SOIL SALINIZATION AND ITS MECHANISM IN CHECKDAM FARMLANDS IN THE LOESS PLATEAU, CHINA

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ABSTRACT

The Loess Plateau is located in middle reaches of the Yellow River in China and facing a serious problem of water erosion. Construction of a check-dam system is one of the most effective measures to conserve soil and water. Primary functions of a check-dam are gully control, flood control and water storage. After the reservoir is filled with sediment and flat land is formed and utilized as a farmland. However soil salinization is observed in check-dam farmlands in some watersheds. Therefore, the author studied on the present status of soil salinization in the farmland and the affecting factors. Xiao He Gou watershed is selected as a study area since the soil salinization occurs in a system scale, and intensive field investigation on status of soil salinization and continuous monitoring of groundwater level in the farmland is conducted in Cao Mao dam farmland. The status of soil salinization is assessed with electric conductivity, pH and sodium absorption ratio. Grain size analysis and measurement of groundwater level are also conducted in order to clarify the relationship among soil texture, groundwater level and soil salinization.

ECe was lower than 3 dS/m in the lower part(from dam body to 1.6 km upstream) of the farmland while it was higher than 3 dS/m in the upper part(from 1.6 km to 2.0 km upstream) of the farmland. Grain size analysis indicated that soil is sandy and there is not apparent difference of soil type in terms of spatial and vertical distribution. Groundwater level in the farmland is higer in the upper part than the lower part. Seasonal fluctuation of groundwater level is observed. The range of groundwater level fluctuation is about 1.0 meter through a year and the groundwater level gradually decreases from sping to autumun except heavy rainfall events and slowly increases during winter without any heavy rainfall events. It is suggested that increase of groundwater level in winter is caused by the frozen soil at least 70 cm from the soil surface and this block the groundwater flow and then the groundwater level decreases in spring when the frozen soil melts. The field surveys at Cao Mao dam farmland indicated that soil salinization is mainly caused by groundwater level rather than soil texture in the farmland.

It is essential to control groundwater level by reducing inflow from upstream dams and the side slope, and improving drainage function in the farmland in order to prevent soil salinization.

KEYWORDS

Salinity, Groundwater, Rain-fed agriculture, Semi arid land

Soil salinization and its mechanism on check dam farmlands in the Loess Plateau, China

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Background

Loess Plateau is famous of its serious water erosion.
(*60～90 % of water erosion occurs in gully.* (Zhang, 1993))

One of the most effective engineering approach to prevent soil erosion is ***Check dam***.

113,500 check-dams were constructed (1960s~70s) and **320,000 ha** of farmland was developed in Loess Plateau. (Xu et al, 2004).

2

Check dam is …,

A multi-purpose dam constructed in a gully.

Flood mitigation | **Prevent Soil erosion** | **Farm land (Rain-fed Agr.)**

Higher labor and land productivity

3

Objectives

Current issue of the check dam farmland is **soil salinization.**
- affects crop growth and
- destroys soil physical characteristics

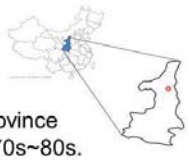
(*Salinization of **rain-fed farmland** is very rare!*)

Immediate GOAL!
Clarify the current situation of salinization and its **mechanism**

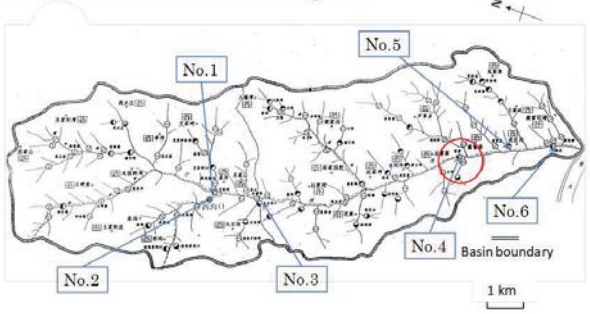
Ultimate GOAL!
Suggestion on design of check dam considering more **effective use of sediment areas**

4

Study area



Location: Xiao He Gou in Zizhou, Shaanxi Province
100 check dams were constructed during 1970s~80s.
6 dams are selected for investigation.



