# WATER PRODUCTIVITY OF COTTON IN FERGANA VALLEY OF CENTRAL ASIA

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**Introduction**

After independence from the former Soviet Union (around 1990), the operation and maintenance of the irrigation systems was neglected due to lack of financial resources. This exacerbated the pre-existing problem of waterlogging and salinity of irrigated lands. For example, in Uzbekistan, the total cultivated area is more than 10.7 million hectares, out of which close to 8 million hectares are subjected to salinization. Today, the actual irrigated area in Uzbekistan is a little over 4 million hectares. In Central Asia as a whole, more than 5.97 million ha of irrigated area out of the total irrigated area of 8 million hectares requires artificial drainage. Drainage is accomplished through a combination of vertical and horizontal drains. About 5.34 million ha of irrigated area is covered with collector-drainage (surface) network. Once again, due to lack of proper maintenance, most of the drainage system is not working properly which further exacerbated the problem of waterlogging and salinity. There were significant investments in drainage in the region until 1990s. However, with the collapse of the Soviet Union, drainage systems are no longer properly maintained and the area under waterlogging and salinity has been steadily increasing: 35 % increase in waterlogged area and 62 % increase in area under moderate to high salinity.

Furthermore, the State/Collective farms disintegrated, with nobody to claim the ownership of irrigation and drainage infrastructure. Land was distributed to local people, irrespective of their prior background in agriculture. In Kyrgyzstan, Kazakhstan and Tajikistan, farmers own their land, whereas in Turkmenistan and Uzbekistan farmers lease their land from the government. Disintegration of large farms has increased the number of farmers the majority of whom have inadequate knowledge/skills of irrigated agriculture. There was insufficient on-farm irrigation infrastructure to distribute water to individual farmers. During the Soviet era, every State/Collective farm had professional agronomists and irrigation specialists for providing advisory services for irrigated agriculture. However, with the collapse of the system, some of this expertise was lost. Without adequate irrigation infrastructure below tertiary level, and without any organizational support for water distribution below the tertiary canal level, irrigated agriculture became chaotic - head-end/tail-end problems, inequity and unreliability in water supply, lack of advisory services on agricultural practices, lack of appropriate farm machinery for operation on small farms, etc. This situation combined with waterlogging and salinity has resulted in significant reductions in crop yields, and by early 2000s food security became a major issue for countries of Central Asia.

After year 2000, through Agricultural Reform Acts, Water User Associations (WUAs) have been formed. This process is not complete in Tajikistan and Turkmenistan. Today, there are close to 66,000 farmers grouped into 1486 WUAs in Uzbekistan. The Governments agencies provide bulk water supply to WUAs, and then it is the responsibility of WUAs to supply this water equitably to individual farmers. Yet, there are problems of equity and unreliability of water supply within WUAs hindering improved water management at plot level.

With a view to address the food security situation arising from water scarcity and inadequate management of irrigation systems, the Swiss Agency for Development and Cooperation (SDC) financed a project for improving water productivity at plot level. The objective of this project was to develop and test an effective mechanism called 'Innovation Cycle' for dissemination of knowledge on improving water productivity to farmers in the Fergana Valley of Central Asia on an experimental basis. To assess the effect of this innovation cycle on improving water productivity, data was collected from several demonstration sites in the countries of Kyrgyzstan, Tajikistan, and Uzbekistan on water productivity of cotton and wheat crops. This paper presents the improvement in water productivity of cotton from the project sites. A separate paper is being prepared on the water productivity of wheat.

**Description of Site Characteristics**

| Province | Site | Field Capacity, mm/m | GWT, cm |
|---|---|---|---|
| Andijon | 1 | 186 | >300 |
| | 2 | 181 | 150 |
| | 3 | 184 | >300 |
| | 4 | 167 | 200 |
| | 5 | 189 | >300 |
| Fergana | 6 | 192 | 160 |
| | 7 | 173 | 160 |
| | 8 | 166 | 150 |
| | 9 | 161 | 140 |
| | 10 | 153 | 250 |
| Namangan | 11 | 160 | >300 |
| | 12 | 184 | 150 |
| | 13 | 192 | >300 |
| Sogd, TJ | 14 | 167 | >300 |
| | 15 | 192 | >300 |
| | 16 | 167 | >300 |
| | 17 | 125 | >300 |
| | 18 | 192 | >300 |

