沙漠研究 **22**-1, 111 -114 (2012)
Journal of Arid Land Studies

"ICAL 1 / DT X"
—Refereed Paper—

An Analysis on Propriety of Paddy Rice and Upland Crop Rotation System in the Lower Ili River Basin, Kazakhstan

Katsuyuki SHIMIZU*[1], Toshihiko ANZAI[2], Natsumi TAKAHASHI[3] and Yoshinobu KITAMURA[1]

Abstract: The lower Ili River Basin in Kazakhstan is located in an arid region where large-scale irrigated agriculture has been developed since the late 1960s. Lately, there has been water-use adjustment between agriculture in the lower part and hydropower in the middle part. Moreover, farmland in this area has been faced with salinity problem. The characteristics of irrigated agriculture in this area are summarized as follows; (1) Conveyance and distribution efficiencies are very low, (2) Continuous irrigation is practiced in paddy rice fields while irrigation for upland crop fields is only once or twice, (3) Upland crop uses the groundwater which is raised by seepages from canals and paddy rice fields. Therefore, to control groundwater level is quite important for agricultural in the area.

This study analyzed temporal and spatial distribution of cropping pattern and water use with considering groundwater level fluctuation in this area since the land development in order to evaluate propriety of paddy rice and upland crop rotation system employed in this area. The results are summarized as follows; (1) Fluctuations of groundwater levels range from 1 m to 2 m in irrigated area. (2) The ratio of paddy rice and upland crops areas has been kept same as before. (3) Water withdrawal for agriculture has reduced. (4) Prevailing crop rotation system would be a sustainable technology in the study area if current amount of water withdrawal is ensured.

Key Words: Arid land, Groundwater level fluctuation, Irrigated agriculture, Salinization, Water balance

1. Introduction

1.1. Water issues in the Ili river basin

The lower Ili River Basin in Kazakhstan is located in an arid region where large-scale irrigated agriculture has been developed since the late 1960s. The Ili River, which is an exclusive water resource for agriculture in this area, is a transboundary river. Due to hydropower and agriculture as well as water use among riparian countries, the deficit of water for agriculture in the lower part of the river has been a concern. Thus, inappropriate water management in the fields threatens to create a salinity problem, which is typical in irrigated agriculture in arid areas. The authors therefore conducted a survey to clarify and evaluate the suitability of the actual water use for irrigated agriculture in the lower Ili River Basin.

1.2. Study area

The Ili River originates from a branch of the Tian Shan Mountains in China and flows into Lake Balkhash through southeastern Kazakhstan. The annual discharge is about 19.6 cubic km, 80% of which comes from Chinese territory. **Figure 1** shows the Ili River and its environs. The lower Ili River Basin is located in a continental arid zone; annual precipitation is only 177 mm and the average temperature is 10.7 degrees Celsius. Kapchagai Reservoir is located in the middle part of the river and stores water during the summer for use in hydropower generation during winter. Therefore, summertime water shortages for agriculture are a concern.

2. Materials and Methods

The authors conducted a field survey at the former Bakbakthi State Farm (BBF), which is a part of the Akdara Irrigation Scheme (AIS) in the lower Ili River Basin. **Figure 2** shows outlines of the BBF. Information on the BBF's land and water use such as cropping pattern, cropped areas, water withdrawal from the Ili River was collected by the Balkhash Water Management Office, Almaty Oblast (BWMO), the BBF, and individual farms. Water discharge data such as amount of water withdrawn from the Ili River, amount of irrigation water conveyed to the AIS and crop water requirements were

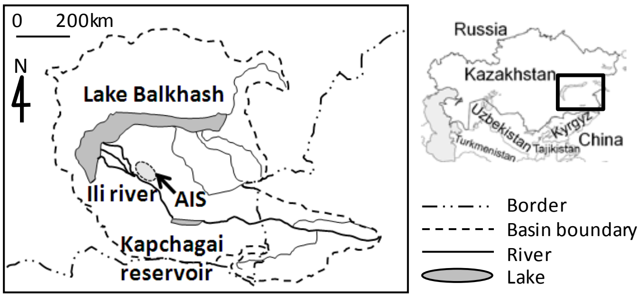

Fig. 1. Outlines of the Ili River Basin.

