Report 2015

Output-1: Collecting and analyzing data on the current status of groundwater levels and salinity, canal water use and salinity, irrigation and drainage layout, soil texture and salinity, climatic data (MS-Excel/GIS, MS Word) – 2015

Title: Evaluate the effect of conjunctive use of canal and drainage waters, different cropping patterns, and improved irrigation practices on control of salinity and waterlogging and delineate most efficient water management and agronomic practices

CRP-DS Action site:	Aral Sea basin (the Khorezm province, Uzbekistan).
IARC Project Team:	Dr. Usman Khalid Awan, Groundwater Hydrologist Dr. Bogachan Benli (ICARDA) - Senior Irrigation and Water Management Specialist Mr. Tulkun Yuldashev - Soil and Water Specialist
Implementing Country:	Uzbekistan
ICARDA Program:	Integrated Land and Water Productivity Improvement in Aral Sea Basin
Research Team (National):	Khorezm Rural Advisory Support Service (Hereinafter KRASS) Scientific information Center for Interstate Commission for Water Coordination (SIC-ICWC)
Data collection site:	Ara Sea and Fergana valley action sites

Title: Evaluate the effect of conjunctive use of canal and drainage waters, different cropping patterns, and improved irrigation practices on control of salinity and waterlogging and delineate most efficient water management and agronomic practices

Overall Objectives (2015-2016)

- Comprehensive analysis of the dryland system to identify the different levels of canal water, groundwater and drainage water quality and quantity at different temporal and spatial resolution
- Identifying the potential of different crops to grown in the dryland system under waterlogging and salinity situation
- Calibrating and validating model for strategic crops (cotton/wheat) under intensive field trials
- Proposing different water management and agronomic practices simulated by SWAP model under different scenarios e.g., optimum salinity levels of irrigation water (canal water, drainage water), cropping pattern, irrigation practices

Outputs - 2015

- Collecting and analyzing data on the current status of groundwater levels and salinity, canal water use and salinity, irrigation and drainage layout, soil texture and salinity, climatic data (MS-Excel/GIS, MS Word) – 2015
- Establishing field trials on conjunctive use of canal water, drainage water and groundwater (MS Word) - 2015

Outputs – 2016

- Calibrated and validated groundwater model (unsaturated zone) for different scenarios (Model)
- Establishing strategies for optimum salinity levels of irrigation water (canal water, drainage water and shallow groundwater), cropping patterns, irrigation practices (MS Word)

Quantified Outcomes (2016):

- Farmers day for demonstrating the use of conjunctive water management strategies under different options
- Meetings and workshops with irrigation officials on use of different techniques for sustainable management of surface and drainage water

Quantified CD Outputs and Outcomes (2016):

- Training to the university students on state of the art tools (2)
- Training to the farmers to manage surface and drainage water in an optimum way (10)
- Training to the authorities for the management of marginal lands at mesoscale (2)

Quantified Gender Outputs and Outcomes (2016):

- Quantifying the role of women in managing irrigation and drainage systems(doc)
- Identifying the areas where women can participate actively for improving the water productivity under saline environment (doc)

Progress towards achieving outputs (2)-2015

Output-1 Collecting and analyzing data on the current status of groundwater levels and salinity, canal water use and salinity, irrigation and drainage layout, soil texture and salinity, climatic data (MS-Excel/GIS, MS Word) – 2015

A level of water consumers association (WCA) was selected to collate the biophysical data in time and space from Fergana Valley and in Khorezm region. A Memorandum of Understanding (MoA) was signed with Scientific-Information Center of Interstate Coordination Water Commission (SIC-ICW) to collect the data from the Oktepa Water Consumers Association of Fergana Valley and with Khorezm Rural Advisory Support Service (KRASS) from the *Nauhas* WCA. The data in ArcGIS and in MS Excel is uploaded as an output in MEL system.

Data analysis for Oktepa Water Consumers Association

As the overall objective of the project is to suggest optimum strategies for managing the surface water, groundwater and drainage water, the interaction between surface and groundwater for Oktepa WCA was studied intensively through a research paper aimed to publish in peer review scientific journal. The *first draft* of the paper is attached below and is already circulated for internal comments.

Understanding surface water – groundwater interactions for managing large irrigation schemes in the multi-country Fergana valley, Central Asia

Abstract

Traditionally, management of large irrigation schemes such as those in the Fergana Valley, is focused on surface water supplies to satisfy crop water requirements. However, recent studies indicated a substantial contribution of groundwater (23 – 30 %), depending on groundwater levels, to these requirements. To manage favorable groundwater levels, i.e., without adverse impacts on crop yields, soil salinity and nutrients leaching, information on, and quantification of, the groundwater recharge and discharge rates at large spatial and temporal scales, as well as understanding mechanisms of interaction between them, is indispensable. With the aim to quantify groundwater recharge, discharge and their interaction, a root zone water balance at the Water Users Association scale was established on a monthly basis for the 10-year period. The analyses showed that the groundwater recharge was 55 % of the surface water supplies, while the net recharge (the difference between the recharge and discharge) was X33 %. The groundwater recharge values were too high even for the large irrigation schemes and can be reduced to save freshwater. One option to reduce high discharge rates is by reducing excessive drainage.

