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IRRIGATION AND DRAINAGE IN KOREA AND ICT APPLICATIONS†

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ABSTRACT

Korea has a long history in rice cultivation and paddy field irrigation. Although Korea has suffered from colonial era and the Korean War during modern history, it has overcome poverty and constructed modernized paddy irrigation systems with information and communication technology (ICT) for achieving rice self-sufficiency. Government driven policy for agricultural infrastructure construction and large-scale agricultural land and water development projects has played a great role along with the rapid economic growth to establish nationwide modernized irrigation systems. In this paper, to provide understanding of Korean irrigation and drainage circumstances, irrigation history in Korea is briefly explained and irrigation and drainage status is introduced. ICT applications for agricultural water resources management is explained with advanced technology adaptation examples. Even though Korea is one of the leading countries adapting advanced irrigation technologies, climate change and operation and maintenance issues exist and ICT is utilized to overcome those challenges. Copyright © 2015 John Wiley & Sons, Ltd.

KEY WORDS: Korea irrigation; drainage; ICT application

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RÉSUMÉ

La Corée a une longue histoire dans la culture du riz paddy et l'irrigation des champs. Bien que la Corée ait souffert de l'époque coloniale et la guerre de Corée au cours de l'histoire moderne, elle a surmonté la pauvreté et construit et modernisé les systèmes d'irrigation des rizières avec la technologie de l'information et de la communication (TIC), au point d'atteindre l'autosuffisance en riz. Les politiques gouvernementales de développement de l'eau agricole à grande échelle, axées sur la construction d'infrastructures agricoles et sur les projets fonciers, ont joué un grand rôle dans une croissance économique rapide et la création à l'échelle nationale des systèmes d'irrigation modernisés. Dans cet article, l'histoire de l'irrigation et du drainage en Corée est brièvement expliquée avant de montrer comment les des TIC –en tant que technologies de pointe- sont appliquées à la gestion des ressources en eau agricole. Même si la Corée est l'un des principaux pays ayant adopté des technologies d'irrigation avancées, il n'en demeure pas moins que le changement climatique et les questions de fonctionnement et d'entretien existent. Les TIC seront utilisées pour surmonter ces défis. Copyright © 2015 John Wiley & Sons, Ltd.

MOTS CLÉS: Corée; irrigation; drainage; application des TIC

INTRODUCTION

The Korean Peninsula is located at the far-east of Asia, while it has a quite sound condition for agriculture with four vivid seasons and moderate temperatures. It was reported from excavated relics that rice cultivation started about 1000 BC.

Korean Peninsula is in the monsoon area so that the wet and dry seasons repeat every year with seasonal variation of precipitation requiring irrigation and drainage systems for stable agricultural activities. Usually, June through August is the wet season, while most of yearly rainfall occurs during this period, and the other 9 months have about 30% of the annual rainfall. Most crops are cultivated during March to October, except for protected farming and winter crops.

Rice is the most important grain as the staple food of Koreans since rice has been introduced. The enhancement

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of agriculture and irrigation of paddy fields have been a principal responsibility for governing the country in Korean history. When the country was faced with hardship accompanying destabilizing social movements or starvation due to natural disasters, such as droughts and floods, the government has attempted to ameliorate these disasters by constructing new irrigation systems or rehabilitating existing ones.

Korea in the present days, as one of the information and communication technologies (ICT) leading countries, use of ICT applications for agricultural water resources management is being made due to its benefits in terms of efficiency improvement and cost effectiveness.

In this paper, to provide understanding of irrigation and drainage circumstances in Korea, irrigation history is briefly explained and irrigation and drainage status is introduced. Also, ICT application cases for agricultural water resources management is demonstrated as the advanced technology adaptation examples.

