矿山生态安全教育部工程研究中心
Engineering Research Center of Mining Environment & Ecological Safety, Ministry of Education

土地复垦与生态重建研究所
Institute of Land Reclamation and Ecological Restoration

# Innovation of filling reclamation with multi-layered soil profile


*Institute of Land Reclamation & Ecological Restoration*

*China University of Mining and Technology(Beijing)*

*Engineering Research Center of Mining Environment & Ecological Safety, Ministry of Education*



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中国矿业大学（北京）
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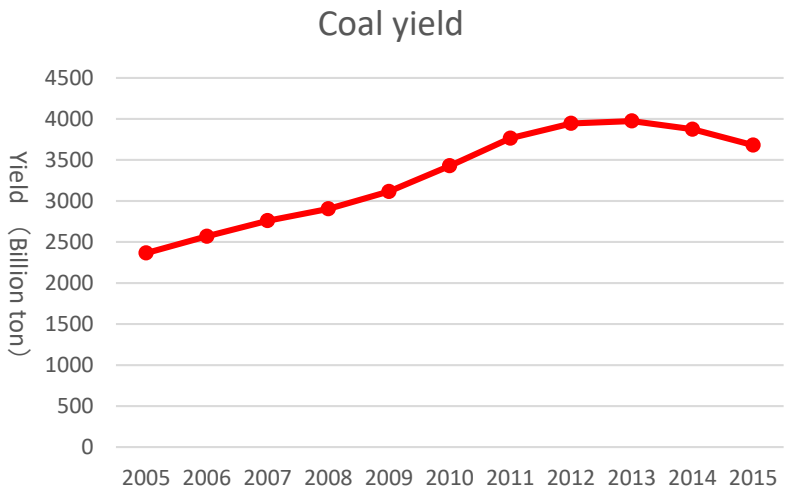
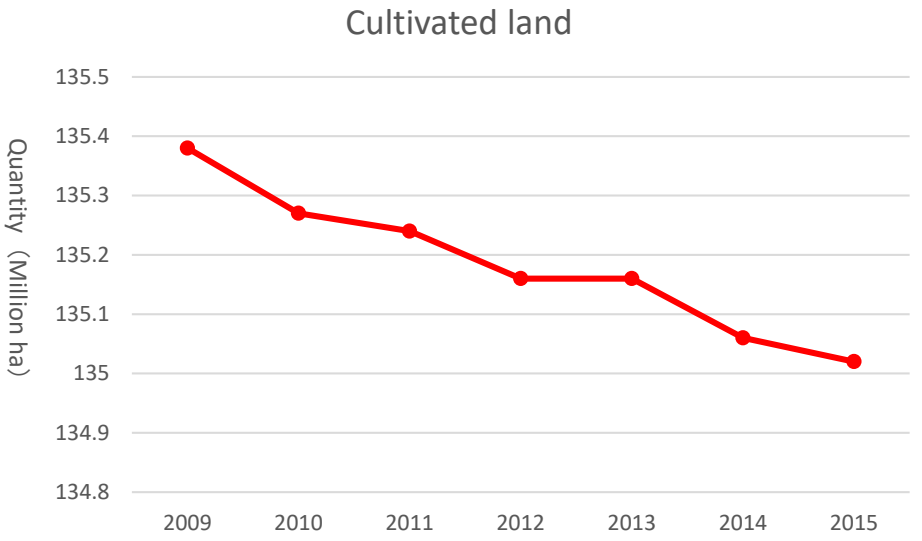
# Outline

- ✓*Background*
- ✓*Problems of filling reclamation*
- ✓ *Innovation of filling reclamation*
  - ✓ *soil cover*
  - ✓*A new method for filling reclamation with multi-layerd soil profile*
- ✓*Conclusions*

# 1. Background




Coal yield and growth rate from 2005 to 2015 in China




Cultivated land quantity variation from 2009 to 2015 in China

Coal is the most important resource in China, accounting for about 60% of energy consumption.
China's coal output was 3.68 billion tons in 2015.
About 85% was from underground mining.

# Damaged land due to mining subsidence






- **Subsidence: over 1 million hectare of subsided land; 70 thousands ha of land will be subsided every year**

# Problem:

- *overlapping region of crop and coal production base, prime farmland and high density population*
- *Conflict between human and land was serious*

***It's very urgent to restore farmland as much as possible!!***

**Filling reclamation could restore much more farmland.**

# 2. Problems of filling reclamation

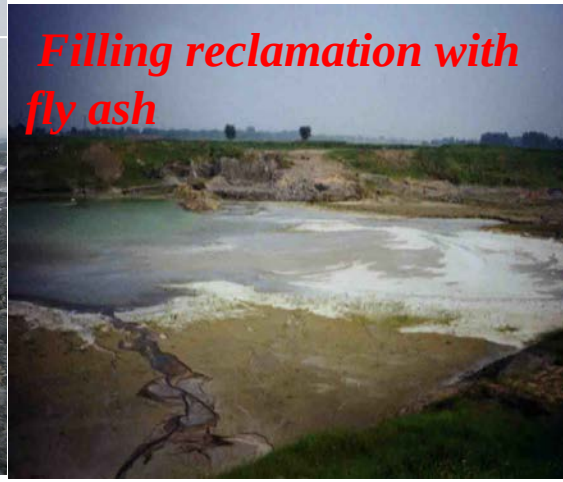
**Disadvantage of *filling reclamation with coal wastes and fly ash***

➢*Filling reclamation needs lots of reclaimed materials, but coal wastes and fly ash has been almost recycled in coal mine area now, there are **no enough reclaimed materials***

➢ *The heavy metal contained in reclaimed materials may cause pollution on the quality of crop products, soil, surface water and underground water---**pollution risk***

***Filling reclamation with coal wastes***


***Filling reclamation with fly ash***



# Technical process is simple and resulting poor soil

Traditional filling reclamation method was: 1) stripping the soils to be reclaimed land; 2) filling the subsided land materials at once; 3) backfilling the soils. This kind of simple soil profile is an unfavorable profile type in pedology, **resulting in poor productivity.**

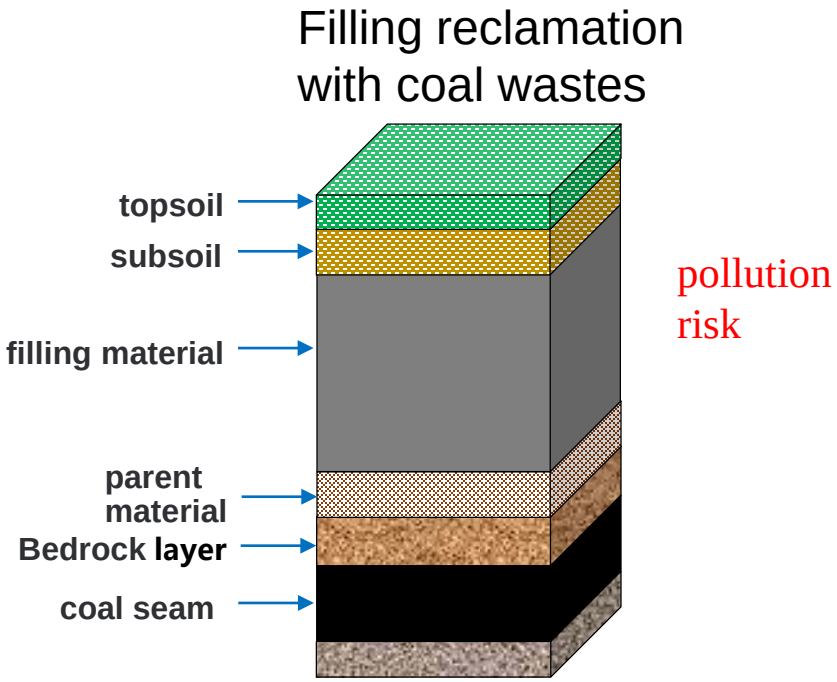



Diagram of Traditional filling soil-sediment profiles

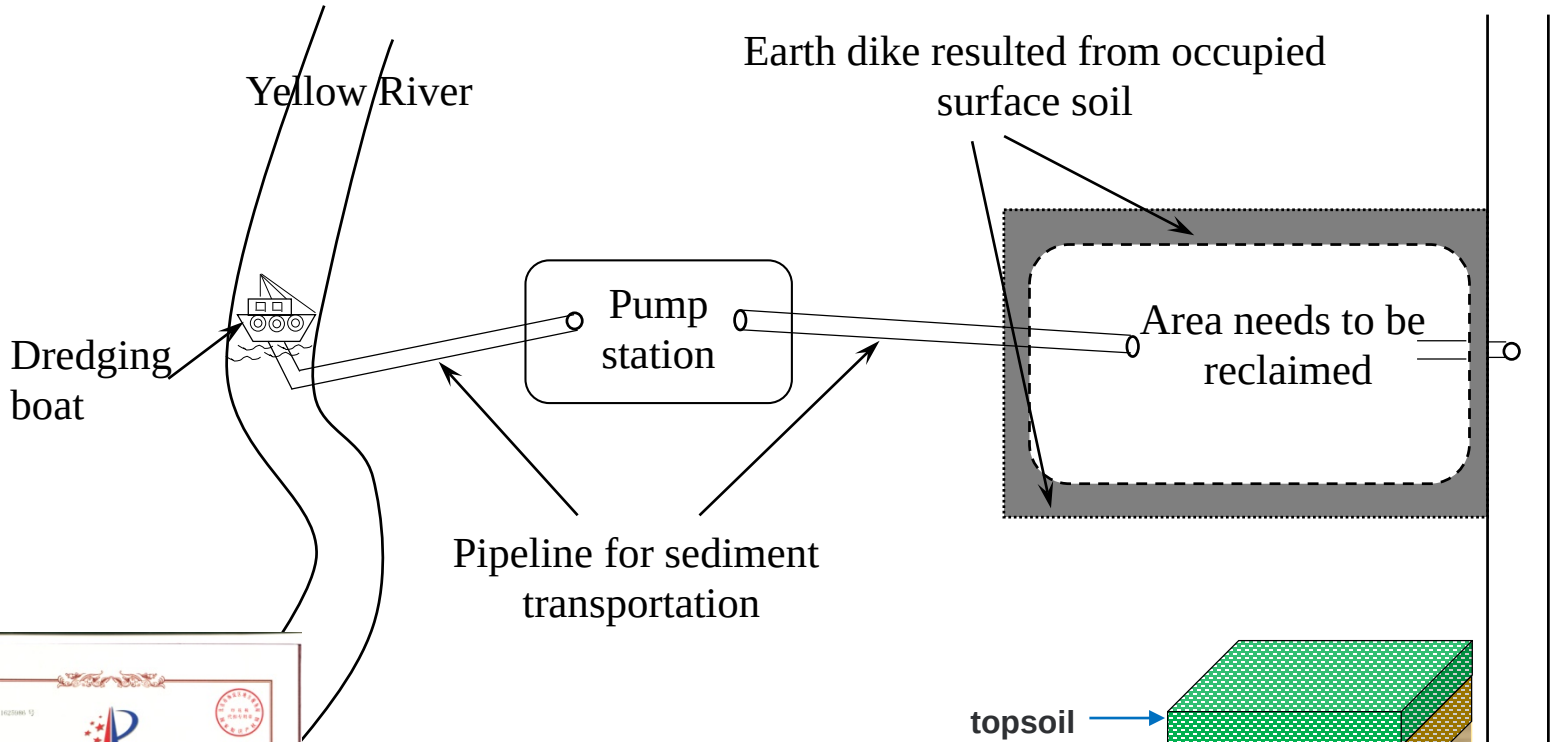
The sediment concentration in Yellow River water is high, and Yellow River has become a river on the ground, which seriously threaten the life and property safety of the masses along the river


*Therefore, Yellow River sediments could be the potential filling materials for reclaiming subsidence land*

