23rd Congress, Mexico City, Mexico 8-14 October 2017 Symposium

Global Review of Institutional Reform in Irrigation Sector for Sustainable Agriculture Water Management, including WUA South Korea

SeongJoon Kim*

본 논문은 올 10월 개최예정인 제23회 ICID 관개배수 멕시코 총회에서 “Global Review of Institutional Reform in Irrigation Sector for Sustainable Agriculture Water Management, including WUA”를 주제로 개최되는 심포지엄에 제출된 컨트리 페이퍼임.

1.0 Introduction

South Korea is located at the far-east of Asia, while it has a quite sound condition for agriculture with four vivid seasons and moderate temperatures (Fig. 1). It was reported from excavated relics that rice cultivation started about 1,000 BC.

South Korea 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 (Fig. 2). 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 (Fig. 3). Most crops are cultivated during March to October, except for protected farming and winter crops.

Rice is still the most important grain as the staple food of Koreans since rice has been introduced (Fig. 4). Table 1 shows the cultivation areas of rice paddy and dry crops from 2006 to 2015. Table 2 shows the standard ponding depth of transplanting method during rice cultivation (Jung et al., 2014). At present, the direct seeding types covers up to about 11 % (110,000 ha) of the total paddy areas. Now, the average rice

* ICID National Member of WG-IOA Professor, Konkuk University, Department of Civil, Environmental and Plant Engineering, #1 Hwayang dong, Gwangjin-gu, Seoul 05029, South Korea (kimsj@konkuk.ac.kr, Tel: +82-2-450-3749, Fax: +82-2-444-0186)

production is 5.0 tons/ha. However, the consumption of rice has been decreased by the change and diversity of food tastes (Fig. 5). Fig. 6 shows the area of vegetable greenhouse by type from 2005 to 2014. The paddy areas were occupied by the greenhouse expansion during 1990~1999 subsidy program of central government and the greenhouse on paddy still consistently increases. The farmers graying and the greenhouse farming increase of young farmers is now accelerating the decrease of rice cultivation. Under the situation, the direct payment to paddy rice farmers was introduced since after the 2001 WTO DDA (Doha Development Agenda). South Korea in the present days (2016) has 17,401 agricultural reservoirs, 7,890 pumping and drainage stations, and 44,848 weirs covering 440,807 ha, 193,087 ha, and 113,901 ha respectively (Fig. 7). The enhancement 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.

As one of the information and communication technologies (ICT) leading countries, the use of ICT applications for agricultural water resources management has been made due to its benefits in terms of efficiency improvement and cost effectiveness. Since 2001, the MAFRA (Ministry of Agriculture, Food and Rural Affairs) and the government agency KRC (Korea Rural Community Corporation) has invested in reservoir water level monitoring project, which targets at nationwide 1,570 agricultural reservoirs having effective storage above 0.1 million ton in order to watch reservoir flow, alert flood and control storage water for drought in real time (https://rawris.ekr.or.kr). KRC also has updated and modernized irrigation practices by introducing TM/TC (tele-metering & tele-control) technology. The project has been completed at 37 irrigation districts since 2001 will be invested until 2021 with total $0.5 billion. Recently during 2009 to 2015, total 113 agricultural reservoirs were rehabilitated to secure 0.28 billion tons of water for flood and drought prevention including stream management flow as part of four major river restoration project ($2.7 billion).

In this country paper, to provide understanding of irrigation sector in South Korea, the history of agricultural policy, institutional and organizational change, the present effort of PIM (Participatory Irrigation Management) and the future direction of irrigation and drainage for sustainable agricultural water management.

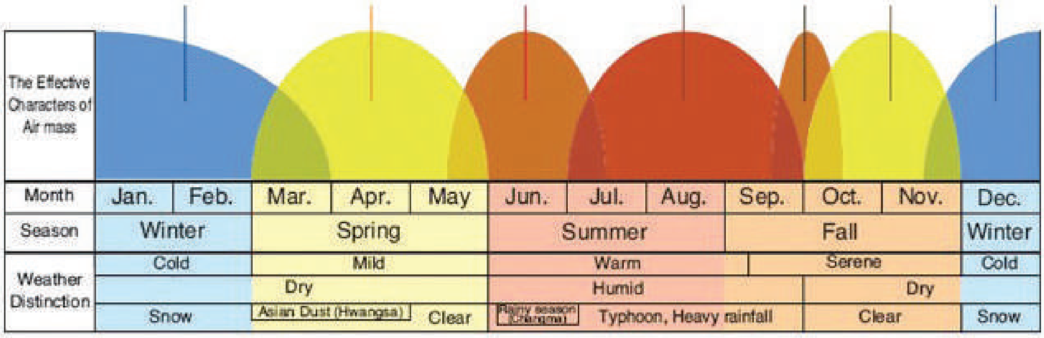


Fig. 1. Seasonal Climate Characteristics of South Korea (http://web.kma.go.kr/eng/biz/climate_01.jsp)

