Shallow sub-surface drainage for mitigating salinization

Technical Manual

Abridged Edition

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*Details of cut-drain are shown in the “Cut-drain Manual” prepared by Hokkai Koki Corporation which is attached to the full version of the “Technical Manual (full version)”.

Japan International Research Center for Agricultural Sciences
https://www.jircas.go.jp/
1-1 Ohwashi, Tsukuba, Ibaraki, 305-8686 Japan
Tel: +81-29-838-6688, Fax: +81-29-838-6693

Farmers’ Council
1A, Ravnaq Street, Tashkent, Uzbekistan
Tel: +99871 267 4094, Fax: +99871 268 1845

For more information

More detailed information can be found in the local governmental office or regional office of the Farmers’ Council.

Japan International Research Center for Agricultural Sciences (JIRCAS)
Farmers’ Council of Uzbekistan (FC)

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This manual recommends the use of shallow sub-surface drainage to mitigate salinization in fields with difficulties in achieving the above target; in those showing little improvement in groundwater or drainage water level; and in those with a high risk of salt accumulation. Generally, shallow sub-surface drainage techniques require a high density of perforated pipes, thus resulting in high construction cost; however, here, we plan to reduce this cost by using cut-drains developed in Japan.

There is a possibility that the salt discharged from the site where salt removal was carried out will accumulate in a river or a different site located downstream. When shallow sub-surface drainage technology is introduced into large farming areas, this environmental issue should be considered deeply by all stakeholders.

This manual was prepared by the following JIRCAS researchers:

Yukio Okuda
Keisuke Omori
Junya Onishi

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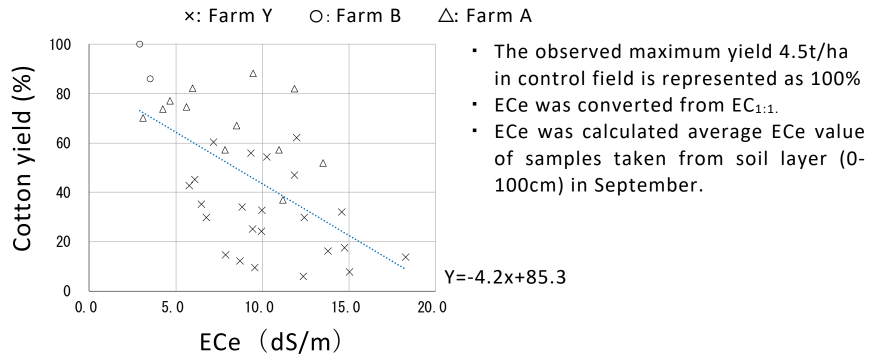
◆ Effect: Increase in Yield

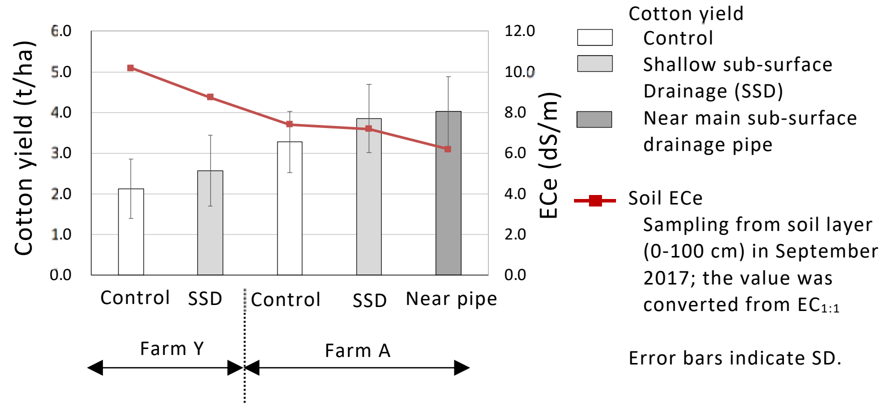
Shallow sub-surface drainage results in a 20 % increase in cotton yield.

A negative correlation was observed between soil ECe and cotton yield; generally, an increase of 1 unit of soil ECe reduced cotton yield by approximately 0.2 t/ha in the research fields.

