Subject 2: Mitigation of Soil Salinization

A Trial of Desalinization by Using a Mole-Drain in the Republic of Uzbekistan

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Summary

Irrigated farmland in the Syrdarya Region of the Republic of Uzbekistan, the area of salt accumulation in the soil is 98%. Leaching is being implemented as a measure to remove the salt in the farmland. However, it does not work well in the central part of the farmland far from the drainage channel and the vicinity of the water channel where the salinity concentration in the soil remains high and the groundwater level remains high because the drainage function is low. We introduced shallow subsurface drainage, which is generally used in the farmland in Japan, as a counter measure to salinity into this region. We adopted a new mole drain or Cut-drain system, which is an inexpensive drainage improvement technology developed in Japan.

We determined that the Cut-drain machine is greatly restricted under dried soil conditions in the arid areas. When using a Cut-drain system, it is desirable that the soil surface becomes dry and the soil in the lower layer holds enough water to have plasticity after the leaching and even after the rainy season. The application of the Cut-drain for leaching in Uzbekistan was confirmed, because it was proven by Cut-drain with the formation of the cavity and the discharge from the outlets partially. However, it requires improving measures against the collapse of the cavity at the time of leaching and the increase of leaching effect.

Key words

Mole-drain, High groundwater level, Subsurface drainage, Salt-accumulation, Desalinization, Dryland, Uzbekistan

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1. Introduction

A stable food supply to cope with the rapid growth of the world's population is essential. Highly productive irrigated agriculture plays a major role in world food production. Irrigated agricultural farmland accounts for approximately 18% of the total agricultural land area (1.5 billion ha) in the world and produces 40% of all agricultural food products (Yamamoto, ed., 2008). Approximately 60% of the irrigated areas are in arid regions where salt accumulates in the soil as the side effect of irrigation (secondary salinization). This is due to the excessive input of irrigation water into soil which contains salt. In addition, poor drainage management triggers rising groundwater levels (Hatcho et al., 1998).

In the arid and semi-arid regions of Central Asia, large scale irrigation has developed, with both the Amu Darya River and the Syr Darya River as the main water sources, and as a result, irrigated farmland has expanded (Tsutsui, 1996). Of the irrigated farmland in the Syrdarya Region of the Republic of Uzbekistan, the area of salt accumulation in the soil is 98% (280 thousand ha). Leaching is being implemented as a measure to remove the salt, and because of that, we can observe the increased effluent water in its volume and the salt concentration in the drainage channel. Therefore, it is considered likely that salt leached by leaching drainage is flowing out to drainage channel. However, it does not work well in the central part of the farmland far from the drainage channel and the vicinity of the water channel where the salinity concentration in the soil remains high and the groundwater level remains high because the drainage function is low. If an adequate drainage facility in farmland cannot be obtained, will be necessary to improve the drainage water draining down to the lower, more permeable soil layer when leaching.

With the assistance of the Ministry of Agriculture, Forestry and Fisheries, the Japan International Research Center for Agricultural Sciences (JIRCAS) conducted studies on measures against salinization by groundwater control in the Syrdarya Region. After the studies, we will introduce shallow subsurface drainage, which is generally used in the farmland in Japan, as a counter measure to salinity into this region. It will prevent the accumulation of salt into the soil and eliminate the salt from the soil. Because it requires a large amount of funding to develop the construction of the full-fledged subsurface drainage network, we adopted a new mole drain or Cut-drain system, which is an inexpensive drainage improvement technology developed by the Institute for Rural Engineering, NARO in Japan (Kitagawa et al., 2014).

In this report, we outline the Cut-drain system which has been introduced in the Republic of Uzbekistan as a case study, provide the results of the test Cut-drain system construction and discuss future problems.

2. Overview of Cut-drain system

2.1 Development background and history

In Japan, the increased productivity of soybean, wheat, and vegetables is provided by the multiple use of paddy fields. Previously, it was a prerequisite to improve drainage by switching the paddy field to farmland. The most effective drainage of agricultural farmland is the installation of a main drain, which is buried with a perforated pipe as a sub-lateral drain. It is also necessary to construct a supplementary drain such as a mole drain, which crosses over the main drain and subsoil breaking. These methods maintain and improve the drainage function of the main drain. This project is being promoted by a public project in Japan, and the main drain can certainly be seen as a significant improvement to farmland drainage. However, it is expensive, and it is impossible to make for a large area of farmland in a short period. On the other hand, simple mole drains or subsoil breaking improves drainage performance, but it has low durability and inferior drainage performance compared to the main drain.

