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DEVELOPMENT OF MOVIES AS THE TEACHING TOOL ON THE MOVEMENT OF IRRIGATION WATER IN PADDY FIELDS MANAGED UNDER VARIOUS CULTIVATION METHODS

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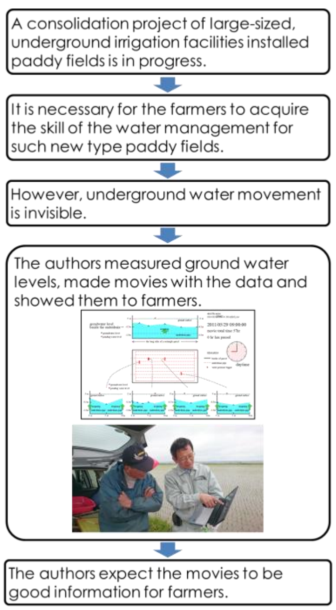
Graphical abstract



Abstract

Hokkaido, the northern most of the four major islands of Japan, is an important rice-producing area. In Hokkaido there are some areas where the numbers of farm households are decreasing and the management scale for one farm household is increasing. In such areas, labor shortage occurs if only the conventional transplant cultivation is used. The necessity for introducing direct-seeding cultivation method has been increasing because by using this method it is possible to save labor. In some of the areas with increasing number of large-scale farm management, the farms employ large lot paddy fields and install underground irrigation facilities, which are useful in direct-seeding cultivation, to improve work efficiency. It is thought that it requires 2 to 3 years for the farmers to learn to effectively use the underground irrigation facilities because use of such facilities is a new experience for many farmers. The authors conducted observation of the groundwater level and depth of ponding in the paddy fields where the above-mentioned improvements were done, and made a movie using the obtained data. The movie is also useful for the authors in understanding the inflow and outflow of the groundwater, which are phenomena occurring underground. At a meeting of local farmers, the authors explained the movement of irrigation water by using this movie. The authors expect that the explanation using the movie will promote the farmers' understanding in effectively using the underground irrigation facilities.

Keywords: Large-scale paddy field, underground irrigation, presentation to farmers, water management of paddy field, direct seeding cultivation, groundwater

1.0 BACKGROUND AND AIM

1.1 Hokkaido: Its Geography and Farming

Hokkaido is the northern most of the four major islands of Japan (Figure 1). The total area of the island of Hokkaido combined with the surrounding small islands is 83,000km^2, accounting for 22% of Japan's total land area. Hokkaido's population is 5.4 million, or 4.3% of the Japanese population. The population density is low at 69 people/km^2 as compared with Japan's population density of 336 people/km^2. The average temperature and precipitation (i.e., average values for the years from 1981 through 2010), to take the city of Iwamizawa in the rice-producing area as an example, are as follows: The annual average temperature is 7.7°C, while the monthly average temperature is the highest at 21.3°C in August and the lowest at -5.5°C in January. The annual average temperature is lower than that of Tokyo, 15.4°C, by 7.7°C. The annual precipitation is also lower at 1,162.6mm than Japan's annual average precipitation of 1,700mm. In Iwamizawa, the total precipitation in the form of snow from December through March when the monthly average temperature is below zero is 375.6mm, about a third of the annual precipitation. From May through August when paddy fields in Iwamizawa need to be irrigated, the total precipitation is 384.6mm. In June and July when the river discharge alone cannot satisfy the need for irrigation water, snowmelt runoff water stored in reservoirs in spring is also used.