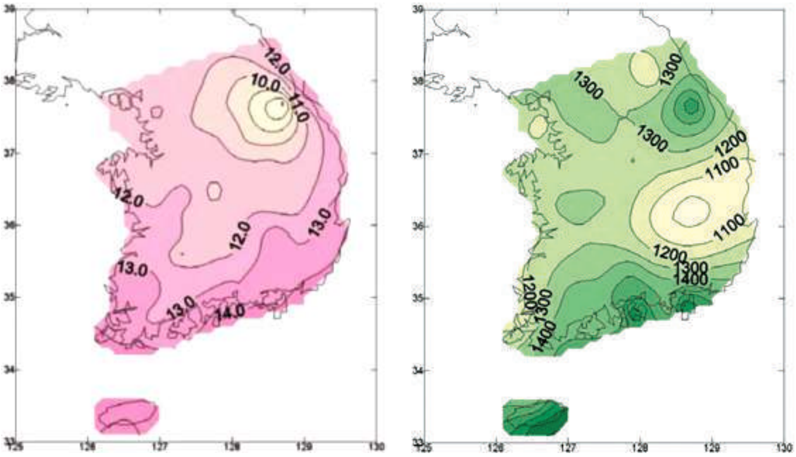


Fig. 2. Yearly normal mean temperature (℃) and precipitation (mm) of South Korea (http://web.kma.go.kr/eng/biz/climate_01.jsp)

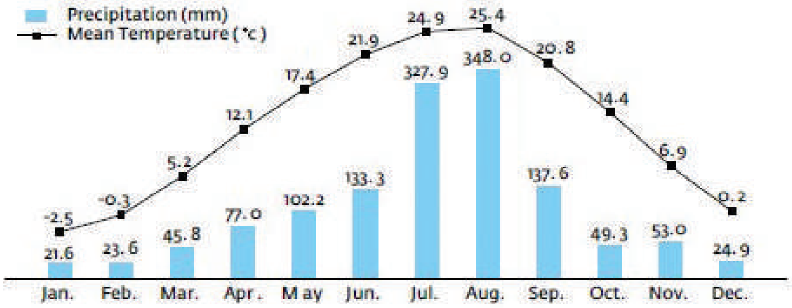


Fig. 3. Monthly normal mean temperature (℃) and precipitation (mm) in Seoul (http://web.kma.go.kr/eng/biz/climate_01.jsp)

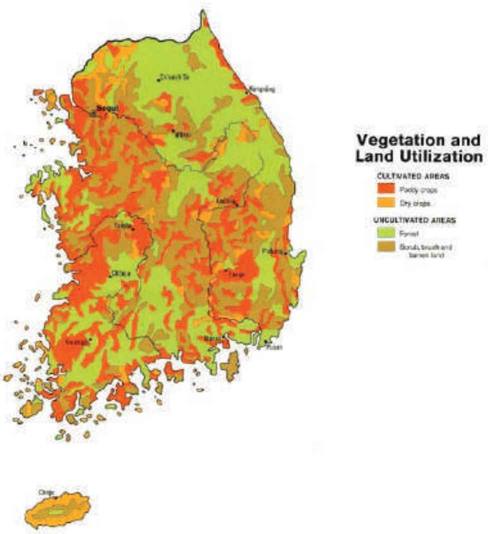


Fig. 4. Present cultivation areas in South Korea

Table 1. Trend of cultivation areas of rice paddy and dry crops from 2006 to 2015 (MAFRA and KRC, 2016)

Cultivation Area (1,000 ha)	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Total	1,800	1,782	1,759	1,737	1,715	1,698	1,730	1,711	1,691	1,679
Rice Paddy	1,084	1,070	1,046	1,010	984	960	966	964	934	908
Dry crop	716	712	713	727	731	738	764	748	757	771