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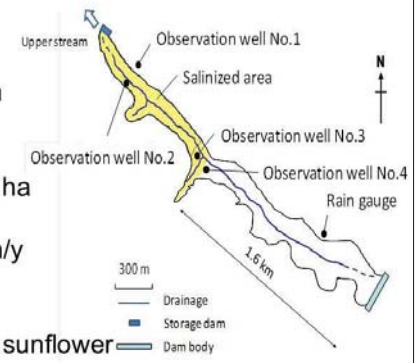
The outlines of study area(No.4)

Cao Mao check dam
Height: 48 m
Length 220 m
Area of farm land: 36 ha
Mean Temp: 9.3 ℃
Precipitation: 430 mm/y
(➔Semi-arid area)
Rain-fed agriculture
Main crops: corn and sunflower



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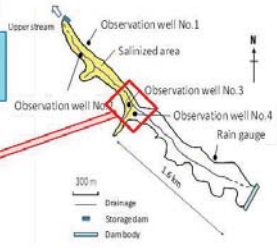
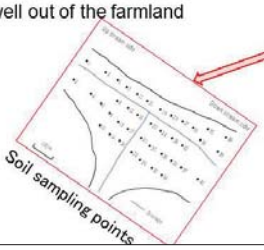
Methodology

Analysis on soil physical and chemical characteristics

Analysis on characteristics of groundwater level fluctuation

3 wells in the farmland and
1 well out of the farmland





Clarify the current situation of salinization and its mechanism

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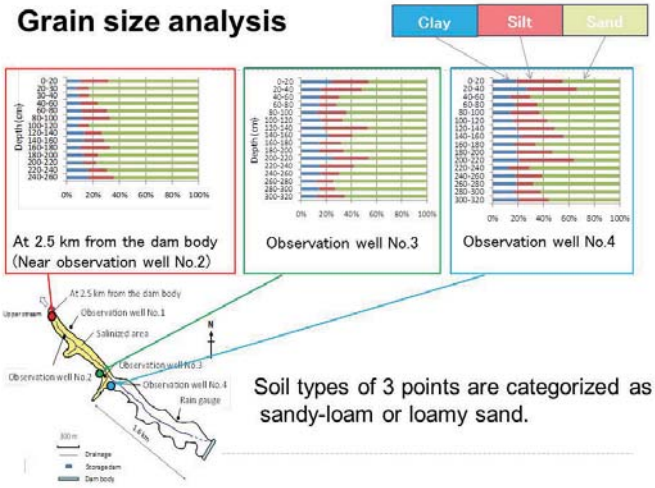
Grain size analysis



Soil types of 3 points are categorized as sandy-loam or loamy sand.

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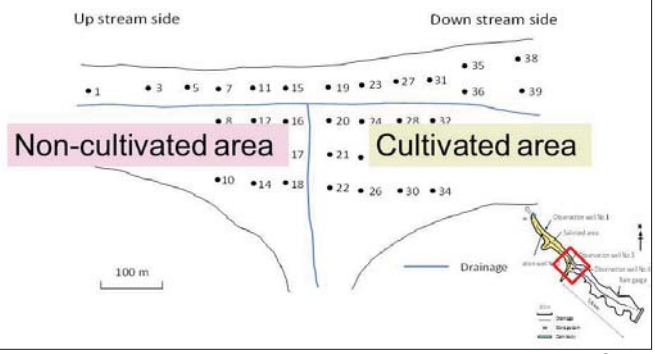
Current situation of salinization

Soil sampling area: Around inflow drainage canal



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Result on soil chemical characteristics

Soil sampling (Mar, Jun, and Sep, 2010)