The Cut-drain system works with water flow cavities. It has been put to practical use, and farmers can quickly and easily install it without any special materials. It works similarly to water flow cavity that are almost 60 cm depth and the same discharge capacity as a main drain.

2.2 Feature of construction method

The distinctive feature of the Cut-drain system is its unique drilling method (**Fig. 1**). Cut two blades (front blade (a) and rear blade (b)) are inserted into the farmland to form a rectangular soil mass, then lifted by 10 cm, creating a gap just below the groove by push-up blade (c). By using the side-cutter (d) a 10-cm square soil mass is then moved from the side of the space into the space below the groove, thereby forming a rectangular water flow cavity of a mole hole (e).

The Cut-drain system attaches a mechanical unit to a tractor and runs it on the farmland to form a water flow cavity at a deep position in the soil. It is a simple technology that farmers can handle skillfully. It is sometimes used in the cavity as a supplementary drain that crosses and connects to the existing main drain. Occasionally, the blades units are inserted into the drainage ditch beyond the ridge and the cavity is used as a subsurface drainage to remove excess water permeated by opening a water passage hollow at the dike slope of the drainage channel (**Fig. 2**).

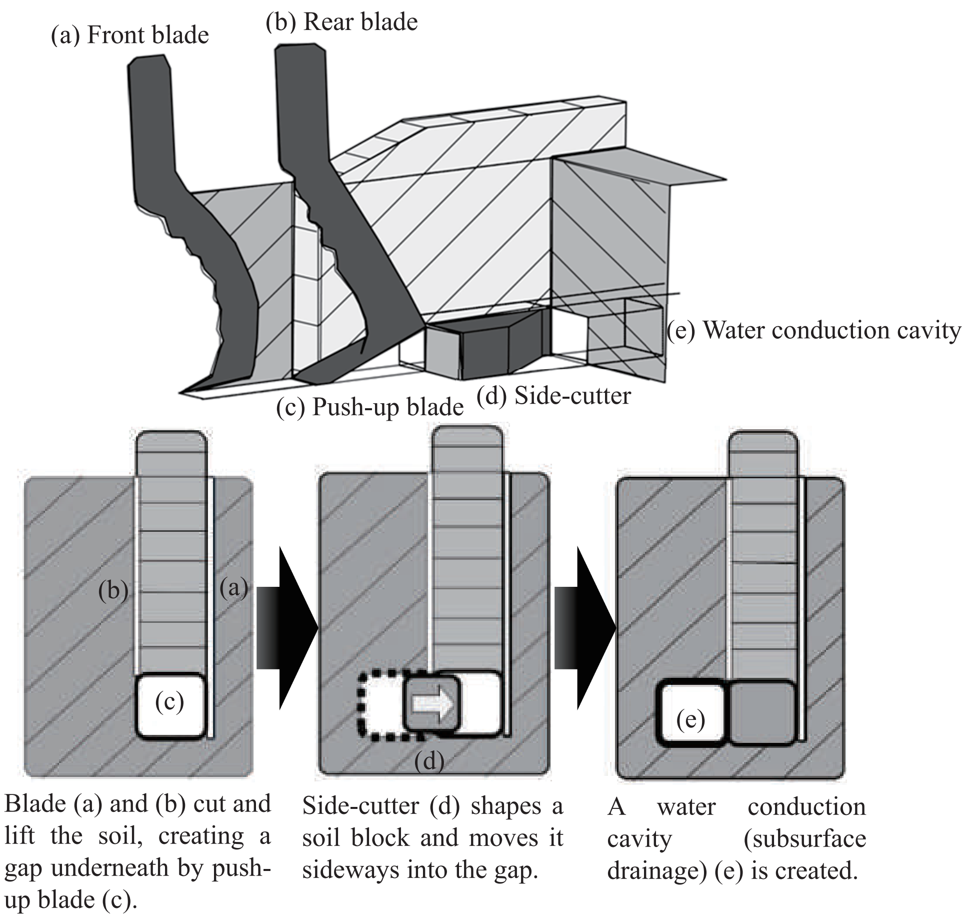


Fig. 1 Structure of Cut-drains

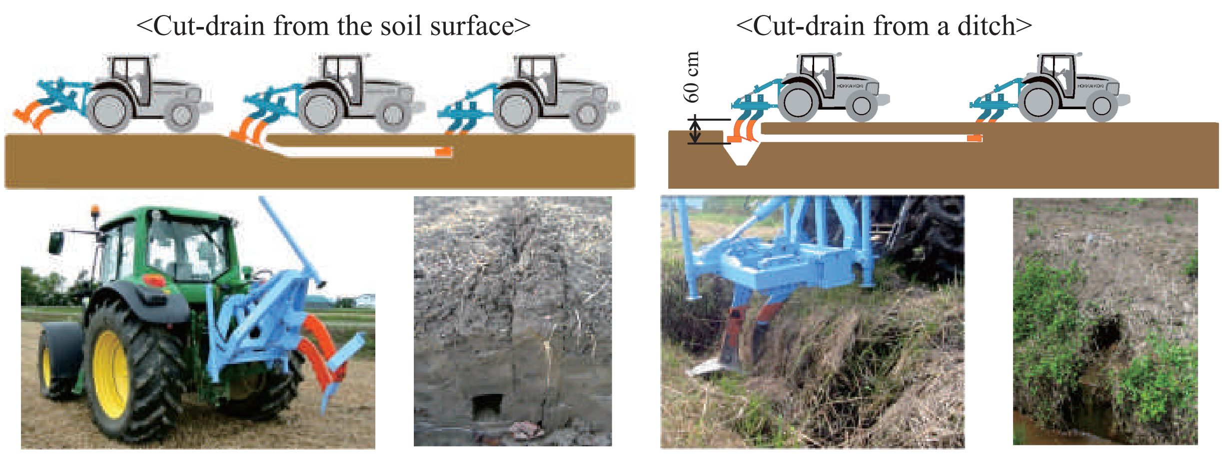


Fig. 2 Drilling method of Cut-drain

2.3 Installation effects and cavity sustainability in wet farmlands

The Cut-drain system used in the field in Japan shows the most drainage volume discharged from the perforated water flow cavity which may meet 5 mm h^{-1} at maximum, and has adequate function, similar to subsurface drainage. As long as the water flow cavity is maintained, which will eliminate surface