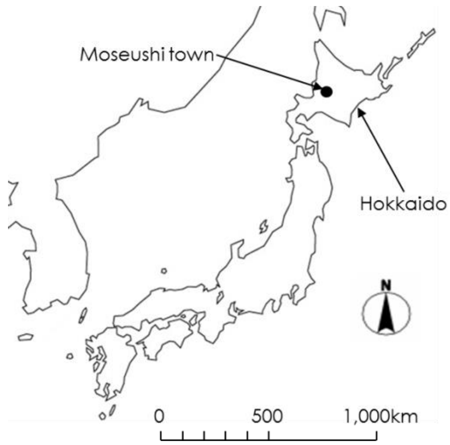


Figure 1 Location of Hokkaido and Moseushi town

1.2 Rice Cultivation in Hokkaido

Hokkaido has a relatively short history of development in comparison with other regions of Japan as the full-scale development of this island as a national policy started in 1869. In 1892, the Japanese government began encouraging rice cultivation in Hokkaido, and development of paddy fields and water facilities was started around 1895. As of 2013, the total paddy field area in Hokkaido is 212,000 hectares, of which 112,000 hectares are used for growing rice in submerged fields. The acreage-reduction target for rice production adjustment in Hokkaido is 47%. The total area of submerged paddy fields in Hokkaido accounts for 7% of Japan's total submerged paddy field area, 1,597,000 hectares.

In the past, rice crops in Hokkaido were seriously damaged from cold summer weather nearly every four years. Cold summer damage has been reduced through various measures. For example, techniques were developed for submerging rice plants in water. In the middle or toward the end of July, the depth of ponding is increased to 15-20cm to protect rice against air temperature that is lower than the water temperature. To apply these techniques, a larger volume of irrigation water was secured and levees between rice paddies were improved. Additionally, cultivation of cold-tolerant rice varieties has been increased. As a result of the project that was launched in 1980 for enhancing rice cultivar improvement to grow rice varieties having excellent eating quality, the quality of rice produced in Hokkaido presently is in no way inferior to the quality of rice from other regions. Hokkaido has developed into one of the major rice-producing areas in Japan. As of 2010, the average rice-paddy acreage per farming household is 6.9 hectares while that of Japan as a whole is 1.0 hectare. In Hokkaido, the rice-paddy acreage per farming household varies greatly from region to region.

1.3 Necessity of Farmland Readjustment and Consolidation

In some paddy areas in Hokkaido, the number of farming households has been declining because farmers are aging and their children don't necessarily inherit their family farms. Consequently, farms have been consolidated and the farm size has become larger in these paddy areas. It is reported that a husband-wife farming households engaging in transplant rice cultivation face a labor shortage when their paddy field area is larger than 20 hectares [1]. For the purpose of enhancing work efficiency, under national farmland readjustment and consolidation projects, large lot paddy fields have been employed and underground irrigation facilities have been built in some paddy areas where large-scale farm management increased. In these areas, completion of underground irrigation facilities has facilitated introduction of direct-seeding cultivation for saving labor.

1.4 Necessity and Overview of the Research Project

Ten national farmland readjustment and consolidation projects are being implemented in paddy areas of Hokkaido. One of these projects is under way in the town of Moseushi (Figure 1) in Uryu district. Under the project, large lot paddy fields are employed, plots of farmland are exchanged or consolidated among farmers so that they can get rid of fragmentation and dispersion of their own paddy fields, irrigation canals are pipelined, and underground irrigation facilities are installed. Improvements of paddy field conditions and irrigation facilities will accelerate introduction of direct-seeding rice cultivation, and thus it is expected that irrigation water requirement will change. In order to ensure stable management of irrigation water and water distribution as early as possible after the completion of the project, 1) farmers need to learn to effectively use the underground irrigation facilities for better management of irrigation water, 2) data should be accumulated regarding the volume of irrigation water intake that changes due to the completion of underground irrigation facilities and also to the increase of direct-seeding cultivation, and 3) the data on the volume of irrigation water intake should be analyzed for each growth stage and also from the viewpoint of inter-day and circadian variations, so that analysis results will be utilized for efficient water distribution management.

With the cooperation of farmers, organizations working on the promotion of the project in Moseushi, and the Hokkaido Regional Development Bureau that is implementing the project, the author has been collecting and analyzing data on irrigation water management in paddy fields, and also has been conducting simulations for the purpose of suggesting water distribution management techniques. The duration of this research is from FY2011 through FY2015.

