“Water control and management for enhancing resilience to natural disasters and improving agricultural productivity”

Review Report

Context

- The panel had to review seven projects of the Institute for Rural Engineering (NIRE), which is one of the 21 Institutes within the National Agriculture and Food Research Organization (NARO). The specific points for the evaluation were:
  - adequacy of approach and procedures;
  - probability of successfully accomplishing the projects objectives;
  - merit and significance.

  In addition to the evaluation of each research project, the reviewers were requested to provide comments, suggestions or recommendations on the entire research programme, in terms of the overall approaches, direction, application, etc.;
- During the presentations and discussions, it was stressed that the research programme has to fit within the Society 5.0 objectives, which are, among others, linked to the sustainable development goals (SDGs). Priority research areas for NIRE that could support this initiative would be:
  - creation of a data driven innovative smart agriculture;
  - development of essential agricultural knowledge and technologies (environmental data, soil, etc.);
  - development of advanced ICT fundamental technologies (artificial intelligence, data linkage, robotics, etc.);
- Some of the ongoing and expected future developments that are expected to have implications for the research programme are:
  - decreasing area of cultivated lands;
  - decreasing number and aging of farmers;
  - aging of agriculture infrastructure;
  - natural disasters;
  - increasing drainage problems due to urbanization;
  - changes in diet, resulting in increased need for dry food crops;
  - policy objective is an improvement of food self-sufficiency from the present 38% to 45%;
- The focus of the research programme of NIRE is on water management for agriculture and disaster reduction/prevention.

General Comments of the Evaluation Committee

We highly appreciate the excellent preparation, supply of information, good presentations and open discussions that we could have during this review mission.

As the population increases and concentrates in urban areas, food security becomes a vital problem for national security. The quick urbanization and dense economy developments make disaster mitigation an urgent and important agenda, especially under climate change scenarios. This NIRE research program is a proper and effective response to the current urgent agenda. The natural disasters cannot be eliminated completely, but to make the society more resilient and well prepared for the emergencies may reduce the impacts to the society as well as the nation as a whole.

Focus on the rural area, NIRE implements research projects to integrate ICT/IOT software technologies and physical engineering improvements such as delivery and drainage canals for better management of the rural and coastal farmlands protection strategy for disaster mitigation. In general, all seven projects have been properly implemented and accumulate conspicuous accomplishments; more impressively, some results have even been successfully implemented for field establishments.

Although we have the impression that all the presented research projects are useful, as mentioned above, they are not so much related to policy development within the Ministry of Agriculture, Forestry and Fisheries (MAFF). It is considered to be important that the research programme and projects are being placed in the context of the developments and policy objectives within Japan, and especially on the context of the programme of the MAFF.

Some further suggestions for future program development include:

1. Research topics directly related to the implementation of the policy to increase food self-sufficiency from 38 to 45% with a focus on environmentally friendly agriculture.
2. Research and dissemination of the results considering the Society 5.0 and focusing on policy development.
3. Water management considering aspects other than agriculture
   1) Water reallocation scheme based on “water pricing” by changing water prices for each industry depending on the amount of water usage and the amount of pollution emission aiming for regional drought prevention by mitigating competitions over water.
   2) Schedule adjustment of irrigation and cropping for climate change.
   3) The tendency of farm crops diversification and intensified economic competitions may lead to more focus on the demand-oriented water supply management for irrigation and also more flexibility in irrigation management on farmers’ side.
   4) Research on integrated water (resources) management considering the water area as an ecosystem should be recommended. It will be useful to analyse the implementation aspects of the European Water Framework Directive (WFD), aimed at making integrated river basin plans by the riparian states and more detailed water management plans within these countries. In these plans, various types of land use are treated in an integrated way.
4. Improving the approaches
   1) More effective and smart water management in the field level using IOT and AI technology.
   2) Trying to “think outside the box” (i.e. unconventionally, from a new perspective) to maximize

the detection/prediction of extreme events.

3) Accepting to explore the limits of the forecasting systems (like in a ‘crash-test’) to explore the maximum utilization span and clearly identify the limits.

