the necessary measures to land reclamation and irrigation sector reform, considering the best experience of advanced countries. Also, it was aimed to establish the correct financial mechanisms, the introduction of a cashless payment system. Thereby, the process of institutional reform at the ALRI began with the transition from administrative management to hydrographic water resources management, as well as the merging of several district departments into one irrigation management system. Regarding the WUA’s, a reform was also carried out to transfer their management from administrative to hydrographic management, and WUA’s were merged in some places. Due to the financial and technical instability of WUA’s, they were reorganized and transformed several times.

Due to the imperfections of policy, regulation, and farmers’ payment ability, the former ministry of land reclamation and water resources (MLRWR) failed to bring water supply and transformation of self-sufficiency to the required level. Because of the deficiencies of funding, unsatisfactory procedures, standards of maintenance and operational works, and the lack of economic mechanisms between water supply organizations and water users, deterioration of technical conditions of irrigation and drainage infrastructure sharply fell. After the reorganization of collective and state farms, there was a problem with the water distribution and land reclamation at the farm level. Therefore, to solve the problem on the 8th of November 1996, adopted water user association law, which regulates the organization and management of water user associations (WUAs) as non-profit organizations to operate and ensure the maintenance of on-farm irrigation systems for the interest of water users. For coping with water distribution, operation and maintenance of on-farm irrigation systems, creating WUAs was necessary. However, according to the ALRI report (ALRI, 2015) at the beginning of 2016, Tajikistan created WUA, which covered almost 60% of

55 irrigated land. WUA is in the process of formation, and they are economically unstable.

56 A crucial problem in water supply organizations is water distribution to each water user be-  
57 cause of a sharp increase in the number of water users resulting from the reorganization of large  
58 farms. A series of challenges for water supply organizations are making contracts, preparing water  
59 use plans, reconciliation act on water supply, maintenance and operation of irrigation and drainage  
60 systems, service fee collection, and providing reliable and flexible irrigation water. Despite im-  
61 plementing a series of programs and strategies, the quality of water supply is getting worse in  
62 Tajikistan. Before the agricultural reform, the amount of water supply for agricultural purposes in  
63 Sugd province was more than 2.8 billion cubic meters; in contrast, within 20 years, this volume de-  
64 creased to about 1.5 million cubic meters. Several factors impacting the decrease of water supply in  
65 Sugd province include deterioration of irrigation systems, mismanagement of transboundary water  
66 resources, difficulties on water distribution to small farms, and low collection for water supply  
67 services.

68 The purpose of this research is to find out the main cause of decreasing water availability  
69 in Sugd province; therefore, conducting statistical analysis is the first step. In other words, this  
70 research examines the relationship between reorganization of large farms and amount of water  
71 distribution. This study further aims to investigate the impact of reorganization of large farms by  
72 grouping districts with more than 50% of pump irrigation areas and more than 50% of gravity  
73 irrigation areas. The final objective of this study is to develop recommendation to government of  
74 Tajikistan on future steps of agricultural and water sector reform.

75 This study employs a panel data analysis to examine region specific issues of agricultural re-  
76 form on water availability. Therefore, it is necessary to examine the cause of decreasing water  
77 supply in Sugd Province. This research seeks to answer the following questions: (1) does the  
78 agricultural land reforms decrease water availability? and (2) to what extent does the land re-  
79 forms effect water demand and supply in irrigation areas? The structure of this study organizes  
80 as follows. Section 2 provides information about irrigation systems and current situation of Sugd  
81 Province, Tajikistan. Section 3 explains data and methodology. In section 4, we report the re-

sults and provide discussion. Section 5 represents the conclusion and some suggestions for future research.