The use of shallow sub-surface drainage resulted in a 20 % increase in cotton yield. Some results obtained from the research fields are shown as below.



Soil salt concentration and cotton yield (2016-2017)

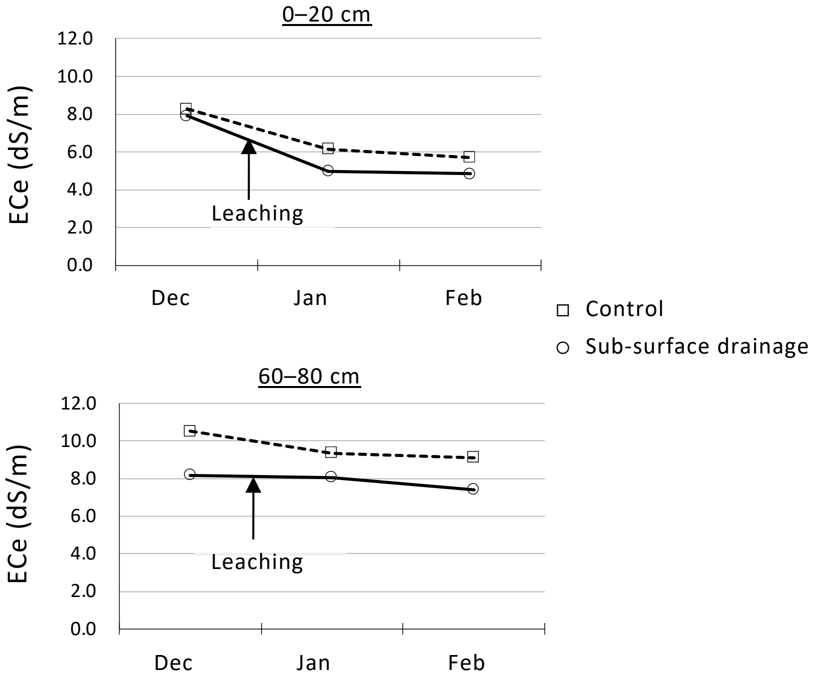


Cotton yield in the field with sub-surface drainage

◆ Effect: Reduction in Soil Salinity

Salinity in the soil surface layer can be reduced by adopting the shallow sub-surface drainage system.

Soil salinity in the surface layer after leaching can be lower in the site where the shallow sub-surface drainage technology was introduced. However, this salt removal effect could not be observed in the lower layers of the soil because the water from the leaching process seeped into areas outside the site.



Leaching period: Dec. 25, 2015 to Jan. 9, 2016

(ECe: Electrical conductivity of an extract of saturated soil paste)

Changes in soil salinity before and after leaching

INTRODUCTION

Background

Several measures can be taken to mitigate salinization, including water-saving irrigation and improving drainage. However, in reality, the only practical measure that is available to farmers is leaching, the efficacy of which is limited by poor drainage and hardened soil, owing to soil compaction from the long-term use of agricultural machinery. Therefore, in 2013, the JIRCAS initiated a new project that focused on developing low-cost drainage technology to improve the efficacy of leaching.

Targets of this manual

- Target areas:
  Irrigated farmland and drainage block in arid or semi-arid regions
- Target groups:
  Government officials, Water Consumers Association (WCA), Farmers

How to use this manual

The main purpose of this technical manual (Abridged Edition) is to provide information to governmental officials, WCAs, and farmers about sallow sub-surface drainage technology which developed as one of the perforated dredgers in Japan (Cut-drain). These information was obtain from verification studies under high-risk salt accumulation. At the same time, in order to promote a better understanding of secondary salinization, the mechanisms of salinization, mitigation measures, and monitoring methods are also described.

1. SALINIZATION AND MEASURES

Salinization

Salinization is the accumulation of salts in the root zone of agricultural soil that reduces crop yields by preventing plants from absorbing enough moisture.

Salinization

In Central Asia, Salinization due to irrigated agriculture is serious, among them, in Uzbekistan, cotton and wheat cultivation by the government order is still going, where, cultivation by the surface irrigation with low water application efficiency is done in a large farmland. As a result, nearly 40% of the irrigated farmland is affected by salinization.