NARO Response to the Comments of the Evaluation Committee

1. The MAFF aims to improve food self-sufficiency by implementing three policies: i) prosperous and competitive agriculture, ii) beautiful and vigorous rural areas, and iii) strong and resilient agriculture and rural areas, in light of changes in the agricultural situation, including reduction of farmland area and the aging of farmers. Specifically, i) aims to strengthen the constitution of core farmers and to improve the profitability of production areas; ii) aims to conserve and manage local resources and build a resource recycling society; and iii) aims to conserve and manage agricultural facilities and prevent natural disasters.

   Research projects to address these three policies has been conducted in NIRE. Project 2 addresses ‘prosperous and competitive agriculture’, Project 3 addresses ‘Beautiful and vigorous rural areas’, and Project 1 addresses ‘Strong and resilient agriculture and rural areas.’ We will contribute to increasing food self-sufficiency rate through the “development of technology to improve agricultural infrastructure”, such as improving the function and maintenance of agricultural infrastructure, increasing the profitability by large-scale agriculture, and strengthening the management of local resources. While promoting this research, we will work in collaboration with projects conducting research on quality of water for agriculture, and rural ecosystems.

2. Project 1-1 includes a research to identify prompt response measures to protect irrigation ponds through an analysis of accumulated data from emergency inspection on irrigation ponds using Artificial Intelligence (AI). We also plan to conduct a research to enable efficient water management with big data obtained from Project 2-1 and 2-2 and stored on the cloud server. We did not introduced in this review meeting, but we also launched projects of developing a robot that identifies the spot of water leakage from pipelines based on the sound of leaking water, a water level prediction technology using AI to support the operation and management of pumping stations during torrential rain) and a technology that checks the open/closed status of sluice gates using AI imaging diagnosis. These are for the realization of Society 5.0.

   We have a policy of regularly exchanging opinions (3 times a year) with the MAFF in terms of promoting research and technology development.

   As an example of our achievements, the field water management system developed in Project 2-1 will be fully introduced in April 2019 as a demonstration project by the MAFF. Furthermore, the automated water distribution control system developed in Project 2-2 received funding from Ibaraki Prefecture. Local surveys were conducted and a schedule for the areas where the system will be introduced was drafted in 2018. Field demonstrations are planned for FY2019 and introduction is expected in FY2020 in the areas that received funding from the Prefecture.

3. Water management considering aspects other than agriculture

1) We appreciate the proposal. In Japan, where the climate is rather humid, streamlining of water management is based on Participatory Irrigation Management. Project 2-2 develops a system using ICT technologies to minimize waste of water and labor (automation of water volume distribution in line with demand) in rural areas with a progressively aging and shrinking population. In the future, it will be essential to consider not only water supply, but also drainage and water quality, so we would like to examine your proposal.

2) We are developing a system that incorporates crop growth models and meteorological information into the Remote-controlled On-farm Water Management System of Project 2-1, in cooperation with other programs in NARO that study the climate change. This will enable automated water management in response to annual fluctuations of the weather. In 2019, we plan to start demonstration tests on paddy fields in Ibaraki Prefecture.

3) Yes, that is correct. In Project 2-2, we built a system to distribute water in response to the needs to use limited amount of agricultural water efficiently. The demand for this system is high, and investigations for introduction started in 2018.

4) To date, NIRE has conducted research on water sources, irrigation and drainage channels, water quality, ecosystems, etc. regarding water use in rural areas. However, there is no research on integrated water management. We will consider it in the future, referencing the WFD.

4. Improving the approaches

1) Yes, that is correct. We would like to contribute to attract more workers to agriculture by improving profitability to cover the costs of hardware such as sensors and communication devices to achieve efficiency and smart systems.

2) We would like to have a new perspective from outside the field of rural engineering research by strengthening collaboration with the private sector and other research institutes.

3) We prefer improving the applicability of the system also under extremely bad conditions. To achieve it, we need to work on numerical simulations, basic experiments, field surveys, etc. and of course, examination of the extra budget.