## 2 Literature review

Reorganization of large farms (kolkhoz and sovkhoz) has become one of the common issues in post-Soviet countries. A number of research papers examined the result of agricultural reform and water availability issues. Studies carried out by researchers mostly focus on the effect of agricultural reform on land and labor productivity and socio-economic situations (Besley and Burgess, 2000, Sklyarova and Balayan, 2008, Zhantemirov, 2011, Lerman and Sedik, 2008, 2009, Rakhmatov, 2009). These studies researchers stated that, in some cases, reorganization of large farms and land distribution to farmers brings positive improvement, but somehow shows no significant change or negative effect.

According to the report for European Commission under the FAO Food Security Programme (Lerman and Sedik, 2008), researchers have analyzed the economic effect of land reform in Tajikistan. Researchers argue that reorganization of large farms contributes to an increase in farmer's income and crop productivity. The major positive effects of the land reform pointed out are the growth of agricultural production by increasing stock and land, increasing productivity on household plots, structural changes and planting profitable crops, and increasing farmers and individual incomes. Additionally, limitations of the reform from the previous studies are the incompleteness of reorganization of large farms, less freedom of farmers on crop planting, and monopolistic cotton market in Tajikistan.

Furthermore, previous studies of water resource management aimed to reveal the rational and effective use of water resources demonstrate that the decentralization of water resource management can improve the condition of irrigation system, change management structure, and integrate approach to water resources management (Wilder and Lankao, 2006, Nhundu and Mushunje, 2010, Kholmatov and Pulatov, 2016, Kimsanov, 2015, Norov, 2010). However, an empirical analysis of

irrigation communities in south India shows that increasing in number of water users has a negative effect on the quality of operation and maintenance of irrigation system. Nhundu and Mushunje (2010) found out that the fast-agricultural reform has brought a reduction of irrigated land, a decline in crop productivity, reducing funds on maintenance of irrigation systems, and a decline in irrigation systems and organizations' efficiency. Finally, most of previous studies focused on impact of agricultural reform and water sector reform separately, which does not address on a statistical analysis of agricultural reform on water availability.

## 3 Methodology

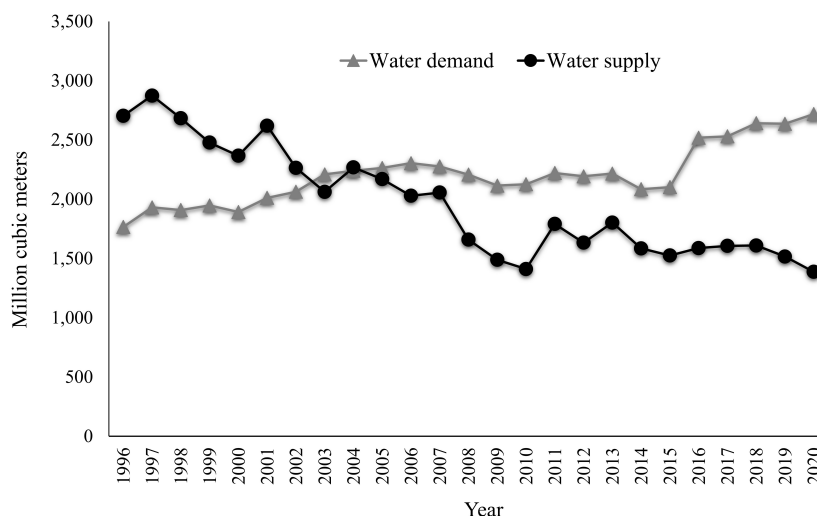
### 3.1 Study area

Sugd province is located in the northern part of Tajikistan in a semi-arid zone. Annual precipitation is 150-300 mm and dry summer reaches up to +45 degrees. Agriculture and farming play an important role in Sugd Province economy and contribute to approximately 30% of the regional income. Total irrigated area in the province counted 286,410 hectares, including 60% of pump irrigation. The number of pump stations is 183 with electricity consumption capacity 5812 thousand kW/h. For the irrigation of agricultural land, this region consumes water intake (2.8 billion cubic meters) from natural resources (river, underground water). Current water management is carried out by administrative boundaries of districts. ALRI has subordinate organizations, which one of them in regional level named "Land Reclamation and Irrigation Department", and 13 departments in district level.