GENERAL INFORMATION

South Korea occupies the southern portion of the Korean Peninsula, which extends some 1,100 km from the Asian mainland. This mountainous peninsula is flanked by the Yellow Sea to the West, and East Sea to the East. Its southern tip lies on the Korea Strait and the East China Sea. South Korea has a humid continental and subtropical climate, and is affected by the East Asian monsoon, with precipitation heavier in summer during a short rainy season, which begins at the end of June through the end of July. Winters can be extremely cold with the minimum temperature dropping below -20 °C in the inland region of the country: in Seoul, the average January temperature range is -7 to 1 °C, and the average August temperature range is 22 to 30 °C. Winter temperatures are higher along the southern coast and considerably lower in the mountainous interior. Summer can be uncomfortably hot and humid, with temperatures exceeding 30 °C in most parts of the country. South Korea has four distinct seasons; spring, summer, autumn and winter. Spring usually lasts from late-March to early May, summer from mid May to early September, autumn from mid September to early November, and winter from mid November to mid March.

Rainfall is concentrated in the summer months of June through September. The southern coast is subject to late summer typhoons that bring strong winds and heavy rains. The average annual precipitation varies from 1,370 mm in Seoul to 1,470 mm in Busan. There are occasional typhoons that bring high winds and floods (Wikipedia.org (Climate of South Korea)).

BRIEF IRRIGATION HISTORY UNTIL 1945

(Korea Rural Community Corporation (KRC) and Korean National Committee on Irrigation and Drainage (KCID), 2014)

Even though rice cultivation in Korea seemed to have started around 1000 BC, records about structural construction as the national projects for irrigation and drainage systems can be found from 60s BC, the periods when the ancient countries were established. The main stream of irrigation and drainage history in Korea concerned basically struggling with floods and droughts to obtain stable food supply, by relying on the ideology that farmers are the fundament of heaven and earth, in Korean 'Nong-ja-cheon-ha-ji-dae-bon'.

Until the modern era, Korean history can be divided into five different periods based on the successive dynasties, agricultural policies and projects as explained for each period in Table I.

MODERN AGRICULTURAL INFRASTUCTURE DEVELOPMENT AFTER 1945

(KRC and KCID, 2014)

Korea unforgettably suffered from the Korean War during 1950 - 1953, 5 years after the end of 2nd World War, and free from the Japanese Colonial era. Almost all infrastructure and even arable farmland had been devastated during the Korean War and industry had largely collapsed. Also a state of social and political chaos left most Koreans in extreme poverty until early1960s.

The urgent agenda given to the new government established in 1961 was to stabilize State affairs by the control of public sentiment. However, the most urgent problem at hand was to establish food supplies. Every spring serious food shortages rampaged through both urban and rural centres because of the occurrence of consecutive droughts. Other than natural disasters, a number of other factors contributed to food shortages including poor agricultural infrastructure, shortage of investment, lack of advanced technology, agricultural materials, such as fertilizers and other agricultural chemicals, the lack also of agricultural machinery, etc. Due to this various government initiatives intended to increase agricultural production could not achieve their goals. Therefore, the government endeavoured to implement various drastic measures to rapidly achieve self-sufficiency of food production (KRC and KCID, 2014).

Since early 1960, the Korean government has strongly driven the national agenda for an economic development plan for every 5 years, including industrial development and large-scale agricultural infrastructure development. Because of this irrigation and drainage systems have been

Table I. Changes in Agricultural Policies and Irrigation and Drainage Projects Implemented before 1945 (KRC and KCID, 2014)