The paddy fields used for the research are outlined in Figure 2 and Figure 3, and a five-year cropping schedule is shown in Table 1. Figure 4 shows gauges installed for measuring groundwater levels in the fields. On the assumption that the profile of the groundwater level is symmetrical with respect to the line marking half the distance between the two adjacent underdrainage conduits, groundwater level monitoring points were placed on either right or left side of the line. The depth of ponding and the groundwater level were measured for the following purposes: 1) Understanding the behavior of water in terms of changes in the depth of ponding and groundwater level, and estimating the water duty; 2) Understanding the differences in the infiltration capacity and the water duty in relation to the differences in the tillage management between transplant cultivation and direct-seeding cultivation. The number of groundwater level monitoring points was determined to be as many as 10 for the following purposes: 1) Observing the differences in the groundwater level change rate that depends on the distance from the intake at an irrigation control unit (i.e., the groundwater level change rate varies depending on the length of the long sides of a rectangular paddy field); 2) Comparing groundwater level change rates between a point near an underdrainage conduit and a point between the two adjacent underdainage conduits in four planes perpendicular to the direction of underdrainage conduits; 3) Understanding variability of the groundwater level for calculating an average groundwater level. The results of this research have been reported [2].

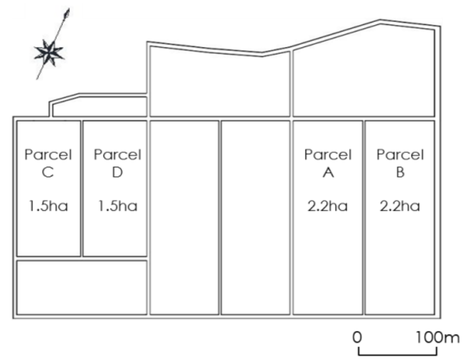


Figure 2 Researched paddy fields

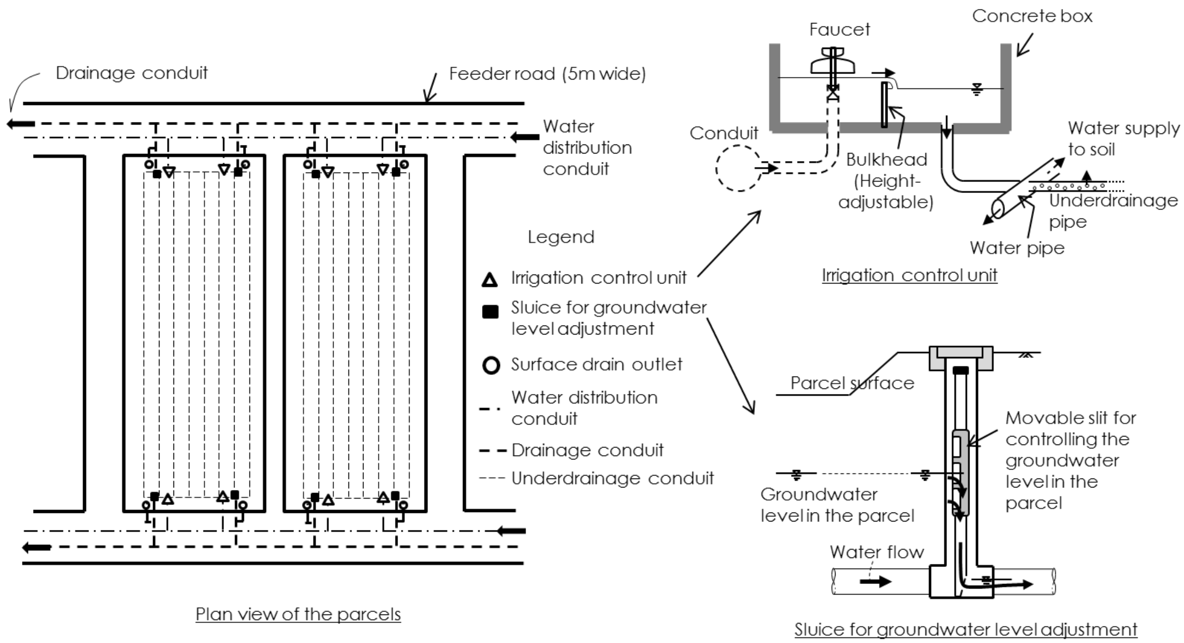


Figure 3 Irrigation and drainage system for parcels

Table 1 A five-year cropping schedule

Year	Parcel A	Parcel B	Parcel C	Parcel D
2011	paddy rice, transplanting culture	spring wheat	paddy rice, direct seeding in flooded paddy field, no puddling	paddy rice, direct seeding in flooded paddy field, no puddling
2012	winter wheat	winter wheat	paddy rice, transplanting culture	paddy rice, transplanting culture
2013	soybean	paddy rice, transplanting culture	paddy rice, direct seeding on well-drained paddy field, no puddling	paddy rice, direct seeding on well-drained paddy field, no puddling
2014	spring wheat	winter wheat	paddy rice, direct seeding on well-drained paddy field, no puddling	paddy rice, direct seeding on well-drained paddy field, no puddling