➔Measurement of **ECe**, pHe, Cation (Na^+, Mg^{2+} and Ca^{2+})
Calculation of SARe (from Na^+, Mg^{2+} and Ca^{2+})

Criteria of salinization(by USDA)

	Normal	Saline	Sodic	Saline - Sodic
ECe(dS/m)	< 4	≧ 4	< 4	≧4
SARe	< 13	< 13	≧13	≧13

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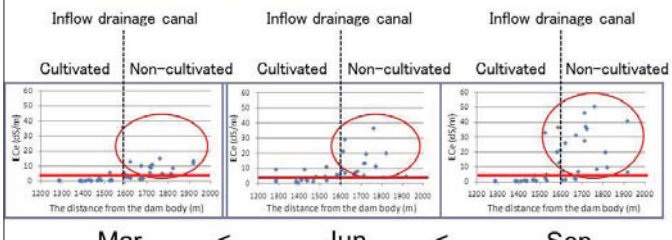
Result on Soil ECe



Mar < Jun < Sep

ECe of cultivated area is less than 4 dS/m, while ECe of non-cultivated area is higher than 4 dS/m.

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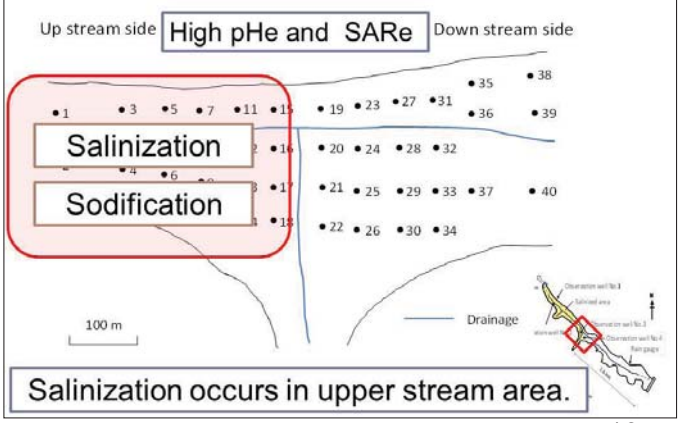
Result on Soil analysis



Salinization occurs in upper stream area.

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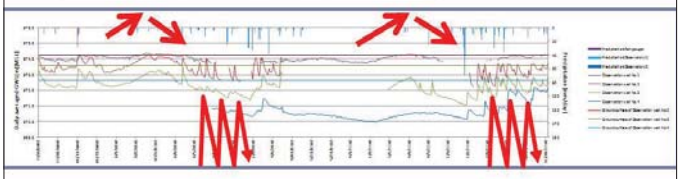
Results on GWL fluctuation



GWL is high (1.5m~2.5m from the ground surface)

Winter(Nov. to Mar.) ➔ Rise Slowly

Spring(Apr. to May) ➔ Drop Slowly

Rainy season(Jun. to Sep./Oct.) ➔ Quick response to rainfall

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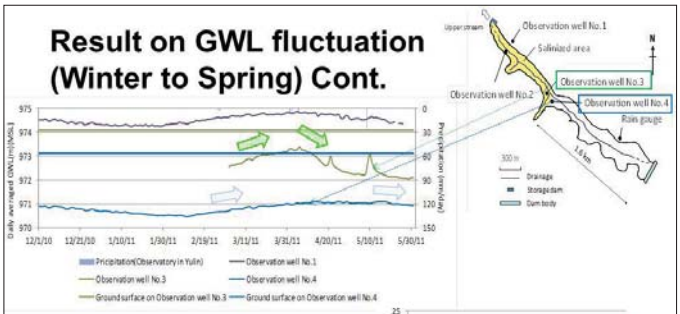
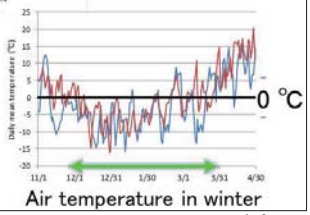
Result on GWL fluctuation (Winter to Spring) Cont.