Keywords: groundwater recharge, net groundwater recharge, water balance, crop water requirements,

Introduction

Groundwater is a critically important global water resource. It is intensively extracted with the rate of 982 km^3 yr^{-1} (Margat et al 2013), ca. 60 % of which is used for agriculture, and the rest for domestic uses (Vrba et al 2004). Around 38 % of the irrigated areas worldwide have facilities for direct use of groundwater (Siebert et al. 2010), while in other areas a capillary rise from shallow groundwater, driven by evapotranspiration, contributes ca. 20 – 25 % of moisture to total crop water requirements (Kahlown et al 2005, Ayars et al 2006, Awan et al 2014, Kazmi et al. 2012). Shallow groundwater within few meters from the surface is, however, also a source of waterlogging and secondary soil salinization (Martius, 2004, Kahlown et al. 2005, Awan et. al, 2011). In some countries (North Africa, Arabian Peninsula, Pakistan), the groundwater is intensively mined with the rates prevailing its replenishment (Qureshi et al 2010, Cheema et al. 2014). In the other areas, contribution from shallow groundwater to crop water requirements is barely accounted for (Awan et al, 2015), which leads to freshwater over-supply (Awan et al 2012). Hence, proper groundwater management is necessary for sustainable food production in these areas.

Water resources from the Amudarya and Syrdarya Rivers are traditionally considered as main source for irrigated agriculture in the Central Asian countries. At the same time, groundwater tables are shallow (e.g., Ibrakhimov et al 2007), and thus, their contribution of 23 – 30 % to the crop water requirements on the one hand, and to salinization and waterlogging, on the other, is substantial (Awan et al, recent). The groundwater recharge takes place mainly through seepage from the conveyance and distribution networks and field infiltrations, and so, is highly connected with surface supplies.

Quantification of the groundwater recharge is of high importance for sustainable groundwater management. The knowledge of recharge supports water management decisions, e.g., for estimation of aquifer's capacity for groundwater abstraction or of drainage networks for prevention of waterlogging and secondary salinization. The knowledge of groundwater recharge will contribute to better estimates of crop water requirements in a particular area. Thus, surface water supplies can be effectively reduced to account for groundwater contribution in arid environments thus saving limited freshwater resources (Awan et al 2015). Moreover, proper quantification of the recharge is essential for modeling of groundwater flow and contaminant transport.

Estimating recharge is a complex problem that requires understanding of the interactions between key processes in hydrological cycles such as rainfall, irrigation, infiltration, surface runoff, evapotranspiration and groundwater level dynamics (Jyrkama and Sykes 2007). The methods for estimating recharge have been classified according to hydrological zones (surface water and groundwater, e.g., Scanlon et al. 2002), the hydro-geological properties (conductivity, storage, etc., e.g., Jime´nez et al. 2010), physical and numerical modeling, tracer techniques (Beekman et al. 1999), water balance and water table fluctuation approaches (Lerner et al. 1990) and remote sensing techniques (Awan et al 2012), among other methods. It is important to choose an appropriate estimation method among various techniques accounting for space and time scales, range and reliability of these methods (Scanton et al 2002).

Water balance (WB) methods are widely used in irrigated agriculture for determining groundwater recharge (Sarwar and Eggers 2006; Mare´chal et al. 2006; Scanlon et al. 2002; Yin et al. 2011). WB employs estimation of all input and output including a storage change, while simpler WTF uses water-level fluctuations in observation wells (Healy and Cook 2002). These methods are applicable for unconfined aquifer types (Healy and Cook 2002) and can provide estimates at individual temporal and point-areal spatial scales (Healy 2010). The objective of this study is to assess the WB method for quantification of the groundwater recharge in the large spatial and temporal scales of the arid irrigated agricultural schemes in Central Asia. The results of this study can be used for scientific purposes (e.g., groundwater flow and solute modeling) and as guidelines for better groundwater management in the environmental settings with shallow groundwater.

Materials and Methods

Research area and environmental settings

The Fergana Valley in Central Asia is geographically situated between latitudes 40º15´ and 41º50´N and longitudes 70º30´ and 73º15´E. The Valley covers in total the territory of 22 km^2 in the three countries Uzbekistan, Kyrgyzstan and Tajikistan (Figure 1). The share of agricultural areas is 40 % to the total, most of which are in Uzbekistan. Large-scale irrigation schemes were constructed during the Soviet Era as virtually all agricultural areas have to be artificially irrigated (ref). The average temperature in the Fergana Valley is 13.1˚C, ranging from −8˚C to 3˚C in

January and from 17˚C to 36˚C in July (Reddy et al, 2012). Due to the arid to semiarid climate with a potential *ET* of 1133 – 1294 mm, which by far prevails the rates of precipitation (109 – 502 mm), all crops are irrigated through surface water delivered from the Syrdarya River. The cropping portfolio is dominated by cotton and winter wheat together occupying more than 80% of the irrigated areas annually, while orchards and vegetables are grown in the rest of these areas (Abdullaev et al, 2005). A complex-hierarchy, mostly earthen irrigation networks were constructed since 1960s for irrigation of crops. Surface and subsurface drainage networks are used to lower groundwater and to regulate optimal air-moisture balance within the soil root zone. Surface, furrow irrigation is a sole method to satisfy crop water demand, with an efficiency of ca. 50 %, which causes groundwater table rise (Tischbein ??). According to the State Hydrogeological Amelioration Expedition in Uzbekistan, groundwater depth is generally within 1 – 3 m below surface during vegetation growth seasons. Detailed data on groundwater depth and other pertinent information were collected in the “Oktepa Zilol Chashmasi” WCA on the territory of Uzbekistan, with a total area of 1946 of which 1438 ha are irrigated (Figure 1).