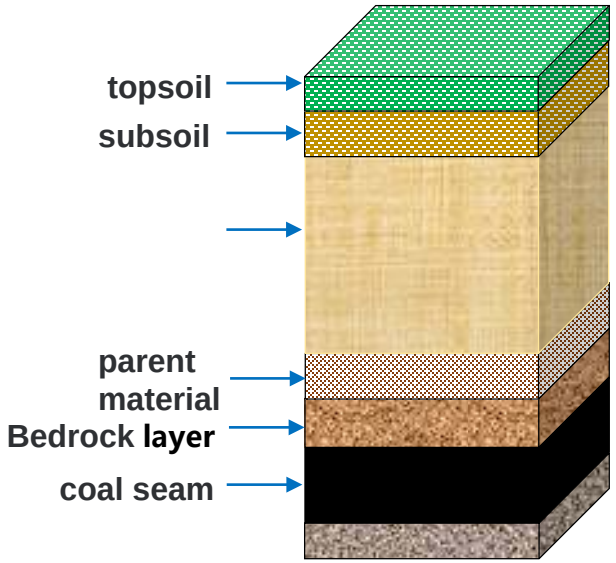
**Advantage of** ***filling reclamation with Yellow River sediments***

- *Reduce the elevation of Yellow River bed, improve the river's flood control, turn the wastes to useful materials*
- *Increase farmland significantly*

# *Process of one-time filling reclamation of mining subsidence land with Yellow River sediment.*







***The technical process of one-time filling reclamation of mining subsidence land with Yellow River sediment.***




Wheat field(normal control farmland )

Grow well

Wheat field(reclaimed farmland )

Grow bad (not enough thickness of covering soil)

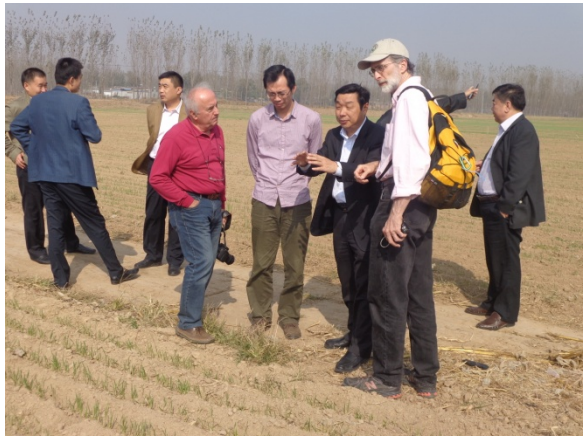
| Treatments | Serial number | Plant number per square meter | Grain number per plant | Plant height per plant/ (cm) | Root length per plant/ (cm) | Dry weigh per plant (g) | Thousand kernel weight (g) | Estimated yield/ ($kg \cdot hm^{-2}$) |
|---|---|---|---|---|---|---|---|---|
| Control farmland | 1 | 635 | 38.37 | 70.9 | 76 | 2.59 | 29.8 | 7365.9 a |
| | 2 | 598 | 39.96 | 72.7 | 82 | 2.59 | 30.14 | |
| | 3 | 613 | 40.07 | 71.6 | 84 | 2.7 | 30.58 | |
| | 4 | 625 | 39.3 | 73.1 | 86 | 2.88 | - | |
| | 5 | 604 | 40.67 | 71.4 | 81 | 2.48 | - | |
| | Mean | 615 a | 39.67 a | 71.94 a | 81.8 a | 2.65 a | 30.17 a | |
| | Standard deviation | 13.52 | 0.78 | 0.83 | 3.37 | 0.14 | 0.32 | |
| Reclaimed farmland | 1 | 515 | 20.67 | 59.3 | 50.24 | 1.51 | 27.74 | 3551.7 b |
| | 2 | 570 | 18.37 | 54.71 | 42.46 | 0.89 | 27.88 | |
| | 3 | 566 | 25.93 | 67.99 | 58.4 | 2.12 | 27.7 | |
| | 4 | 553 | 18.35 | 55.28 | 46.5 | 1.06 | - | |
| | 5 | 537 | 21.14 | 62.43 | 51.48 | 1.95 | - | |
| | Mean | 548.2b | 20.89b | 59.94b | 49.82 b | 1.50b | 27.77b | |
| | Standard deviation | 20.21 | 2.77 | 4.91 | 5.32 | 0.48 | 0.08 | |

# Poor productivity Why?







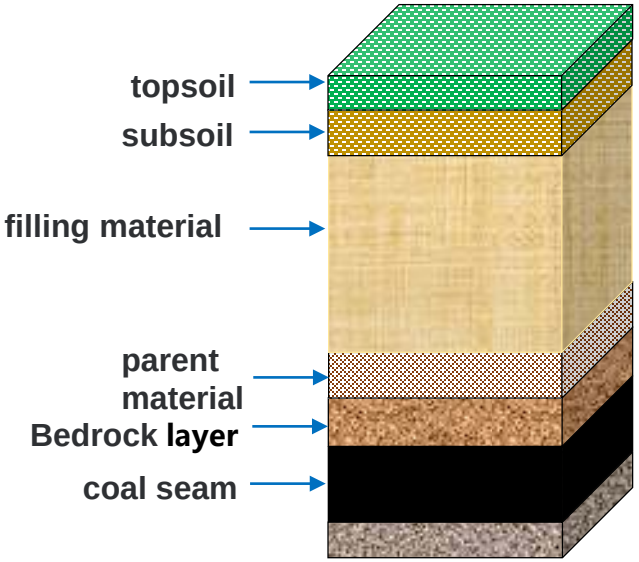


Traditional filling reclamation method was: 1) stripping the soils to be reclaimed land; 2) filling the subsided land materials at once; 3) backfilling the soils. This kind of simple soil profile is an unfavorable profile type in pedology, **resulting in poor productivity.**

**Topsoil is not good. Thickness of soil cover is not enough.**

**Soil profile is not good.**

Filling reclamation with
Yellow River sediment




limited capacity to retain water and nutrients

**Innovation needed**

Diagram of Traditional filling soil-sediment profiles

# 3. Innovation of filling reclamation

- ✓ *soil cover*
- ✓ *A new method for filling reclamation with multi-layered soil profile*

HU Zhenqi,DUO Linghua,WANG Xiaotong. Principle and method of reclaiming subsidence land with inter-layers of filling materals[J].
**Journal of China Coal Society**, 2018,43(1):198-206. doi:10. 13225/ j. cnki. jccs. 2017. 4003

# 3.1 Optimum thickness of soil cover?

*traditional profile "Yellow River sediment covered by soil*

Laboratory experiment ——The optimal thickness of soil in filling reclamation with Yellow River sediment

**Planting corns in laboratory：**

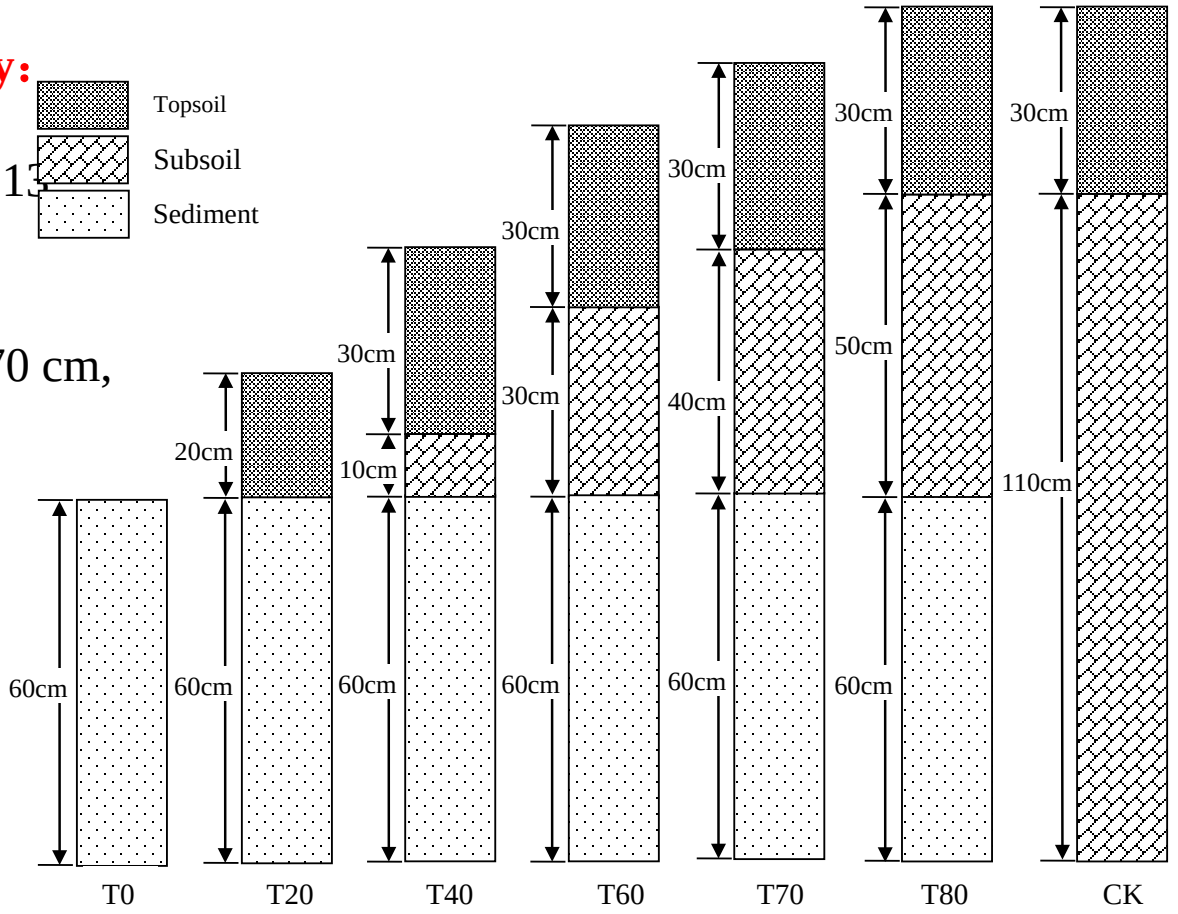
Form 04/25/2013 to 07/05/2013

**Soil thickness:**

0 cm, 20 cm, 40 cm, 60 cm, 70 cm, 80 cm, CK

**Stages：**

Seedling stage；
Elongating stage；
Flare opening stage；
Tasseling stage；
Flowering stage，
Then, stop the experiment.

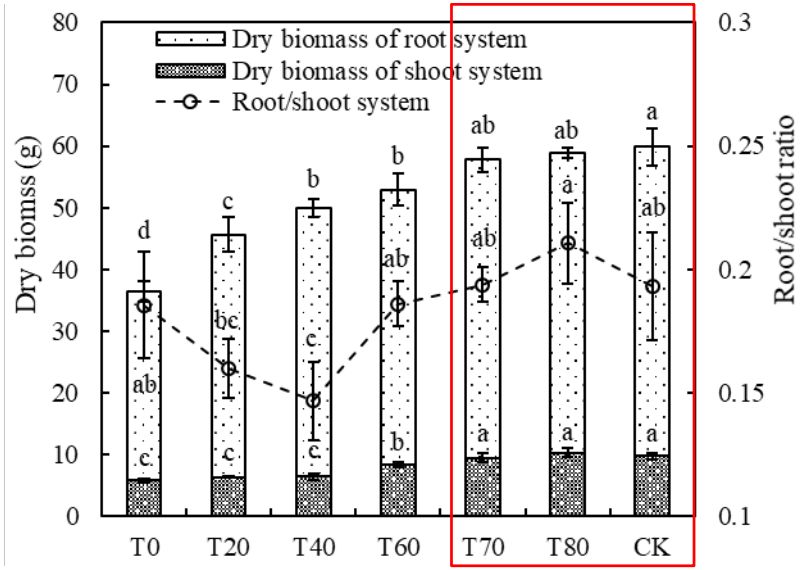



CK soil profile

# 3.1 Optimum thickness of soil cover?

*traditional profile "Yellow River sediment covered by soil*

Laboratory experiment ——The optimal thickness of soil in filling reclamation with Yellow River sediment




T0 has the min dry biomass of root and shoot system is 30.72 g, 5.67 g, respectively.
CK has the max dry biomass of shoot system is 50.21 g.
T80 has the max dry biomass of root system is 10.24 g。

**If no enough soil for cover? How to handle this problem?**

# 3.2 A new reconstruction method for reclaiming subsided land with Yellow River Sediments

***New idea: sandwich profile***

Multilayered soil profiles were favorable for maize growth, water-holding and storage capacity and nutrient preserving capability.