Period	Agricultural policies	Irrigation and drainage projects
Three Kingdoms Era (57 BC~AD 668)	• securing land, promotion of agriculture	• construction of reservoirs: Byeokgolje, Nulje, Hwangdeungje, etc.
	• emphasis on rice culture in AD 33 in Baeckje and further emphasis on irrigation	• rehabilitation of reservoirs • reclamation of lands
Unified Silla Dynasty (AD 668~935)	• establishment of an administrative division • reformation of the land system • promotion of agriculture	• rehabilitation of reservoirs and embankments
Goryeo Dynasty (918~1392)	• reformation of the land system	• rehabilitation and construction of reservoirs and embankments
	• land reclamation and establishment of harvest quota system	• tideland reclamation on Ganghwado Island in resistance to the Mongolian invasion of 1235
Joseon Dynasty (1392~1910)	• agriculture first policy • establishment of land system • promotion of rice transplanting	• construction of reservoirs and weirs (1781), total 3,378 nationwide, including Chukmanje, Gyeongyangji, Manseokbo, Jajeombo, Eojidunbo, etc. • institutionalization reservoir management with enactment of 'Jeeonjeolmok (formal manual for reservoir management, 1778) • attempt of land consolidation (1419): 'Jeongjeonbeop' (the Land Consolidation Act) • promote river embankment projects • establishment of first irrigation association (1908)
Japanese Colonial Era (1910~1945)	• implementation of land survey (1910)	• planning and implementation of long term irrigation development
	• planning for increased production of rice (1920)	• administrative reorganization and strengthening of rrigation system development
	• planning for rice production increase (1940)	• establishment of the Joseon Federation of Irrigation Associations (1940)

recovered rapidly, and rice self-sufficiency was achieved early 1990s along with economic success. The changes in agricultural policies and irrigation and drainage projects after 1945 are depicted in Table II.

BASICS OF AGRICULTURAL WATER USE IN KOREA

Korea has about 1 million hectares paddy rice fields and about 80% of irrigated paddy fields with over 63,000 agricultural water management structures (MAFRA, 2012). Reservoirs contain the main water resources for paddy fields and other structures including pumping stations and diversion weirs share about half of the agricultural water supply. Aging and a large number of irrigation facilities are burdens for operation, maintenance and sound management of agricultural water resources and it requires a breakthrough to solve the cost and labour demands.

Agricultural water use is typically concentrated during the end of April to early June for rice transplanting. Rice transplanting has to be accomplished before the start of the wet season, usually the beginning of the monsoon, so that every agricultural reservoir has to store the water for rice transplanting during the dry season right after the rice harvest. Figure 1 depicts monthly average rainfall and temperature in Seoul in comparison with the rice cultivation periods.

From the national water plan (Ministry of Construction and Transportation, MCT, 2006), agriculture consumes 160 billion m^3/year as a major water user among the industrial sectors with 47% water use ratio, about double of municipal water use (Table III).

STATISTICS OF IRRIGATION STRUCTURES IN KOREA

Agricultural dams for reservoirs and pumping stations are the typical main irrigation structures in Korea, and diversion weirs, pumping wells and infiltration galleries are usually used as auxiliary irrigation structures. Pumping stations take water from rivers and lakes. The large-scale pumping stations are generally operated for water uptake from lakes, which were formed by sea dikes for tidal land reclamation.

Total number of irrigation facilities in Korea was 69,323 in 2009. The number of pumping wells is 23,478 (33.9%) showing what is the most popular facility for paddy irrigation, though the irrigated area is smaller than the area served by reservoirs, pumping stations and diversion weirs. The

Table II. Post-1945 Changes in Agricultural Policies and Irrigation and Drainage Projects (KRC and KCID, 2014)