2015	spring wheat	winter wheat	paddy rice, transplanting culture, no puddling	paddy rice, transplanting culture, no puddling

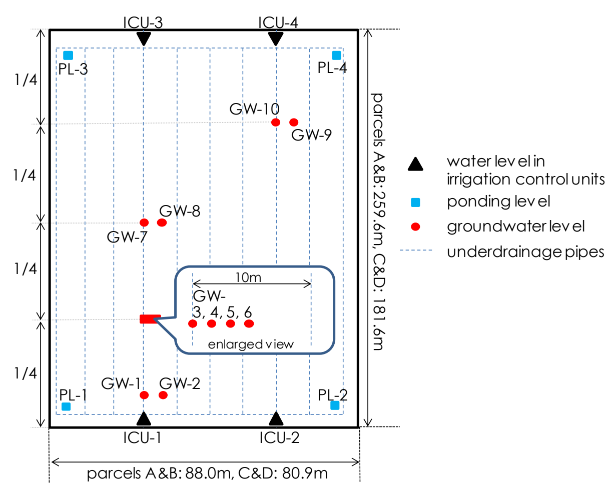


Figure 4 Water level gauge installation points

1.5 Aim of Creating a Movie by Using Obtained Data

Because use of underground irrigation facilities is a new experience for many farmers in Moseushi, it will require 2 to 3 years for the farmers to learn effective use of the facilities through trial and error. Subsurface drainage of paddy fields has become more important after the completion of the project because paddy fields increased in size from 0.3 ha/parcel to 2 ha/parcel. In this regard, farmers need to understand how field drainage performance is influenced by soil management including subsoil breaking and creation of mole drains.

The time necessary for farmers to familiarize themselves with effective use of underground irrigation facilities can be reduced if they understand the water movement in fields, especially how water moves underground, when they are given explanation about underground irrigation facilities on the basis of observed data. Farmers need to understand water movement in terms of the following aspects: 1) The time required for underground irrigation water to reach various points of a field, and the routes that underground irrigation water takes to move upward for saturating topsoil; 2) Lowering of the groundwater level immediately after starting subsurface drainage by opening underdrain relief wells, and an immediate decrease in the depth of ponding in conjunction with the lowering of the groundwater level.

Data on groundwater levels are collected at 10 monitoring points per paddy field, and they are usually plotted on a chart as shown in Figure 5. The chart helps us to understand temporal changes in the groundwater level of a paddy field and the relative height of the groundwater level around the paddy field. However, this type of chart is not useful for understanding the temporal changes in the groundwater level in a plane perpendicular to the direction of underdrainage conduits, the changes that the authors and farmers would like to see. In order to understand water movement in paddy fields, it is necessary to create a movie that shows the changes in the groundwater level due to irrigation and drainage in four planes perpendicular to the direction of underdrainage conduits and also in a cross-section along a long side of a rectangular paddy field.