Section 1: Countermeasures to natural disasters to achieve resilient rural areas

Project 1-1 Disaster prevention support system for irrigation ponds

Information integration, communication, and exchange are keys for emergency responses. This project is considered to be an important project for rural area safety. The developed Disaster Prevention support System for Irrigation Ponds (DPSIP) is expected to be a very effective risk forecasting system, which is at the end of its test phase and will be implemented in practice from April 2019, in combination with the Sharing Information Platform for Disaster Science and Disaster Resilience (SIP4D). The project also completed the failure prediction algorithms under earthquakes and heavy rainfalls for early warning and effective evacuations. Several recommendations and suggestions are listed below.

1. Improvement of the current systems:
   1) It is not clear how the system maintains effective operation if some connection in the network is broken among agencies.
   2) Presently, the information is only delivered to municipalities, because the system is still in development, but at some point, it is likely that the citizens will be willing to be informed directly… did you start to think about it?
   3) This system may be further linked with other regional disaster mitigation information systems from other institutions or agencies; the data format/standard needs to be studied for better interoperability.
   4) The database system backups may be a vital factor for this system. Mirror site or remote backup may have to be considered for higher system robustness during the disasters.
   5) The crowdsourcing issue is an important and difficult one at the same time. Any human being with a smartphone can contribute to surveillance and assessment efforts, even in near real time. However, there is always a risk of manipulation/ false news / false alarms. The question is one of balance: what can be gained vs what can be lost?
   6) What is the involvement of insurance companies? Are they co-financing some of NARO's research?
2. Improvement of the safety management for the irrigation ponds:
   1) Most of the about 200,000 irrigation ponds are more than 200 years old and work to categorize them in relation to their risk of failure is already ongoing. In light of this, it is recommended that first a safety standard will be agreed upon that the dams of these ponds would have to fulfil in relation to the risk of failure. When such a standard would have been agreed upon, to implement an overall inventory of the existing dams in order to complete the categorization of the risk of failure and the need for redesign.
   2) When new dams to be constructed, their design should be based on the same safety standard.
   3) When developments are being planned downstream of irrigation dams it is recommended to analyse whether special provisions would have to be made to reduce, or prevent damage, when the upstream irrigation dam could fail.
   4) On the other hand, it is recommended to analyse if in existing situations it could be useful to install such provisions that when an existing dam would fail the downstream damage will be

as least as possible.

5) A monitoring/inspection/reinforce program may be planned and implemented if budget is available to increase the resilience of the pond irrigation system.

The rating is: **A – good quality and minor revision needed.**

NARO Response to the Comments of the Evaluation Committee

1. Improvement of the current systems:

1) In a disaster area, telecommunication channels will be crowded, and communication is expected to become difficult. Even when there are difficulties with connections, the disaster notification system of the DPSIP temporarily stores input information in a mobile terminal and the information is sent out automatically once the connections improve. When there is a poor connection, the map for risk level information may not be displayed, but text-based emails will be distributed to inform users which irrigation ponds are dangerous to be around. Research and development on mobile communication hubs have been conducted under the research project of Strategic Innovation Promotion Program (SIP), envisioning the aforementioned scenarios.

2) Yes, together with MAFF, we consider providing of information on the position and names of irrigation ponds and a map of the assumed flood inundation in the event of a collapse via a website accessible to the public. The "risk level information" linked to evacuation measures will not directly be communicated to the residents, because the evacuation advisory notices and evacuation orders should be passed to the residents via the municipality in the current system.

3) The current SIP4D system connects different systems converting data formats. Therefore, the exchange of information is possible without concerning the data format of each system connected. However, as pointed out, it is necessary to standardize the format to ensure a smoother interoperability.

4) At present, cloud backup and backup on a clone server are in progress, targeting full-scale operation.

5) A certain level of security is achieved with ID/password to access the data from smartphones. The system was improved to confirm who submitted reports and who deleted information by asking for the names.

6) At present there is no research funding or involvement from insurance companies.