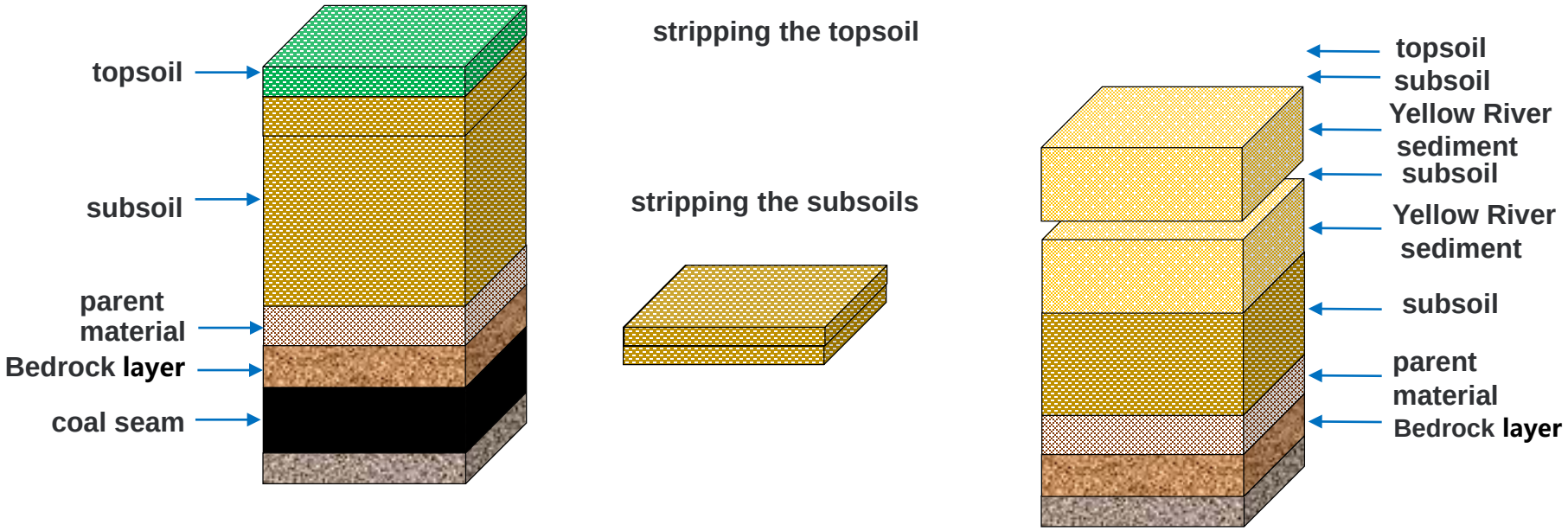
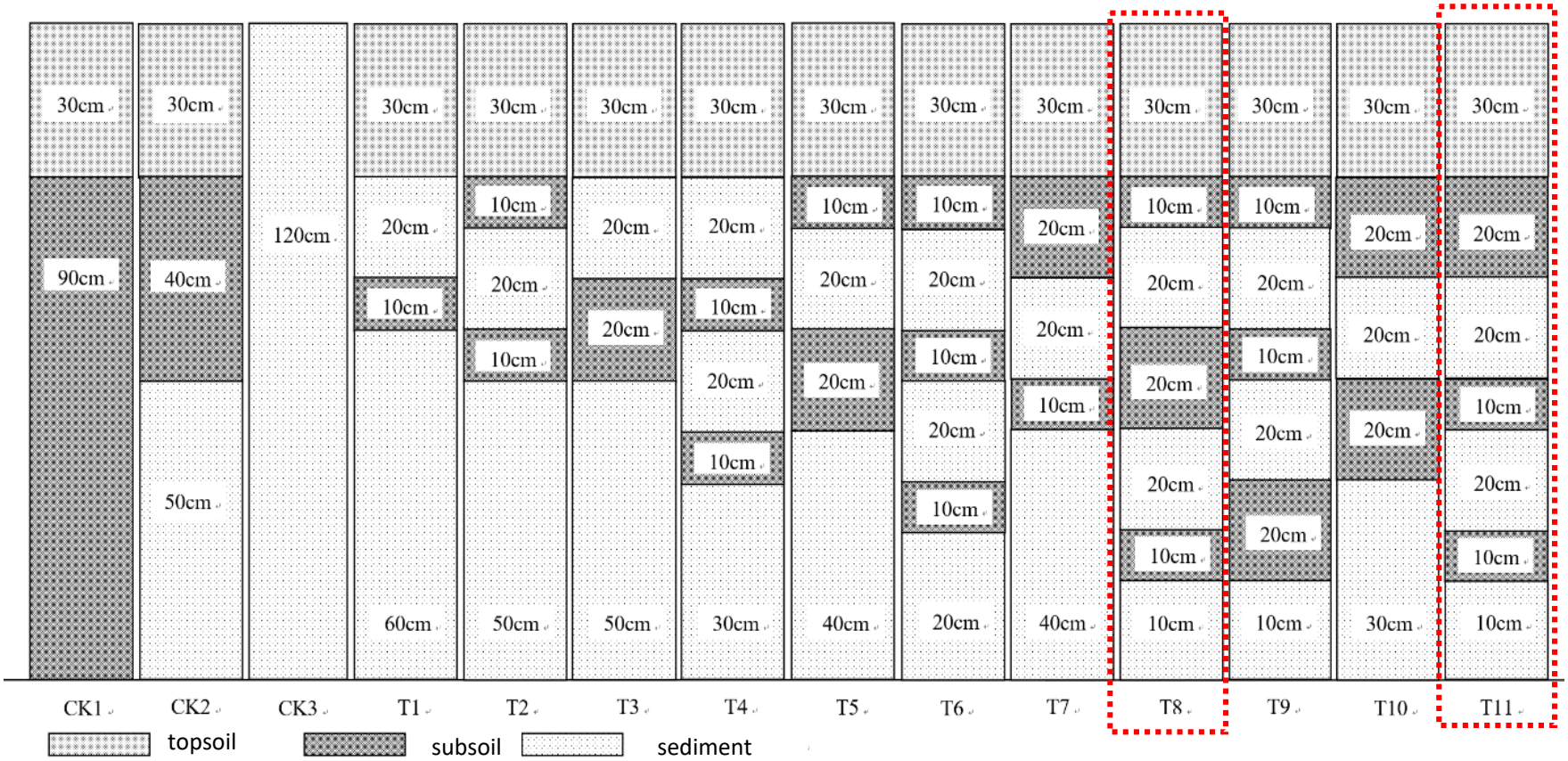


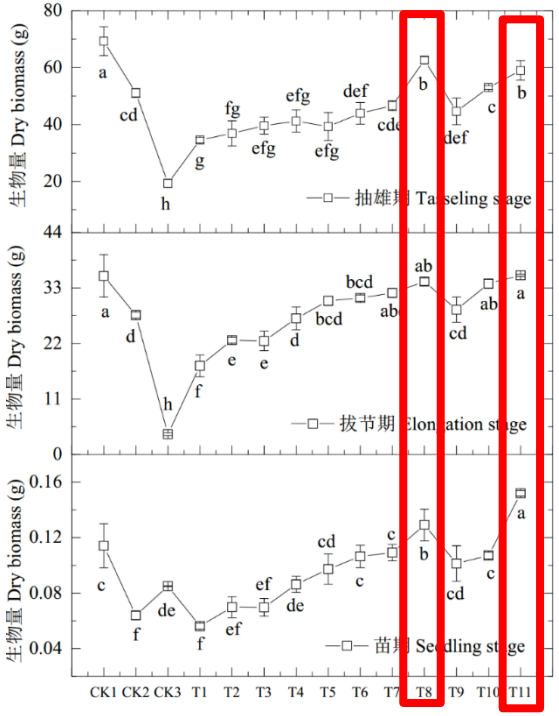

Diagram of multilayered soil-sediment profiles

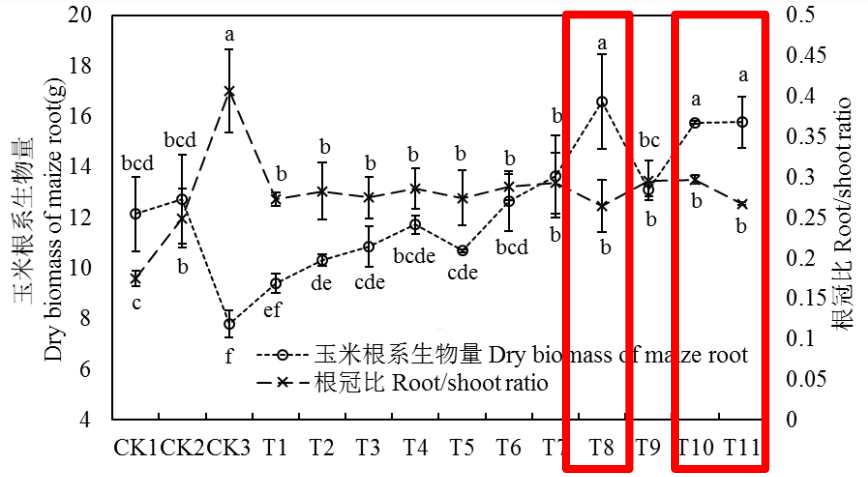
# Laboratory simulation test




laboratory simulation test design of different multilayered soil-sediment profiles

Hu Z, Shao F, Mcsweeney K, et al. Reclaiming subsided land with Yellow River sediments: Evaluation of soil-sediment columns[J]. Geoderma, 2017, 307:210-219.