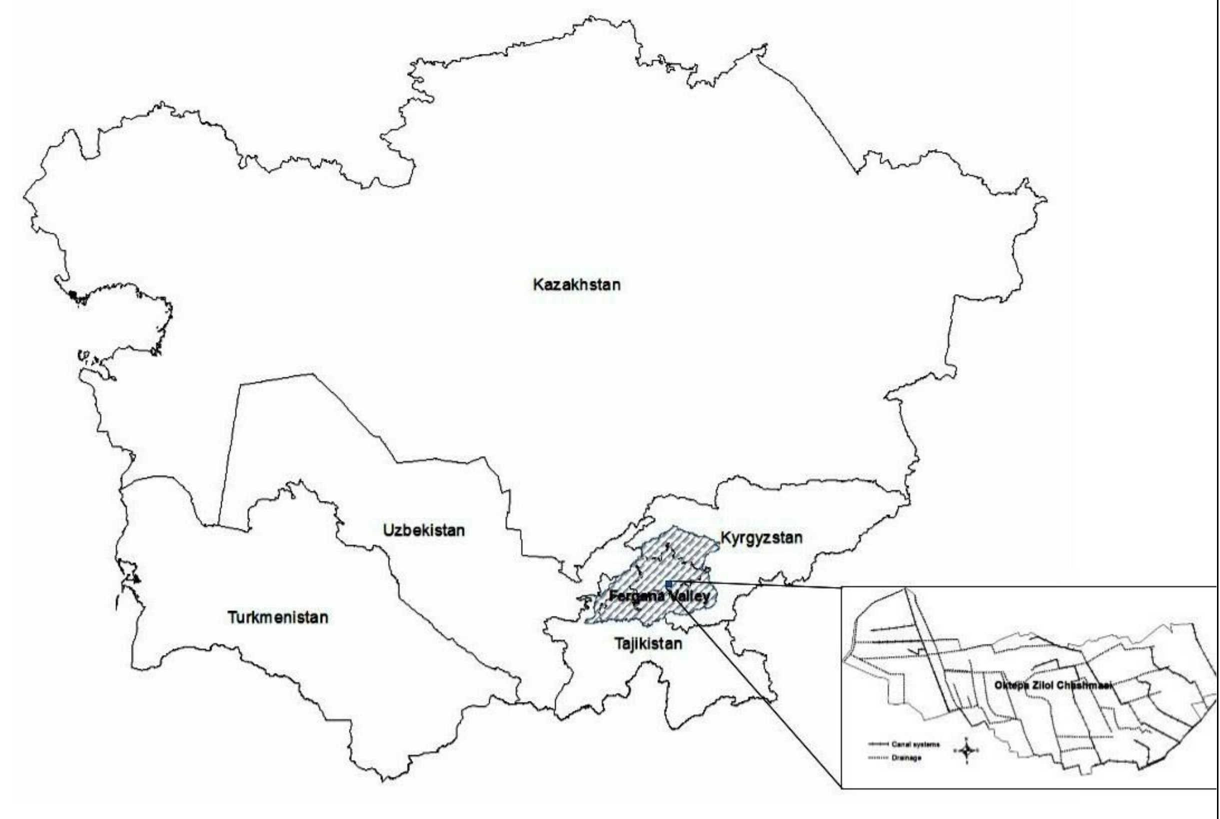

Figure 1. Geographic location of the Fergana Valley and Oktepa Zilol Chashmasi Water Consumers' Association

Hydrogeological zone mapping by the Institute of Hydrology and Engineering geology (Mirzaev 1974), indicates an existence of the three areas in the Fergana Valley with the natural groundwater recharge (mainly along the river pathways), groundwater spring discharge zone and groundwater upwelling zone with discharge to drains (Karimov et al 2010). The Oktepa Zilol Chashmasi WCA is located in the zone of the groundwater upwelling zone. This zone in general has a limited transmissivity, where groundwater table is controlled by drainage networks.