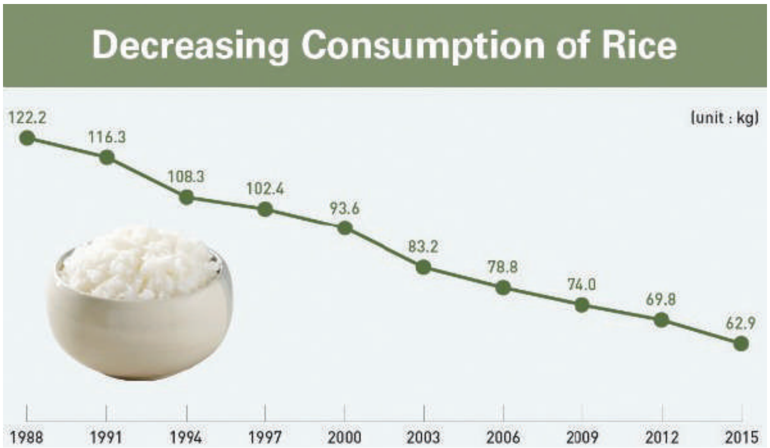
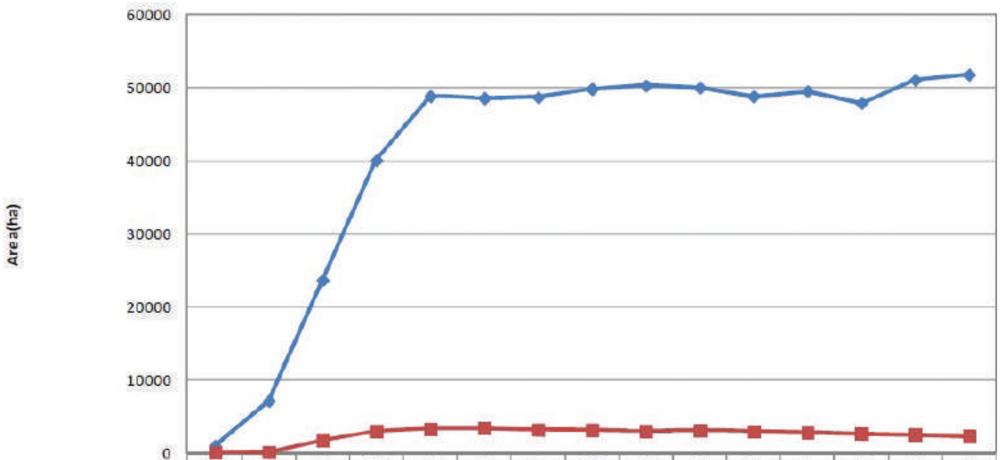


Fig. 5. Consumption of rice from 1988 to 2015 in South Korea (http://kostat.ko.kr)



	71	80	90	95	00	05	06	07	08	09	10	11	12	13	14
Vegetables	1014	7,141	23,698	40,077	48,853	48,574	48,680	49,828	50,297	50,024	48,835	49,537	47,924	51,058	51,781
Ornamental plants	91	180	1,752	3,054	3,336	3,448	3,232	3,208	3,063	3,112	2,994	2,856	2,674	2,553	2,381

Fig. 6. Area of vegetable greenhouse by type since 1971 (unit: ha) (MAFRA and KRC, 2016)

Table 2. Standard ponding depth of transplanting method during rice cultivation (Jung et al., 2014)

Date	5/11 –5/31	6/01 –6/30	7/01–7/31			8/01–8/20		8/21 –8/30	9/1 –9/10	9/10 –9/20
Growing stage	Trans–planting	Tillering	Panicle initiation/ booting			Heading/ flowering		Ripening/draining		
Observed ponding depth (mm)	132	50	34	58	86	38	74	103	3	0
Recommended by Government (mm)	60	40	0	60	60	60	60	40	20	0

