Actual Condition of Vertical Drainage for Farmland Salinization in the Republic of Uzbekistan

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Summary

In irrigated agricultural area of Central Asia, drainage channels, subsurface drainage, and vertical drainage have been constructed as countermeasures for soil salinity. However, these drainage functions have worsened due to lack of regular maintenance. In particular, the number of vertical drainage facilities is drastically reduced, and the availability of operating facilities has decreased. This report studied whether vertical drainage affects the groundwater level by using monitoring results and analyzing them at area-wide of Water Consumers' Association (WCA).

As a result, there was no clear relationship between the operation of vertical drainage and groundwater level. Although vertical drainage affected the location 500 m away, it is not considered to greatly influence WCA. As the operation ratio of vertical drainage becomes very low, we need to reconsider the plan of groundwater level control by vertical drainage within each WCA or interrelated WCAs. It is also clear that the relationship between groundwater levels and the fluctuation of salinity levels has not been understood at WCA. Cooperation among the related local government organizations and WCAs needs to be strengthened to find a solution to the salinity problem with monitoring and countermeasures. This needs to focus on the measures against salinization except for the measures against high groundwater level.

Keywords

Vertical drainage, Groundwater, Salt-accumulation, Soil salinity, Syrdarya region, WCA

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1. Introduction

Large-scale irrigation development has been carried out in the five Central Asian countries of Uzbekistan, Kazakhstan, Kyrgyzstan, Turkmenistan, and Tajikistan since the 1960s, with the Amu Darya River and the Syr Darya River, which flow into the Aral Sea being used as the main water resources. With the development of irrigated agriculture, waterlogging and salt accumulation has occurred due to excessive irrigation and inadequate drainage facilities. As a counter measure, salt removal operation has been implemented by drainage improvement projects and leaching works.

By the 1990s, a drainage network of approximately 200 thousand km was developed in these five countries, with the provision of 48 thousand km of subsurface drainage and the construction of 7,700 vertical drainage wells (Dukhovny et al., 2005). However, new drainage facilities have not been constructed and regular maintenance of the current drainage facilities has not been adequate since those countries became independent of the Soviet Union in 1991. As a result, these drainage functions have worsened. In particular, the number of vertical drainage facilities is drastically reduced, and the availability of operating facilities has decreased.

The Japan International Research Center for Agricultural Sciences (JIRCAS) was conducting studies on measures for mitigating salinization through groundwater control in the Syrdarya Region of the Republic of Uzbekistan (**Fig. 1**). This is an arid and semi-arid region of Central Asia which has the highest salt concentration in the soil. Our studies have focused on the serious salt accumulation area of Mirzaabad district in the Syrdarya Region. This report is based on data for the Mirzaabad, which was obtained from relevant organizations regarding the analysis of the relationship among the operation ratio of vertical drainage, groundwater fluctuation, and soil salinization.

2. Materials and methods

2.1 Vertical drainage data

Vertical drainage is a water pumping facility with wells to control the groundwater level. Based on boring surveys, the wells are mined down to the clear water aquifer. The wells in the Syrdarya Region were drilled down to a depth of 30 to 120 m. The facilities are operated and managed by the Department of Pumping Station, Energy and Communications (UNES: Russian abb.), a local organization of the Agriculture and Water Resources of Uzbekistan Government. A record of monthly electricity consumption from 2011 to 2013 was obtained from the UNES for all vertical drainages managed in the Mirzaabad. We confirmed the locations of vertical drainage and their management directly by field surveys. We also obtained other information about vertical drainage from the Research Institute of Irrigation and Water Problem (RIIWP) surveys.

As a case study, one vertical drainage facility (depth: 52 m, strainer pipe position: 28 to 44 m) was selected in 2014, and observation wells at groundwater level were installed at 60, 100, 250 and 500 m away from the vertical drainage well. In the observation wells, we measured the depth of groundwater level (measuring groundwater potential by open only at the bottom, depth of 35 m) and the surface groundwater level (full open pore, depth of 5 m) and recorded the fluctuation of the groundwater level during vertical drainage operation.