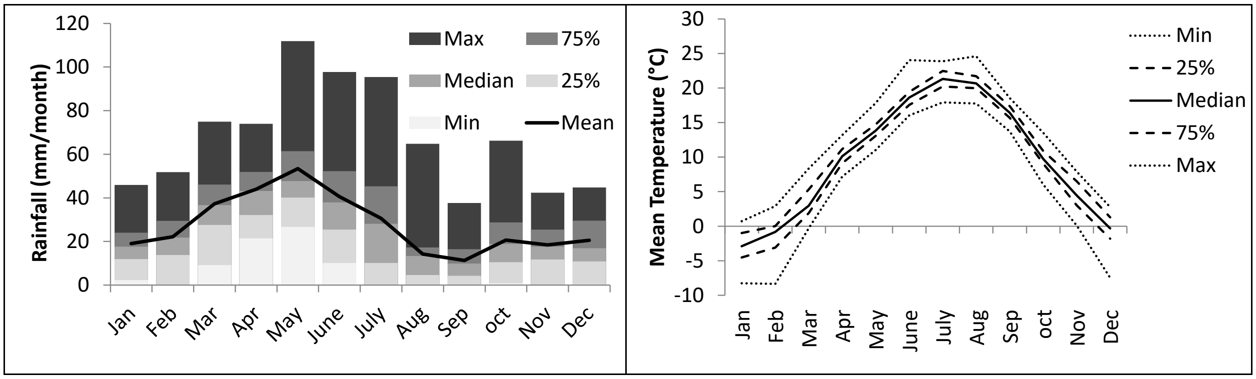

Figure 2. Monthly rainfall and temperature patterns in the Fergana Valley, estimated from the 1972 -2010 daily rainfall and temperature data

Water balance method

A water balance (WB) method is an accounting of the changes in water flow in and out of the area under consideration including the changes in storage. In the WB method used in this study, a groundwater recharge is estimated as a residual (ΔS) of the difference between the groundwater recharge and discharge, after various other components contributing to changes in groundwater, have been measured or calculated (Scanton et al 2002). In the current study, the WB is estimated using the following formula.

$$(\mathit{Gross\ Irrigation} - ETc + P + GW_{in}) - (DD + CR + GW_{out}) = \Delta S$$

where I, CR and P are irrigation water, capillary rise from groundwater into a vadose zone and precipitation, respectively, GW_{in} and GW_{out} lateral volumes of subsurface flow in and out of the research area, ET potential crop evapotranspiration, DD drainage discharge, FL losses of the irrigation water within fields, CL losses of irrigation water in the irrigation network, and ΔS the change in saturated groundwater storage. All the components are in mm per unit time. To simplify the water balance equation, it is assumed that the vertical groundwater flow prevails in this region (Mirzaev 1974) and so, lateral flow inside or outside of the area is negligible.

$$(\mathit{Gross\ Irrigation} + P - ETc) - (DD + CR) = \Delta S$$

Estimating water balance components

Crop specific evapotranspiration

Actual evapotranspiration was estimated utilizing the FAO-56 methodology (Allen et al. 1998) using the FAO CROPWAT model. The sources of the climate data for the calculation of the potential ET were obtained through previous studies and from the http://rp5.ru/ website. Effective precipitation (Brouwer and Heibloem 1986), relative humidity, air temperature, wind speed and solar radiation data were cross-checked between these two sources and used in this study. Wind speed is usually measured at the height of 10-12 m; these readings were converted into 2 m values following FAO-56 methodology. Coefficient values of the main crops grown in the region (cotton, winter wheat, vegetables) were obtained from the studies of the Scientific Production Association "SANIIRI".

Capillary rise

In the presence of shallow groundwater and in conditions of the ET prevalence over precipitation, upward moisture movement from groundwater into the soil root zone is high. The values of the capillary rise were obtained from previous studies of Forkutsa et al (2009), Akhtar et al (2013) and Awan et al (2014). This upward flux starts from April and decreases in October, when ET is negligibly low (Figure 3). The capillary rise is higher in May and lower in June and August due to the irrigation events that decrease capillarity (Karimov et al (HYDRUS paper). These fluxes virtually stopped from October.