water stagnation by improving drainage, the roots of the crop in the field are expected to develop and its growth and the crop yield will be improved. The Cut-drain system does not use a pipe, so it is necessary to consider the formability of the cavity at the time of construction and the fall of the soil due to water flowing in the cavity. The applicability of the Cut-drain system in Japan is highly preferred in clay and peat soil (**Fig. 3**).

Fig. 3 Profile of Cut-drain

Conversely, it cannot be used in soils of S, LS, SC, SCL, SL, SiC, SiCL, SiL (soil texture classification of the International Society of Soil Science standards) with sand or high silt content. L has a short durability life and it needs to be rebuilt every few years. The main farmlands appropriate for the Cut-drain are rotational paddy fields, upland fields, and grassland. Paddy fields necessarily require ponding, and therefore, it is used as a supplementary drain combined with the main drain in which a relief well to control drainage is installed.

3. Utilization of Cut drains in Uzbekistan

3.1 Drainage technology in Uzbekistan

In the Syrdarya Region, open drainage is approximately 3 to 4 m depth, deep subsurface drainage is 2.5 to 3.0 m depth, and vertical drainage is a facility for direct groundwater pumping. These drainage facilities have mainly been constructed since the 1960s to control the groundwater level. The current problems that are occurring are 1) that sediment is deposited in the open drainage, 2) that the subsurface drainage outlet is clogged, and 3) that the vertical drainage operation efficacy declines. There are many challenges to controlling groundwater, and despite the financial constraints, the Uzbekistan government is also conducting drainage maintenance of drainage, while simultaneously conducting renewal projects and new construction projects to secure drainage functions (**Fig. 4**).