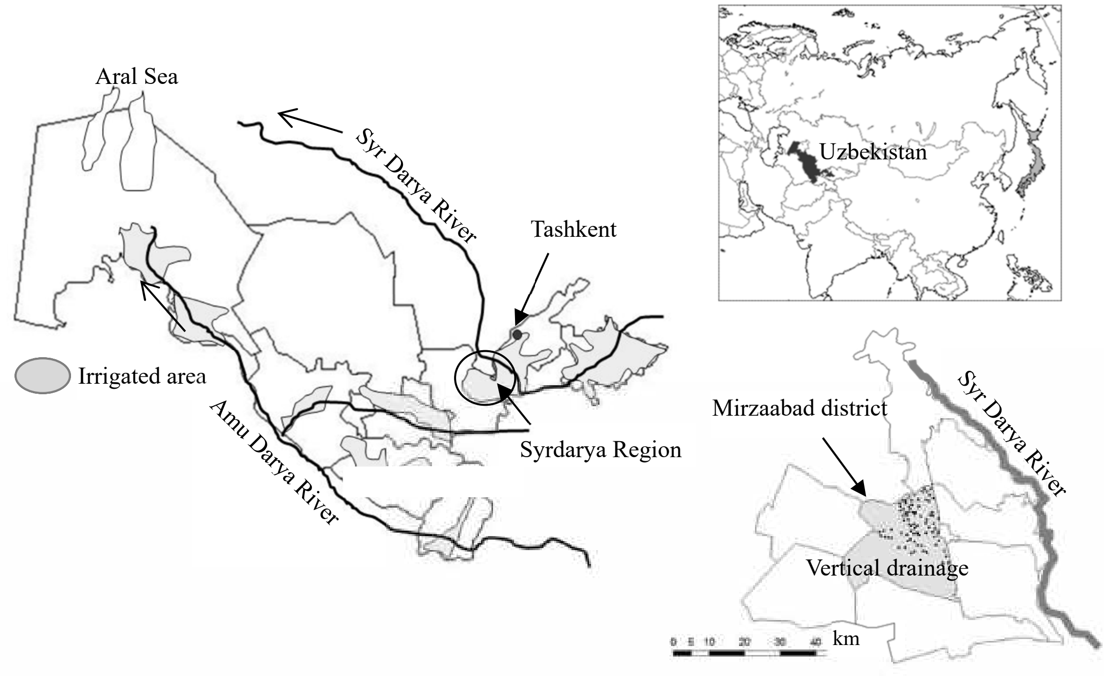

Fig. 1 Study area

2.2 Monitoring data of groundwater and soil

The groundwater level and salinity of groundwater and soil are monitored by the Hydro-Geological Melioration Expedition (HGME), which is a local organization of the Ministry of Agriculture and Water Resources of Uzbekistan. The HGME developed the data of the monitored area, sorted it into several levels, and then mapped the values in each level. Previously, the drawing on the map was conducted by hand, but advanced mapping technology of Geographic Information Systems (GIS) are being implemented for the Mirzaabad in Uzbekistan.

In this survey, GIS area data of groundwater level and salinity of groundwater and soil from April 2010 to March 2013 were obtained as well as all observational data for the observation well regarding the groundwater level of 2012.

3. The current condition of the survey area

3.1 Facility situation of vertical drainage

Construction of vertical drainage in Uzbekistan started in the early 1960s, and the number of facilities peaked in the middle of the 1990s. A number of facilities have not been updated and well maintained since that time, and the number of facilities is decreasing. The number of facilities in 2002 dropped to 79% in Uzbekistan nationally compared to the peak and also 38% in the Syrdarya Region. In addition, electricity consumption has also begun to decline since the 1980s, to 14% of its peak in the region (**Fig. 2**).