The data are collected from annual reports of former MLRWR and ALRI. In figure 1, the information of water supply and water demand in Sugd Province from 1996 to 2020 is demonstrated. The amount of water supply sharply decreased from 2.8 billion cubic meters to 1.5 billion cubic meters. Nevertheless, water demand for agricultural land slightly increased. Notably, the irrigation infrastructure was constructed during Soviet Union periods, and they have not provided rehabilitation works. According to the annual report of the Committee Land Management and Geodesy



Figure 1: Water supply and demand of Sugd province in Tajikistan from 1996 to 2020. Source: SAUGRT (2021), Statistical compendium for Sugd Province. Water demand calculated from cultivated areas by type of crops.



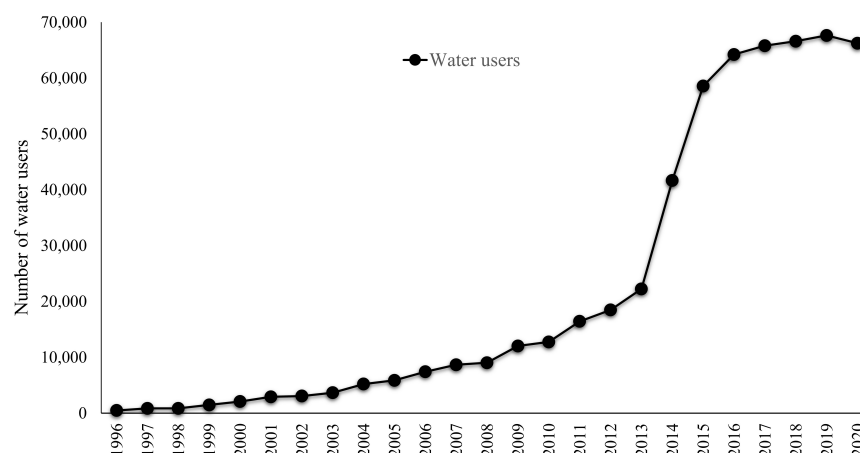
of Tajikistan (CLM&G) from 1996 to 2020, the number of water users (farmers) in Sugd province increased from 1.5 thousand to around 60 thousand.

In figure 2, details the number of water users (farmers) in Sugd Province. It shows that reforming of large farms “Kolkhoz and Sovkhoz” and land distribution to farmers has gradually increased. According to the annual report of the Committee Land Management and Geodesy of the Republic of Tajikistan (CLM&G) from 1996 to 2020, the number of water users (farmers) in Sugd Province increased from 1.5 thousand to around 60 thousand.

According to the data of statistical agency, the cultivated land including second time planting crops in gravity and pump irrigation areas. It can be seen that cultivation in both areas slightly increased. Recovering agricultural production in Tajikistan associated with land distribution to households and farmers (Lerman and Sedik, 2008).

Agricultural reform following the collapse of the Soviet Union led to a large increase in the number of water users in agriculture, especially at the level on-farm irrigation systems. As a result of the land reform in 1996, former large collective and state farms ranging from 500 to 4-6 thousand hectares have been privatized and split up into hundreds or thousands of small farms.

Figure 2: Number of water users in Sugd province from 1996 to 2020. Source: Annual report of the Committee Land Management and Geodesy of Tajikistan



However, most of irrigation system, such as canals, collectors, and pump stations in the Soviet era have been designed for the huge farms. In the reform 2014-2015, large farms (10 to 100 hectares) were again reorganized and land was distributed to farmers. This has led to the neglect of the on-farm irrigation systems, increasing problems with the distribution of irrigation water, drainage functions, and decreasing water productivity.