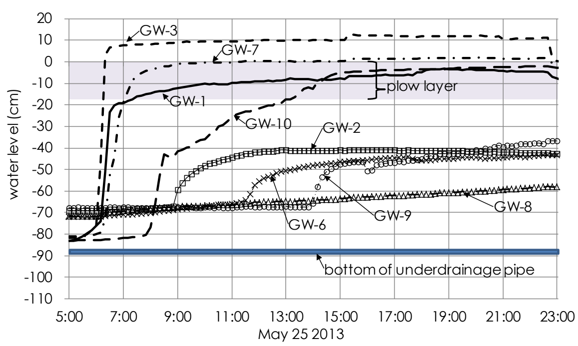


Figure 5 Usual expression of temporal change of groundwater level

2.0 RESULTS AND DISCUSSION CONTENT AND CREATION OF A MOVIE

2.1 Information Included in the Movie

Figure 6 shows one scene of the movie. A plan view of a parcel used for research is placed in the center. Around the parcel, a cross-section along a long side of the parcel and four planes perpendicular to the direction of underdrainage conduits are placed. Each plane is connected to the plan view with a line to indicate its location in the parcel. Measured values of the groundwater level are plotted on the four planes and the cross-section by using blue dots, these dots are connected with a line, and the space underneath the line (i.e., groundwater surface) is shown in light blue. Because groundwater level monitoring points are located on either right or left side of the line marking half the distance between the two adjacent underdrainage conduits, the space in light blue is made symmetric with respect to the line.

When water was supplied by irrigation or rainfall, or underdrain relief wells were opened, raindrops or thick up-arrows are added to make it easier to understand the causes of changes in the groundwater level or the depth of ponding.

For the purpose of giving presentations, this movie is created by showing actual phenomena at any time intervals. Thus, a clock is placed in the upper right-hand part of the screen to indicate the intervals being used. The clock is shown in four different colors for early morning, daytime, evening, or night.

Every year, at the time of the first irrigation of the submerged paddy field used for the research, the authors made sketches to record the spread of irrigation water on the field surface. These sketches are superposed on the relevant plan views of the field.

2.2 Making of an Animation File

The authors produced a program as a macro of the graphic software Hanako (JustSystems Corporation) for creating each page of the movie. By using this graphic software, up to 99 pages of pictures can be stored in animation GIF. The authors used this feature for creating a movie file. Other types of software are also available for creating graphics on pages by using a macro and for storing them in the form of a movie.

3.0 RESULTS

3.1 Movie Example

Figure 7 shows consecutive pictures created with a macro. These pictures can be shown in the form of a movie by using a computer and a projector. The pictures in Figure 7 show the changes in the groundwater level at 2-hour intervals starting at three hours before the start of water intake, namely from 2:00 to 18:00 on May 25, 2013, in parcel D used for direct-seeding in a well-drained paddy field. The water intake on that day was the first intake in the irrigation period, and it was implemented immediately after seeding. In 3 hours after the start of water intake, the surface of the field was partially wet. In fact, the surface did not gradually get wet outward from the area near the irrigation control unit. The central part along the long sides of the parcel was wet in 2 hours after the start of water intake. On the other hand, in 3 hours after the start of water intake, the groundwater level was at more than 0.5m below the surface at the place marking half the distance between the two adjacent underdrainage conduits. This suggests that water supplied by underground irrigation moves upward from conduits and spreads laterally after reaching the surface.