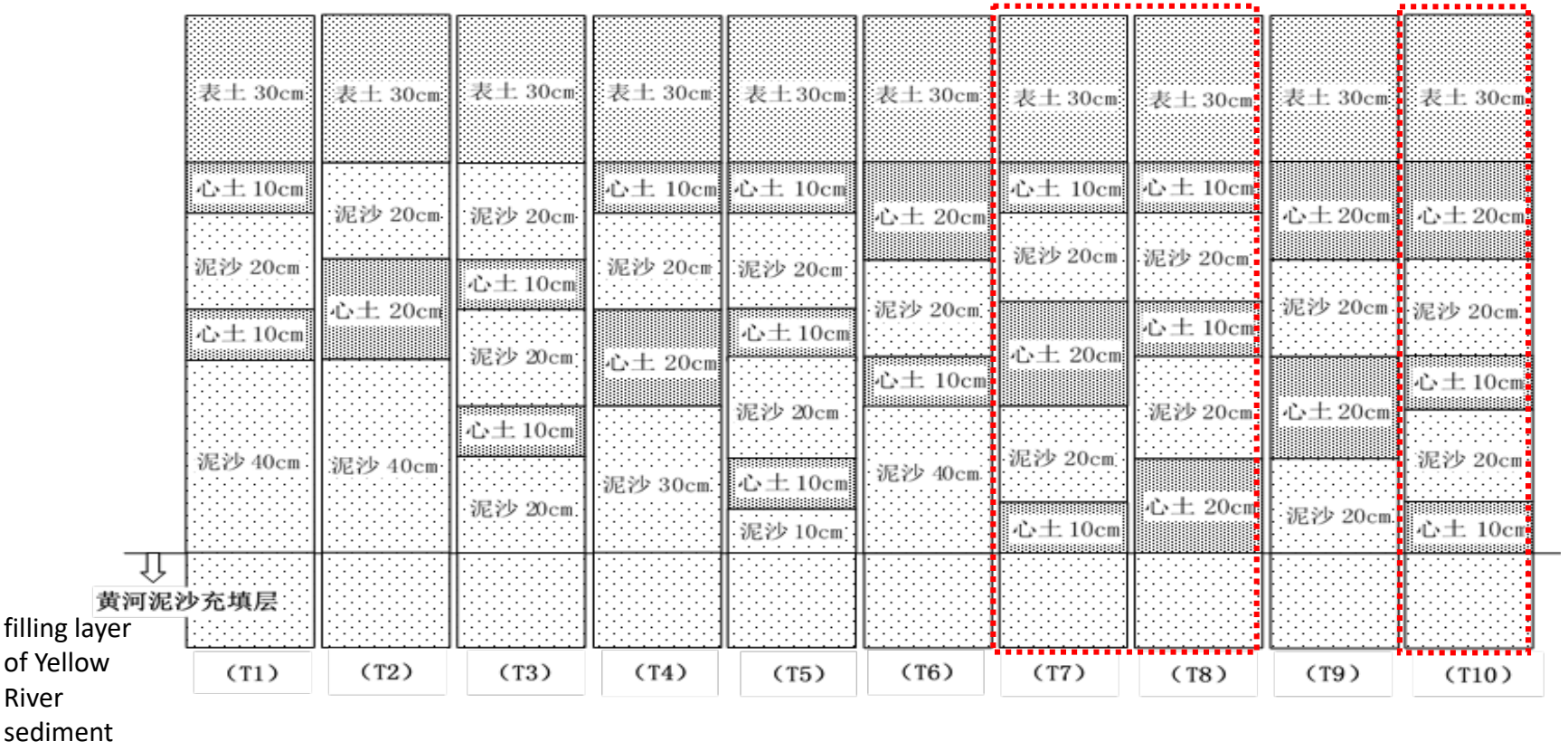

Compared to CK1, T8, T10, T11 had an increase of dry biomass of root system at 36.64%, 29.78%, 29.96%.

**Results and Discussion**：Compared to CK2 (traditional soil reconstructed profile, i.e. filling materials of Yellow river sediment cover with 70cm soil), T8 and T11 had an increase of 22.60%, 15.50% for plant growth, respectively.

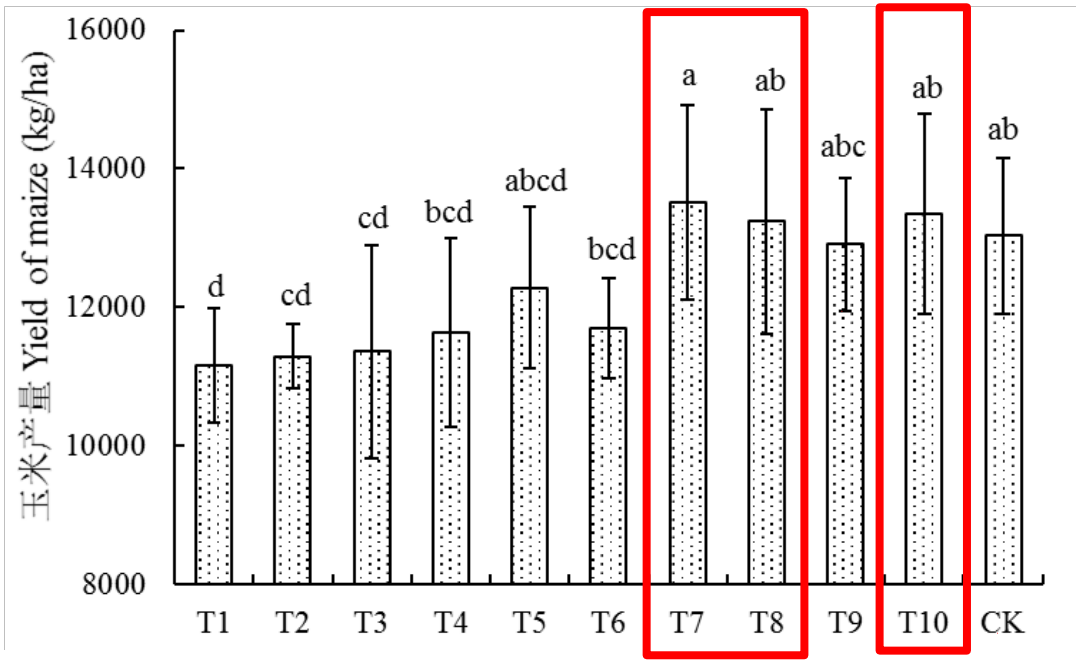
The results illustrate that multilayer soil profiles were favorable for maize seed germination and root growth.

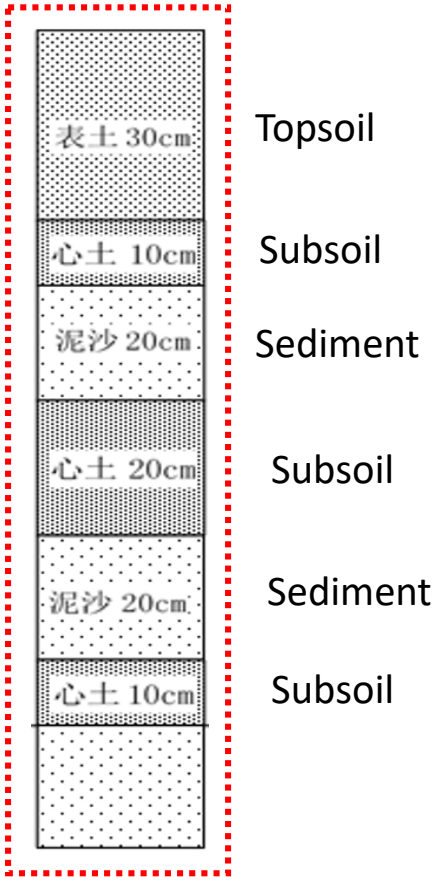
Hu Z, Shao F, Mcsweeney K, et al. Reclaiming subsided land with Yellow River sediments: Evaluation of soil-sediment columns[J]. Geoderma, 2017, 307:210-219.

# Field test




Field experiment design of different multilayered soil-sediment profiles




**Results and Discussion**： Compared to contrast(traditional soil reconstructed profile, i.e. filling materials of Yellow river sediment cover with 70cm soil), T7,T8 and T10 had an increase of 3.68%,1.59%, 2.42% for maize yield, respectively.

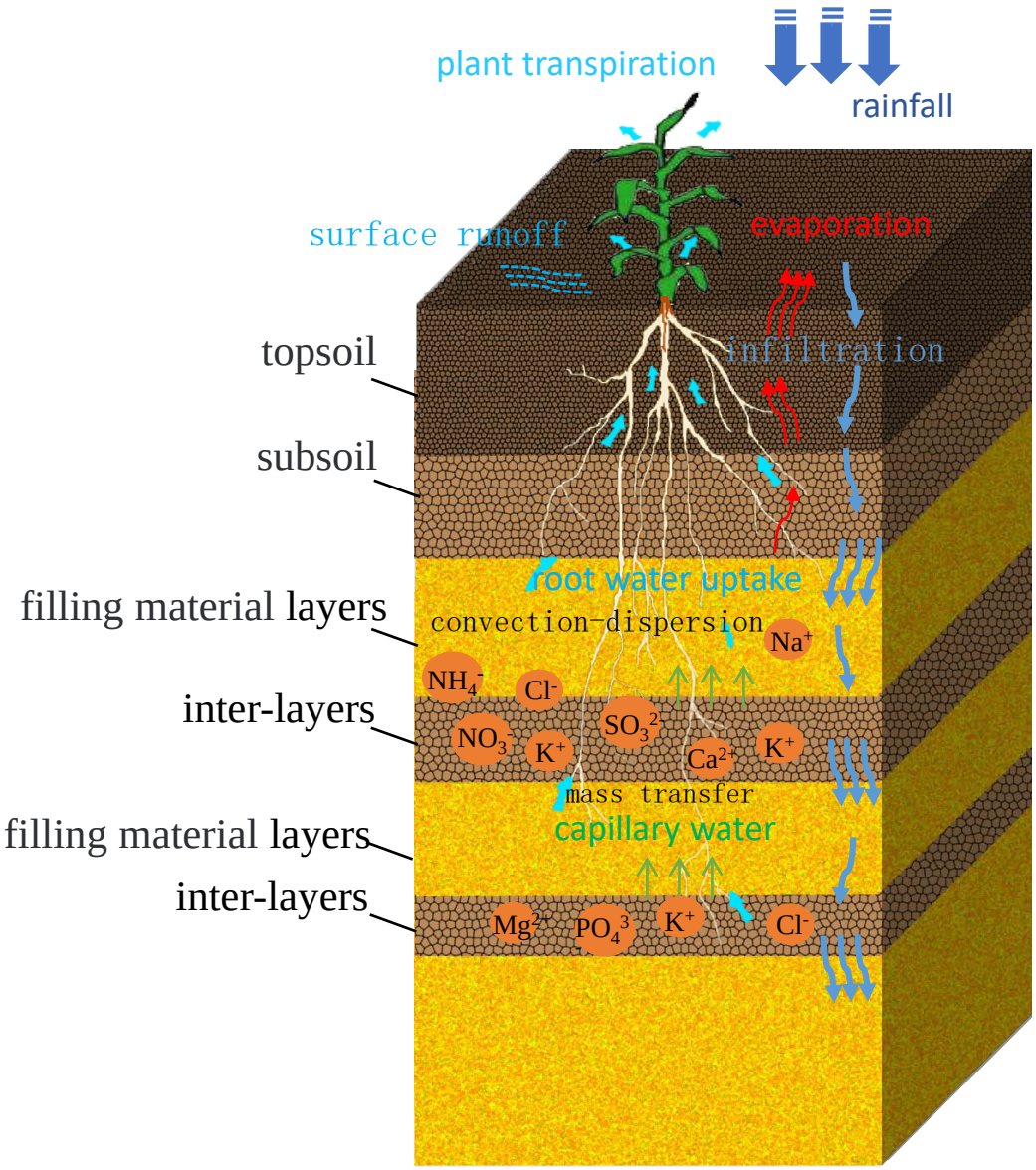
**T7 is the best**

- **What is the mechanism of the multilayered soil profile?**
- **What is the optimum multilayered soil profile?**

***NSFC 41771542***

***2018-2021***

- **Multi-layered soil profile----- inter-layers**
- **What is the function of interlayers**



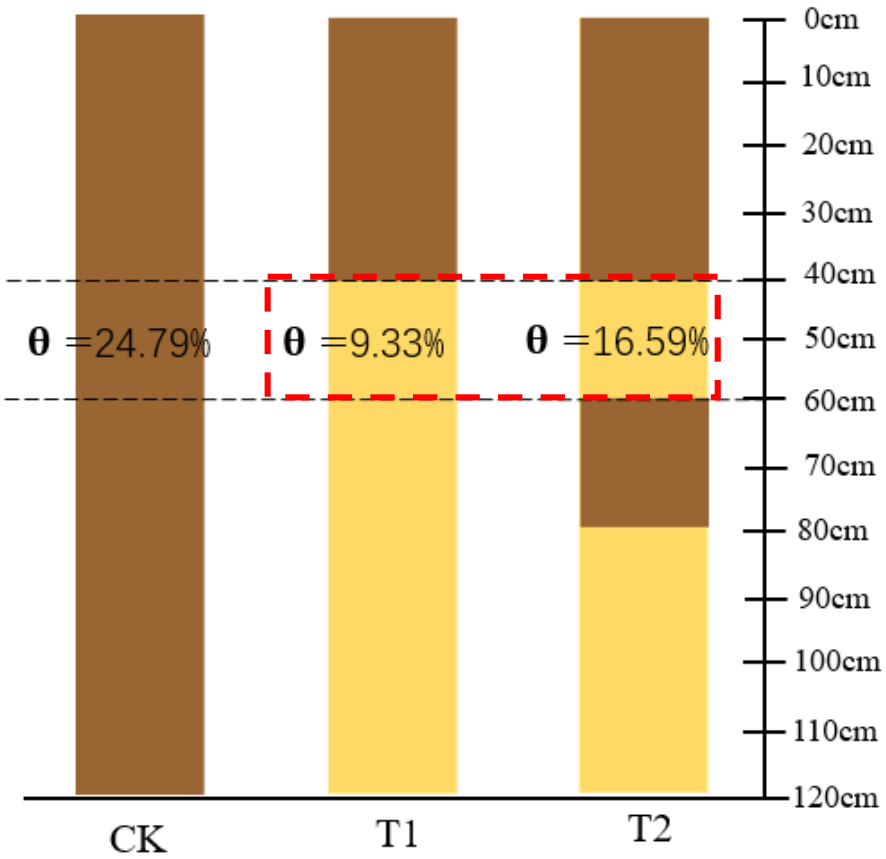

The effect of inter-layers :

- ✓ Improving the characteristics water movement and solute transport.
- ✓ Increasing the moisture and nutrient content of the filling material layer above the interlayer.