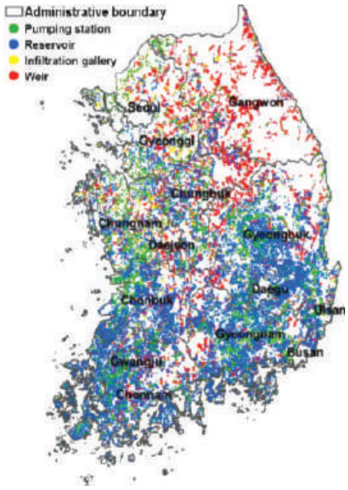


Fig. 7. Distribution of irrigation and drainage facilities in South Korea

2.0 Legal Frameworks

2.1 Review of institutional and organizational aspects of irrigation and drainage sector

Fig. 8 shows the institutional and organizational transition of irrigation and drainage (I&D) sector of South Korea from 1906 to present. Historically, the modern irrigation management started with the establishment of the Jeonbuk Water Users' Union in 1908. The beginning of I&D organization in Korea was 'Irrigation Union'. In 1938 after that, the federation of 'Irrigation Union' was founded as 'Land Federation'. Another one, 'Agricultural Land Corporation' was launched in 1942 as a government agency by merging ULIA (Union of Land Improvement Associations, 1962~1970) and GDC (Groundwater Development Corporation, 1969~1970). The 3 organizations was modified by the government law in 1962, civil law in 1962, and agricultural community modernization promotion act in 1970 respectively. In 2000, the 3 organizations were unified with equal rights to KRC (Korea Rural Community Corporation) to enhance operational efficiency of I&D sector and to strengthen services to farmers. At that time, the KRC was in charge of two third parts of the total irrigation areas with about 20% facilities and the remains were to local governments. The KRC raised operation and management (O&M) funds through profitable business, such as sales of irrigation water, lease of facilities and disposal of assets together with supports from central government.

Since the KRC organization, the irrigation water was provided free of charge and the operation expenses of KRC were totally supplied from the central government. The yearly water charge before 2000 was 5 kg of rice per 10 are. The farmers union is now existed as 'Managing Board of Representatives' with central board (14 farmers) and branch boards (1,139 farmers) nominally. Thus, the Participatory Irrigation Management (PIM) by the FLIAs farmers was almost disappeared since 2000 and the irrigation responsibility was totally transferred to KRC as the Public Irrigation Management (called PubIM in our case). Fig. 9 shows the present Public Irrigation Management Structure. Now, the farmers cannot participate in decision making for irrigation management in KRC areas and cannot elect union and regional office leaders. Because the KRC forms the boards, and nominates the central and regional representatives, now the farmers had no decision-making authority.

In 2000, even though South Korea has grown the GDP world ranking as 12th, the agricultural water use occupies about 65% with 35 % irrigation efficiency which is less than 38 % for the 93 developing countries in 1998. Under the particular situation of aging farmers, aging facilities, and pushback on the priority list by the government industrial policy, the KRC has strived to improve the management and operation efficiencies by introducing TM/TC (tele-metering & tele-control) technology.

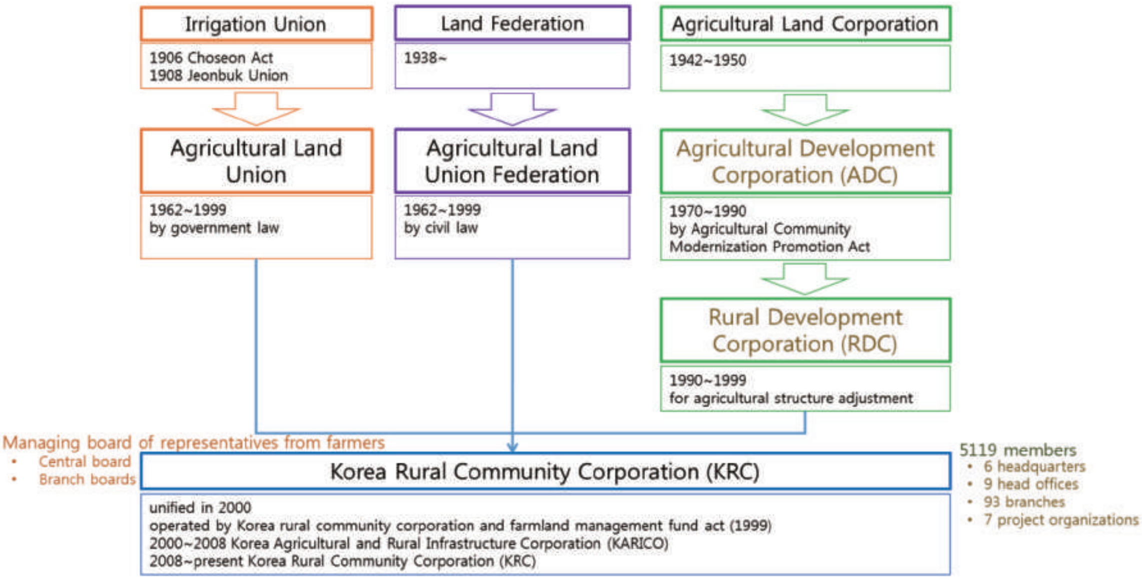


Fig. 8. Government Organization of Irrigation Management in South Korea since 20th Century