2. Improvement of the safety management for the irrigation ponds:

1) The safety criteria for irrigation ponds are stipulated in the Land Improvement Design Guidelines -"Irrigation Pond Maintenance" (2015)- set out by the MAFF. Irrigation ponds situated upstream of the residences and facilities, which may cause casualties in the event of

a collapse, require prioritized in disaster prevention measures. Improvements are initiated to ensure that these ponds satisfy the safety criteria required in case of earthquakes and torrential rain. However, re-maintenance with civil engineering work takes time. Therefore, the government focuses on measures to enable rapid evacuation in the event of a disaster. Utilization of the DPSIP is one of the measures and the system has been developed.

2) Repair work or the construction of new irrigation ponds is normally executed based on design guidelines presented by the government.

3) An evaluation of seismic capacity and seismic retrofit, and hazard map drafting as measures to prevent human casualties should be conducted for an irrigation pond once the area downstream of the pond is developed and it is designated as a disaster prevention irrigation pond.

4) Refurbishments are executed based on investigations and analyses of earthquake events, and the results of diagnosis. Similar investigations are also required to take torrential rain measures.

5) The MAFF is installing observation equipment, preparing hazard maps, implementing the required reinforcement measures, and moving forward to share disaster information using DPSIP, after the torrential rain of July 2018.

Project 1-2 Countermeasure techniques for water-related hazards in coastal farmlands

Protection of the coastal farmlands is an essential task and becomes more important after the tsunami hit due to the Great East Japan Earthquake. The mindset shift from complete resistance to strategically yielding spaces for the energy dissipation proposed in this project is a major leap in the natural disaster risk management. The concept has been previously verified by physical hydraulic modeling. This project uses numerical simulation models to test the effectiveness of this strategy under different scenarios including global climate change. The results are substantial and useful and have also been implemented in the field.

There are some recommendations and suggestions as follows.

1. Disaster prevention farmland:

1) The high durability banking is considered effective, as well as the third dike. Maybe, it will be effective to cultivate salt tolerant crops at the farmland between the high durability banking and the third dike.

2) Since the results from this project may be used to establish design guidelines/standards for future implementations of the disaster prevention farmlands (e.g. the 2nd inland dike, farm road, etc.), some more hydraulic modeling may be needed under different scales for further verification of the design guideline/standard for future coastal farmland prevention.

2. Countermeasure technique for tsunami floods:

1) As far as possible damage to the drainage pumping station is concerned, it is strongly recommended that the engines be placed above the highest water levels that can be expected. This would prevent damage, and retain the operation of the engines and the power supply. Maybe, one can think of positioning such station on a high durable bank.

3. Long-term storm-surge prediction:

1) In future projections of flood risk, not only the changes in typhoon patterns, but also the possible land subsidence in the protected area and sea level rise would have to be taken into account.

2) What the reviewers missed in the presentation was a wider view on the research presented. Who else is working on rare typhoons in Japan (the Japan Meteorological Agency (JMA) perhaps), with whom are you collaborating? How do you include the impact of potential climate change in these simulations?

The rating is: **A – good quality and minor revision needed.**

NARO Response to the Comments of the Evaluation Committee

1. Disaster prevention farmland:

1) Several dozens to several hundreds of years may pass until the next large-scale disaster takes place, so from a farmer's financial perspective, it is appropriate to plant high-yield crops, even in coastal areas. The data collected for long-term after the Sumatra earthquake and tsunami and the Great East Japan Earthquake should lead to the development of rapid recovery methods to desalinate farmland inundated after a tsunami.

2) It is essential to mitigate the damage by properly arranging facilities for agriculture. In order to develop guidelines, it is required to clarify the characteristics of each facility. Thus, an evaluation has been conducted on the tsunami mitigation effect of farm roads and drains using a hydraulic model experiment.

2. Countermeasure technique for tsunami floods:

1) It is difficult to completely protect drainage pumps from flood damage caused by a tsunami, but it is essential to restore them as quickly as possible. Requirements for the height of electrical equipment installation have been added to the 2018 revision of the design standards for water-proof drainage pump stations. The construction of drainage pumping stations that can prevent inundation damage are expected in the future.