* Corresponding Author: shimizu@muses.tottori-u.ac.jp
4-101 Koyamacho-minami, Tottori-City, Tottori, JAPAN (680-8553)
1) Faculty of Agriculture, Tottori University, Japan
3) Graduate School of Agriculture, Tottori University
2) United Graduate School of Agriculture, Tottori University

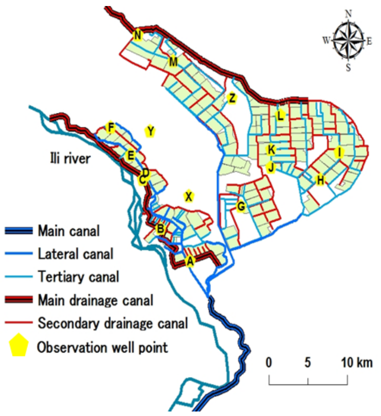

Fig. 2. Irrigation and drainage system layout of the study area.

collected from a series of annual reports on water use in the Akdara Irrigation Scheme. The information on the transition of structures of agricultural production, cropping patterns, and on-farm water management was collected from the BBF. Water samples were collected from irrigation and drainage canals, and Lake Balkhash to examine the impact of quality of drainage water on the lower part of the river.

3. Results and Discussion

3.1. Land use and cropping pattern

The total irrigated area of the AIS is 31,800 ha. The BBF has 9,500 ha of irrigated area. The farm was established in 1968 during the Soviet era and the Soviet Union placed great importance on the farm for rice production. During the period of the state farm, required materials and machinery were provided by the government. After Kazakhstan's independence was regained following the collapse of the USSR, state farms were privatized and became cooperatives between 1993 and 1995. After privatization, the BBF lost all government support. The BBF had been composed of five brigards which are agricultural production units. These brigards became five independent agricultural farms, which were subdivided into small farms. At present, there are 41 individual farms in the AIS.

3.2. Paddy rice and upland crop rotation

Due to climate conditions, the cropping period is limited from early May to late August; the irrigation period is 120 days. The major crops are paddy rice, wheat, and alfalfa. In the Soviet era, 6- or 7-year crop rotations were used and about 40 to 50% of the cropped area was devoted to paddy rice cultivation. This crop rotation was employed to have irrigation for paddy rice leach out the accumulated salts during upland crop cultivation in the fields by converting paddy rice to upland crops in those fields. Alfalfa is grown not only for fodder crop but, since it is a legume, for fixing nitrogen. The

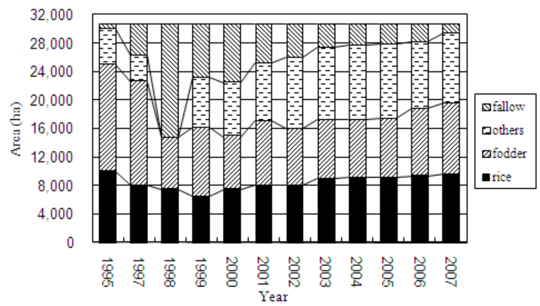

Fig. 3. Cropped areas in the Akdara Irrigation Scheme.

area of one rotation block is about 100 ha, and within this block the same crop is cultivated.

After privatization of the BBF, the privatized farms have kept the crop rotation system. **Figure 3** shows the cropped area in the AIS from 1995 to 2007. The figure shows that total cropped area excluding fallow has decreased to less than 50% of the original irrigated area in 1998 due to disorganization on farms during the transition period. However, the total cropped area has recovered gradually, currently reaching the 1995 level. The ratio of paddy rice area to cropped area has also increased, to about 10,000 ha, while the upland crop area has not changed much. However, while the ratio of the alfalfa area decreased, the area devoted to other crops, such as industrial crops, increased.