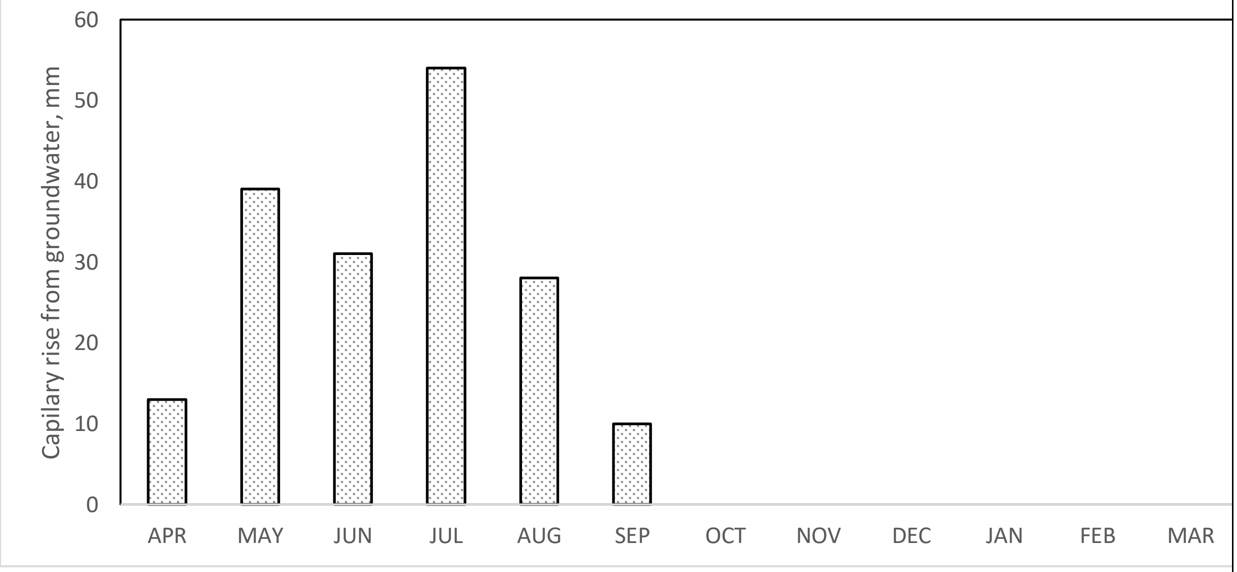

Figure 3. Upward capillary flux, mm in the “Oktepa Zilol Chashmasi” WCA of the Fergana Valley

Irrigation and drainage data

The irrigation water supply and drainage discharge data were provided in the 10-day basis by the local irrigation management organization. The data were collected for the study period and monthly averaged.

Results and discussion

Groundwater recharge

The highest groundwater recharge expectedly took place during the season with highest water demand due mainly to irrigations and seepage from the distribution networks (Figure 4). Overall, the average annual recharge was 780 (±76) mm (or 62 % of the total water supply) during the study period. These recharge values are similar to the findings of Abdullaev et al (YEAR) estimated for the environmental and management settings in the Fergana Valley. On a monthly basis, 203 (±105) mm of freshwater recharged the aquifer in the period of May to September.

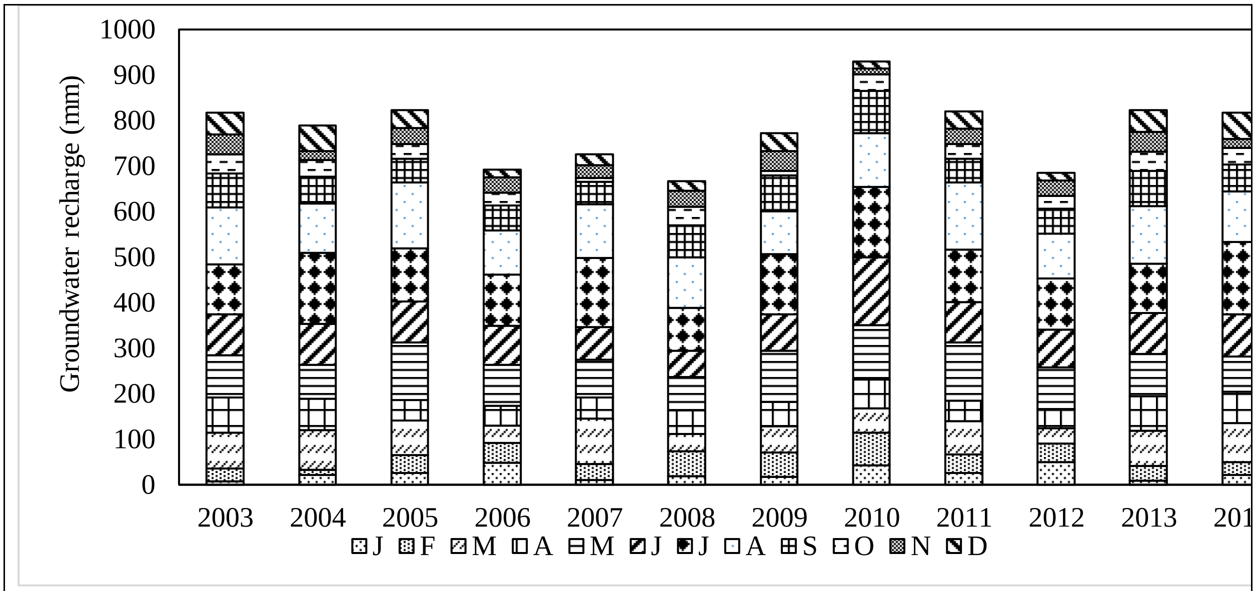

Figure 4. Monthly groundwater recharge in the “Oktepa Zilol Chashmasi” WCA during 2003 – 2014

Groundwater recharge vs groundwater levels

On an annual basis, the average groundwater table changes following years with different water availability (Figure 5). The groundwater table was deep during the drought years 2001 and 2013 – 2014, and shallow during the water-ample years 2003, 2006, 2009, 2011 and 2012. In the long run, the groundwater in the WCA was stable at 168 (±10) cm below surface. The groundwater recharge also closely followed the annual water availability, increasing in water-ample years 2009 and 2010, and decreasing in low water years 2008 and 2012 (Figure 5).