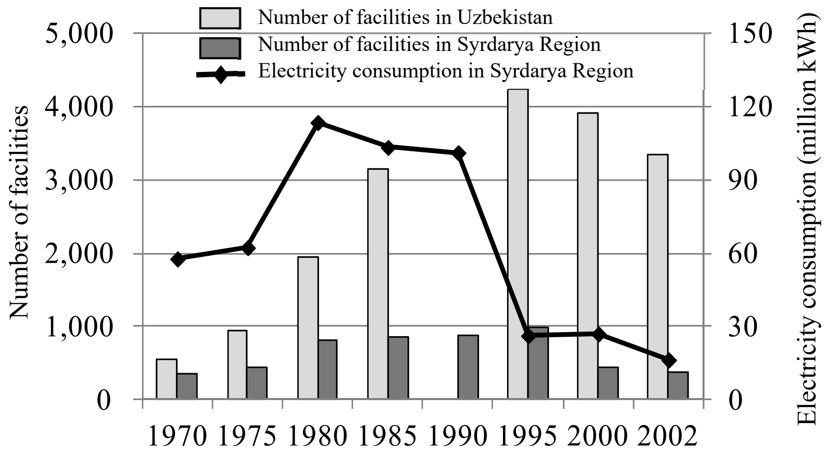

Fig. 2 Decline in the number of facilities and electricity consumption

It is reported that one vertical drainage facility covers an area of approximately 100-150 ha, and there are 373 sites in the region, where it comprised approximately 50 thousand ha in 2007. However, the annual operation rate is only 20%. According to UNES, the renewal of facilities is being promoted as one of the farmland improvement measures projects and in 2013, the number of facilities had reached 450. Based on the results of groundwater and soil monitoring by the HGME, but only when specifically requested by the farmers, the operation of vertical drainage is to be conducted. When examining the amount of electricity consumption by month, there is a peak in summer, which plays a role as supplemental water for the irrigation period.

There were 17 Water Consumers' Associations (WCAs) in the Mirzaabad district, which were surveyed in 2012. Vertical drainage facilities which covered 11 WCAs were located on the eastern side of the region. The number of facilities was 80. The number of facilities per one thousand ha, where a WCA has a piece of irrigated farmland, is 3.6 on average, 6.7 at maximum, and 1.1 at minimum, which is a large variation in the number of facilities. While 80 locations can be seen in the consumption of electricity and 95% of facilities were operating over three years from 2011 to 2013, some facilities have been in operation only on a trial basis or have not been in operation for more than one year. The consumption of electricity depends on each facility.

In the Syrdarya Region, the combination of salinity area rate and groundwater salinity is being researched to determine the target groundwater level for vertical drainage. According to RIIWP, in order to avoid the risk of salinization, it is preferable that the target groundwater level is deeper than 1.9 m in April, and deeper than 3.5 m in August and September.

3.2 Monitoring of groundwater level

There are 2,030 observation well sites run by HGME in the Syrdarya Region. Within the area, 284 observation wells exist in the Mirzaabad district, meaning one location per 140 ha. The groundwater level is measured by HGME technical workers every ten days, who also take a sample and measure the salinity of groundwater from the observation wells in April, July, and October. The monitoring results are divided into five stages of groundwater level and salinity (**Table 1**). This information is sent to UNES to control the groundwater level and is also applied for implementation of the leaching in December and January in winter and further leaching.

Table 1 Groundwater level and salinity in the Mirzaabad district (April 2012)

Groundwater level (m)	0.0-1.0	1.0-1.5	1.5-2.0	2.0-3.0	>3.0
Area (thousand ha)	1.9	5.4	14.0	17.6	2.2
Salinity (g L^{-1})	0-1	1-3	3-5	5-10	>10
Area (thousand ha)	0.0	7.0	20.9	10.9	2.2

3.3 Monitoring of soil

Measurements of soil salt concentration are taken in April and October each year. Measurement points differ, depending on the land use and the time of year. These measurements were taken at 1,570 locations (one location per 26 ha) in 2012. For this, HGME technical workers travel around the field and measure EC values at three levels of depth (0-30 cm, 30-70 cm, and 70-100 cm) using a soil insertion type EC meter. This EC meter was developed by RIIWP and converted to EC_e (soil salinization levels expressed as electrical conductivity (dSm^{-1}) by saturation extraction) values from the measured salinity of the interstitial water of the soil and the temperature of the ground. According to the FAO standard, No salinity (EC_e <2), Low (EC_e 2 to 4), Moderate (EC_e 4 to 8), High (EC_e 8 to 16), and Extraordinal High (EC_e > 16) salinity (FAO, 2002).