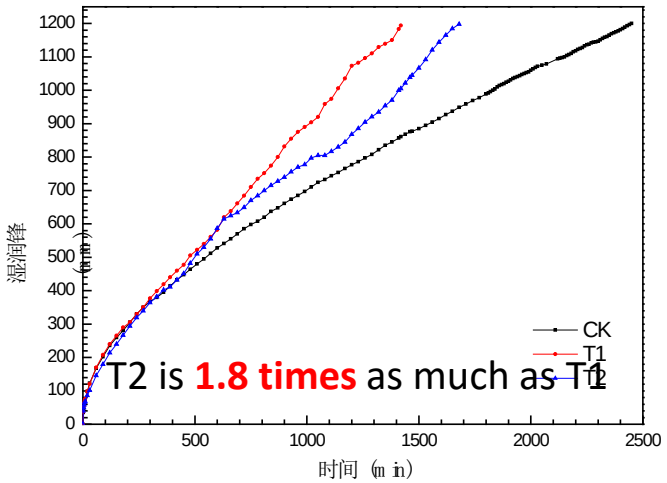
**Conceptual model for multi-layered soil profile**

# Water movement on Layered Soil Reclamation with Yellow River Sediments

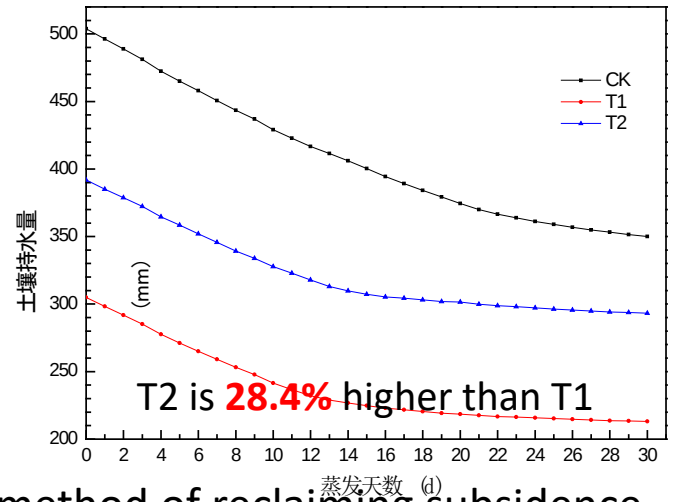
**two-layers soil profile** with poor water retention, After filling **soil interlayer**, the water content increased by **80.68%.**




*Infiltration performance*




*Water-holding capacity*

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**Soil profile reconstruction with multi-layered according to the natural structure.**

**Keys:**

1. **position of the interlayer**
2. **Numbers of interlayers**
3. **Thickness of the interlayers**

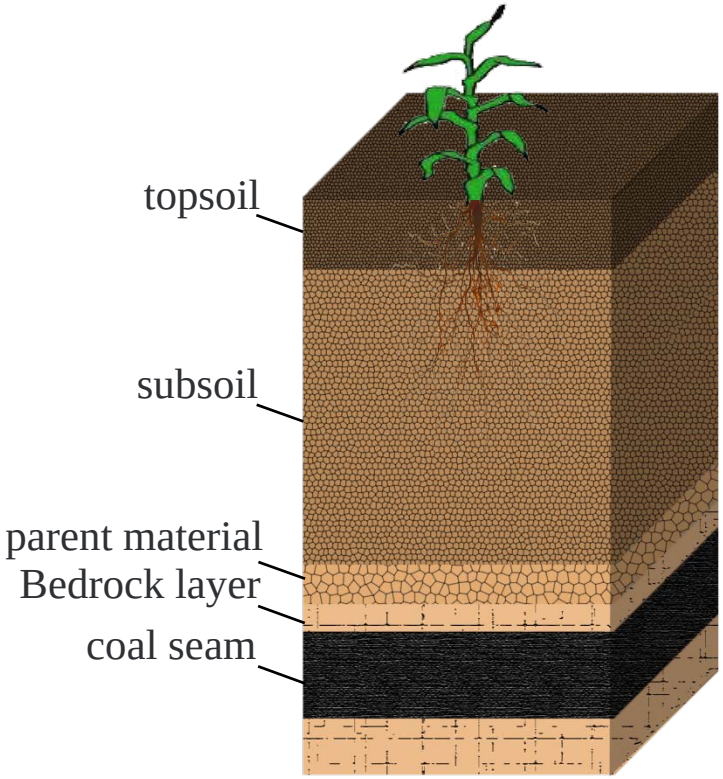



Fig.1 Natural soil profile pattern

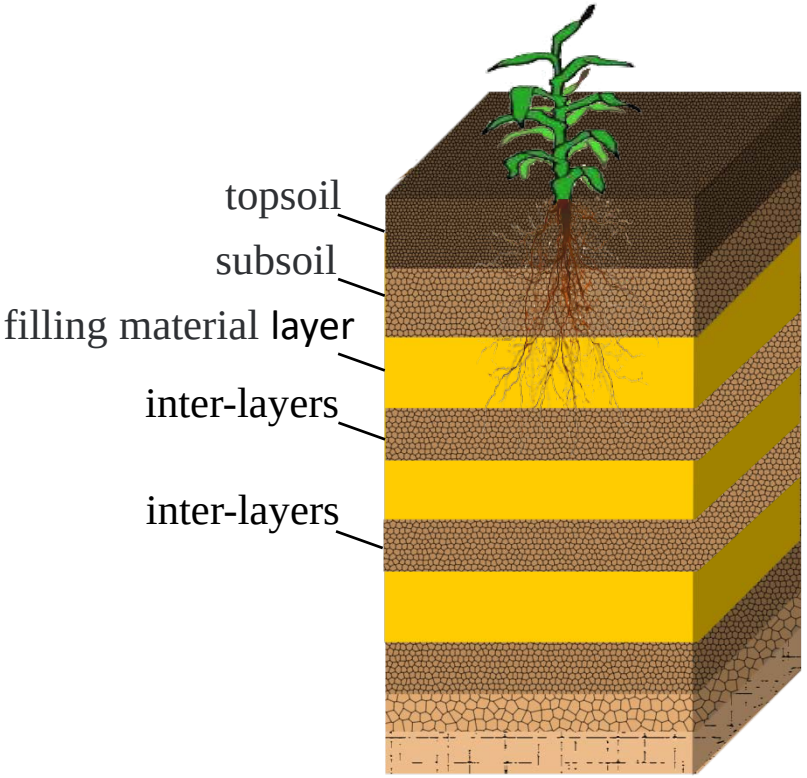
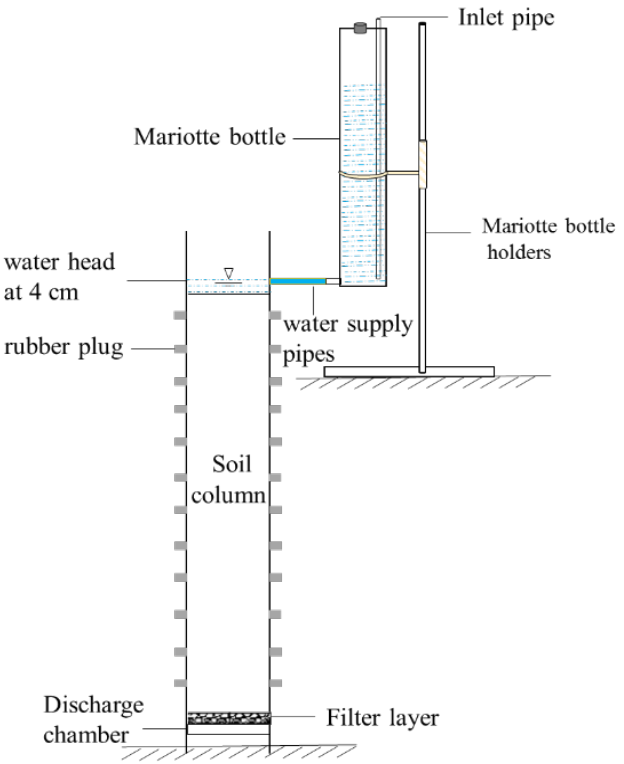



Fig.2 E3 multi-layered soil profile pattern

**Infiltration and evaporation experimentation on soil columns of a homogeneous loam and five kinds of layered soil profile reconstructions with Yellow River sediments under identical conditions were conducted in a laboratory**