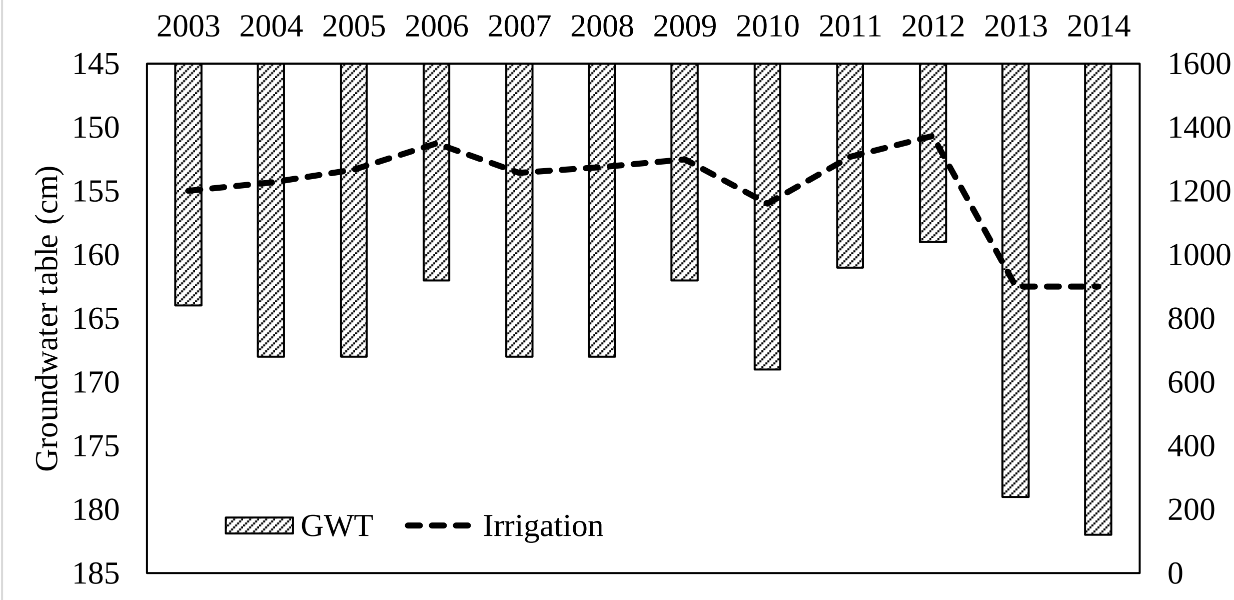

Figure 5. Long term average groundwater table, cm and irrigation water supply, mm in the "Oktepa Zilol Chashmasi" WCA during 2003 – 2014

Figure 6 is showing the average monthly effect (2003-2014) of groundwater recharge on groundwater levels. The trend of fluctuations in groundwater levels is somehow following the trend of recharge rates. The recharge rates increase from November to March including the leaching period. This increase in recharge from 31 mm per month to 127 mm per month the causes an increase in groundwater levels from 172 cm to 161 cm below the surface. These results further show that high recharge rates during leaching period are the main source of rise in groundwater levels whereas groundwater levels do not increase substantially during the vegetation season. Awan et al. (2013) reported that over drainage design causes the groundwater levels not to rise during the vegetation period to a critical level although there are several bottlenecks in the drainage system.

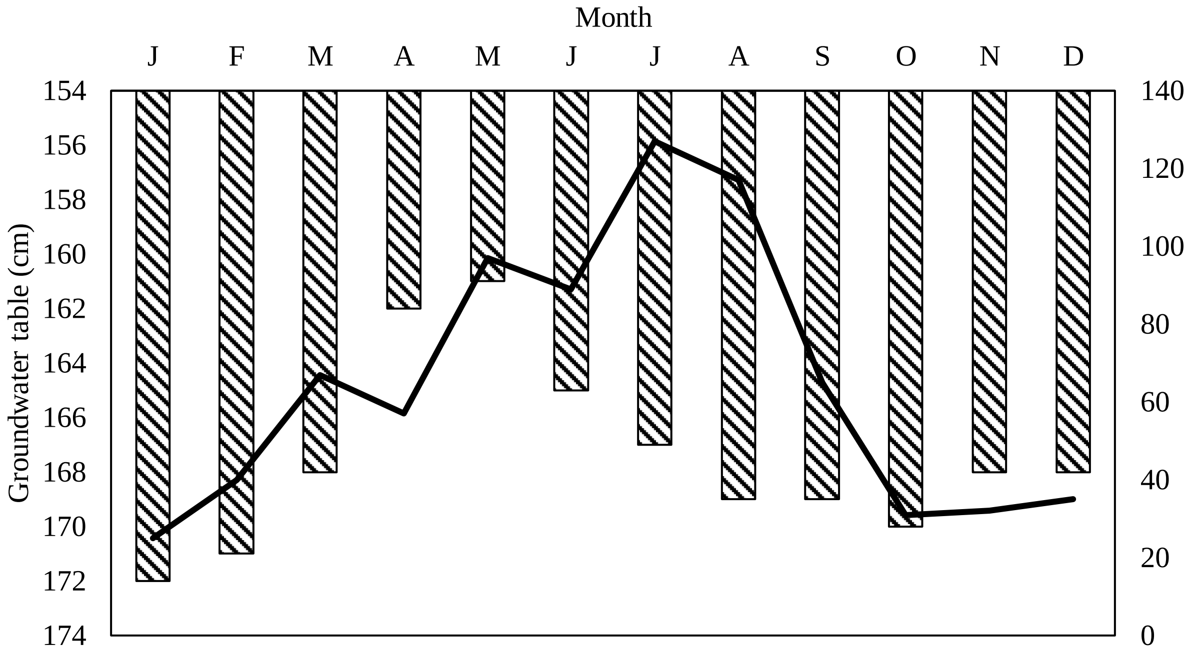

Figure 6. Long term average groundwater table, cm and groundwater recharge, mm in the "Oktepa Zilol Chashmasi" WCA during 2003 – 2014

Groundwater discharge

During the study period, the groundwater *discharge* was estimated as 698 (±8) mm, thus being ca. 45– 60 % of the irrigation supplies (Figure 7). Ca. 45 mm (7 %) of groundwater was discharged during leaching periods, thus leaving the agricultural area mostly with drainage. The highest portion of groundwater discharge also took place during the crop growth period (13 %), which was partly a soil moisture replenishment through capillaries. The lowest discharge was 683 mm in 2010 and 684 mm in 2004, while the highest was 708 mm in 2008.