The application rate of fertilizer has drastically decreased. Soil fertility relies on the fixation of nitrogen by alfalfa. If they are not able to assure a sufficient rice yield from the second and third years of rice crops, the farmers turn the paddy rice fields into alfalfa fields.

The farm lot size is 1 to 2 ha (100 m × 100～200 m) and the rotation block is about 100 ha. The average yields of paddy rice and wheat are 3.5 to 4.0 t/ha and 2.0 t/ha, respectively; these are lower than the average yields in Kazakhstan, but the yield of alfalfa is high, 10.0 t/ha, since it is harvested 3 times per year.

3.3. Water use and management

3.3.1 Water balance

Annual water intake to the irrigation area is about 700 Mm^3. Of that, 136 Mm^3 drains into the Ili River. Since the designed value of the conveyance efficiency is 0.75 and the distribution efficiency is 0.60, system efficiency is estimated as 0.45(=0.75 × 0.60). That is, only 45% (315 Mm^3) of water intake from the river (700 Mm^3) reaches the fields. Possible reasons for such low efficiency are that all of the canals are earthen and that the total length of the main and secondary canals is as long as 270 km. Under such conditions, lots of seepage and evaporation occur through conveyance and distribution. **Figure 4** shows the annual water balance in the

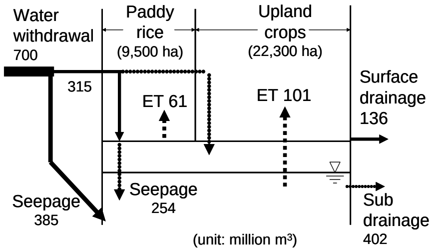

Fig. 4. Water balance in the Akdara Irrigation Scheme (2007)

irrigated district. Crop evapotranspiration is estimated by Blaney-Criddle method. The evapotranspiration rates for paddy rice and upland crops are estimated as 644 mm and 450 mm, respectively. Multiplying them by the cropped area, the water requirement is estimated 162 (=61+101) Mm^3. From the balance of the paddy fields, seepage from paddy fields was estimated 254 (=315-61). Lots of seepage from canals and paddy fields raises the ground water level of the whole farm. The overall irrigation efficiency of the irrigated district is estimated as 0.23. However, considering that seepage from paddy fields effectively leaches salts from the field, 45% (=315/700) is used effectively (Shimizu *et al.*, 2010).

3.3.2 On-farm water management

Continuous irrigation is practiced to the paddy rice fields while no irrigation is done to upland crops fields. Soil water moves upward by capillary action from the raised groundwater table as discussed above. Then, water is supplied to upland crop fields through groundwater.

Practically, nobody works at upland crop fields except seeding and harvest period due to no irrigation. On the contrary, average area to manage paddy rice field is 25 ha per person. However, none of the field workers have their own vehicles to go around his fields. Therefore, all what he can do is to check water depth, inlet and outlet of paddy field on foot. Under the current situation, it can be said that this rotation system saves the manpower by using much amount of water to paddy fields.

3.4. Fluctuation of groundwater level

3.4.1. Temporal and spatial distribution of groundwater level

As discussed above, lots of seepage from canal and paddy fields raise the groundwater level in the irrigation period. **Figure 5** shows the fluctuation of groundwater level. As shown in the figures, groundwater level raises about 2 m during the irrigation period. This groundwater behavior enables upland crops to get water from the groundwater since water moves upward due to capillary action in arid areas and also promotes salinization in the upland crop fields. Therefore, control of groundwater level is very important in this area in terms of water supply to upland fields from