In the Syrdarya Region, soil salinity maps are created using the same standard values and divided into four levels of No salinity, Low, Moderate, and High. High includes High Intensity. The map indicates that areas greater than Mild in Uzbekistan is 49%, in the Syrdarya region is 98%, and those in almost all Mirzaabad district are 100% (**Table 2**). Information on soil salinity will also be sent to UNES, together with groundwater data, and they will be used to make a plan of future salt damage counter measures.

Table 2 Soil salinity level

(unit: thousand ha)

	No salinity	Low	Moderate	High
Uzbekistan (2011)	2,195.5	1,361.0	624.6	124.0
Syrdarya Region (2011)	4.6	231.7	47.1	3.6
Mirzaabad district (2012.4)	0.1	22.3	17.8	0.9

4. Results

4.1 Vertical drainage and groundwater level

4.1.1 Changes in groundwater level of WCA

We verified that vertical drainage controls the groundwater level by dividing areas into three categories: (a) operation of vertical drainage (11WCAs: 22 thousand ha), (b) no vertical drainage (2WCAs: two thousand ha), and (c) no vertical drainage but using the subsurface drainage (4WCAs: 17 thousand ha). We then compared these areas and found that the groundwater level in each area tends to be lower from May to October, then increases from October to February. When the vertical drainage operation peaked during June to August, the groundwater level in the area (a) did not show a particularly significant downward trend compared with the (b) and (c) areas (**Fig. 3**).

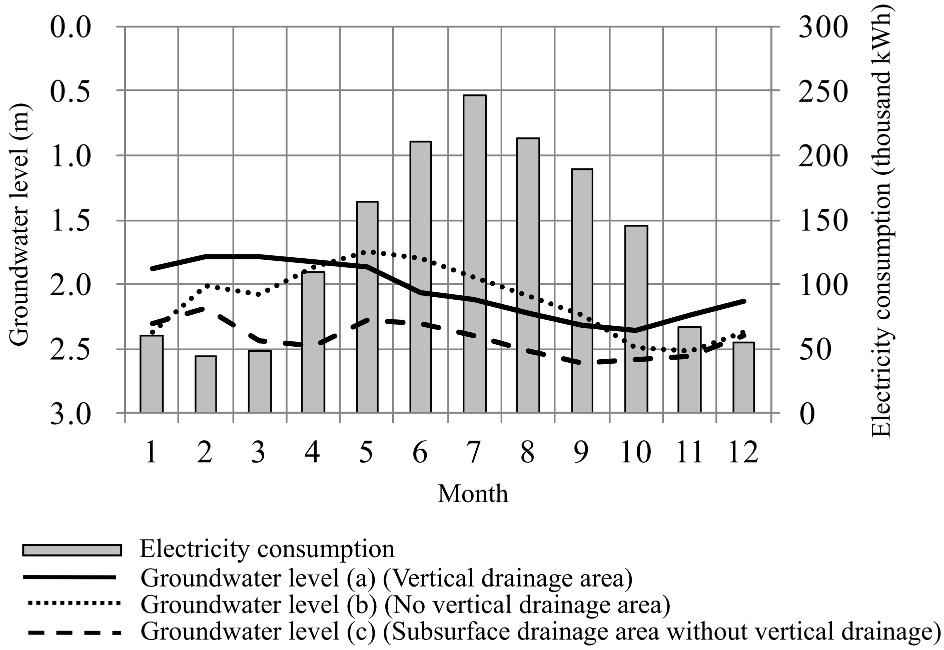

Fig. 3 Changes in groundwater level due to differences in drainage conditions (2012)

When comparing electricity consumption per hectare with annual average groundwater level, the low groundwater level in the WCA area showed a trend of increased electricity consumption (**Fig. 4**). The vertical drainage has not conspicuously lowered the groundwater level in the WCA area. In addition, it is assumed that the operation is being prioritized in the WCA areas where the groundwater level is high.