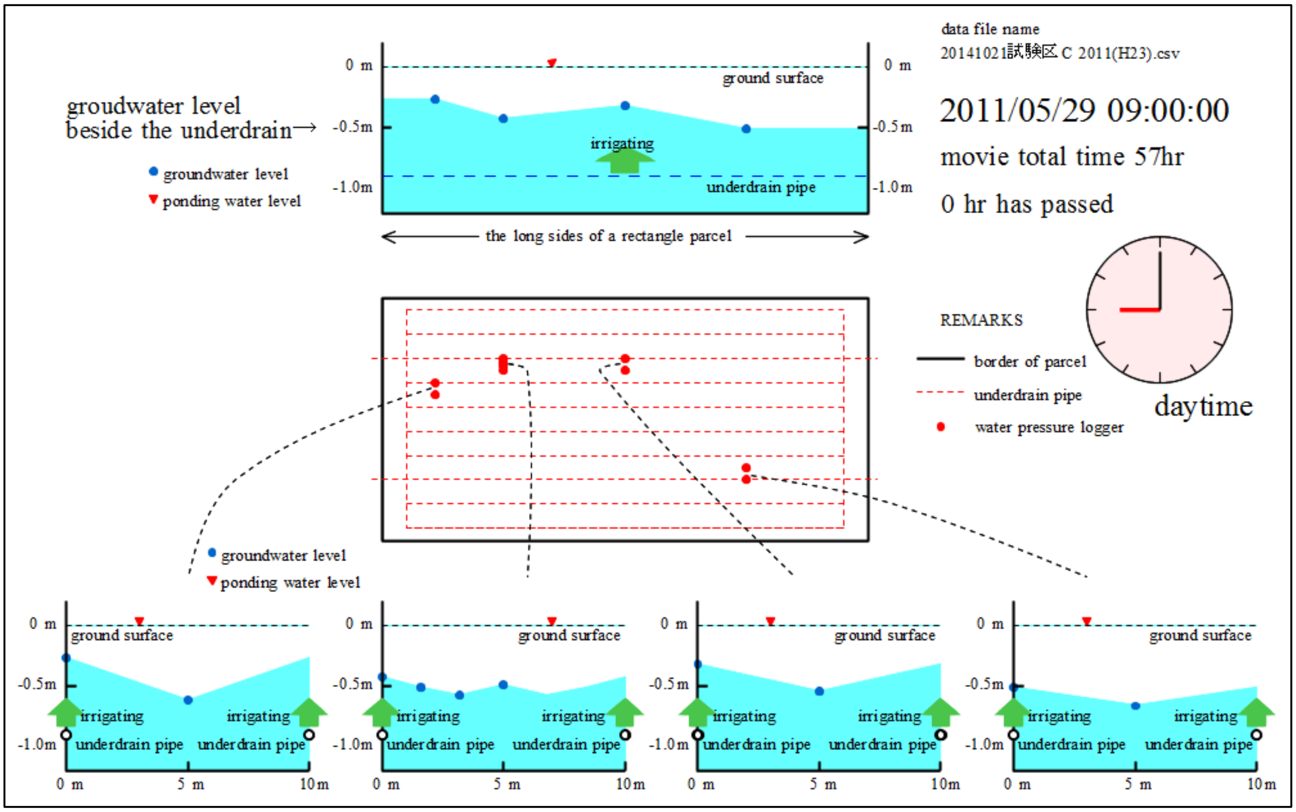


Figure 6 One scene of the movie

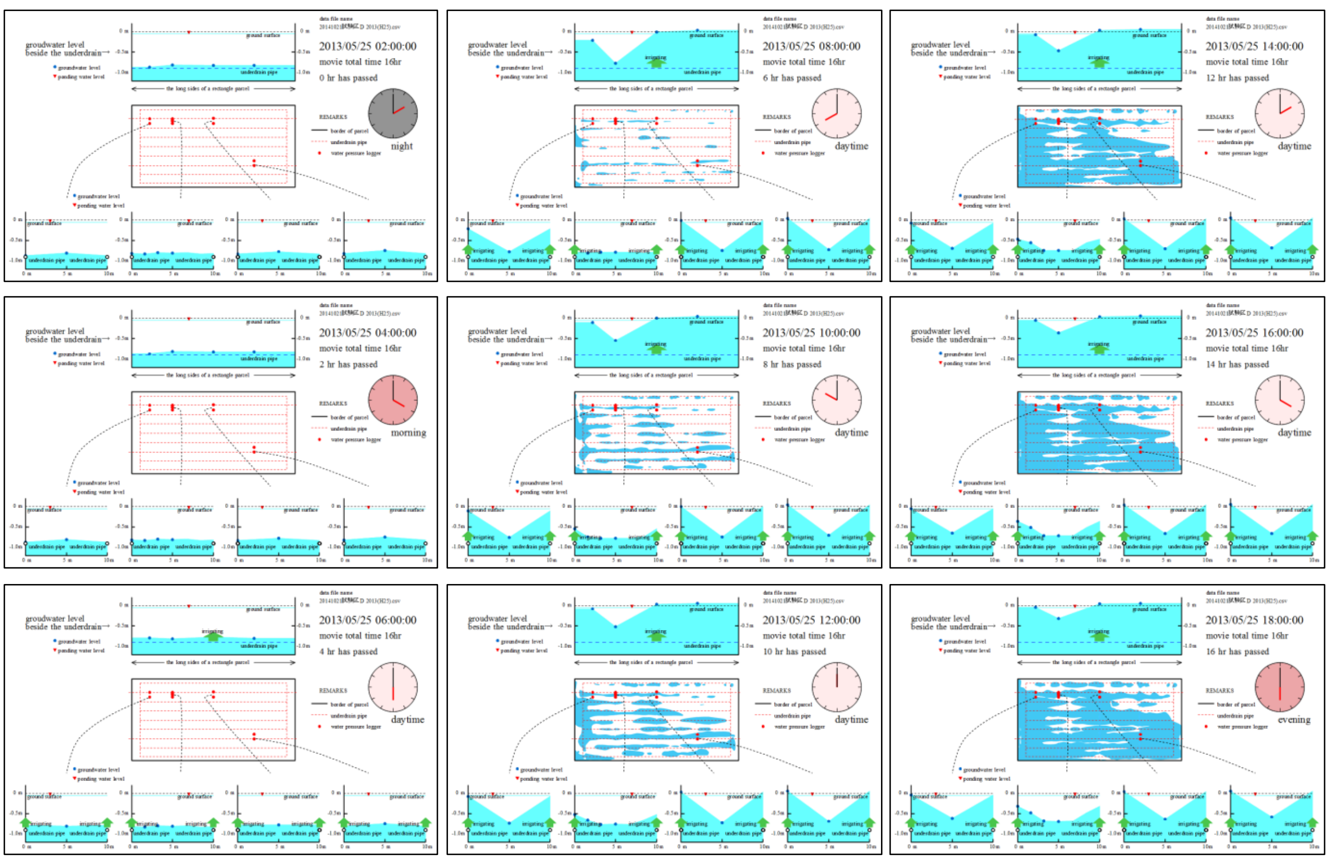


Figure 7 Consecutive pictures of the groundwater level in Parcel D used for direct-seeding in a well-drained paddy field

3.2 Presentation of a Movie to Farmers and Engineers in the Farmland Readjustment and Consolidation Project

The authors have been using the movie file for explaining the water movement in the paddy fields used for this research to the owners of these parcels. Explanations by using the file have also been given at sessions held by a group of farmers studying direct-seeding cultivation and at workshops of engineers from the Hokkaido prefectural government and the Hokkaido Regional Development Bureau who are in charge of the introduction of large lot paddy fields.

Farmers and engineers who viewed the movie told the authors that the movie was very useful for understanding water movement in paddy fields.

4.0 SUMMARY AND DISSEMINATION OF THE RESEARCH OUTCOME

The authors created a movie depicting the changes in the groundwater level and the depth of ponding in connection with irrigation and drainage. In the paddy fields used in the movie, underground irrigation facilities were installed in conjunction with the introduction of large lot paddy fields in a government project. The movie was used for giving explanations of water movement in paddy fields to farmers and engineers involved in the government project, and they evaluated the movie highly because they could easily understand the water movement. The authors intend to disseminate the research outcome not only by giving presentations at workshops, etc., but also by distributing presentation files and making the movie openly available on the Internet.

The authors use the movie for presentations in the hope that the movie helps farmers to deepen their understanding of the water movement in their paddy fields and also to improve their skills for water management. It is also hoped that farmers will obtain clearer understanding of the soil management methods that are necessary for securing satisfactory drainage performance of paddy fields. The authors will check if these hopes have come true by asking for feedback from farmers.

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