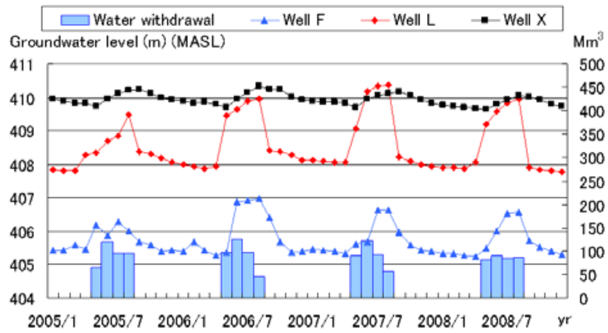

Fig. 5. Groundwater fluctuation in the Akdara Irrigation Scheme. (Wells F and L locate in the irrigated area while Well X is out of the irrigated area. Location of Wells F, L, and X is referred in Fig. 2.)

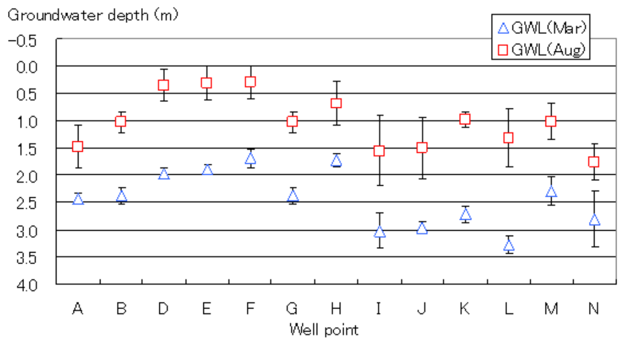

Fig. 6. Range of groundwater level in March and August (Anzai *et al*, 2010). (Wells A~N locate in the irrigated area.).

groundwater and prevention from water logging and salinization by keeping high groundwater table. **Figure 6** shows the range of groundwater depth before irrigation period and mid irrigation period. As shown in the figure, groundwater tables at Wells D, E, and F in August are close to the ground surface since the wells are located in the western part of the BBK, which is relatively low.

3.4.2. Affecting factors of fluctuation of groundwater level

Affecting factors of fluctuation of groundwater level is analyzed by multiple linear regression analysis. Dependent variable is groundwater level in Aug (1994, 1999～2002, 2004～2008) and independent variables are ratio of paddy area, ratio of poor drainage area, and irrigation rate (m^3/ha, 1999, 2002, 2004～2008). Ratio of paddy area is calculated by the ratio of paddy rice area to the field area within the 500 meter of each observation well from the result of field investigation as shown in **Figure 7**. Ratio of poor drainage area is also calculated by the same method as mentioned above and poor drainage area is referred from the annual report from the Jetsu hydrogeology expedition of Committee on Water Resources, Kazakhstan. Irrigation rate is calculated from the paddy rice are and amount of water delivered to the lateral canals. These data is collected from the water management office.

The result is shown in **Table 1**. Clear correlation is observed between groundwater level and the ratio of paddy

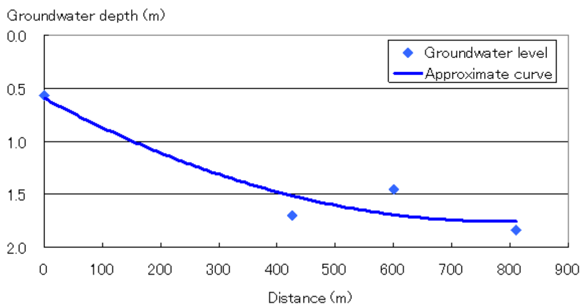

Fig. 7. Relation between the distance from paddy field and groundwater level.

Table 1 Results of multiple linear regression analysis.