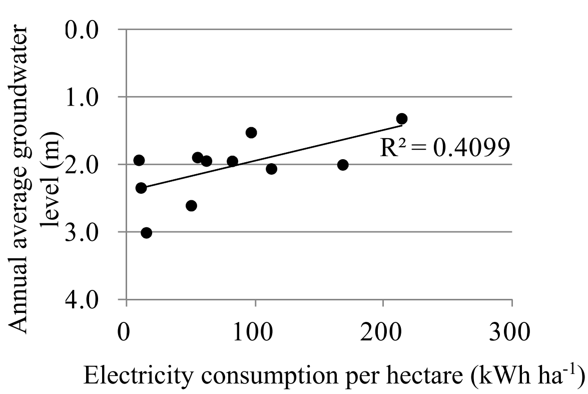

Fig. 4 Electric consumption trend in 11 WCAs

The reason we cannot see the large fluctuation of groundwater level may be because the number of vertical drainage facilities in the WCA farmland is small and the operating ratio is low (a short period of pump operation hours). The causes of low utilization rates are delays in maintenance repair, frequently occurring power outages, expensive electricity bills, and theft.

4.1.2 The fluctuation of groundwater level in the facilities

With the WCA standard we could not confirm, with clarity, the effectiveness of vertical drainage and we therefore surveyed the cases of one vertical drainage operation. For example, the fluctuations of groundwater level at nearby facilities were observed for 46 days in 2014 between October 26th and December 11th. During pumping, the groundwater level of the observation well installed in the deep section could be observed 60 m from the vertical drainage facility. The groundwater level was influenced within 10 minutes and it repeatedly descended and ascended, according to the operation and stop of the pump. At 500 m away from the facility, the observation well showed subtle fluctuations within 30 minutes.

Normally the groundwater level starts to rise from October, and we could therefore see the rise in every observation well location. The water level of 60 m away from the facility raised the least at both the high deep layer and surface layer from our observation date to another date in December. It showed only 2 cm difference in rise of the deep layer and 3 cm of surface layer, compared with those 500 m away from the facility (**Fig. 5**).

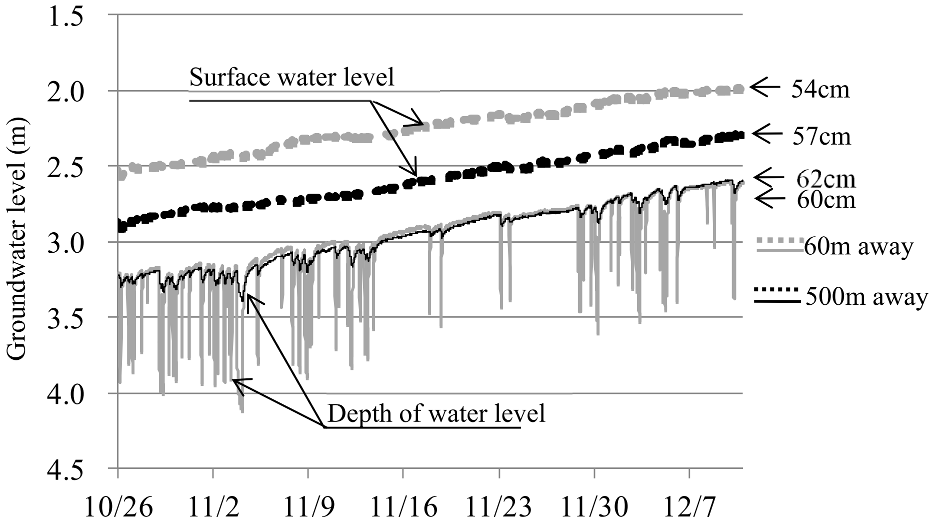

Fig. 5 Changes in groundwater level during vertical drainage operation

When we observed the vertical drainage alone, even if the groundwater level in the deep layer was 500 m away, the effect could be seen, but the influence on the surface layer was small. It was less affected because the survey period was the rise time of groundwater level in winter and it was the short period. Despite the low effect of surface water control, there was a possibility that vertical drainage was used during this period. The efficacy of fluctuation was not adequately seen at the WCA areas, and we therefore need to focus on the necessary timing and areas of vertical drainage operation and then consider aspects of implementation such as concentrate and consecutive operation period.