Construction of subsurface drainage (New construction project with financial assistance from aid agency)

Existing vertical drainage (Power costs are high and operating hours are limited)

Fig. 4 Deep subsurface drainage and vertical drainage

3.2 Cut-drain system in Uzbekistan

It is apparent that subsurface drainage is effective in Japan when desalting salt damaged farmland (Kaneko et al., 2002). Furthermore, it has been shown that the installation of subsurface drainage is effective for leaching with waterlogging in the farmland, even in arid areas (Abou et al., 2005). We have installed two shallow subsurface drainage (sub-lateral drain depth approximately 1 m, extension length 200 m, with rice husk as the hydrophobic material) as a technology to eliminate the excess of infiltration water in the testing field in the Syrdarya Region, and we studied the effect on the field. However, it was limited to installing the main drain in the same manner as that of Japan regarding material supply and budget, but unlike Japan, to install a main drain in Uzbekistan. In order to reduce construction costs and the use of material, the Cut-drain system was introduced on a trial basis to examine its applicability. The outline of the construction of the Cut-drain system and the leaching effect has been clarified and will now be explained.

3.2.1 Problems in the construction of Cut-drain

(a) Capability of tractor

Agricultural equipment such as tractors are imported from Europe. The basic functions such as hydraulics and PTO (rotational power take-off) of the tractor can be utilized in Uzbekistan. However, some frequently-used tractors had functions that often broke down, but those parts continued to be used without renewing them for emergency measures such as welding. A tractor was observed in the Syrdarya Region which could not be subtly controlled, for example horizontal or height adjustment.

(b) An appropriate period of construction viewed from soil moisture

The soil moisture condition in the test field is shown in **Fig. 5**. In the brown lowland soil (soil texture: L) found in the test field, the soil moisture is low to the lower layer in the dry season and does not have plasticity. Immediately after the dry season in October 2014, when attempts were made to connect the drainage ditch for the Cut-drain, the soil did not deform even when the Cutting blade was brought into contact with the soil (depth of 70 to 90 cm), and the Cutting blade could not be inserted. In contrast, when this was attempted with a slightly high viscosity light gray soil (soil texture: CL) in which the soil moisture was also high, it was able to be drilled properly (**Fig. 6**). Afterwards, three trials were conducted regardless of whether or not the soil moisture condition was acceptable. The trial constructions were conducted firstly at the beginning of the rainy season in November 2014, the second in December 2014 before leaching, and the third trial was in April 2015 after leaching in the trial field under the same construction conditions.

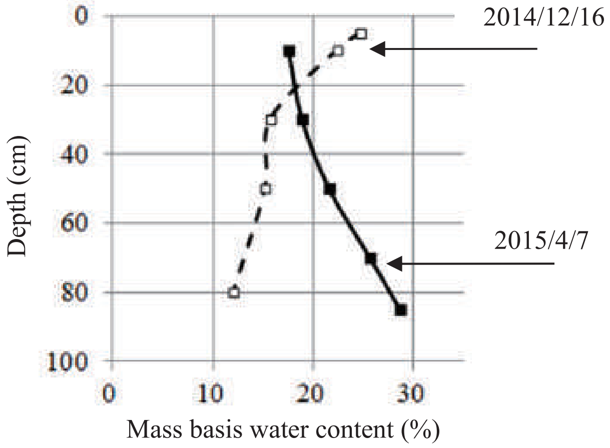


Fig. 5 Soil moisture condition

Fig. 6 Drilling situation of the Cut drain operated in Uzbekistan

During the second construction in December, the tractor wheels occasionally slipped when pulling the mechanical unit because the soil surface was wet, and the earth was crushed. Moreover, even if the Cutting blade could be inserted, a perforated portion could not be formed because of inadequate plasticity due to dryness in the lower soil layer. The soil surface was firmly dried in the construction in April and the machine unit could be towed without any problem and there were the appropriate perforated portions formed. The characteristics of the soil moisture condition significantly affected the workability and hole formation. Regardless of the dry weather in Japan, the drying of the subsoil maintained the same condition of the plasticity and therefore, the use of the Cut-drain system was not a major problem. However, we determined that the Cut-drain machine is greatly restricted under dried soil conditions in the arid areas. When using a Cut-drain system, it is desirable that the soil surface becomes dry and the soil in the lower layer holds enough water to have plasticity after the leaching and even after the rainy season.

3.2.2 Problem of using a Cut-drain system for leaching

(a) To scour by an excessive inflow of leaching water

Leaching in the Syrdarya Region is mainly conducted between December and January. In preparation for leaching, 30 to 50 cm high ridges are made and then the farmland is divided into sections. According to the recommendations of the salt damage measures implemented by agencies of the Uzbekistan Government, its shape is divided into 50 m per side if the terrain gradient is less than 1/500, and the amount of water for leaching is set to 2,500 to 4,000 m^3 ha^{-1}. Leaching water is ponded into the compartment and it is allowed to stay there for two weeks, where it is left to naturally permeate into the subsoil.