3. Long-term storm-surge prediction:

1) It is difficult to predict future subsidence, but the impact of rising sea levels as a result of climate change should be taken into account.

2) The Meteorological Research Institute and the Japan Agency for Marine-Earth Science and Technology make global climate change predictions in Japan. The Disaster Prevention

Research Institute, Kyoto University, conducts downscale simulations using regional models for typhoons in Japanese coastal waters and provides the data required for coastal disaster research. These research organizations are linked through research projects funded by the Ministry of Education, Culture, Sports, Science, and Technology, and research integrating the impact of climate change is progressing.

Section 2:State-of-the-art technologies on land consolidation and water management

Project 2-1 Subsurface water level control system and remote-controlled on-farm water management system as new paddy field irrigation technologies

This project concerns an innovated sub-irrigation and automation scheme that may be automated and use precious water supply more efficiently. This may also be a relief to current labor aging and shortage problems in rural Japan. This project is considered to be a good one to couple with the MAFF goals.

The software and hardware parts have been well studied and established, but some more analysis in the financial/economic feasibility study may be needed. The use of pumping water for grain-crops irrigation may become a dilemma to the current Society 5.0 campaign to link with the UN SDGs.

Several recommendations and suggestions are listed below.

1. Further research for applying the systems in practice:
   1) It will be more convincible if an economic analysis and the scalability studies were included. In the current extension to the 12,500 ha, what is the average farm size? Is any aggregation among neighboring farms possible to make a bigger farm size? This may also be a good response to the current MAFF goal of enlarging farm size.
   2) It would be useful to investigate in which way cost savings in the application of the system can be obtained, considering that the FOEAS can only be implemented in practice when a high government subsidy (90 %) is being made available.
2. Collaboration within the program:
   1) This project is recommended to be integrated with the automation system developed in project 2-2 for more synergic results.

The rating is: **A – good quality and minor revision needed.**

NARO Response to the Comments of the Evaluation Committee

1. Further research for applying the systems in practice:
   1) Japan has a collection of land improvement projects that are funded by the nation and prefectures. One of these is the land reclamation project that includes the expansion of field

plots, and the refurbishment of irrigation and drainage systems. A plot size formed by the project is roughly 0.3 – 1 ha of flat to gently sloping land and 0.2 - 0.3 ha of steeply sloping land. The subsurface water level control system (FOEAS) is introduced in these fields.

Expansion of field plots by the accumulation of neighboring farmland is implemented through the above land reclamation project, irrespective of the introduction of the FOEAS. Introduction of the FOEAS in the project depends on the soil and the preference of the farm owner. Subsurface drainage without underground irrigation may be chosen instead.

2) The FOEAS is a technology that provides underground irrigation to subsurface drainage. Subsurface drainage has been introduced for many years in highly subsidized land reclamation projects and the FOEAS will be introduced for similar projects. The construction cost of the FOEAS is around 1.2 times of subsurface drainage. We want to reduce cost once there is an increasing number of farmers who wish to introduce the FOEAS at their own expense.

2. Collaboration within the program:

1) Agreed. We would like to investigate the operating methods when an automatic water supply control system is introduced in a FOEAS field.

Project 2-2 Reorganization and restructuring technologies of canal water delivery system

The proposed smart and automated irrigation management system may be an answer to the shortage and aging of the rural labors as well as the more efficient use of the limited water resource. Regarding the Supervisory Control And Data Acquisition (SCADA) system, it is a widely applied and proven system. Therefore, there may be trust that the system can be effectively applied in Japan.

It is understood that water resources become more limited and that there will be more competition for water. Therefore, efficient water use will be an important item in the operation. On the other hand, farmers are expected to diversify their cropping pattern and to achieve higher yields. This implies that they will apply more fertilisers and pesticides, which may result in water quality problems.

Several recommendations and suggestions to the project are listed below.

1. Further research for applying the Irrigation and Drainage Automation System (iDAS):

1) There are a large number of sensors used in this system. A sensor maintenance and re/calibration, and sensor malfunction detection scheme need to be researched and established to guarantee the system functionality.