According to the annual report of ALRI in 2015 ALRI (2015), the quality of providing services is decreasing due to the reorganization of large farms, and they faced a great deal of difficulties on water distribution and water fee collection. State water management departments of ALRI in one district has to serve on average 15,000 hectare of land. Before the reorganization, there was 12-15 large farms, for which irrigation system was designed, while after reorganization the reorganization becomes more than 15,000 farms. For water management in the level of on-farm irrigation system, government created WUA in 2006; however the function was not as good as expected. Water service tariff which collect ALRI is inadequate to provide operational and maintenance works in the irrigation system. In addition, WUA's membership fee is limited for the maintenance of the on-farm irrigation system.

Another important issue is that more than 60% of agricultural land irrigated by pump stations

in Sugd province. Most of the pump stations in Sugd province are considered as cascades like the pump stations in Zafarobod district. As discussed earlier, most of pump stations were constructed from 1950 to 1980. The over use of pump equipment and pipelines reduces the efficiency of pumps.

Water resources management on irrigation sector conducts on traditional and administrative-territorial principles. ALRI is in the national level while in the province level is regional land reclamation and irrigation department in Sugd region. It includes 13 district land reclamation and irrigation departments (LRID): 1) Aini, 2) Asht, 3) Gafurov, 4) Gonchi, 5) Isfara, 6) Istaravshan, 7) Konibodom, 8) Mastchoh, 9) Panjakent, 10) Rasulov, 11) Shahriston, 12) Spitamen and 13) Zafarobod. General structure of the management of the operation of irrigation and drainage systems ALRI.

Sugd region is located in the Sirdarya river basin comprising of 11 districts and 8 towns. To provide irrigation water to agricultural land in this area deals with one regional and 13 district organizations of land reclamation and irrigation. The main sources of water for irrigation are Sirdarya, Serafshan, Isfara, Khodjabakirgan, Isfana and Aksu rivers. Isfara, Isfana, Khodjabakirgan, and Aksu are tributary of the Sirdarya river. Sirdarya, which crosses four Central Asian countries, mainly formulates in Kyrgyz Republic and flows to Uzbekistan then to Tajikistan, and then to Uzbekistan. Most of water resources considered as trans boundary resources.

Dankov (2007) argues that the agrarian sector in Fergana Valley plays an important role in socio-economic development in Central Asia, which includes 4.3% territory Uzbekistan, 40.4% in Kyrgyz Republic, and 17.6% in Tajikistan. Dankov states that an acute shortage of water and land resources, non-effective economic reform, the unfavorable investment climate and border regime.

## **3.2 Data**

The data used in this study is the secondary data obtained from the ALRI and former MLRWR, CLM&G, and Statistical Agency (SAURT). The data collected for 13 districts of Sugd province in Tajikistan. This database of this study includes:

(A) Data obtained from annual reports of ALRI: (i) The amount of distributed water from 1996

to 2020, (ii) percentage of collected payment for water service fee from 1996 to 2020, (iii) the pump irrigation area collected from technical characteristic of pump stations.

(B) Data obtained from annual reports of CLM&G: (i) Number of farmers (water users) from 1996 to 2020.

(C) Data obtained from SAURT: (i) total cultivated area for agricultural production, including second time planting crops at the same area, (ii) the actual water demand from 1996 to 2020 was calculated from cultivated area by type of crops. According to antimonopoly service under the government of Tajikistan from 1st of April 2011, water service tariff from state irrigation system for each agricultural crop in one hectare determined the average limit water consumption. For example, one hectare of cotton needs 10,000 cubic meters; rice needs 37,000 cubic meters; fruit trees needs 9,500 cubic meters; and potato needs 6,500 cubic meters,

(D) The gravity irrigation area from 1996 to 2020 calculated from total cultivated area minus pump irrigated area.

### **3.3 Statistical analysis**

This research uses a panel data for 25 years from 1996 to 2020 to examine the impact of agricultural reform, known as reorganization of large farms (kolkhoz and sovkhoz), and increasing number of water users on water availability (amount of water distribution) in Sugd Province of Tajikistan. The data consists of the amount of distributed water, number of water users, actual percentage of collected payment for water services, gravity irrigated area, pump irrigated areas, and actual irrigation water demand. The results of this study can indicate the impact of agricultural reform on the irrigation sector.