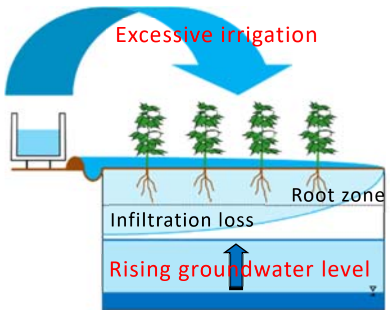
Salinized land in Central Asia

Country	Irrigated area (ha)	Area affected by salinization (ha)	Area affected by salinization (%)
Uzbekistan	4,198,000	2,141,000	51
Kyrgyz	1,021,400	49,503	5
Tajikistan	742,051	23,235	3
Kazakhstan	2,065,900	404,300	20
Turkmenistan	1,990,800	1,353,744	68
Central Asia	10,018,151	3,971,782	39.6

Source: Irrigation in Central Asia in figures (FAO, 2013, FAO Water report 39, p68)

Cause of salt accumulation

There are mainly two factors of salt accumulation under irrigation agriculture, namely the introduction of salt with irrigation water and the elevation of groundwater levels, as a result of excessive irrigation and poor drainage.



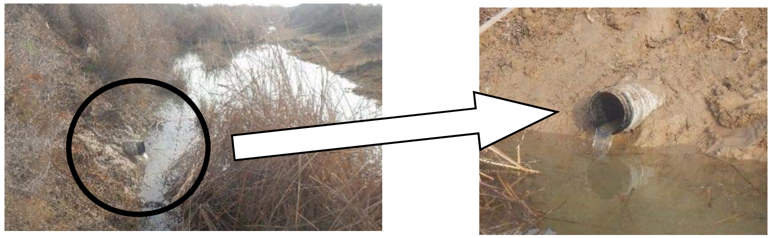
Cause of salt accumulation

◆ Effect: Discharging Salt from the Field

Shallow sub-surface drainage can remove salt from the field after the leaching process.

The level of salt removal obtained using the shallow sub-surface drainage technology, which is a combination of main sub-surface drainage and cut-drains, was expressed as Total Dissolved Solids (TDS). Experimental results showed 3-25 % TDS from the field in the leachate after the leaching process. It is conceivable, however, that some of leaching water leaked out to other places.

The research field after leaching



Outlet on the wall of the drainage canal

2.4 Costs and Effect

◆ Cost

The construction costs consist of excavation and backfill works, drain pipes, hydrophobic materials, cut-drain operation, etc.

The construction costs for the combination of the main sub-surface drainage and cut-drains amounted to a total of 2,970,000 UZS/ha (1,050 USD/ha). Works and materials vary depending of the size and leveling condition of the field area, condition of open drainage connection, etc.

Item	1,000 UZ/ha
Earthworks (drilling/backfilling)	390
Sub-lateral drains (perforated pipe Φ100 mm, including shipping)	1,250
Collecting drain (non-perforated pipe, including shipping)	630
Filter material (rice husk including shipping and installation)	250
Cut-drain construction (tractor operation, fuel, etc.)*	200
Cut-drain drilling unit rental**	80
Other (wages for manual labor)	170
Total	2,970***

* Calculated based on field experience (constructed in December 2015)
** Depreciation assuming estimated durability of seven years over an annual land area of 50 ha.
*** Exchange rate: 2,825 UZS/USD as of December 2015

Perforated pipe with filter textile

Hydrophobic material (Rice husk)

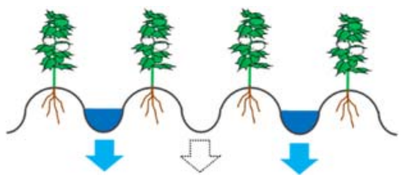
Materials for main sub-surface drainage

Preventative measures

In order to prevent salinization, it is necessary to limit both the influx of salt and the height of groundwater tables.