A total of 18 (13 sites in Uzbekistan and 5 sites in Tajikistan) demonstration sites were selected for conducting research on water productivity of cotton. All the demonstration sites were selected from the Water Users Associations (WUAs) of the WPI-PL project. For all the demo fields, information on soil texture, field capacity, depth of watertable from the ground surface (from Hydro-Melioration Expedition of Uzbekistan), area of the fields was collected (See Table). All the fields are irrigated using furrow irrigation, with runoff from the downstream end. The fields are sloping with undulations. Flow measurement structures were installed at all the demonstration sites to measure inflow into and outflow from the fields. For every field, farmers get recommendations on the amount of different fertilizers to be applied, and information on irrigation system operation plan, based upon the expected water supply during the irrigation season. Information on the irrigation norms (based upon hydro-module zoning) is also provided to WUAs.

To collect data from farmers' fields, a simple user-friendly form which describes the location of farm, area covered with major crops, type and kilogram of seed farmer applied per ha, amount and cost of fertilizer and pesticides used per ha, cost of equipment for tillage and cultivation, cost of labor, amount of irrigation water applied per hectare, cost of transportation, fixed costs for agricultural production, and finally yield of major crops was developed and used. In addition, climatic data from the nearest weather station for each of the 18 sites were gathered for calculating reference evapotranspiration of cotton crop at the given locations.

**Methodology to Calculate Water Productivity**

There are several definitions of water productivity (WP). The most commonly used definition is given as the ratio of the crop yield, $Y_{crop}$(kg/ha), divided by the consumptive use of water by the crop, $ET_{actual}$ ($m^3$/ha), which is given as

$$WP = \frac{Y_{crop}}{ET} \qquad (1)$$

in which $Y_{crop}$ = is the measured crop yield under natural and irrigated conditions; and ET = estimated/measured seasonal evapotranspiration or crop water use. The above definition is independent of the source of water used for ET. The source of water for ET may be a combination of one or more of the following: rainfall, groundwater, residual soil-moisture from previous season or irrigation water. The other commonly used definition of WP is given as follows:

$$WP_I = \frac{Y_{crop} - Y_D}{V_I} \qquad (2)$$

in which $WP_I$ = irrigation water productivity of crop, kg/$m^3$; $Y_D$ = crop yield under dryland conditions (rainfall, residual initial soil-moisture content from previous season, groundwater contribution), kg/ha; $V_I$ = cumulative volume of irrigation water applied during the crop growing season, $m^3$/ha.

The water productivity definitions provided above (Eqs. 1 and 2) do not provide any indication of efficiency of water application at field level. Sometimes, farmers apply 1.5 times more water than what is required by the crop; yet, the actual water use by crop (ET) only goes up by less than 25% of its water use under normal conditions. In order to capture the inefficiency of water application by farmers, the following definition of water productivity is proposed here:

$$WP_G = \frac{Y_{crop}}{V_{all}} \qquad (2)$$

in which $WP_G$ = gross water productivity, kg/$m^3$; and $V_{all}$ = volume of water applied to a field from all sources (rainfall, residual soil-moisture, groundwater, and irrigation water), $m^3$/ha.

**Results and Discussion**

Water productivity of cotton crop was calculated for the 18 demonstration sites for the 2009, 2010, and 2011 irrigation seasons. As a policy, the Government of Uzbekistan, measures and records the yield of all cotton fields every season. Yield data for the nine demonstration sites was obtained from the Governmental records. During the 2010 season, cotton crop was grown only at three of the nine demonstration sites. These yields, along with the detailed cost of production, are shown in Table 2. Most of the research effort went into estimating the consumptive use of cotton crop and the total amount of water supplied from all sources (initial soil-moisture content, groundwater contribution, irrigation, and rainfall) for all the nine demonstration sites in 2009 and the three demonstration sites in 2010.

Information on daily rainfall amounts (in millimeters) and daily weather conditions was obtained from the nearest weather station for each of the nine demonstration sites. Penman-Monteith equation, as described by Allen, et al (2000) was used to compute the daily evapotranspiration of a reference crop (short grass), $ET_{ref}$, for each of the 18 sites. Based upon the depth of the watertable and the soil-texture, groundwater contributions to the crop rootzone were calculated. Information on dates and amounts of rainfall, daily groundwater contributions, daily $ET_{ref}$, and dates and amount of irrigation for each site was used to calculate soil-moisture balance in the root zone. In the simulation, the following assumptions were made:

1. The soil-moisture content in the crop rootzone was assumed to be close to field capacity at the beginning of the season.
2. The maximum rooting depth of cotton was assumed to be 1.6 m. The active rooting depth at the beginning of the season was assumed to be 0.30 m, and the rooting depth was assumed to increase to its maximum rooting depth linearly by the end of vegetative period. In situations where there was a high watertable, the maximum rooting depth was set equal to the lowest level of the watertable which typically occurred during the second half of the crop growth season.
3. If the calculated soil-moisture content on any given day was higher than the field capacity soil-moisture content for that soil, due to irrigation or rainfall, the soil-moisture content was set equal to the field capacity soil-moisture content for that soil.