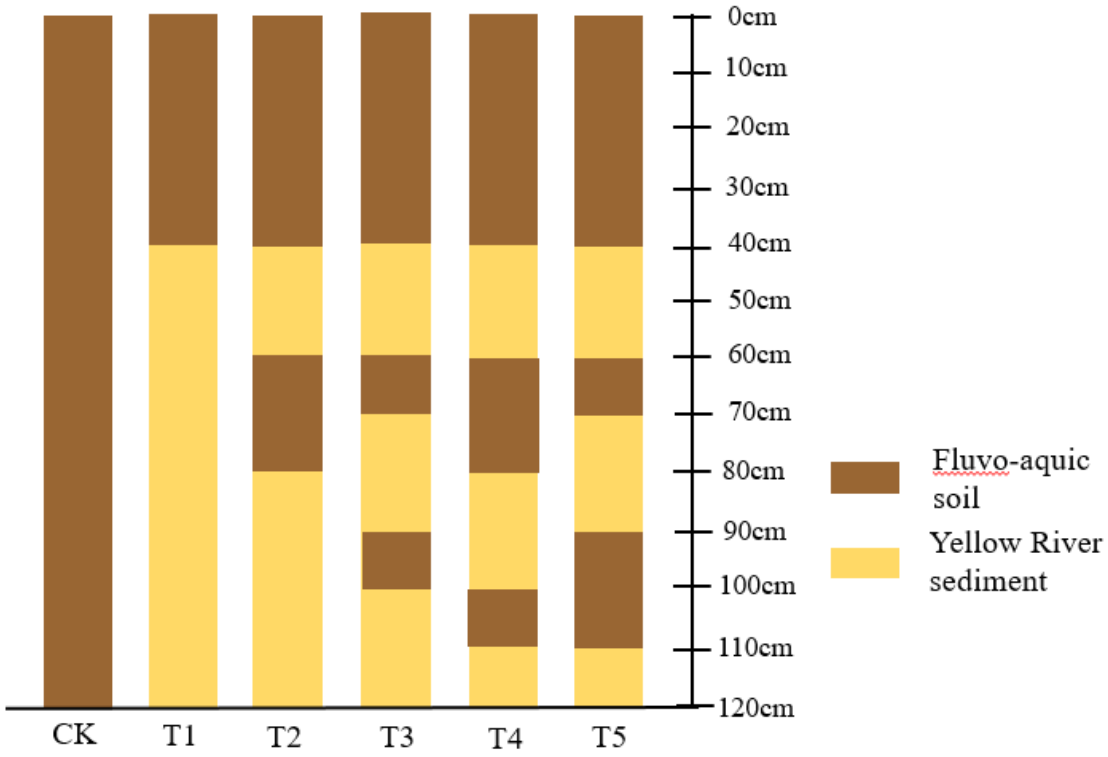
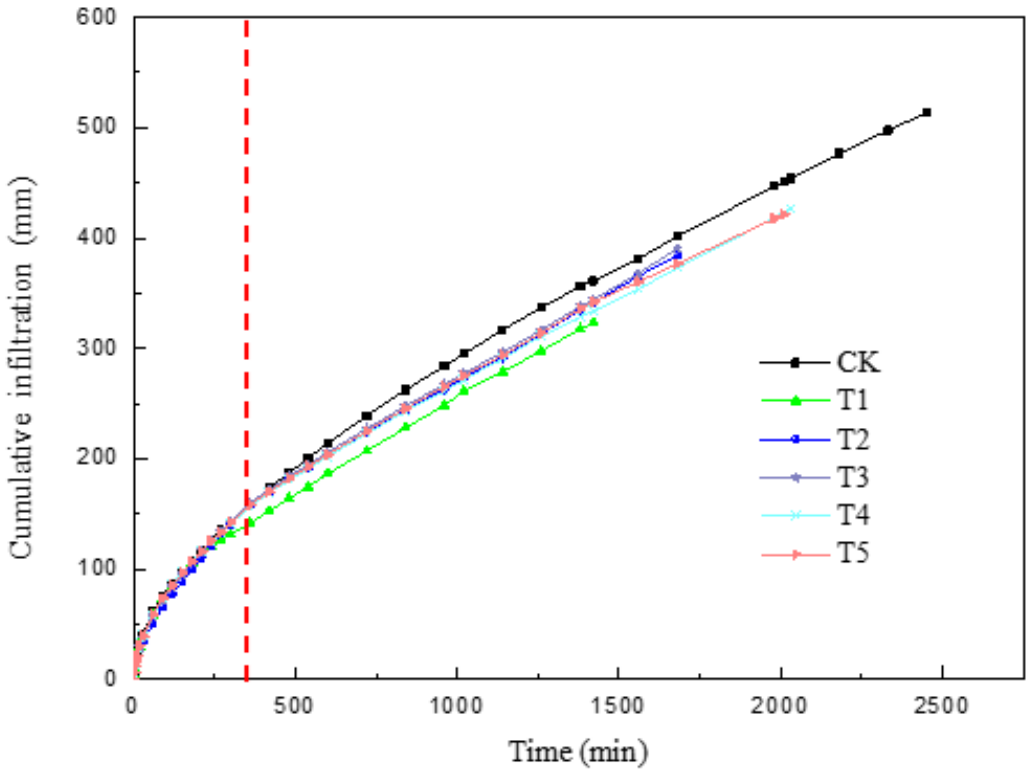




**Diagram of different multilayered soil-sediment profiles for reclaiming subsided land with Yellow River sediment**

## *Infiltration performance*

Cumulative infiltration



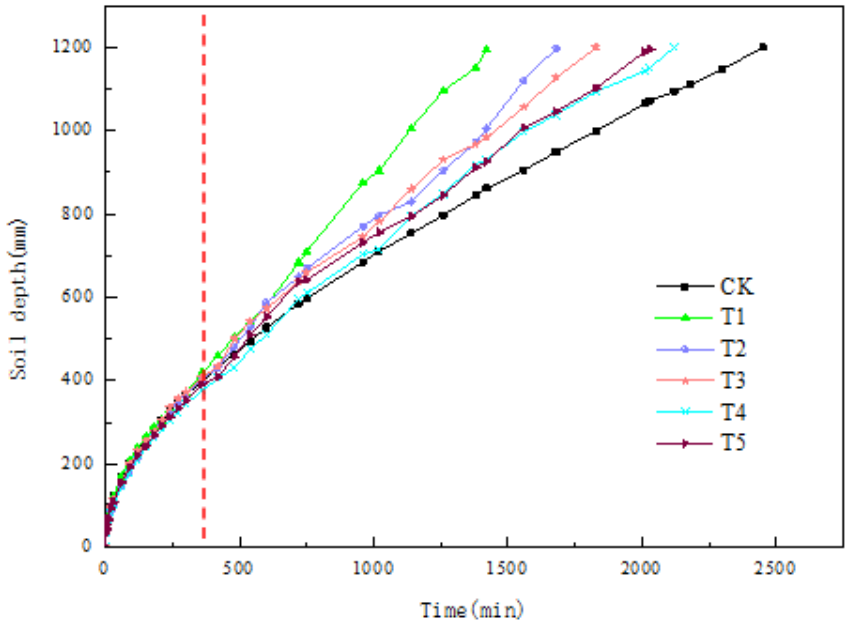

Cumulative infiltration in different soil-sediment profiles

**cumulative infiltration of T2~T5 were between T1 and CK. That indicated the soil interlayer had the effect of reducing permeability, which can reduce water infiltration on the profile T1.**

**interlayer of 40 cm in T4 and T5 had a better water blocking effect than the total thickness of the 20 cm soil interlayer in the T2 and T3 profiles.**

*Infiltration performance*

## Wetting front




| depth (cm) | wetting front transport rate (mm/min) | | | | | |
|---|---|---|---|---|---|---|
| | CK | T1 | T2 | T3 | T4 | T5 |
| 0~10 | 4.76 | 4.76 | 4.45 | 4.17 | 4.35 | 4.45 |
| 10~20 | 1.49 | 1.51 | 1.35 | 1.47 | 1.32 | 1.33 |
| 20~30 | 0.85 | 0.91 | 0.92 | 0.88 | 0.81 | 0.81 |
| 30~40 | 0.62 | 0.60 | 0.61 | 0.62 | 0.65 | 0.67 |
| 40~50 | 0.55 | 0.70 | 0.72 | 0.74 | 0.73 | 0.72 |
| 50~60 | 0.48 | 0.74 | 0.9 | 0.84 | 0.85 | 0.82 |
| 60~70 | 0.39 | 0.76 | 0.5 | 0.46 | 0.43 | 0.45 |
| 70~80 | 0.38 | 0.78 | 0.37 | 0.54 | 0.38 | 0.52 |
| 80~90 | 0.36 | 0.76 | 0.45 | 0.56 | 0.51 | 0.58 |
| 90~100 | 0.36 | 0.78 | 0.64 | 0.42 | 0.61 | 0.42 |
| 100~110 | 0.33 | 0.76 | 0.77 | 0.59 | 0.37 | 0.35 |
| 110~120 | 0.33 | 0.76 | 0.77 | 0.58 | 0.45 | 0.37 |

average decrease 46.%

25. 0%  38. 2%  27. 6%

**This indicated that a reconstructe soil profile configuration with two soil interlayers is better than a single soil interlayer. The thickness of the first soil interlayer of 20 cm is better than 10 cm. furthermore, The interlayer is thicker, and the water resistance is stronger.**

**Infiltration and evaporation experimentation on soil columns of a homogeneous loam and five kinds of layered soil profile reconstructions with Yellow River sediments under identical conditions were conducted in a laboratory**

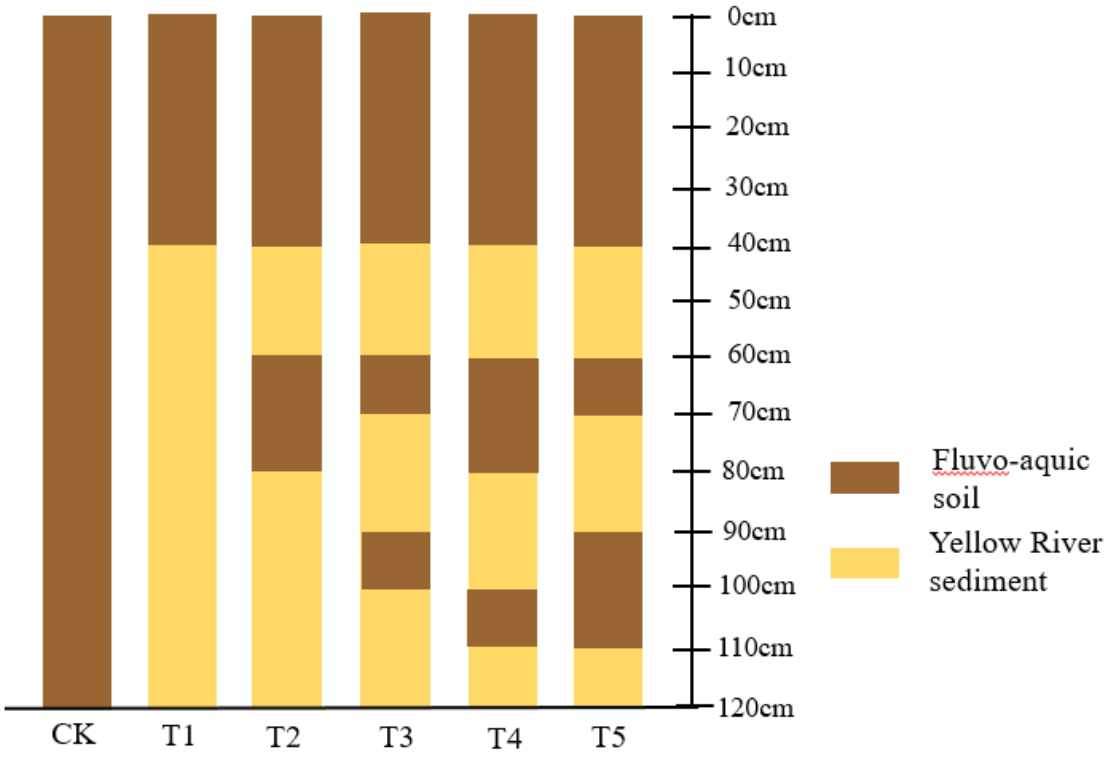
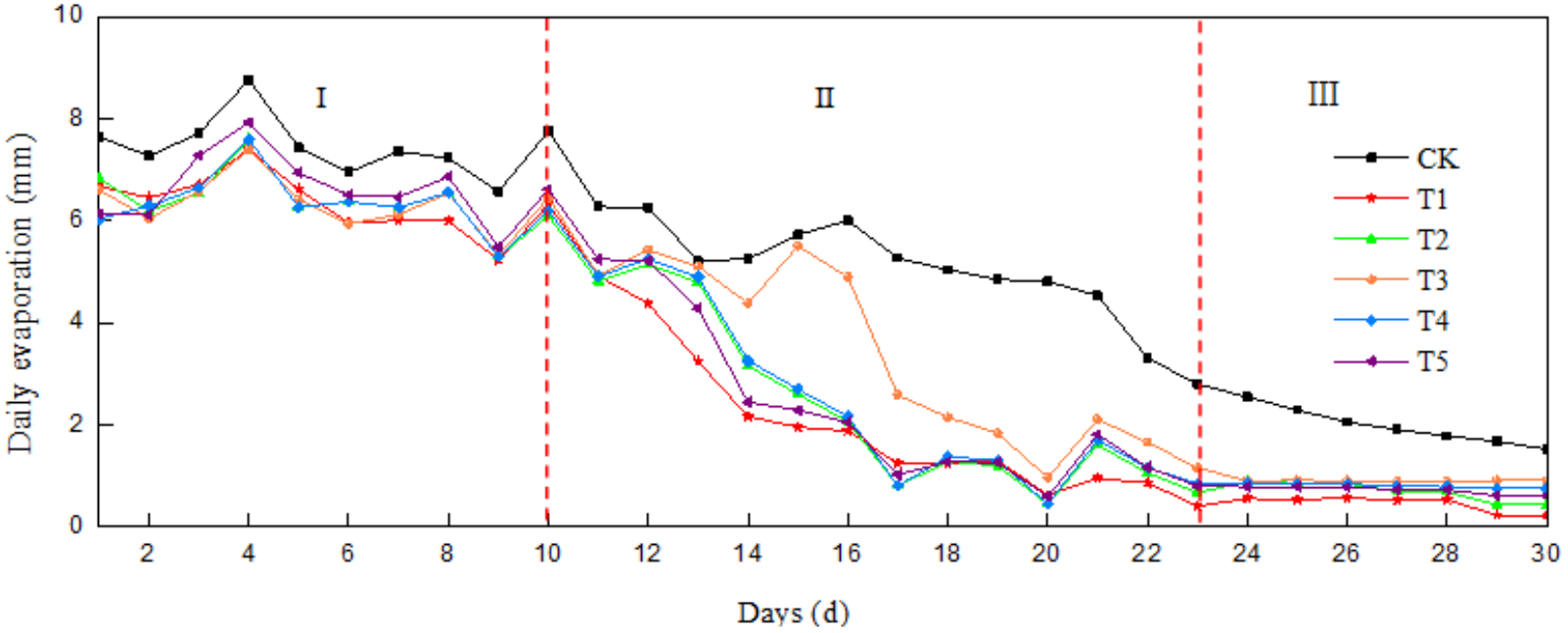