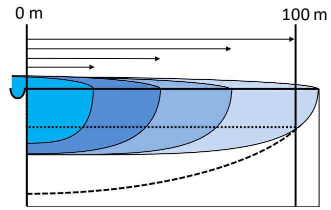
- Water saving irrigation
- Improving drainage function
- Land leveling
- Suppression of capillary rising
  Mulching, Deep plow, Capillary barrier

Alternate Furrow Irrigation (AFI)



Irrigate every other furrow

Surge Flow Irrigation



Irrigate Intermittently

Water saving irrigation

Remediation measures

In contrast to preventative measures, the purpose of remediation measures is to remove salt that has already accumulated

- Flushing
- Leaching
- Application of soil-improvement agents
- Scraping
- Hardpan breaking (Sub - soiling)
- Phytoremediation

Leaching

Sub - soiling

2. SHALLOW SUB-SURFACE DRAINAGE

2.1 Concept of the Technology

Shallow sub-surface drainage is an effective measure against salinization.

The shallow sub-surface drainage types discussed in this manual target shallow groundwater in fields at high risk of salt accumulation, with the goal of reliably removing salts via directing post-leaching infiltration water into drainage canals and thus improving field drainage performance in a relatively shallow soil layer (60–90 cm below soil surface).

- Higher water levels in drainage canals
- Higher groundwater levels
- Little effects of salt removal due to the presence of a hardpan or other factors

Adaption of shallow sub-surface drainage system could be facilitated by combining it with “cut-drain”.

It is economical to have the main sub-surface drainage cross at right angles to cut-drains. It is desirable to have the main sub-surface drainage running perpendicular to the ridges, while having cut-drains running parallel to ridges. As irrigation water flows along the ridges from the higher point to the lower point, via the created cut-drains parallel to the ridges, water can flow toward the main sub-surface drainage.

◆ Durability of Mole Holes

It is necessary to recreate cut-drains every few years.

According to the Cut-drain Manual (Hokkai Koki Corporation), the durability period of mole holes in type L soil (loam with clay content of 25–37.4 %) is 2 to 3 years; thus, it is necessary to recreate them every few years. Because leaching occurs every winter, large amount of water passes through the mole holes; this event is suspected to shorten their durability even further.


Cut-drain hole after construction


Case 1: Deformed hole


Case 2: Collapsed hole

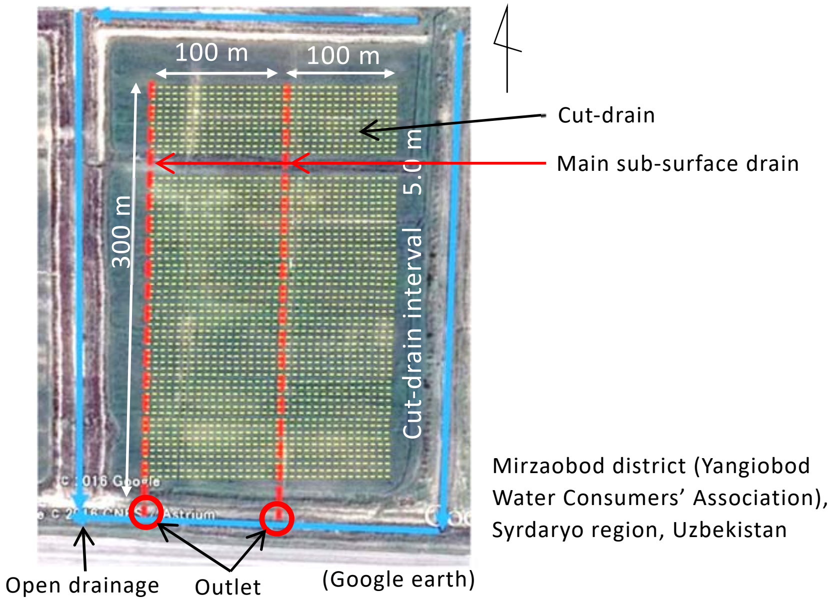
Preferential flow may occur in the vertical air gaps above a cut-drain formed by the blades of the drilling unit. If a large amount of preferential flow originating from leaching and irrigation water flows into the air gaps, mole hole collapse may occur. One preventative measure that can be adopted to minimize the occurrence of preferential flow is to increase soil moisture prior to cut-drain construction. Increasing soil moisture can be accomplished by furrow irrigation along the cut-drain construction line, with water kept from the adjacent furrows where the tractor will run.