These simulated values of daily soil-moisture content were used to calculate the daily soil-moisture stress coefficient which was then used to estimate the daily actual evapotranspiration, ET, of cotton. For the purpose of this research, the $K_c$ values suggested by Allen, et al (2000) were used. The daily Kc values were obtained by linear interpolation of the values suggested by Allen, et al (2000). The seasonal amount of irrigation water applied, rainfall amounts received, groundwater contributions to crop rootzone, and the simulated total consumptive water use of cotton crop were calculated for all the sites, and are presented in Figure 1. It is clear from Figure that the seasonal consumptive water use of cotton crop, $ET_a$, varied from 4500 $m^3$/ha to 8000 $m^3$/ha, depending upon the soil texture, irrigation amount, and climatic conditions. The total amount of water applied to fields varied from 5000 $m^3$/ha to 12,000 $m^3$/ha. In general, the lowest total water applied and $ET_a$ occurred in 2011 because it was a dry year!

Cotton yields from the demo plots varied from 2000 kg/ha to 5500 kg/ha, with an average yield of about 3,400 kg/ha, whereas the average yield of the adjacent fields was about 3000 kg/ha (Figure 2). Even though 2011 was a dry year, cotton yields during 2011 were as good as yields during 2010 which was a wet year. Farmers were very efficient in using irrigation water during 2011.

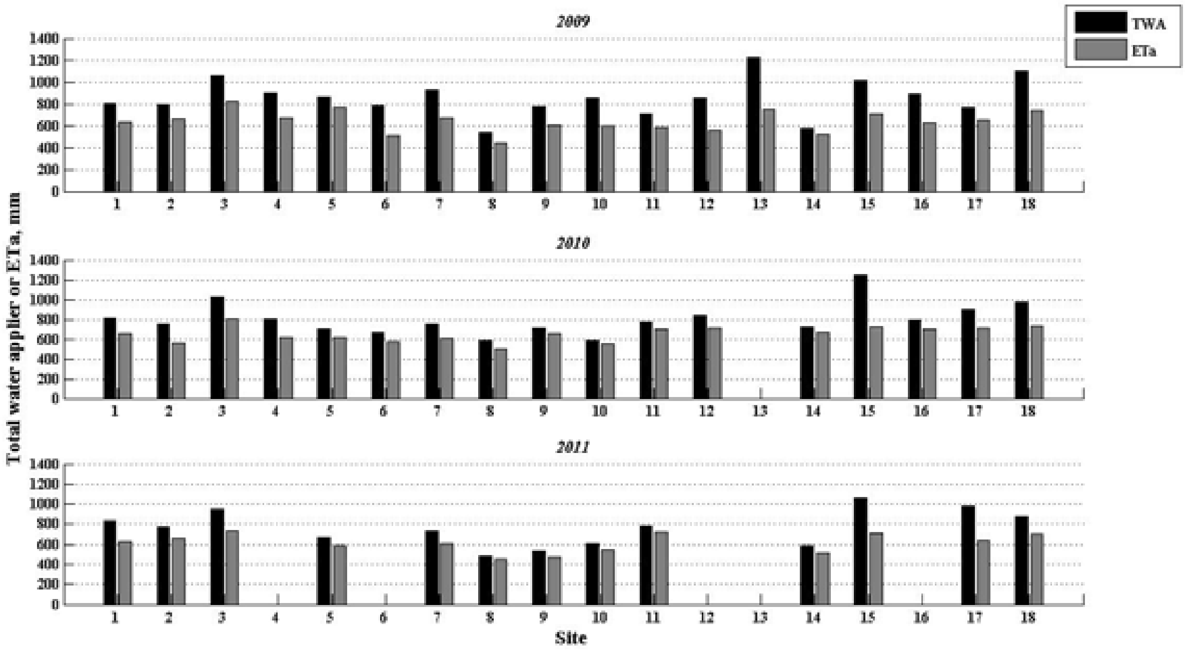


Figure 1 - Total water applied (TWA) and crop evapotranspiration (ETa) for the demo plots