Difference of GWL fluctuation between Wells **No. 3** and **4**



0 ℃

Air temperature in winter

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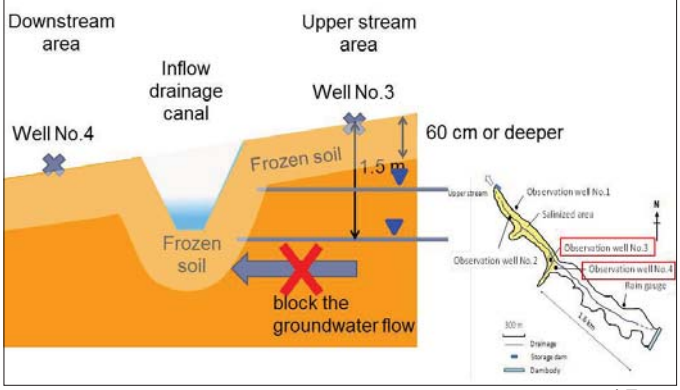
Result on GWL fluctuation (Winter to Spring) Cont.



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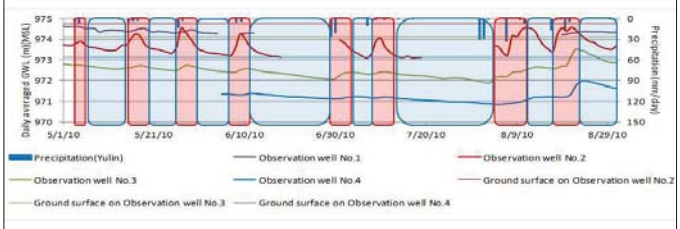
Result on GWL fluctuation (Rainy season)



GWL rises rapidly when it rains and drops after rain

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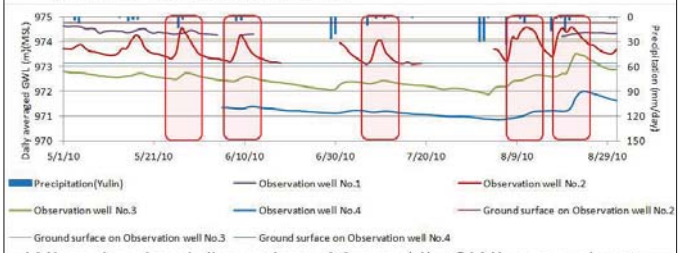
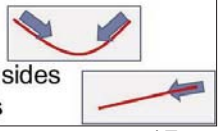
Result on GWL fluctuation (Rainy season) Cont.



When it rained (less than 30 mm/d), GWL rose about 1 m in well No.2.

➔ There are another factors such as

- Surface runoff from both slope sides
- Inflow from upper stream dams



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Mechanism of salinization

	GWL fluctuation		Salinization
Winter	GWL rises by frozen soil	➡	GW including salt reaches near ground surface.
Spring	GWL drops by melting frozen soil	➡	Salinization occurs due to high ET and GWL.
Rainy season	GWL rises rapidly by rainfall	➡	When it rains, GWL gets high and salinization occurs by high ET.

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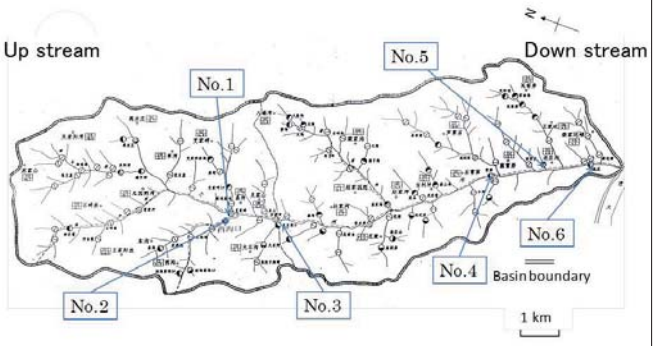
Salinization in Check dam system