Construction of a cut-drain immediately after irrigation

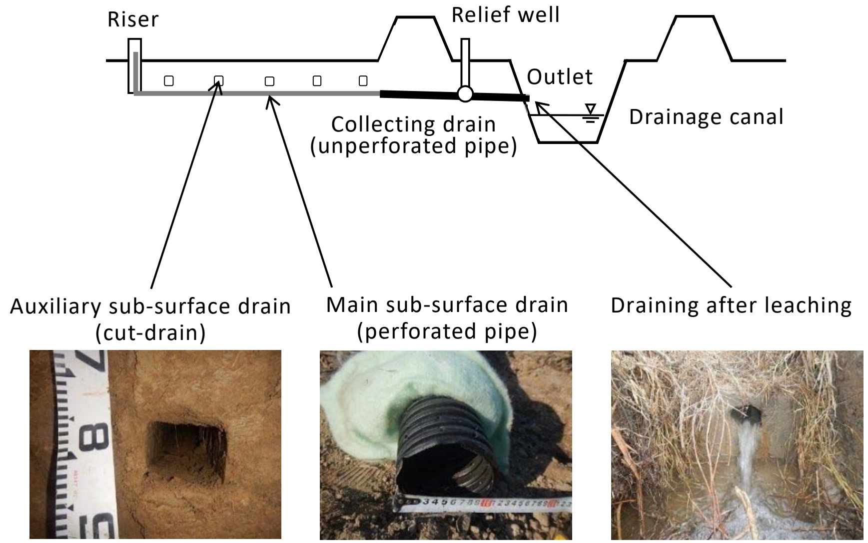
◆ Recommended Length and Interval

The length of and interval between cut-drains should be decided based on topographic condition and drainage volume.

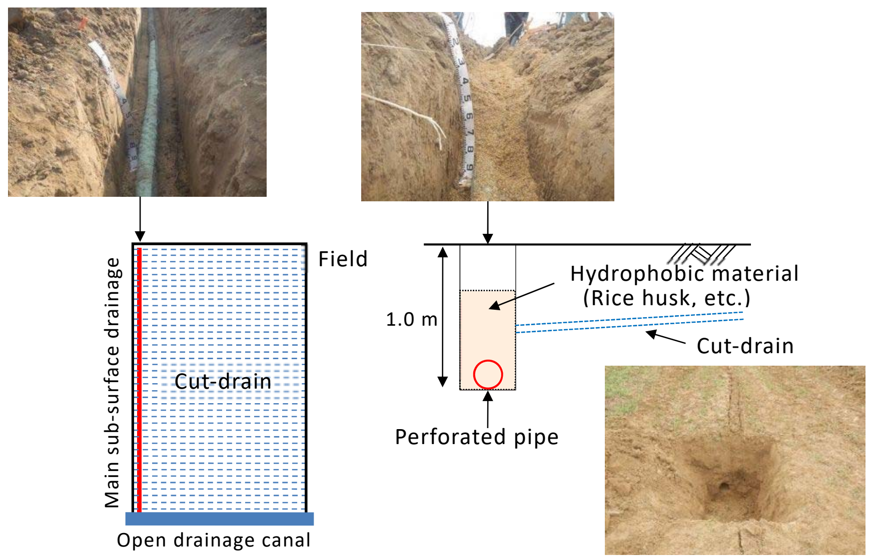
It is desirable to create drains on leveled land, as it is difficult to keep drains at a constant depth on undulating sites. The length of cut-drains is constrained by the topography of the land and the depth of the main sub-surface drainage; however, cut-drains are normally up to 200 m long. Although the standard interval between cut-drains in Japan is 2.5–5 m, when taking into consideration the planned sub-surface drainage volume, the permeability coefficient of the site, and thickness of the topsoil, the interval may be calculated to be around 4–18 m.