**Diagram of different multilayered soil-sediment profiles for reclaiming subsided land with Yellow River sediment**

# *Evaporation performance*

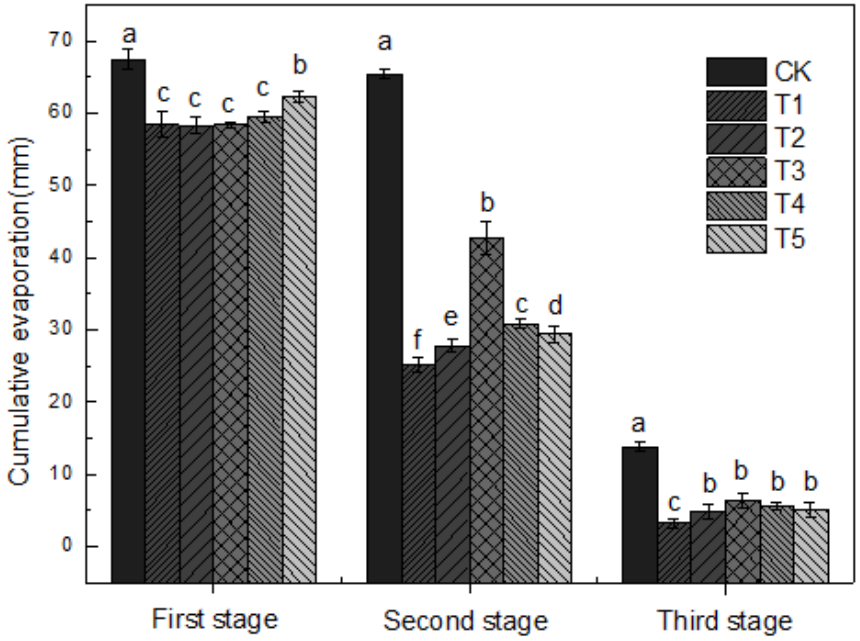
Evaporation intensity



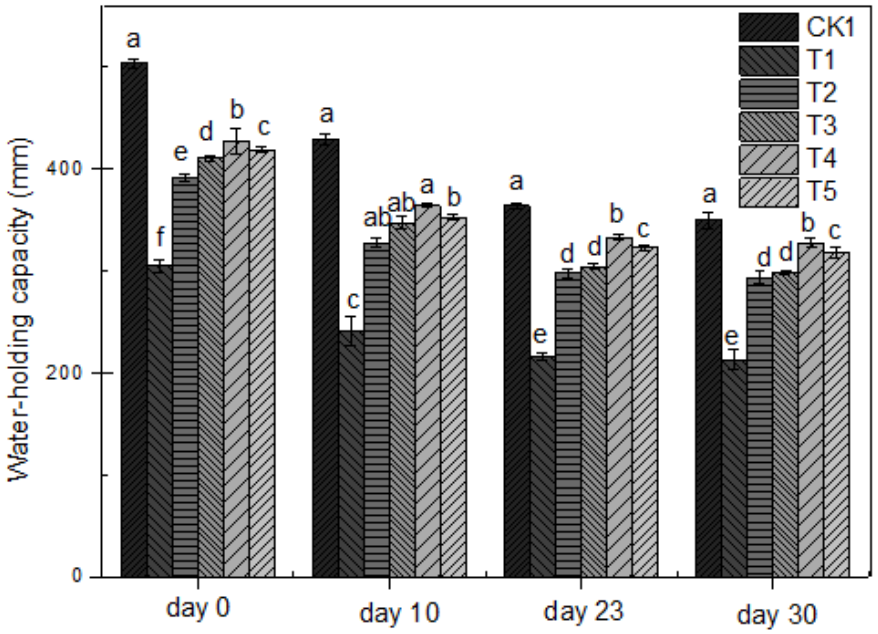

- ✓ Day0 ~Day10: atmospheric evaporation power leaded to topsoil water recharge from deep soil and **a lot of soil water is lost** .
- ✓ Day10 ~Day23: intensity of soil evaporation is mainly influenced by the soil water conductivity, and the **evaporation rates gradually decrease**.
- ✓ Day10 ~Day23: intensity of **soil evaporation was low** and tended toward stagnation.