2) Like in Taiwan, some irrigation systems may have an open-tree like hierarchical relationships and the farm irrigation is under system planning with less irrigation decision freedom (the irrigation canals may not always have water supply available for irrigation). Temporal

storages (pond or pressurized tank) may be needed to implement a system like the one proposed in this project.

2. Further research for more efficient water management:

1) Land Improvement Districts (LID) are to a large extent in charge for the operation and maintenance of the irrigation and drainage systems. They are organized around irrigation canals, which is good. At present there are about 5000 LIDs. With an agricultural area of about 45,000 km2 this implies an average area of 9 km2 per LID. It may be expected that LIDs increasingly will have to deal with water quality aspects and with drainage as well and that water quantity and water quality management will become more integrated. In fact, many developed countries are already in the stage of integrated water (resources) management. In light of such developments, it may be expected that an area of 9 km2 is too small for effective operation and maintenance, and that in the future, larger units will be required. Research to identify optimal areas for LIDs could be encouraged. Such research could make use of the present experiences with the SCADA system.

The rating is: **A – good quality and minor revision needed.**

NARO Response to the Comments of the Evaluation Committee

1. Further research for applying the Irrigation and Drainage Automation System (iDAS):

1) The existing system is already equipped with a simple failure detection system, but the types and the number of sensors used in future research are expected to increase. As a result, the indicated maintenance, management, calibration, and risk of failure are expected to increase. Therefore, we plan to continuously collect data on the durability and maintainability of the sensors and the system, and to investigate the development of technology to discover and counter problems during our ongoing empirical research.

2) The purpose of this system is to resolve water distribution management issues that occur at an upper-level of the management, beyond the level of individual farmers, as you indicated. We are aware that temporal storage is a key factor to secure flexibility in water distribution. We are also planning to conduct research on methods to determine the optimal capacity of facilities for system operation, and methods to optimize the operation of existing facilities.

2. Further research for more efficient water management:

1) The scale of beneficiary land area managed by LIDs in Japan varies quite widely from 50 ha to 10,000 ha (0.5-100 km2) per LID.As of 2018, 71 LIDs haves a beneficiary area exceeding 5,000 ha (50 km2). Currently, most of the beneficiary areas, in which a renewal land improvement project is carried out, still encounter problems that require the promotion of comprehensive water management for both water volume and water quality. Therefore, from a research perspective, we want to continue to support LIDs through development of water

distribution technology based on the SCADA. We also want to be proactively involved in addressing problems related to administrative measures for resource management in agricultural basins, and to transmit information accordingly.

Project 2-3 Developing and promoting the spread of farming drainage techniques

The tractor attachments developed in this project have been tested for domestic and foreign extensions, and found to be effectively useful in constructing underground drains for upland cultivation on paddy farms. It was found that this device is not practically usable for sandy and gravel soil, but it is okay because most of the original paddy fields are more clayey and farms with sandy soil have less drainage problems.

1. Alternative approach to field drainage:

1) Surface drainage improvement to reduce the chance/duration of inundations on farms and so mitigating the underground drainage needs may be another solution for cultivation of upland crops in paddy fields. This is the current situation of farms with rotational cropping pattern (alternating paddy and dry crops) in Taiwan.

Photo: provided by Prof. Su

The rating is: **S – high quality and no revision needed.**

NARO Response to the Comments of the Evaluation Committee

This technology was introduced as one of the improving of soil drainage with an underground drainage system. We are currently developing and commercializing a line-up of soil layer improvement technologies to deal with soil conditions that are an impediment to production.

1. Alternative approach to field drainage:

1) We learned about the implementation of rice and upland crop rotation using practical surface drainage, which is a technique widely integrated in Taiwan. Surface drainage is also a major technology in Japan. We are working on a combined and separate use of surface drainage and underground drainage.