Water productivity (WP) values were calculated based upon the yield (Fig. 2) and $ET_a$ values (Fig. 1), whereas $WP_G$ values were calculated using crop yield and TWA values. The WP values ranged from 0.35 kg/m$^3$ to 0.89 kg/m$^3$, with the average value of WP being 0.55 kg/m$^3$. Figure 2 also shows that the $WP_G$ values ranged from 0.2 kg/m$^3$ to 0.80 kg/m$^3$, with an average value of 0.40 kg/m$^3$.

Ibragimov, et al (2007) reported water productivity values of 0.46-0.50 kg/m$^3$ from their experiments (not farmers' fields) conducted at the Central Experiment Station of the Uzbekistan National Cotton Growing Institute near Tashkent in years 2003, 2004 and 2005. As opposed to the WP values reported by Ibragimov, et al (2007), the WP values reported here are from farmers' fields (demonstration sites), and are higher than the values received at controlled experimental sites. Similarly, Unlu, et al (2007), from their experimental sites in Turkey, reported irrigation water productivity (WPI) values of cotton crop under different irrigation treatments, and these values ranged

from 0.22 kg/m$^3$ to 0.53 kg/m$^3$, the average value being around 0.36 kg/m$^3$. These values are significantly less than the WP values obtained in Fergana Valley.