Leaching in the test field was carried out on 27 December, 2014 and 15 January, 2015. There was a significant difference between a large amount of discharge in some ditches and less discharge in other ditches under the same the Cut-drain system conditions. After the profiles of the Cut-drains were checked on the construction lines, cavity collapses were observed. There is a possibility that infiltrated water flowed down into the cavity through the vertical groove which was made by the blade of the Cut-drain. In contrast, at two normal subsurface drainage outlets, discharge was observed after leaching (**Fig. 7**).

Cut drain (December 30)
3 days after leaching

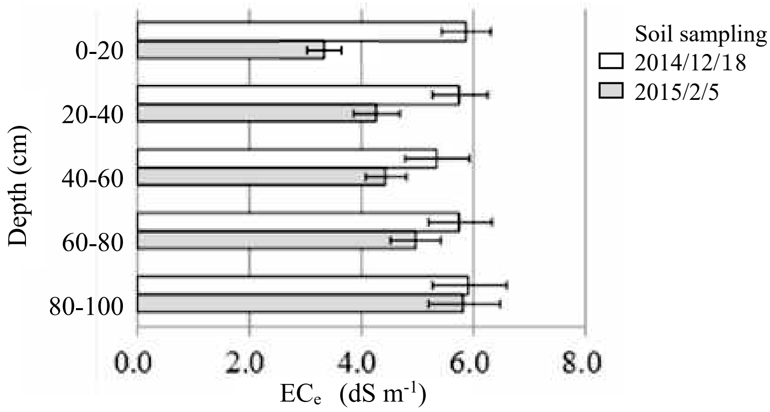
Pipes (2 m) were inserted to protect the Cut-drains

Shallow subsurface drainage (January 3)
7 days after leaching

Fig. 7 State of discharging from outlets after leaching

(b) Effect of leaching to reduce soil salinity

We took the sample of soil which was divided into five layers of depth (0-20, 20-40, 40-60, 60-80, 80-100 cm) and analyzed that how much salt remained in each soil layer before and after leaching. When looking at EC_e (electrical conductivity of the saturated extract of soil), the salt was mostly eliminated on the surface layer after leaching (**Fig. 8**).



Leaching took place on December 27, 2014.
EC_e is an estimated value converted from $EC_{1:1}$
Error width is standard error (each layer n = 8)

Fig. 8 Soil EC_e before and after leaching

In the test field, there was a hard soil layer 30 to 50 cm below the ground surface, which prevented the permeation of leaching water. At the time of leaching, a preferential flow was mainly generated through the Cut drain vertical groove. Hence, the amount of penetration below the hard soil layer was reduced. Therefore, it is considered that the leaching of salts mainly occurred at the surface (upper layer than the hardpan). We needed a counter measure to permeate down the leaching water below the lower layer of the hardpan to reduce the salinity in the subsoil.

The application of the Cut-drain for leaching in Uzbekistan was confirmed, because it was proven by Cut-drain with the formation of the cavity and the discharge from the outlets partially. However, it requires improving measures against the collapse of the cavity at the time of leaching and the increase of leaching effect. If the Cut-drain as the supplementary drain, which is easy to use for repeated re-installation on the field is used, it could also be expanded to the main drain and save construction cost. Installing a combination of the main drain and supplementary drain as the Cut-drain system in the Syrdarya Region, similar to the paddy fields in Japan, should be considered.

4. Conclusion

A drain drilling technique or 'Cut-drain' needs to be constructed with soil moisture conditions suitable for perforation formation. It needs to cope with excessive drainage, which leads to the collapse of the perforated cavity. There is also the problem that improvement of permeable drainage through the hard soil layer is necessary. However, the simple structure and novel construction methods are highly anticipated by farmers, engineers, farmer instructors, and agricultural machinery makers and distributors in Uzbekistan. In the future, it will be important to develop the technology suitable for the local area for solving the problems, in conjunction with Uzbekistan's engineers. The combination of the main drain and perforated cavity is a typically used drainage technology in Japan, which eliminates the infiltration water properly. In Uzbekistan, there are many areas where farmland with salt accumulation and fields with reduced drainage functions are the main obstacle to agricultural productivity. Those places certainly require the use of inexpensive drainage with improvement technology, such as that developed in Japan.

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