Period	Agricultural policies	Main issues and policies for construction of agricultural infrastructure
1945~ 1959	*Poor food supply and stabilization of grain price* • grain collection and price control • farmland reform (1949) • 3-year plan for increased agricultural production (1949~1951)	*Period of rehabilitation* • projects for restoration of irrigation and drainage • rehabilitation of war damages • expansion of irrigation and drainage facilities
1960~ 1969	*Construction of infrastructure systems for self-sufficiency of food* • increased farmers' income and food production • establishment of 5-year economic development plan • legislation of Framework Act on Agriculture (1967)	*Period of project launching* • legislation of farmland improvement projects • implementation of survey of resources for upland and tideland reclamation • intensive development of irrigation facilities (pumping stations and groundwater) • implementation of land consolidation to modernize of rural areas
1970~ 1979	*Agricultural policy for increased production* • enactment of the Saemaeul Movement* (1970) • stabilization of income and structural adjustment • continuation of stabilized agricultural production • self-sufficiency of staple grains (1977) • continuous growth of agricultural sector	*Period of project expansion* • launching large-scale comprehensive agricultural development: 13 projects Including Geumgang·Pyeongtaek Project, Yeongsan River Basin Agricultural Development Phase I Project • expansion of upland and tideland reclamation, and land consolidation projects
1990~ 1999	*Turning point of agricultural policies* • strengthening of competitiveness of agriculture • stabilization of agricultural production capacity • establishment of for 42 trillion won investment and loan program for agricultural sector (1991) • establishment of 5-year plan for new agricultural policy (1993) • legislation of Framework • Act on Agriculture and Rural Community (1998)	*Period of project rearrangement* • legislation and revision of related acts and laws • implementation of upland rearrangement project (1994) • adoption of large-scale units based land consolidation project • introduction of multiple use concept to farmland improvement project
After 2000	*Structural adjustment and support for FTA* • structural adjustments and establishment of welfare policies • strengthening of competitiveness of agri-food industry • legislation of special act in support of FTA (2004) • establishment of mid- and long-term plan for 119 trillion won investment and loan for agricultural sector (2004)	*Period of structural adjustment* • establishment of 5-year plan for improvement of life quality for farmers and fishermen (2005) • full revision of 'Act onRural Community Rehabilitation' (2007)

*The Saemaeul Movement was a political initiative launched to modernize the rural Korean economy based on Korean traditional communalism, which provided rules for self-governing and cooperation in traditional Korean communities. It was intended to rectify the growing disparity of the standard of living between the nation's urban centres, which were rapidly industrializing, and the small villages, which continued to be mired in poverty

*Source: Extracted from '50-Year History of Agricultural Policy', Korea Rural Economy Institute

number of agricultural reservoirs is 17,569 (25.3%) and pumping stations is 7,467 (10.8%). 18,114 diversion weirs (26.1%) and 2,696 infiltration galleries (3.9%) have operated for paddy irrigation (Figure 2). During the two decades from 1990 to 2009, the number of irrigation facilities has increased from about 57,600 to 69,324, with 11,724 facilities constructed (20.4%), while decreasing the number of reservoirs, diversion weirs and infiltration galleries, and increasing pumping stations and wells.

Agricultural reservoirs are the main irrigation facilities in Korea supplying more than half of the agricultural water to 453,000 ha paddy fields (56.2%) with 17,569 reservoirs showing that reservoirs are the main agricultural water source structure. However, 52.1% of the agricultural reservoirs were constructed before 1945, the end year of World War II, and about 90% of the reservoirs were constructed at least 40 years ago. Only 561 reservoirs (3.2%) were installed within 20 years ago (Figure 3). These statistics imply that agricultural reservoirs are suffering from operation and maintenance problems, including shortage of storage, spillway capacity and deterioration.

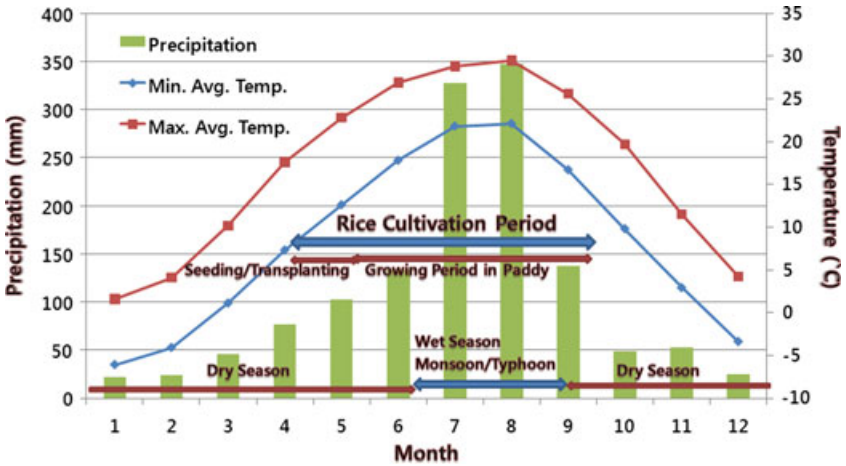

Figure 1. Monthly average precipitation and maximum and minimum temperatures of Seoul in reference to rice cultivation periods (Seoul)