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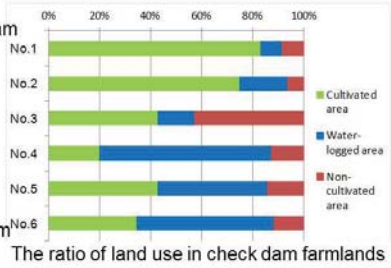
Salinization in Check dam system

Up stream

Down stream



The ratio of land use in check dam farmlands

Dam No.4, 5 and 6 in down stream area have large water-logged area.

Salinization tends to occur in the dam farmland in downstream of the watershed.

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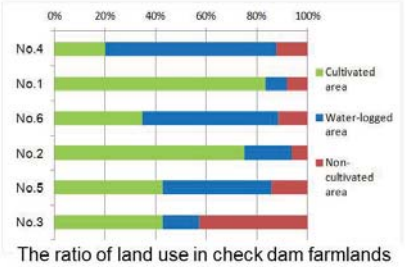
Salinization in Check dam system

Large

Small



The ratio of land use in check dam farmlands

Dam No. 4 and 6 have large water-logged areas.

Salinization tends to occur in large scale dams.

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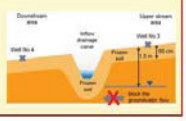
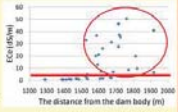
Conclusions

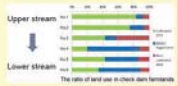
GWL in **Cao Mao dam** farmland rises by **frozen soil** in winter and **rainfall** in rainy season. Therefore, salinization occurs by both high GWL and high evapotranspiration.



In the downstream side of farmland, salinization does not occur due to low GWL. In the upstream side, **elevation of the original ground surface** is high. Therefore, **GWL is always kept relatively higher** after farmland formed and then salinization occurs.



Salinization occurs at farmland
- **large scale** dams
- dams in **lower stream** of Xiao He Gou.



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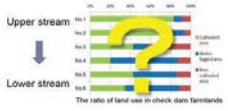
Future Study

In order to make sure the mechanism, the following measurements are required.

- Seasonal change of soil EC (continuous monitoring)

What is going on **between Sep and Mar?** Keep increasing or not?

- Ratio (or area) of salinized area in check dam farmland for different check dams.



- Hydraulic gradient of groundwater and elevation of original ground surface (or sediment thickness) of farmland

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Chair Suenaga: Thank you. Okay. The second speaker is Dr. Shimizu. He holds a doctorate degree in Agriculture from Osaka Prefecture University, Japan. His expertise is in the area of on-farm water management. He worked at IWMI, International Water Management Institute, in Pakistan and Sri Lanka, then at National Institute for Rural Engineering in Japan; and he is currently working at Tottori University, Japan, as Junior Associate Professor. His today's title is "Soil Salinization and Its Mechanism in Check-dam Farmlands in the Loess Plateau, China." Dr. Shimizu, please.

Dr. Katsuyuki Shimizu: Thank you, Chairman. Good afternoon, ladies and gentlemen. I am Katsuyuki Shimizu from Tottori University, Japan. It's my honor to make my presentation on this title.

Loess Plateau is famous of its serious water erosion; 60% to 90 % of water erosion occurs in gully. To prevent soil erosion, one of the most effective engineering approaches is constructing check-dam. Currently, about 114,000 check-dams have been constructed during 1960s and 70s and 320,000 hectares of farmland was developed in Loess Plateau.