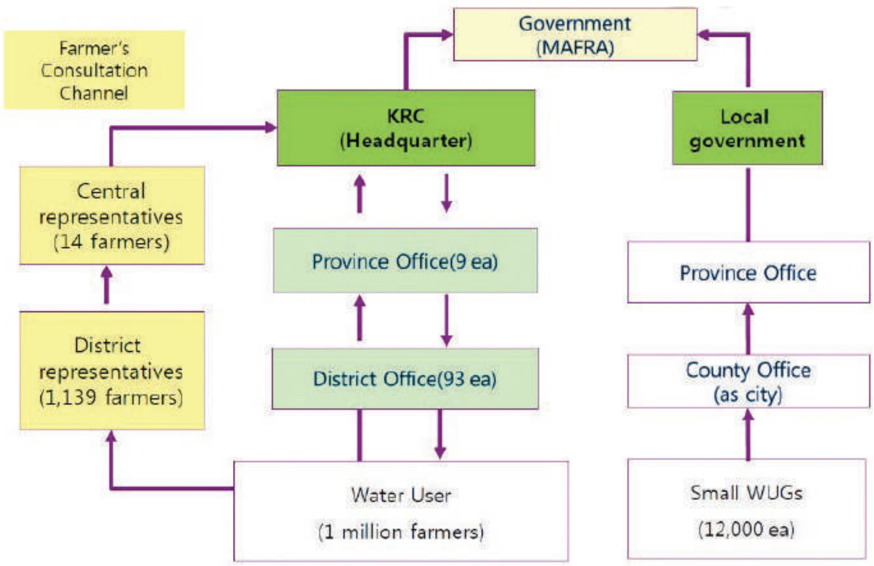


Fig. 9. Public Irrigation Management Structure since 2000 (Lee and Kim, 2011)

2.2 Issues and challenges related to land and water

Before telling about the issues and challenges of our future land water, we need to understand couple of things which have been affected to agricultural land and water in South Korea.

Firstly, 'Large scale project for integrated agricultural development' started in 1969 acquiring loans from IBRD, ADB, and OECF. Together with the graduation of GATT-BOP in 1989, the on-going large scale projects were continued with 100 % support of government subsidy. Almost the projects were conducted with land reclamation projects along the west coast. Presently still we have 2 large projects of Saemangeum (1991~) and Yeongsan (Phase I: 1972~1986, Phase II: 1976~2007, Phase III: 1985~, Phase 4: 2001~) river basin agricultural development (Fig. 10 and Fig. 11). With the aid of the projects, we accomplished 100% of rice self- sufficiency ratio by overcoming the population growth.

Secondly, as shown in Table 3, the government agricultural policy was turned to 'rural community' development from 'agricultural infrastructure' development since 1990 for farmers' protection from the coming GATT-UR and FTA, and rural life quality improvement. The 'Special Act for Rural Community Development' was enacted in 1990, and in 1991, a comprehensive plan of a 42 trillion won investment and loan plan for the agricultural sector during 1992~2001 was established. Thus, the budget for agricultural land and water development has been decreased by finishing the pre-existing large scale projects while the welfare budget for rural community development has gradually increased until present. The government legislated a Direct Payment Program for paddy field agriculture in 2000, a Direct Payment Program for compensation of income from rice in 2002, and a Special Act for Improved Quality of Life in 2005. At present, the rice and dry crop subsidies are about $850/ha and $360/ha respectively.

Thirdly, the environmental problem has become the social issue since 1990. The compensation for fishery rights by tideland reclamation, the value comparison between mudflat ecological system and agricultural land development impeded and retarded the project progress for a long time. In addition, the nonpoint source pollution from agricultural lands and point source pollution from rural communities are still the critical issue to prevent the water quality decline by increasing investment in BMP and village-unit sewage treatment facilities.