Table III. Water use statistics about the industrial sectors (Unit 0.1 Billion Ton) (Ministry of Construction and Transportation, MCT, 2006)

Year	1965	1980	1990	1994	1998	2003
Total water resources	1,100	1,140	1,267	1,267	1,267	1,240
Total use	51.2	153	249	301	331	337
Municipal	2.3 (4%)	19 (12%)	42 (17%)	62 (21%)	73 (22%)	76 (23%)
Industrial	4.1 (8%)	7 (5%)	24 (10%)	26 (8%)	29 (9%)	26 (8%)
Agricultural	44.8 (88%)	102 (67%)	147 (59%)	149 (50%)	158 (48%)	160 (47%)
Environmental	-	25 (16%)	36 (14%)	64(21%)	71 (21%)	75 (22%)

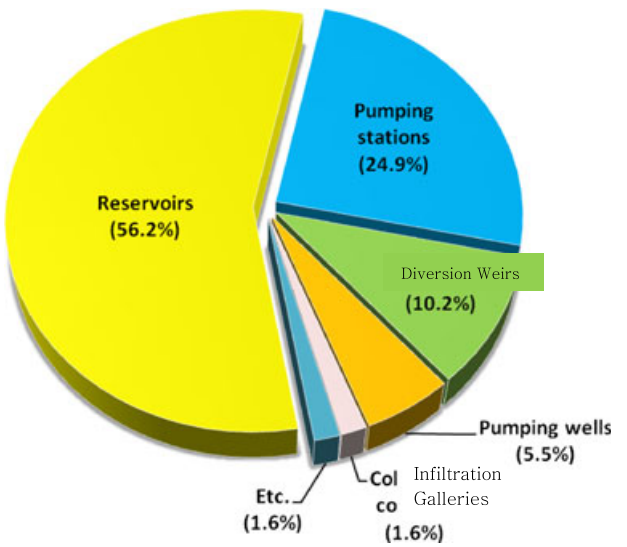

Figure 2. Ratio of irrigation area depending on the different water source facilities (MAFRA and KRC, 2012)

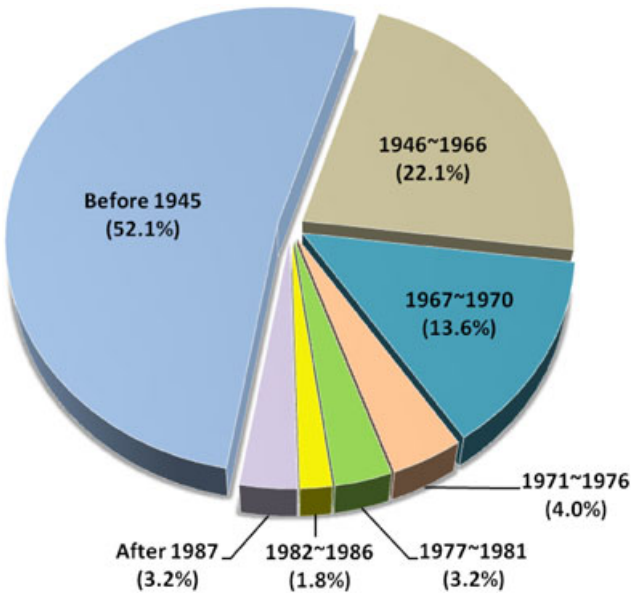

Figure 3. Ratio of number of reservoirs by construction year (MAFRA and KRC, 2012)

For paddy field irrigation, a larger number agricultural dams have been constructed compared to multipurpose and hydropower dams, but for most agricultural reservoirs the capacity is smaller than 100,000 cubic meters as demonstrated in Figure 4. It explains that a large number of small irrigation facilities is operated for small irrigated areas.