4.2 Variation of soil salinity of WCA

We analyzed the relationship between the variation of soil salinity and groundwater level at the chosen 17 locations of WCA from April to October 2012 and also classified the soil salinity class of HGME. The salt accumulation in soil was classified as: no salinity = 1, low = 2, moderate = 3, and high = 4. The weighted average by the area according to the category was taken.

As a result, the evaluation of the soil salinity rating changed from 2.48 in April to 2.79 in October. Therefore, it had reached 113% fluctuation ratio at 100% as of April. The maximum concentration rate was 132% and the minimum rate was 98% at each WCA location. Some locations did not show increasing numbers despite the high soil salinity season. The groundwater level classified by WCA until just before October was considered to be affecting this rate of change compared with the average groundwater level from April to September of (a) operation of vertical drainage, (b) no vertical drainage, and (c) no vertical drainage but using the subsurface drainage, mentioned above. However, there was no explicit correlation found (**Fig. 6**).

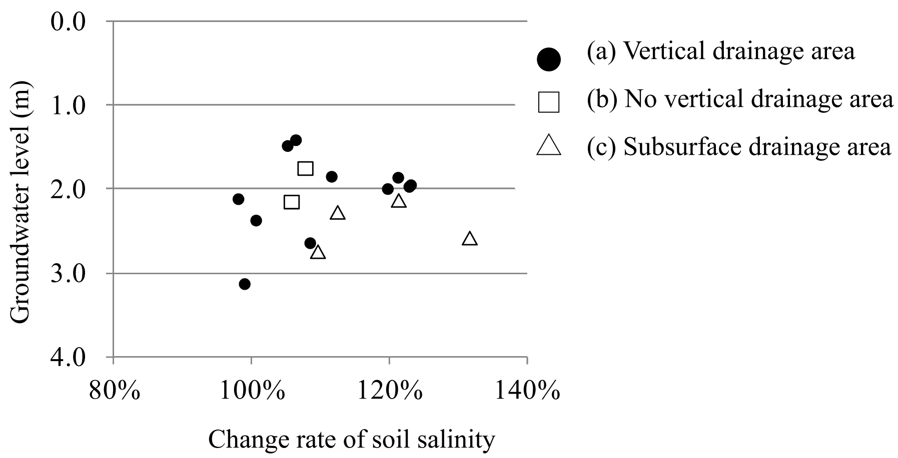

Fig. 6 Rate of change of soil salinity and groundwater level (2012)

Even if the groundwater level is deep, the soil salinity may be highly concentrated, and if the groundwater level is shallow, the soil salinity may not change. This result might be affected by the influences of not only groundwater level or salinity but also soil composition, water control technology by WCA, drainage function, type of salt, the land use situation (amount of abandoned cultivated land), and other factors. Therefore, such uniform measures taken by WCA might be less effective in the field.

In order to ensure that the effects of salinity measures, including vertical drainage are realized, it will be necessary to clarify these factors, scrutinize them well, and then strengthen the coordination between monitoring and counter measures.

5. Conclusion

The Syrdarya Region is in the Republic of Uzbekistan which is an irrigated agricultural area of Central Asia. Through the monitoring of groundwater and soil, drainage improvement work and leaching are planned so as to implement counter measures against salinization. This report studied whether vertical drainage affects the groundwater level by using monitoring results and analyzing them at WCA level. There was no clear relationship between the operation of vertical drainage and groundwater level. Although vertical drainage affected the location 500 m away, it is not considered to greatly influence WCA.

As the operation ratio of vertical drainage becomes very low, we need to reconsider the plan of groundwater level control by vertical drainage within each WCA or interrelated WCAs. It is also clear that the relationship between groundwater levels and the fluctuation of salinity levels has not been understood at WCA. Cooperation among UNES, HGME, and WCA needs to be strengthened to find a solution to the salinity problem with monitoring and counter measures. This needs to focus on the measures against salinization except for the measures against high groundwater level.

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