Maybe some of you are wondering how we can make farmland in the check-dam. I will explain. In Loess Plateau, check-dam is a multipurpose dam constructed in gully. This is the downstream of the check-dam. After constructing dam, check-dam is functioning as flood mitigation and preventing soil erosion. After the area is fully covered with sedimentation, farmers start planting crops and then a new check-dam is built in the upper streams. Farmers are growing the corn or sunflower. Check-dam farmland has higher labor- and land-productivity compared with the agricultural land on the slope side.

The current issue occurred in check-dam farmlands is soil salinization which affects crop growth and destroys soil physical characteristics. I think salinization on rainfed farmland is very rare. I set up the immediate goal to clarify the current situation of salinization and its mechanism which leads to the ultimate goal to suggest on design of check-dam considering more effective use of sediment areas.

The study area is located in Xiao He Gou. Gou means watershed in Chinese. This shows the watershed basin. There are 100 check dams constructed during 1970s and 80s. We have conducted intensive field survey in one check-dam here and we also conducted the field survey of six check dams, 1 to 6.

This figure shows the outlines of check-dam number 4 for intensive survey. This means dam body and this is gully and soil sedimentation is covered. Height and length of dam is 48 meters and 220 meters respectively. Farmland area is 36 hectares. Annual precipitation is about 430 millimeters. Rainfed agriculture is practiced and major crops are corn and sunflower.

To clarify the current status of soil salinization and its mechanism, we got soil and water samples in the check-dam farmland to conduct analysis on soil physical and chemical characteristics and also on characteristics of groundwater level fluctuation. Because in most of cases groundwater has a strong relationship with soil salinization, waterlogging and soil salinization. We set up the three observation wells in the dam site, 1, 2, 3, and the other one in the outside of check-dam. And we got soil sample in this red square. Why we chose this area, because we can see the distinct border of non-cropped area and cropped area. Yellow hutch means non-cropped area – non-cultivated area.

As to grain size analysis, we got three samples from most upstream of the dam farmland and near the border upstream of the border and downstream of the border. This figure shows the ratio among clay, silt and sand. What I want to tell through this figure is soil types at three different points are more or less same and categorized as sandy soil.

We got the soil samples here near the border of non-cultivated zone and cultivated zone. This blue line is inflow drainage channel and this blue line also main drainage channel flowing into the downstream.

We got the soil sample and measured ECe and pHe and cation to calculate SAR. This table shows the criteria of saline soil defined by USDA. Here I mainly talk about the ECe.

This figure shows the change of ECe in different points. X axis shows the distance from dam body. At the point of 1600 meters from the dam body, there is inflow drainage channel. As I mentioned, this is the distinct border. When we look at these figures, at the downstream of inflow channel, soil EC is less than 4 dS/m while EC of upstream of inflow drainage canal is higher than 4 dS/m. And EC value got higher from March through June to September.

Considering the result of pHe and SAR measurements, this non-cultivated zone is categorized saline and sodic soil. We can say soil salinization occurs in upstream of the area.

Next, I talk about the fluctuation of groundwater level. This figure shows the groundwater level for 2 years. Groundwater depth, which means distance from the soil surface to the groundwater table, ranges 1.5 to 2.5 meters, so it's very high. When we look at the seasonal fluctuation during the winter from November to March, groundwater level rises slowly. During spring from April to May, groundwater level down slowly. During the rainy season from June to September or October, sometimes we can see the quick response of groundwater level to the rainfall. Next, I'll talk about this in detail.

As to groundwater level fluctuation from winter to spring, so this green line means groundwater level at number 3, upstream of inflow canal, and blue line shows the observation well number 4, downstream of inflow channel. Although two points are not so far, but we can see the big difference of groundwater level, This figure shows the air temperature during winter from December to March. Sometimes during winter time, air temperature becomes below zero. So considering these groundwater fluctuation and air temperature, I can express the difference of groundwater level like this. This figure shows number 3 and number 4 downstream.