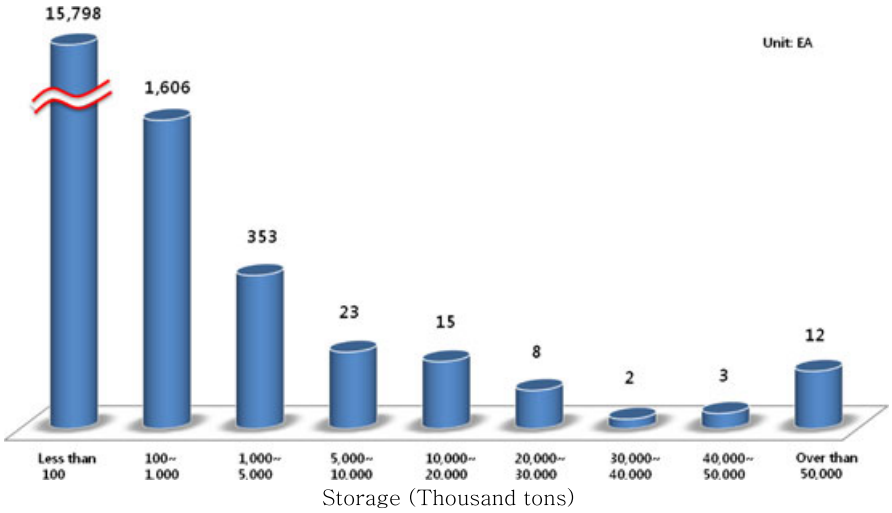

Figure 4. Number of agricultural reservoirs by effective storage (MAFRA and KRC. 2012)

Drought resistant capacity of water resource facilities is quite important because the structures have to supply irrigation water during the drought period. In Korea, agricultural water resource structures are designed to overcome a 10-year or more return period drought. The ratio of irrigation facilities that can resist 10-year or more return period drought is increasing. The percentage of number of facilities that can irrigate during a 10-year drought was 62.5% in 2009 from 39.4% in 1990, an increase of 23.1% due to large-scale structure construction and maintenance efforts.

In 2009, total length of irrigation canals and drains was 184,036 km with irrigation canals of 116,395 km (63.2%) and drains of 67,641 km (36.8%).

Irrigation canal and drain improvement is steadily implemented to increase irrigation efficiency. Earth, lined and flume canals are quite typical waterways for irrigation in Korea and drop, chute and gates are usually used for slope declining and water distribution in irrigation networks. Structured canal ratio has been increased due to the effort for irrigation efficiency improvement as shown in Figure 5.

ICT APPLICATION FOR AGRICULTURAL WATER RESOURCES MANAGEMENT

Korea is one of the ICT leading countries in the world, and the Ministry of Agriculture, Food and Rural Affairs (MAFRA) and KRC have been adapting ICT to agricultural water resources management. KRC, which is mainly in charge of agricultural infrastructure management in Korea has been operating ICT networks for irrigation structures monitoring and maintenance. KRC developed and constructed databases for water resources management, including surface water and groundwater. KRC monitors in more