Based on the hypothesis in this research, the amount of water demand (thousand meter cube per year) and water supply (thousand meter cube per year) are used as dependent variables. The number of farmers, gravity irrigated areas, pump irrigated areas, and percentage of collected payment are independent variables in our model.

The regression equation to estimate the irrigation water demand is follows:

$$Waterdemand = \alpha + \beta_1 W.users + \beta_2 Gravityarea + \beta_3 Pumparea + \beta_4 Payment + \epsilon \quad (1)$$

The regression equation to estimate the irrigation water supply is follows:

$$Watersupply = \alpha + \beta_1 W.users + \beta_2 Gravityarea + \beta_3 Pumparea + \beta_4 Payment + \epsilon \quad (2)$$

In this study, the an independent variable represents the number of water users farmers. A district with a large number of water users will tend to have decreased the amount of water supply. An increase in number of water users in district is expected to decrease on water supply amount. Another independent variable represents the gravity irrigated area. The gravity irrigated area applied in this study to estimate the effect of increasing of gravity irrigation area on water supply. Another purpose of adding this variable is to determine the effect of increasing number of water users on gravity irrigation. The next independent variable represents pump irrigated area. This variable was used to estimate the decreasing amount of water supply in pump irrigated areas. More than 60% of the Sugd province irrigated by pump station. The last variable represents the percentage of collected water service fee. Irrigation sector is transferring to self-sufficiency system, and future development of this sector depends on the creation of the cycle economic mechanism. The quality of provided services, operation and maintenance of irrigation networks, salary, tax, electricity cost, and other expenses relate to the amount of collected fees. Insufficient collected payment will negatively affect the quality of service for the next year. To determine the effect of reorganization of large farms on water supply, this study used a panel data regression with fixed effect model. In order to analyze the impact of the increasing number of water users on the amount of water distribution, it is necessary to use the following regression.

Table 1: Summary statistics

Variables	Unit	Mean	SD
Water supply	Thousand cubic meter per year	151,321	127,303
Water demand	Thousand cubic meter per year	169,624	78,266
Water users in prefectures	Number of farmers	1882.829	2732.899
Gravity irrigation areas per year	Hectare	10685.840	9748.551
Pump irrigation area per year	Hectare	13152.110	10644.580
Payment	Percentage of collected payment	67.424	32.630

## 4 Results

The purpose of this research is to identify the impacts of land reforms on irrigation water demand and water supply. In table 1, we report the description of the data.

We identify the impacts of other explanatory variables, for instance, number of water users, gravity irrigation areas, pump irrigation areas, and percentage of collected payment. This study uses a panel regression model with fixed effect model to analyze the effect of land reform on water availability from the starting period of land reform policy implementation from 1996 to 2020. We have collected data of 299 observations on 13 districts of Sugd province for 25 years. In order to determine which model is appropriate for data analysis, Hausman test was applied. In this model, a null hypothesis is appropriate with a random effect model while alternative hypothesis is appropriate with a fixed effect model. The probability value of the diagnostic test is less than 1%. It means that outcome of the test is to reject null hypothesis and accept alternative hypothesis.

In table 2, we report the results of a fixed effect regression model. This results show the relationship of water demand with number of water users, gravity irrigated area (ha), pump irrigated area (ha), and percentage of collected payment. According to the results, increasing number of water users in Sugd region negatively effects water supply. Number of water users have been identified to be very important to describe water demand in Sugd Province. The result shows that the coefficient of water users is statistically and economically significant. It means that holding other variables constant if the number of water users increase by one unit, it might decrease water demand by 1.92 thousand cubic meter.