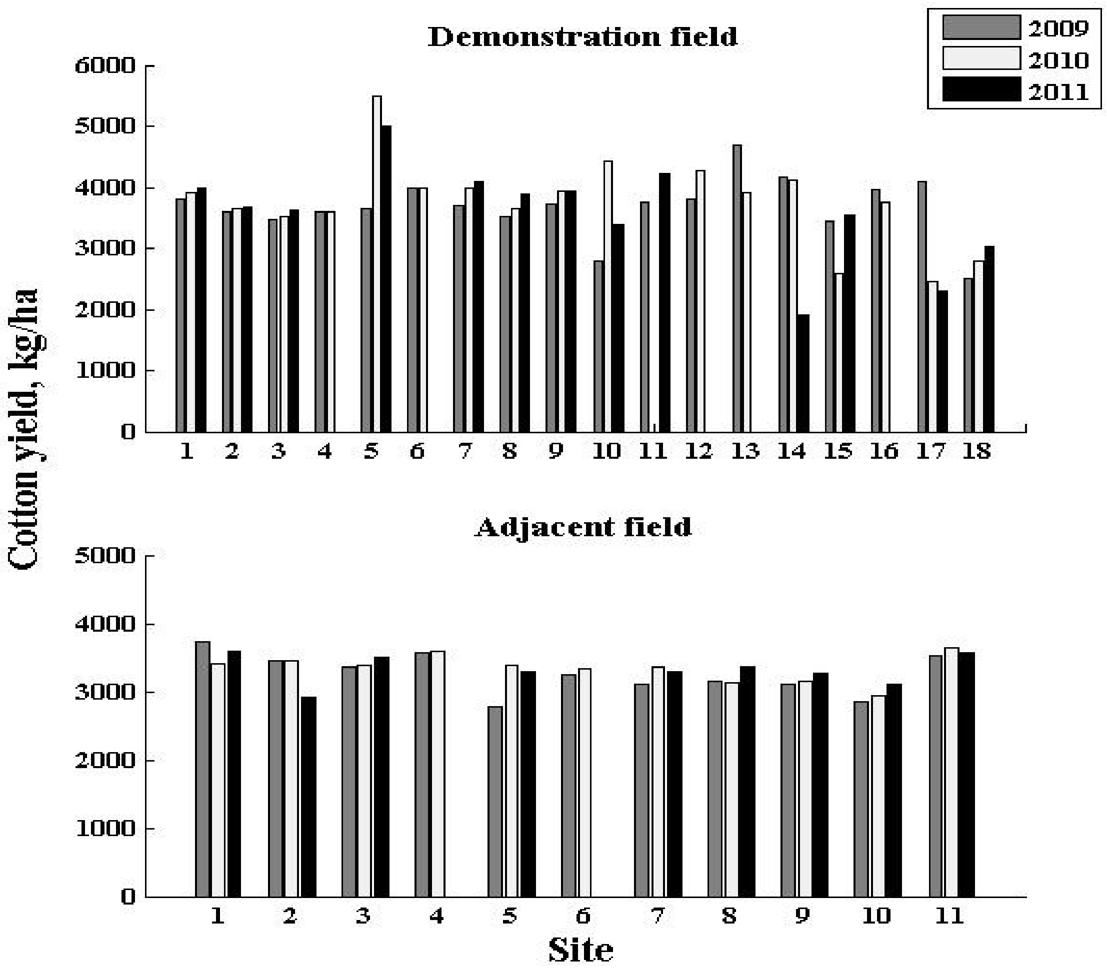


Figure 2 - Cotton yields from demo fields and adjacent fields

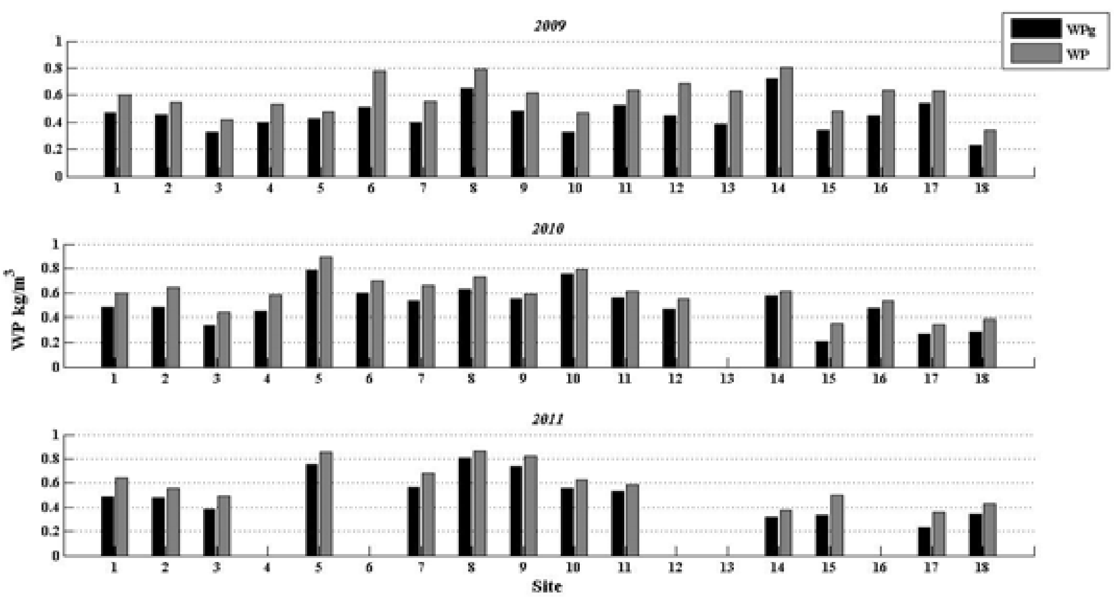


Figure 3 - WP and WPG values for demo fields for years 2009, 2010 and 2011

There is a difference of 0.15 kg/m$^3$ between water productivity (WP) and gross water productivity ($WP_G$) values (Figure 3). This difference basically indicates the potential for improving water productivity through improved irrigation management at field level by proper design and operation of irrigation systems (irrigation scheduling). This improved irrigation water management at field level includes minimizing non-beneficial use of water such as runoff water, deep percolation water, minimizing evaporation from stored soil-moisture, proper utilization of local groundwater, etc. With the assumption that a large fraction of the water losses that occur at field level are re-captured and re-used for irrigation elsewhere, this difference of 0.15 kg/m$^3$ between WP and $WP_G$ implies that there is a potential for increasing cotton by more than 30% with a given quantity of irrigation water. This also implies that there is a potential for saving 30% of water, and produce the same quantity of cotton.

**Summary and Conclusions**

The ETa, TWA, and crop yields for cotton crop were calculated for 18 demonstration sites for the irrigation seasons of 2009, 2010, and 2011. Based upon this, the WP and WPG values were calculated for all the sites for the three irrigation seasons. The demonstration site farmers were provided with information on improved agronomic practices and irrigation water management practices. Hence, there was a difference in yield of close to 500 kg/ha between the demonstration site farmers and farmers from adjacent fields. The WP values achieved in the demonstration fields are higher than the yields reported from experimental plots in Uzbekistan and Turkey. The calculated difference between WP and $WP_G$ indicates that there is a potential for saving 30% of water without affecting cotton yields.

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