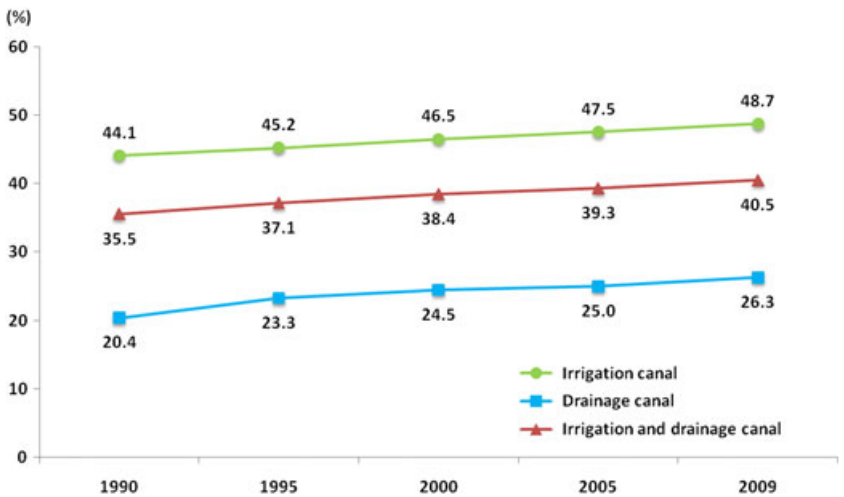

Figure 5. Ratio of structured canal during last 20 years (MAFRA and KRC. 2012)

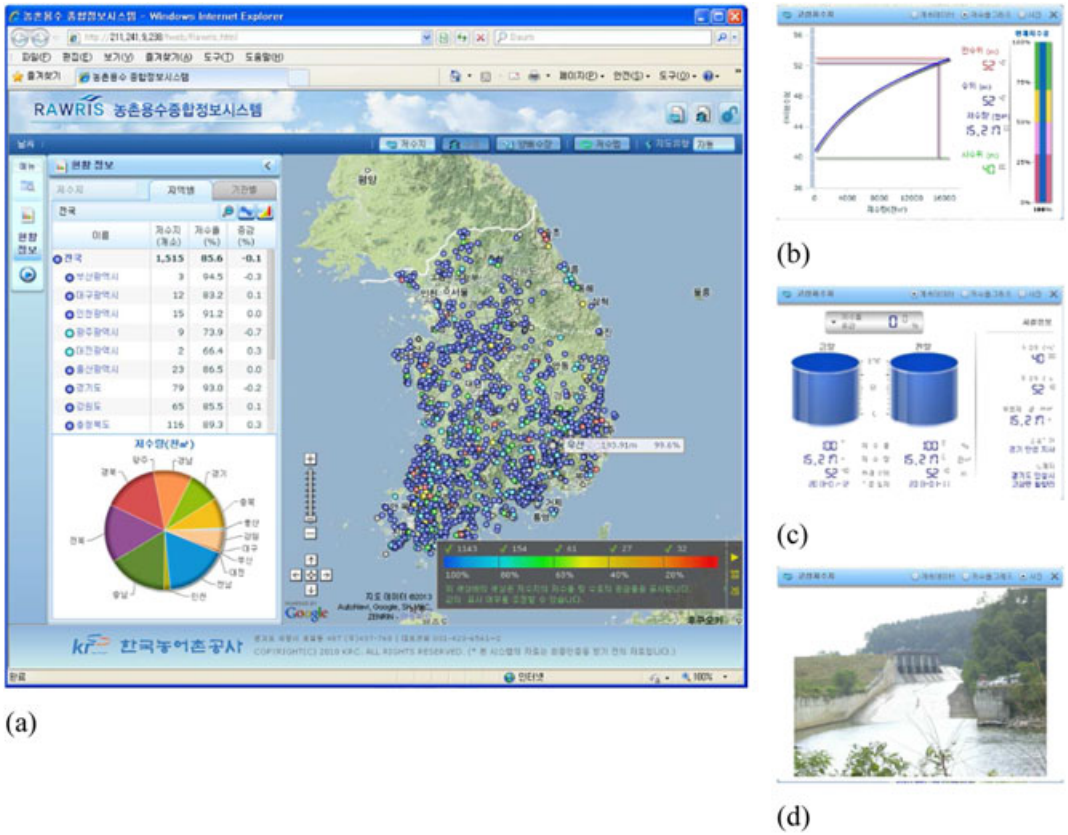

Figure 6. Rural Agricultural Water Resource Information System (RAWRIS) web page displaying reservoir location on GIS map and storages status in table/colour ((a): Main page, (b) A selected reservoir water level status, (c) A selected reservoir information, and (d) CCTV screen of a selected reservoir)