When the winter started due to low temperature, the soil gets frozen. Actually in the field investigation, we observed at least 60 centimeters soil was frozen. Then the frozen soil blocked the groundwater flow. Then groundwater level increased slowly. But when the spring comes, frozen soil melts then groundwater started flowing again. Then groundwater level is going down.

Next I talk about the groundwater level fluctuation in rainy season. I briefly explain. Groundwater level rises rapidly when it rains and drops after rain.

This red line is the observation well number 2 is the higher upper part. There are differences between 3 and 4, but no significant change of soil. That's why there are other factors, such as surface runoff from both slope sides or inflow from upstream side at the upper part.

Considering these results, mechanism of salinization can be explained. In winter, groundwater level rises by frozen soil and groundwater including salt reaches near ground surface. In spring, groundwater level drops by melting frozen soil, salinization occurs due to high evapotranspiration and groundwater level. During rainy season, groundwater level rises rapidly by rainfall; and when it rains, groundwater level gets high and salinization occurs by high evapotranspiration.

Next I talk to salinization in check-dam systems, not only in one check-dam but as system. I briefly tell you the conclusion.

Salinization tends to occur in the dam farmland in downstream of the watershed. There are many check dams in the watershed, but most of check dams located in the downstream of the watershed has a high possibility of soil salinization.

Salinization tends to occur in large-scale dams compared to the smaller one.

I conclude my presentation. Groundwater level in Cao Mao dam farmland rises by frozen soil in winter and rainfall in rainy season. Therefore, salinization occurs by both high groundwater level and high evapotranspiration. In the downstream side of farmland, salinization does not occur due to low groundwater level. In the upstream side, elevation of the original ground surface is high. Therefore, groundwater level is

always kept relatively higher after farmland formed and then salinization occurs. Salinization occurs at farmland with large-scale dams and dams in lower stream of Xiao He Gou watershed.

For further study; in order to make sure the mechanism, the following measurements are required. Seasonal change of EC and ratio of soil salinized area and hydraulic gradient of groundwater and elevation of original ground surface of farmland.

My presentation is over. Thank you very much for your kind attention.

Chair Suenaga: Thank you very much, Dr. Shimizu. He introduced the status of salinization in check-dam farmlands in Loess Plateau, China. He also explained about the mechanism of the salinization in the farmlands. Do you have any questions and comments to his presentation? Yes, please.

Male Questioner: Thank you very much. This was very interesting topic because I did not understand why you have the salinization in the upper stream. But I realized that frozen causing such problems. So if it's so, the dam construction causes the salinization. So if there is no dam, we don't have to worry about the salinization.

Dr. Katsuyuki Shimizu: Thank you very much for your comment and question. Main purpose of constructing check dams is to prevent flood and soil erosion. This is the most important role. After sedimentation accumulated, luckily flat land is formed then farmers living near the check-dam start growing some crops. I think to answer to your question if there is no check dam no salinization in the original ground surface, yes, I think so.

Dr. Takashi. Kosaki: Okay. So, very difficult to follow the two good ways. Yeah, okay, thank you very much.

Dr. Katsuyuki Shimizu: Thank you.

Chair Suenaga: Thank you. Any other question? No question and comments? Yes, please.

Dr. Osamu Koyama: I am Koyama from JIRCAS. Thank you very much for interesting examples. But maybe Chinese people already think about the problem. They must have some kind of solution. Do they have any kind of solutions for this problem?

Dr. Katsuyuki Shimizu: Thank you very much for your comment and question. So far as I know, Chinese researchers who major in Civil Engineering they mainly focuses on preventing flood and soil erosion. So far as I know there are few research papers about soil salinization in check dam farmland.

Dr. Dinesh Sharma: This would mean that the issue is not so serious for Chinese.

Dr. Katsuyuki Shimizu: Thank you very much for your comment. Maybe, high-class officers do not care about this, but people living near the check-dam are concerning about this, I think.

Chair Suenaga: Okay. Thank you very much, Dr. Shimizu. So, I pass the chair to Dr. Shono.