Section 3: Efficient management and utilization of regional resources in rural areas

Project 3-1 Prediction of drought and inundation in a changing environment

The state of development of NARO's own hydrological distributed model was presented and illustrated with simulation results from selected catchments in the project. One of the main challenges faced by NARO's hydrologists in modelling the rainfall-runoff hydrology at catchment scale is linked to the large anthropogenic activities of Japanese catchments, where upstream areas are heavily influenced by reservoir storage and downstream areas are strongly impacted by irrigation withdrawals for paddy fields. To deal with anthropogenic activities, it was necessary to adopt either a semi-distributed or a distributed approach, and the model presented is indeed distributed (based on square grids topologically linked according to topography), and includes both reservoir storage modules and irrigation accounting modules. To cope with lack of actual measurements in these modules (for many of the reservoirs the actual inflows and releases are not known, for the paddy fields the pumped amounts are not known), NARO's hydrologists had to model the average behaviour of paddy irrigation. The results which were presented to us compared favourably to the hydrologic measurements.

Changes in drainage patterns due to larger plots have been analysed, as well as impacts of climate change. With respect to this project, it may also be relevant that the Climate Change Adaptation Act will become effective by December 2018.

The model didn't include land uses and water demands other than agriculture. The omissions of the interactions among sectors may be a major deficiency.

There are some recommendations and suggestions as follows.

1. Refining of the model:

1) Japan is one of the most densely populated developed countries in the world. Thus, it may be expected that in the periods that are being analysed in the model, much more changes will take place than just changes in plot size and in impacts of climate change. Therefore, it is recommended to pay attention to all foreseeable changes in the river basins that will be analysed with the model, and to consider not only the water quantity but also the water quality aspects.

2) In addition, there is increasing considerations with respect to environmental flow in river basin management in developed countries. Such aspect would also have to be considered in the application of the model.

3) It seems that the inundation modeling was done with a hydrological instead of hydraulic model. If so, the results may not be realistic.

4) The flooding problems are catchment related, and the drought problems may be manipulated/mitigated by water management/reallocation among catchments and/or water use sectors. The natural disasters of flood and drought have very different characteristics and it may be difficult to study in a single model to get detailed insights for building a decision support information system.

5) Drought risks are much more complicated than flooding because it may be deeply influenced by water resource management. Drought may be predicted in a general hydrological sense,

but allocation or reallocation of limited water supplies may mitigate the impacts.

2. Suggestions in applying the model:

1) It is suggested that long-term forecasts (especially as used in water supply studies) be more conservatively used.

3. Collaborating with other institutions:

1) While several developments in a river basin are outside the scope of agriculture and require input and/or commitment of other disciplines, it is recommended to undertake further development of the model in cooperation with other relevant institutions. The integration as followed in Project 1-1 may serve as an example of such a cooperation.

2) We would have been interested to hear more how this model compares to other Japanese hydrological models such as, for example, the Real-time Flood Risk Map implemented by the JMA (https://www.jma.go.jp/en/suigaimesh/flood.html).

The rating is: **A – good quality and minor revision needed.**

NARO Response to the Comments of the Evaluation Committee

Current version of the model is based on a fixed catchment environment (land use, population, industrial water use), but the changes in catchment environments are important to consider for future development. The details are presented in the responses below.

1. Refining of the model:

1) We are currently working on building a model that expresses long-term (150 years) changes in past and future water uses (including population and industrial water demand) to elaborate the impact of long-term climate changes. Water quality in agricultural areas was actively studied from the 1990s to the 2000s, and the countermeasures were adopted accordingly. At present, no major issues have been detected except endorheic basins. Thus, the priority for modeling water quality in this project is low, but continuous monitoring of water quality in endorheic basins has been conducted.

2) Environmental flow has been increased for the past decades due to growing environmental awareness. Increases in the environmental flow may affect the drought risk assessment. Therefore, environmental flow was included in the current model.

3) We use different types of models depending on the purpose: grid-based hydrological models for drought risk assessment and hydraulic models for flood risk assessment of lowlands.

4) As mentioned in 3), we use different types of models depending on the purpose. The models and data are also optimized to meet the required accuracy for each application. Decision makers use model-based evaluation as one of important reference information for decision making.