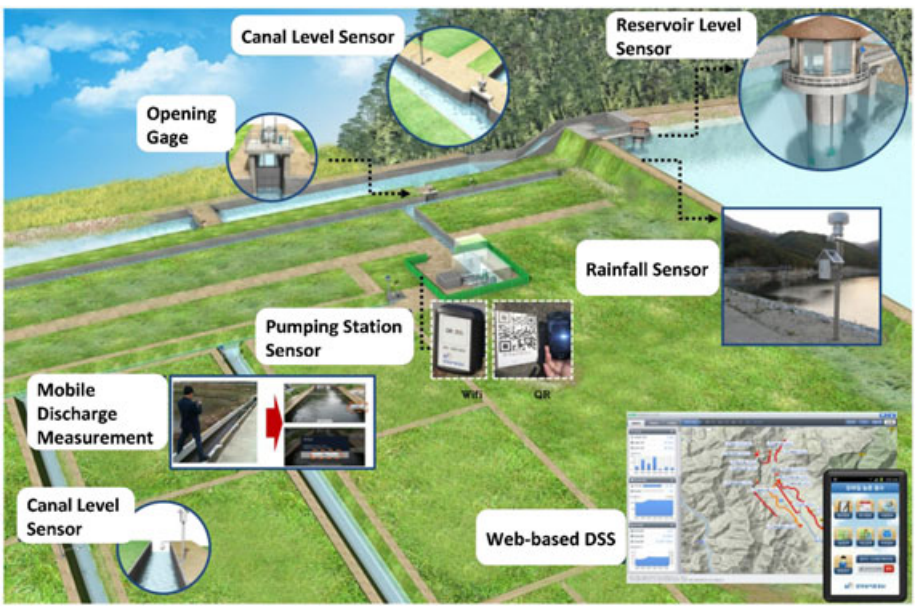

Figure 7. Schematic diagram of ICT irrigation management, smart irrigation

than 1,500 reservoirs the water level using level sensors and 3G wireless network and operates websites for irrigation information, including reservoir storage and irrigation scheduling. The Rural and Agricultural Water Resources Information System (RAWRIS) and Rural Infrastructures Management System (RIMS) are the KRC backbone databases for agricultural water resource structure management (Figure 6).

Smart agricultural water resources management systems have also been introduced in irrigation districts as the prototype projects managing and monitoring the irrigation system from the water resources to the irrigated fields. The smart agricultural water resources management system integrates data transmitted through a 3G wireless network from the water level sensors in reservoirs, canals, and rainfall gauges (Figure 7). Also, it gathers data from the meteorological stations and canal gate opening status. All those data collected through wireless and wired communication networks are stored in databases and analyzed and facilitate in the water management solutions to provide appropriate information for water management.

CONCLUSIONS

In this paper, irrigation history and status of Korea was briefly introduced. Korea has quite a long irrigation history since 1000 BC and a large number of modern irrigation facilities are operated for paddy field irrigation supplying water for rice cultivation. Although Korea has suffered from Japanese imperialism during World War II and the Korean War, the Korean government has poured great efforts to construct modernized irrigation systems to achieve stable rice self-sufficiency along to rapid economic development since 1960. Thanks to government driven policy, irrigation systems in Korea these days are armed with modernized and advanced technologies as a leading ICT country. Nevertheless, agricultural water resources structures can be vulnerable in operation and maintenance facing to aging and climate change. Those vulnerability can be summarized into five issues:

- large number of facilities to be maintained burdening in cost;
- aged and deteriorated facilities difficult to resist drought, flood and future climate change;
- varied sizes and capacities difficult to find adequate management solutions;
- scattered locations difficult to be managed adequately;
- mixing of different types of facilities difficult to find adequate maintenance solutions.

To overcome those issues, ICT can be an alternative solution and has been adopted vigorously to monitor and manage agricultural water resources. Databases and wireless sensor networks have been operating for smart agricultural water resource management to enhance water management efficiencies.

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