Design of the shallow sub-surface drainage system



Structure of a shallow sub-surface drainage system



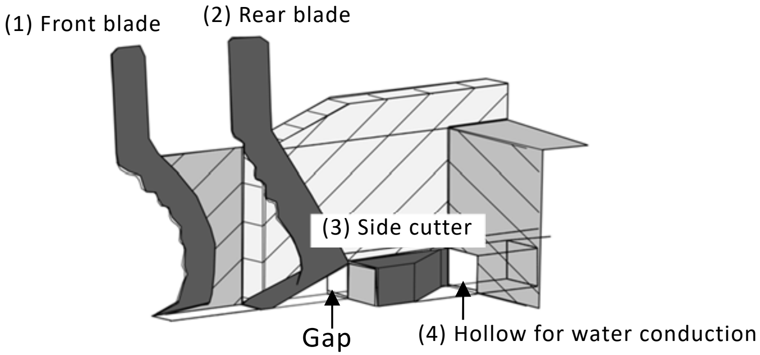
Layout and cross section of sub-surface

2.2 Structure of Cut-drains and Drilling Method

Cut-drain is a simple sub-surface drain-drilling unit towed by a tractor.

Cut-drains are formed via a unique drilling method. First, two blades (front blade (1) and rear blade (2)) are inserted into a field, which then and lift a soil cuboid by 10 cm, creating a gap underneath. A side cutter (3) then shifts an adjacent 10 cm soil block sideways into the newly created cavity, leaving a water conduction hollow (4), which serves as a sub-surface drain. The cut-drain drilling unit is attached to and towed by a tractor. Cut-drain drilling is thus a simple technique that farmers can easily incorporate into their routine farming practices.

There are two ways the cut-drain unit drills hollows: drilling from the ground surface and drilling from inside a drainage canal.



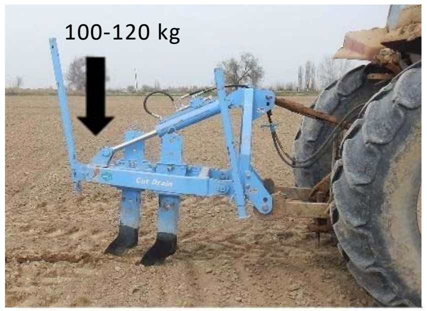
How to create cut-drains (roles of blades)

The use of side cutter with an anti-uplift board and the addition of weight on the base frame are useful ways of securing the recommended depth under hard soil condition.

In case that the blades do not penetrate deeply into the soil in spite of appropriate soil moisture content, measures to prevent uplifting of the drilling unit must be taken, such as the use of side cutter with an anti-uplift board and the addition of a 100–120 kg load on the base frame.

Side cutter without anti-uplift board

Anti-uplift board



Load on the frame (see the arrow)

◆ Recommended Depth of Drains

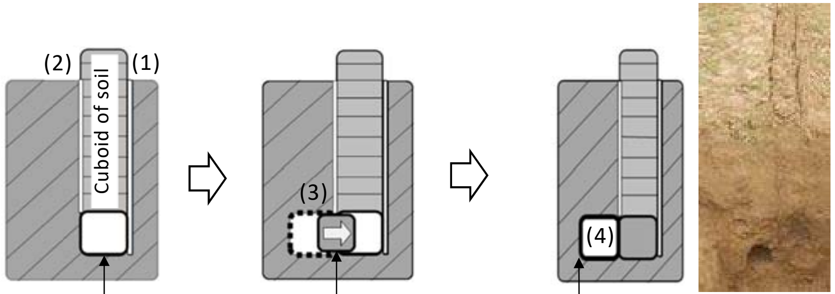
The desirable drain depth is approximately 60–90 cm beneath the surface of the ground under hard soil condition.

Although the length of the blade on the drilling unit can be adjusted to a depth of between 60 and 120 cm by manipulating the degree of insertion of blades through its holes, if too much of the blade is inserted into the ground, resistance increases, and there is the possibility that the blade will bend. Therefore, the third hole from the top is often used to create at a depth of 60–90 cm.