Table 2: Estimation of the panel regression for the amount of water demand in Sugd region

Explanatory variable	Coefficient
Water users	1.9162*** (0.5402)
Gravity irrigation area	6.5299*** (0.6161)
Pump irrigation area	7.0469*** (1.0809)
Payment	−1.0256** (48.1593)
Constant	3823.022*** (13673.56)
Sample size	299
Number of districts	13
R-squared	0.6925
Country FE	<i>YES</i>
Hausman test (chi2)	13.75***

\*\*\* significant at 1 % percent level

\*\* significant at 5 % percent level

\* significant at 10 % percent level

Standard errors are in parentheses.

Table 3: Estimation of the panel regression for the amount of water supply in Sugd region

Explanatory variable	Coefficient
Water users	−7.6044*** (1.0892)
Gravity irrigation area	0.9365 (1.2245)
Pump irrigation area	−3.1645 (2.1482)
Payment	131.855 (95.7156)
Constant	182469.9*** (27175.81)
Sample size	299
Number of districts	13
R-squared	0.57
Country FE	<i>YES</i>
Hausman test (chi2)	26.82***

\*\*\* significant at 1 % percent level

\*\* significant at 5 % percent level

\* significant at 10 % percent level

Standard errors are in parentheses.



Based on the regression result, the area of gravity irrigation has positive effect (-6.53) on the water demand amount. In other words, the increasing area of gravity irrigation increase the level of water demand by 6.53 thousand cubic meter. The result shows that increasing pump irrigation area has a positive relationship with water demand (7.05). It means that increasing 1 hectare in pump irrigation area might increase water demand by 7.05 thousand cubic meter. As most pump stations were constructed from 1950 to 1980 with low efficiency, increasing cultivation territory or second time cultivation in pump irrigated areas associated with water demand. Another important issue is that most of pump stations are considered as cascades. Water demand of farms which located in the second, third, and fourth cascades has a high amount of water loss. Collection of payment for providing services has a negative impact on water demand (-1.03). Result of regression indicates that increasing water fee collection by 1% will decrease water demand by 1.03 thousand cubic meter.

Table table 3 shows the result of a fixed effect model regression on water supply. The result shows that the coefficient of water users is statistically and economically significant. It means that holding other variables constant if the number of water users increase by one unit, it might decrease water availability by 7.6 thousand cubic meter.

## 5 Conclusion

This study discusses the effect of reorganization of large farms, the areas of gravity irrigation, the areas of pump irrigation and water fee collection on the water demand and supply in Sugd province, Tajikistan. By employing the panel data from 1996 to 2020, this paper finds that reorganization of large farms have been identified to be very important to describe water demand and supply in Sugd Region, Tajikistan. Past studies indicate that agricultural reform in Tajikistan contributes to the growth in land and agricultural production, this study shows that agricultural reform significantly associated with decreasing of water availability and increasing water demand in Sugd Province. In other words, decreasing water availability might bring a negative effect on

agricultural production in Sugd province.

However, this study encountered several limitations such as the effect of transboundary water resource management, annual precipitations, and deterioration rate of irrigation systems. As long as the level of water in reservoir and water flow from upstream countries always fluctuate, there was not a possibility to include these data. Another reason of limitation is the lack of data on depreciation rate of irrigation systems and data on annual precipitation in this area. Furthermore, there is a lack of database in water resource management organizations. Thus, a future study needed to analyze at district level by employing a monthly data including limitations of this research.

Tajikistan has a limited irrigated land, and implementation of correct agricultural reform (reorganization of large farms) plays a vital role in providing food security, increasing farmer's income and provision of workplaces in the country. Water availability is the most important resource for increasing crop yield, and plays a significant role in the sustainable agricultural reform. A gradual decrease in water availability in Sugd Region, which has a dry and hot season in vegetation period, might bring serious problems for the development of agrarian sector. Rehabilitation of pump station and irrigation systems and redesigning of irrigation system to the size of farms, implementation of new water supply technologies, water measurement facilities, creation of database, and cultivation of more profitable crops with less water demand in pump irrigation areas shall be necessary steps for the policy of agriculture and water sectors reform in Tajikistan.

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