5) As water management procedures by human (reservoir operation, water intake operation from

rivers, etc.) were incorporated into the model developed in this project, it can be a very effective tool in drought risk assessment and scenario analysis for water resources management.

2. Suggestions in applying the model:

 1) We are currently working on projects using relatively accurate short-term predictions (from hours to days) of numerical weather models for water management and flood prediction. Fundamental research for the use of longer weather prediction (months) that have a large degree of uncertainty is ongoing to investigate the applicability.

3. Collaborating with other institutions:

 1) A project on the flood risk assessment in low-lying farmland using real-time rainfall data provided by the JMA is ongoing. In this project, the results will be provided to the SIP4D, similar to project 1-1. The data will be used to determine evacuation routes during or after torrential rain.

 2) The model presented by the JMA evaluates the “basin rainfall index” that indicates the risk of flooding from rivers (water overflowing levees). The basin rainfall index is calculated using a lumped rainfall-runoff model with a simple hydraulic calculation based on uniform flow.

 Conversely, the system developed in this project is to predict flooding within a levee (inundation of low-lying farmland by poor drainage to rivers). The risk of flooding within a levee is assessed based on spatial distribution and elevation of farmland using a grid-based hydrological model, and two-dimensionally displayed.

Project 3-2 Investigation techniques of groundwater flow dynamics for rural groundwater management

The presented method concerns groundwater analyses related to landslides. The method that is applied here is quite unique in Japan. The method plays a role in the implementation of the Landslide Prevention Act of 1958. In relation to it, a new sampling technique has been introduced. It is understood that the method is effective and would have to be widely applied. While landslides and related damages are problems in Japan, such development needs full support.
Several recommendations and suggestions are listed below.

1. Causes of the landslides:

 1) Groundwater may not be the principal factor causing landslides (e.g. rainfall pattern and land use)

2. Collaboration outside the NARO:

 1) The reviewers would have been interested to hear more concerning the wider context of landslide studies in Japan. Indeed, the JMA has a real-time landslide map

(https://www.jma.go.jp/en/doshamesh/index.html) and it would be interesting for us to know whether you have experience using this map, and whether NARO's science could contribute to its improvement etc.

The rating is: **A – good quality and minor revision needed.**

NARO Response to the Comments of the Evaluation Committee

Determining the groundwater flow mechanisms that trigger landslides is important to implement appropriate and rational measures against landslides. Environmental tracers are also important and useful tools to achieve this goal.

1. Causes of the landslides:

1) Landslides are generated by the addition of "trigger factors" such as groundwater or earthquakes to "structural factors" such as the topography and geology. Groundwater as a trigger factor becomes problematic because the groundwater pressure (pore water pressure) elevated by infiltration of rainfall and melting snow reduces the effective stress on the sliding surface. Rainfall patterns and the land use prone to water infiltration are related to landslides, and therefore it is essential to evaluate how these factors ultimately affect the elevation of groundwater level and pore water pressure. Clarifying the groundwater recharge from the surface, including rainfall patterns, and the subsequent flow mechanism is an important research topic for landslides.

2. Collaboration outside the NARO:

1) Research on landslides includes topographical analysis, slope stability analysis and displacement observations using GPS from the perspective of slope stability. Research is also conducted on the impact of hydrological groundwater processes on the occurrence of landslides. This includes monitoring of groundwater levels and pore water pressure, hydrogeological characterization, geophysical exploration, analysis of groundwater flow, and research using the environmental tracers we introduced earlier. A large number of techniques are used because of the anisotropy of groundwater flow, which depends on the complex geological environment of slopes. The environmental tracer method is considered to be an effective method for directly ascertaining the flow of groundwater.

Landslide Risk Map published by the JMA mainly shows the risk level of soil failure on the surface of the slope and debris flow using the index on the amount of rainfall that has accumulated in the soil. It does not address landslides generated at a deeper layer or mountain collapse. Although a direct link with this risk map is currently not confirmed, we would like to promote an appropriate collaboration with other organizations for research and dissemination of research results.