# *Evaporation performance*

## Water-holding capacity




Evaporation intensity in different soil-sediment profiles



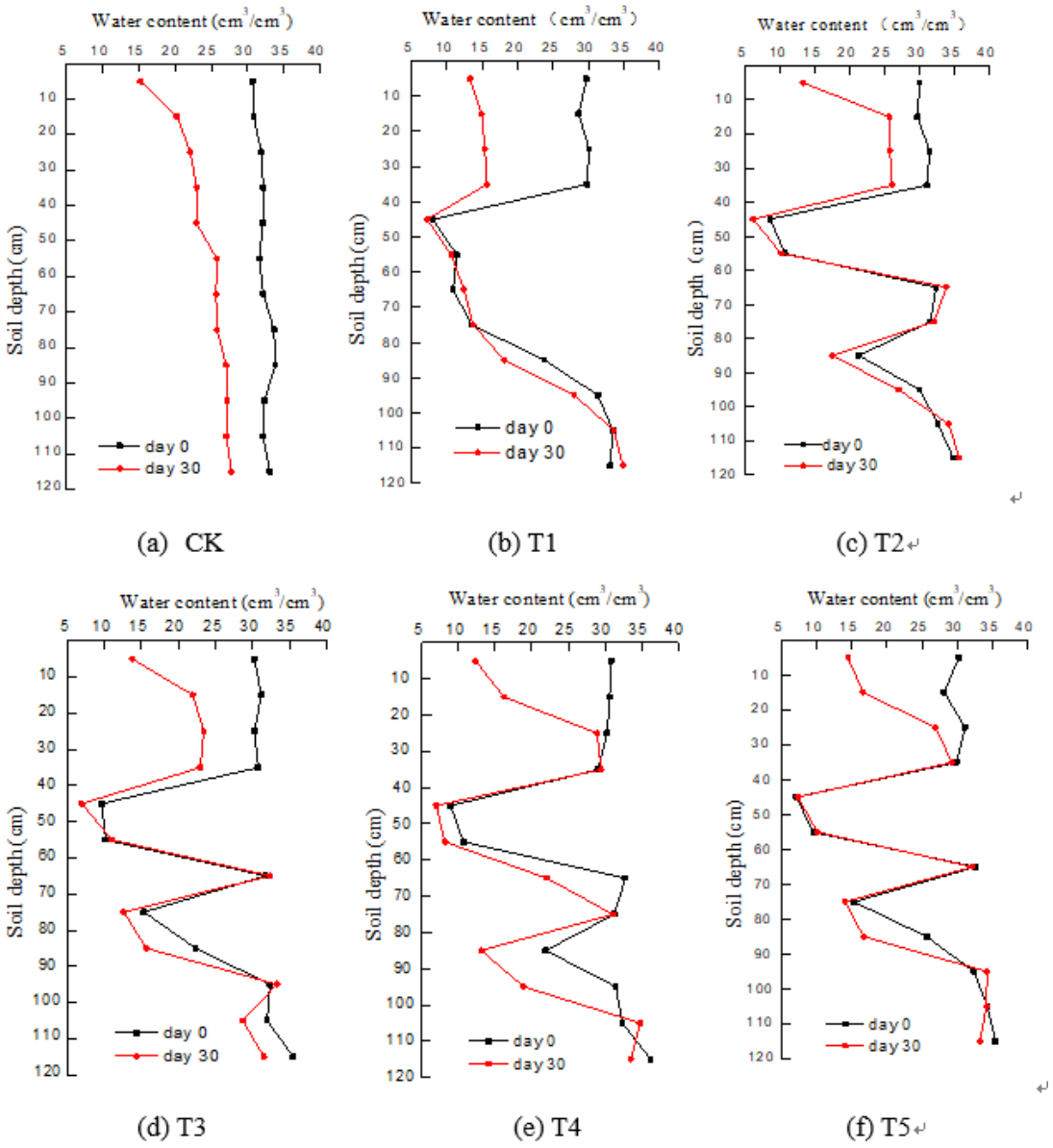

Histogram of water-holding capacity in each soil column

# *Evaporation performance*

***Profile water content***

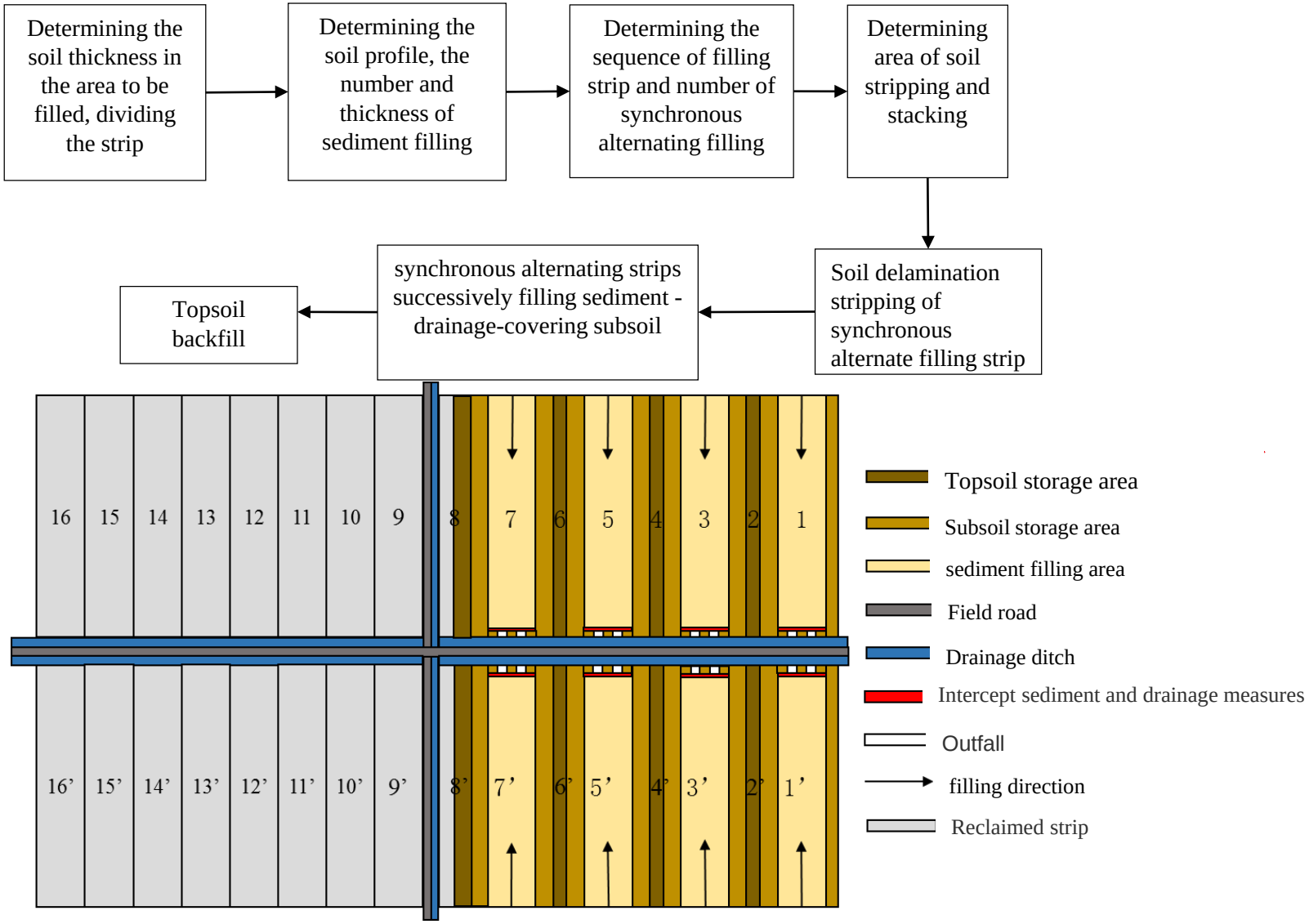
**interlayer change the vertical distribution of water in soil profiles, T2, T3, T4, and T5 were below 40 cm layers.**

**The soil water content in the sediment layer of the Yellow River was approximately 7 $cm^3/cm^3$, and in the interlayer it increased to more than 30 $cm^3/cm3$, showing the accumulation of water.**




Profile water content in different soil-sediment profiles

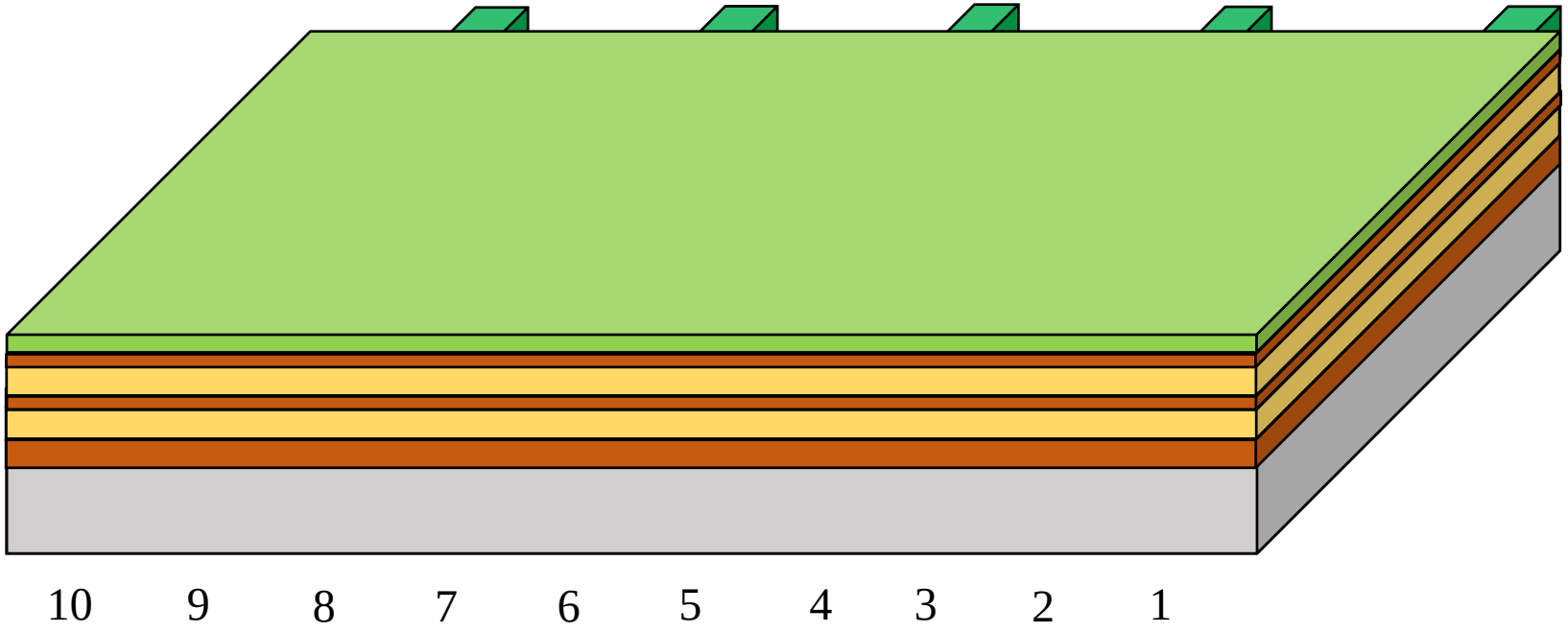
# *Process of multiple filling reclamation of mining subsidence land with Yellow River sediment.*



# Technology of alternating multiple filling reclamation

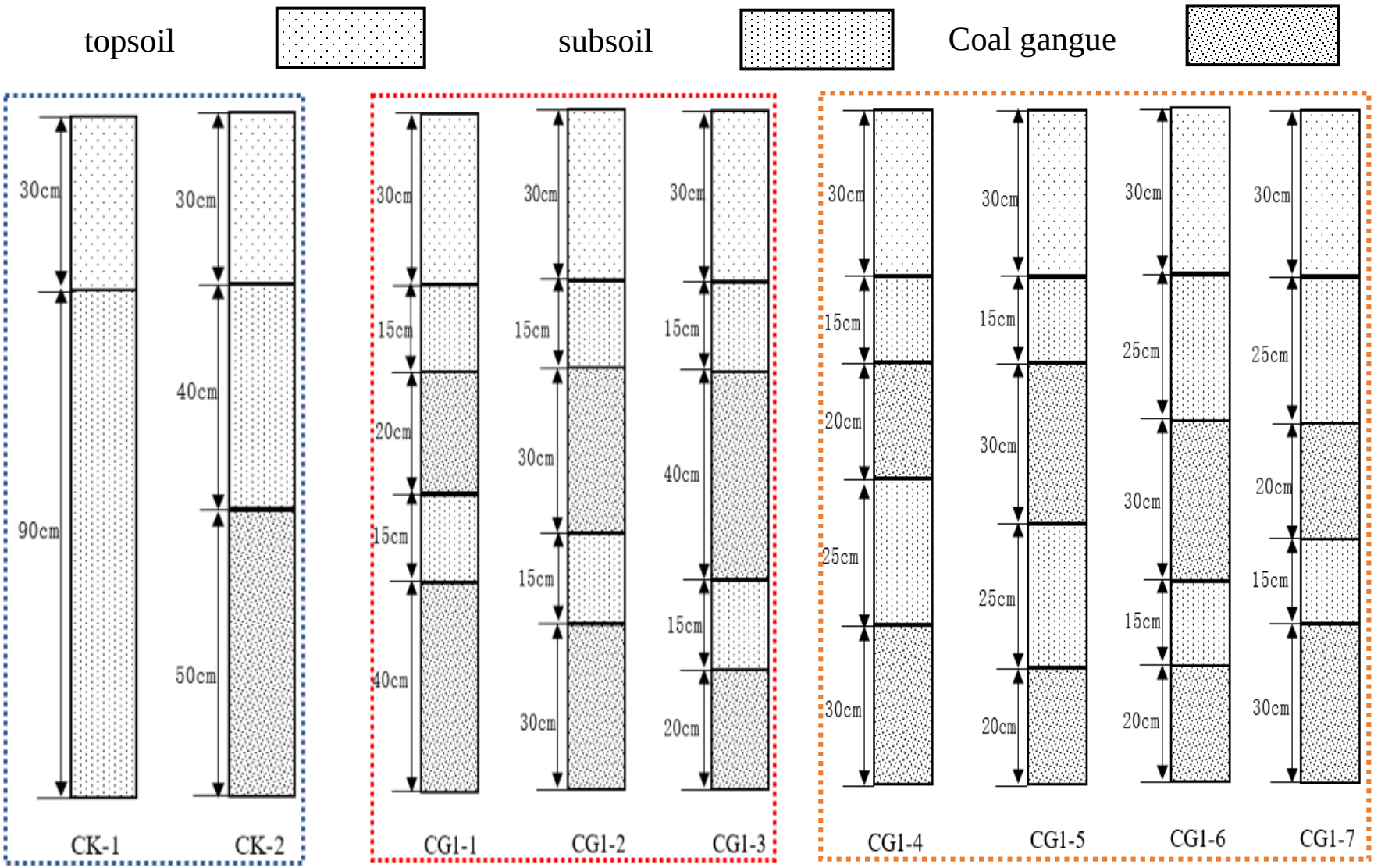
synchronous alternating strips successively filling sediment -drainage-covering subsoil

Co Div A s Strip St lay lay lay la **Land leveling** ively alternate filling



# Technique for Soil Profiles Construction in Reclaimed Land Filled with Coal Gangue

- In order to solve the problems that the present coal gangue filling reclamation soil has a single level and the structure of the upper soil and the lower coal gangue leads to poor soil water and nutrient retention, based on the study of interlayer soil profile in reclaiming subsided land with coal gangue, a new profile which can save soil and be suitable for crop growth will be selected.



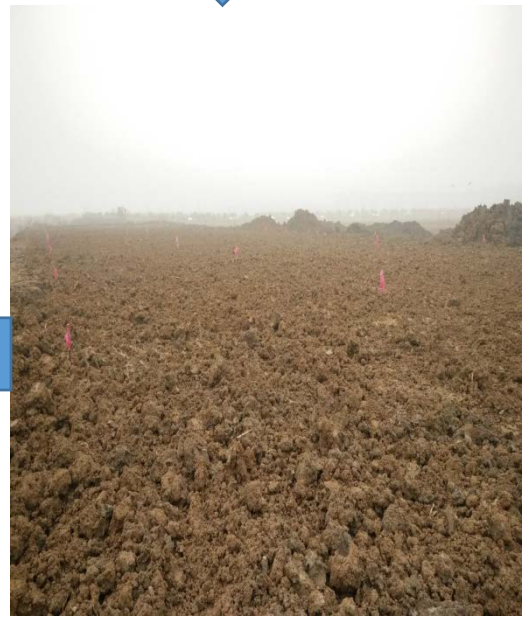

Control Group

Soil thickness:60cm

Soil thickness:70cm

# Interlayer Profile Design



# 4. Conclusions

- ✓ The innovation of soil reconstruction method is the multilayered soil profile with soil inter-layers in filling materials.
- ✓ Multilayered soil profiles benefits in retaining water and fertilizer, which is good for the growth of crops.
- ✓ The keys are the position, number and thickness of soil inter-layers.

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# *THANK YOU FOR YOUR ATTENTION!*

# *QUESTIONS OR COMMENTS*

***Welcome to Institute of Land Reclamation & Ecological Restoration, China University of Mining and Technology (Beijing), and Engineering Research Center of Mining Environment & Ecological Safety, Ministry of Education***


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