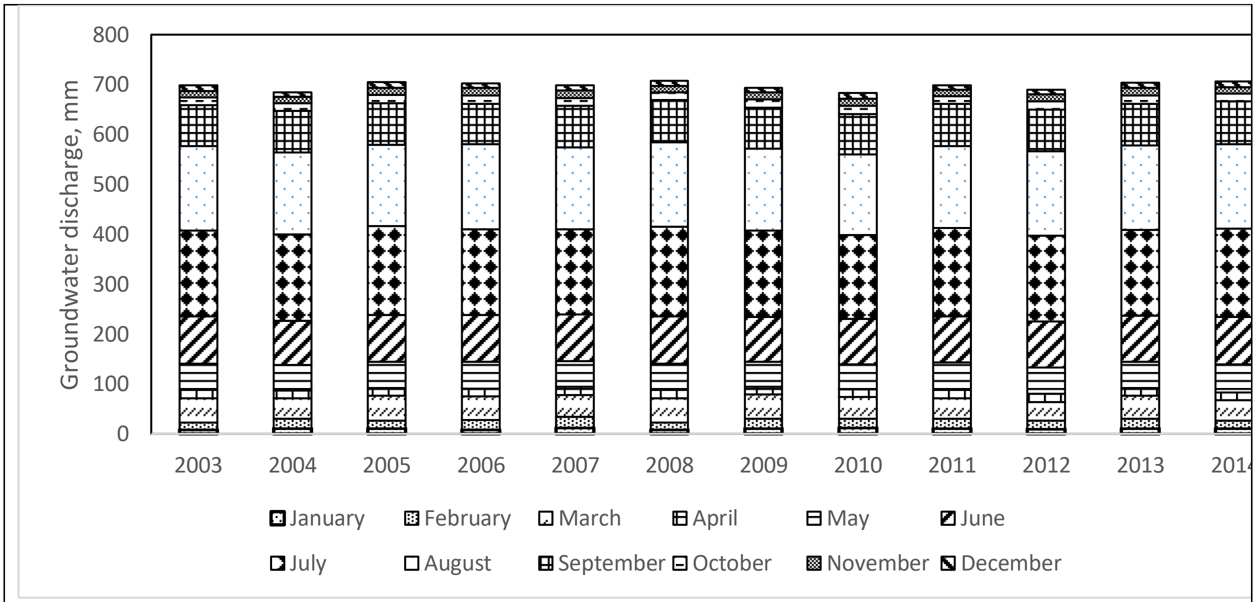

Figure 7. Monthly groundwater discharge, mm in the “Oktepa Zilol Chashmasi” WCA of the Fergana Valley during 2003-2013

Net groundwater recharge

Figure 8 shows that the net groundwater recharge varies significantly between the years however the annual trend of variation is almost uniform. The maximum net recharge rates are during the leaching period (104 ± 12 mm) whereas the values goes to negative during the vegetation season which means that drains are removing the water out from the system. The minimum net groundwater recharge is mostly during the month of July-August due to less irrigation and more drainage.