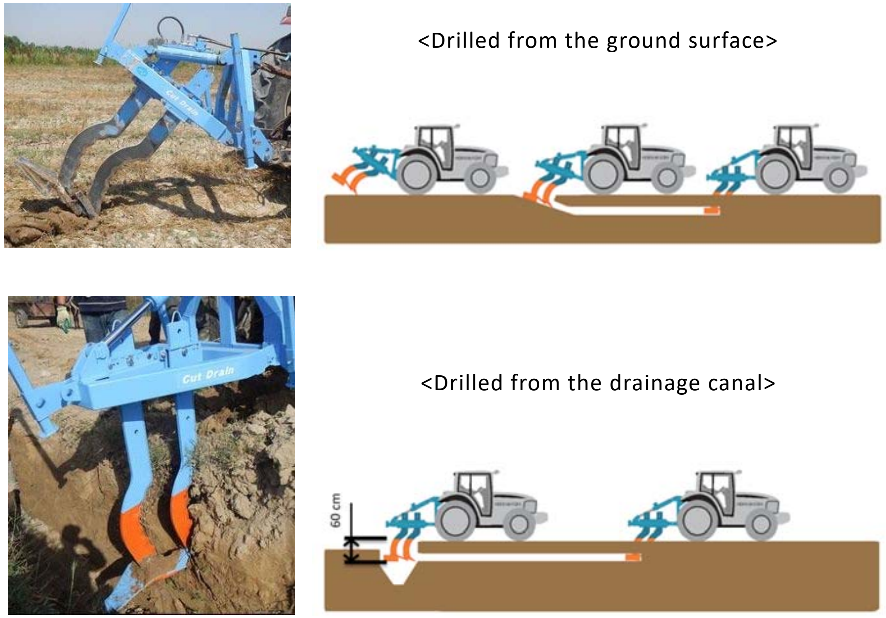
Blade of the drilling unit

Setting the third hole of the blade

Constructed mole hole
(depth 70-80 cm)



Movements of soil masses during the construction of a cut-



How to drill a cut-drain

2.3 Precautions concerning the Application of Cut-drains

◆ Feasible soil texture

Because cut-drains are hollows and not pipes, the feasibility of the hollows and the risk of soil collapse due to water discharge by discharging water through them, among other issues, must be considered before they are created. In Japan, the feasibility of cut-drains is high in soil types such as clay and peat. On the other hand, sand and other soil types with high silt content, such as S, LS, SC, SCL, SL, SiC, SiCL, and SiL (internationally recognized soil texture types), are unsuitable; for fields with soil texture type L, for instance, cut-drains do not last long and must be reinstalled every few years (Kitagawa et al. 2010).

◆ Cut-drain in arid areas

In situations where cut-drains are used in arid areas, as compared with cases where they have been used in Japan, some constraining factors that need to be considered for drain construction are indicated below. Furthermore, in order to maintain the shape of the mole holes, it is necessary to take measures to ensure the suppression of preferential flow and the provision of less water for irrigation.

- Recommended time to create drains
- Recommended depth of drains
- Recommended length of each drain and the intervals between drains
- Durability of mole holes

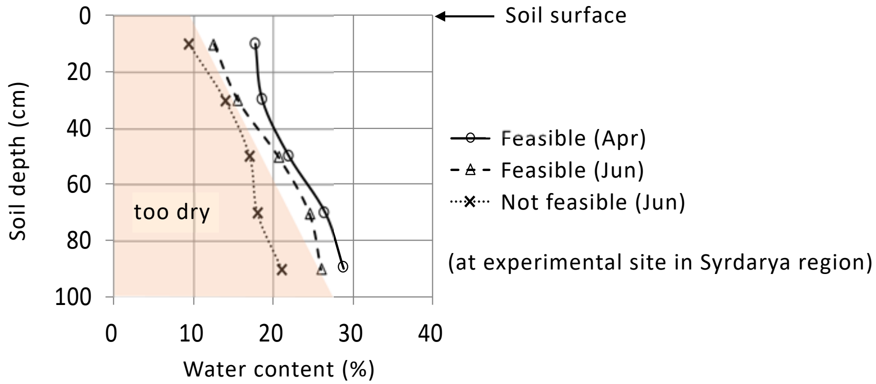
◆ Recommended Time to Create Drains

Cut-drain should be constructed under appropriate soil moisture condition.

If drains are made when soil moisture is low and the soil is hard, the blades of the drilling unit that is pulled behind a tractor will ride up, disabling the unit to construct drain. According to test results, a soil moisture content of 10 - 18 % is ideal for making cut-drains.

Towing under moderate soil moisture condition

Uplifting the drilling unit



Appropriate soil moisture for cut-drains