Well	MCC (R)	CoD (R2)	t-value paddy	drainage	irrigation
A	0.82	0.67	-1.69	-0.16	0.58
B	0.92	0.85	-3.54	2.01	1.84
D	0.33	0.11	-0.77		-0.15
E	0.20	0.04	0.36		-0.06
F	0.40	0.16	-0.92		-0.29
H	0.59	0.35	0.08	0.92	-0.82
I	0.68	0.46	-1.43	0.64	0.64
J	0.45	0.20	-0.59	0.20	-0.58
K	0.63	0.40	-0.09	-0.55	0.95
L	0.97	0.93	-2.13	-3.46	3.17
M	0.58	0.33	-0.27	-0.70	0.87
N	0.42	0.17	-0.62		0.83

(MCC: Multiple Correlation Clustering, CoD: Coefficient of determination, paddy, drainage, and irrigation stand for ratio of paddy area, ratio of poor drainage area, and irrigation rate, respectively.)

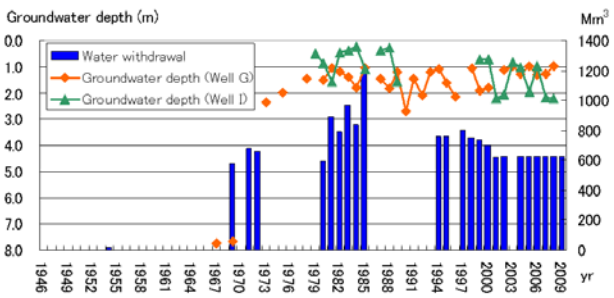

Fig. 8. Water withdrawal and groundwater level in the study area.

rice area at Wells A, B, I, and L while clear correlation of groundwater level to the ratio of poor drainage area and irrigation rate is not observed. It is suggested that huge amount of seepage from irrigation canals raise the groundwater level in the whole irrigated area to some extent. More detail survey on affecting factors of groundwater fluctuation should be conducted.

3.5. Suitability of crop rotation system

Taking all things related to land and water uses in the study area into account, suitability of crop rotation system is discussed. Firstly, currently peak of groundwater level has not dropped although water withdrawal has drastically decreased in 1990s as shown in **Figure 8**. It means that upland crops can get water from the groundwater.

Secondary, cropped area currently recovered after the confusion of collapse of USSR as shown in Figure 3. It means that even groundwater level rises about 2 m during irrigation period as shown in Figures 5 and 6, serious salinization has not occurred so far as crop rotation is practiced.

Considering saving water or reducing water withdrawal from the river, frequent surface irrigation would be one of the options. However, it might be practical to irrigate paddy and upland crop fields in view of both current manpower and mobility in the study area

At last, as to current impact of agricultural water use in the study area on environmental aspect, that is, conservation of Balkhash, total water withdrawal (last 5 year average; 700 Mm^3) is about 9 % of the river discharge during irrigation period and also only 4% of the total annual river discharge (same as above; 17,716 Mm^3/y). Agricultural water use does not affect the environment to the downstream (Shimizu *et al.*, 2010).

4. Conclusion

Roles of rice and upland crop rotation are discussed. Taking agricultural land and water uses, groundwater level, manpower and environmental aspect into consideration, current crop rotation system is sustainable if at least current amount of water withdrawal is ensured.

Acknowledgement

This study is supported by the Global Center of Excellence for Dryland Science Program of Tottori University and the Project "Historical Interactions between the Multi-Cultural Societies and the Natural Environment in a Semi-Arid Region in Central Eurasia" of Research Institute for Humanity and Nature. The authors would like to thank for their support.

References

Anzai T., Kitamura Y., Shimizu K. (2010): Characteristics of groundwater level fluctuation of the irrigation district in the lower Ili river basin, Kazakhstan, *Upland agriculture*, **624**: 13-16 (in Japanese).

Jetsu hydrogeology expedition of Committee on Water Resources (1991, 1995, 2001 and 2005~2008): *Annual report on water use in the Akdara Irrigation Scheme* (In Russian).

Shimizu K., Kitamura Y., Kubota J. (2010): Agricultural Water Use and Its Impact on the Environs in the Lower Ili River Basin, Kazakhstan. *Applied Hydrology*, **22**: 74-80.