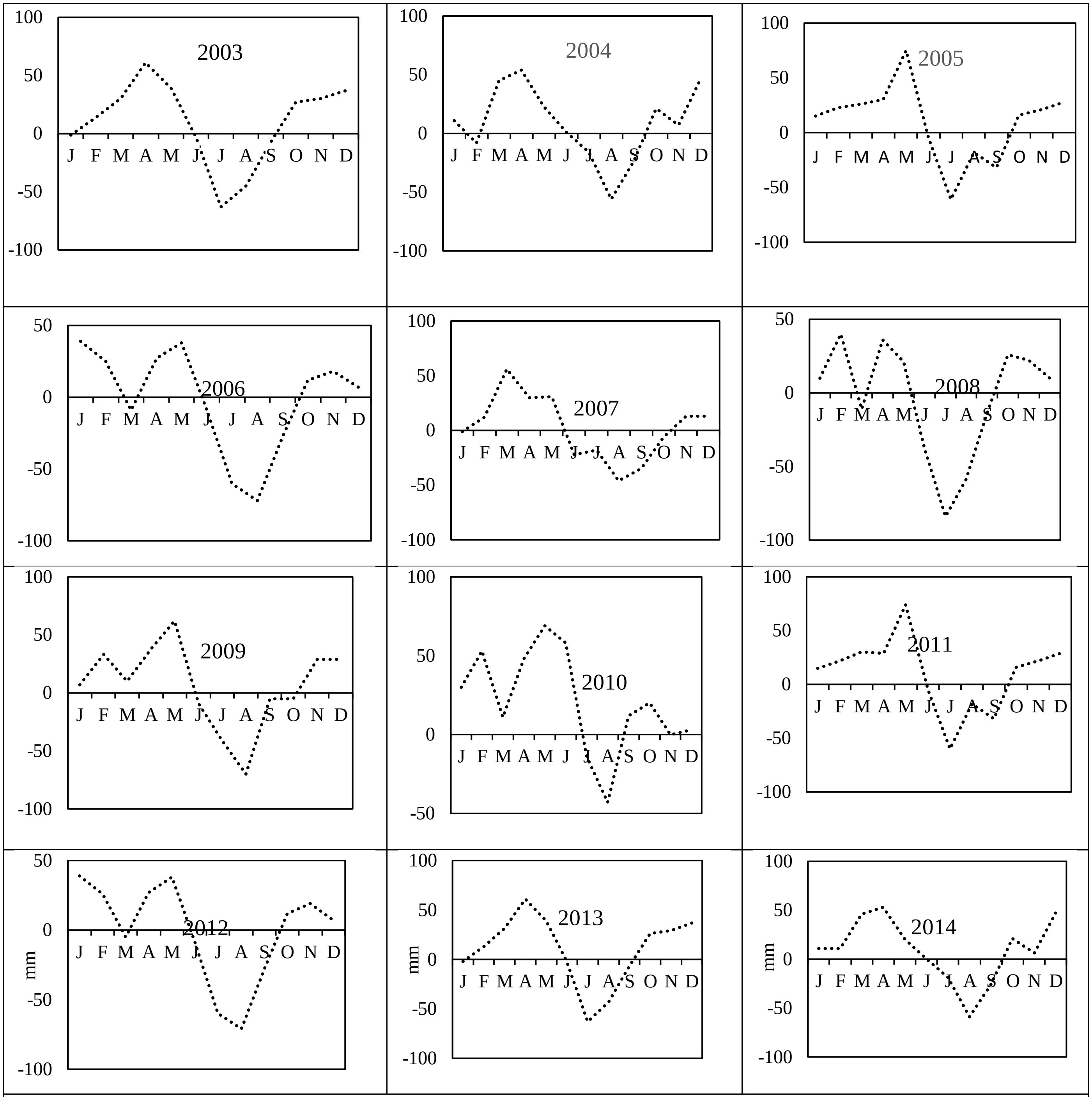

Figure 8. Monthly net groundwater discharge, mm in the “Oktepa Zilol Chashmasi” WCA of the Fergana Valley during 2003-2013

Net groundwater recharge vs groundwater levels

The net groundwater recharge and groundwater levels varies significantly during the years. The net groundwater recharge is negative during 2006 to 2008 means that groundwater levels were lower during these periods.

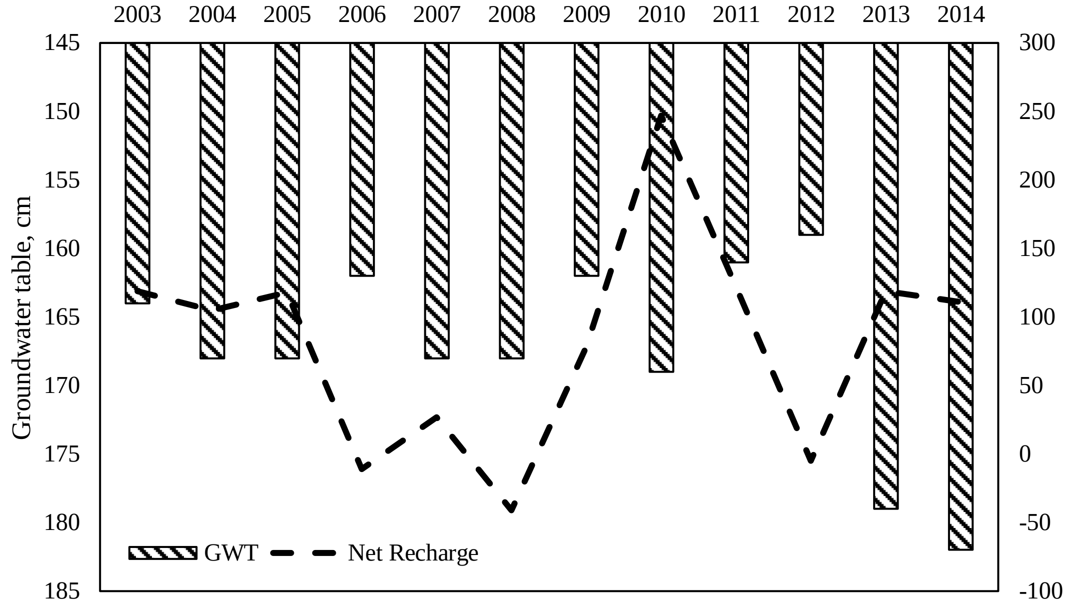

Figure 9. Long term average groundwater table, cm and groundwater net recharge, mm in the "Oktepa Zilol Chashmasi" WCA during 2003 – 2014

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