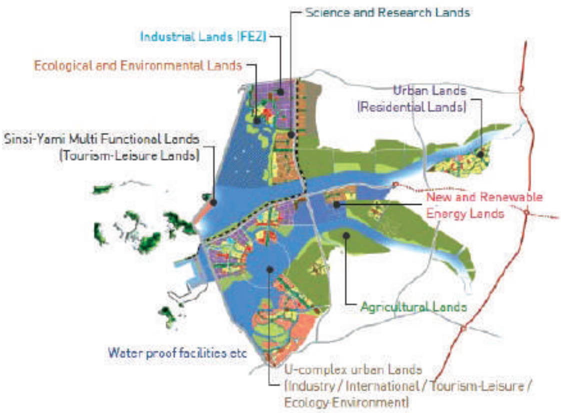
Lastly, the climate change approached to agriculture as a big threatening factor. The 2001 spring extreme drought for 3.5 months and the mega flood by Typhoons of 2002 Rusa and 2003 Maemi provoked to re-plan the irrigation and drainage infra for future climate change adaptation and mitigation.

The ICT application to I&D facilities has been the solution to implementation method.

With the above agricultural policy changes and factors to solve the future agricultural land and water problems, presently we need some new emerging issues and challenges for our national food security with safe, stable, and efficient I&D.

By the tendency of holding for rapid decrease of rice paddy area and gradual increase of dry crop area, we need some suitable irrigation system for cry crops using the existing irrigation networks and need to improve the irrigation efficiency by recommending drip irrigation system. For the increase of greenhouse cultivation by young generations, the farmers need all the year round customized irrigation water under their own water supply facilities, for example, personal groundwater development. Because of this kind of groundwater abuse for warmth keeping during winter periods cultivation, we need to recharge the used warmth keeping groundwater. This also will help to solve the stream drying phenomena which have been a social problem since 2000 by the increase of winter groundwater use, temperature increase bringing earlier spring, and dry spell increase during spring periods.

Recently, the smart farming boom using the fully controlled environment with ICT has been created. We can foresee that the smart farming and further smart crop production factory would be alternative solutions for our limited land and water problems. The 'smart' cultivation can be an attractive job market by accomplishing one's own little world water–food–energy nexus.



Division and facilities	Ratio (%)	Lands (km²)	Remark
Total	100.0	282.9	
Agricultural Lands	30.3	85.7	
U-complex urban Lands	23.8	67.3	Industry / International / Tourism-Leisure / Ecology-Environment
Industrial Lands (FEZ)	6.6	187.0	
Science and Research Lands	8.1	23.0	
New and Renewable Energy Lands	7.2	20.3	
Urban Lands	5.2	14.6	Residential Lands
Sinsi-Yami Multi Functional Lands	0.7	1.95	Tourism-Leisure Lands
Ecological and Environmental Lands	15.0	42.4	
Water proof facilities etc	3.1	8.9	

Fig. 10. Saemangeum large scale project outline (www.isaemangeum.co.kr)

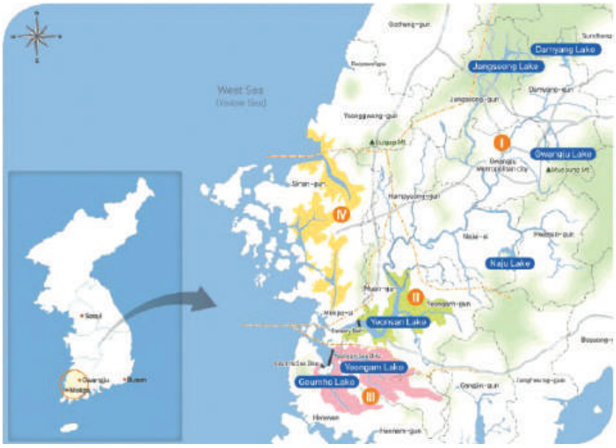


Fig. 11. Yeongsan large scale project outline (KRC and KCID, 2014)

Table 3. 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

1980~1989	Diversification of policy goals for staple grains • Persistent growth of agriculture and farmers' income • Stabilization of food production • Improvement of rural structure • UR negotiation and import opening	Period of project diversification • Establishment of 10-year plan for development of agricultural water • Expansion and quality improvement of land consolidation projects • Farmland management fund and substituted farmland development system • Establishment of comprehensive measures for rural area (1986)
1990~1999	Turning point of agricultural policies • Strengthening of competitiveness of agriculture • Stabilization of agricultural production capacity • Establishment of for 42 trillion won investment & 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

2.3 Need for institutional and organizational structure reforms for sustainable water management

The present agricultural water situation in South Korea can be summarized as follows. The irrigation water became free of charge since 2000 by the government policy. The KRC has been working steadily to raise the irrigated paddy areas and now they reached to 80.6 % (752,598 ha) in 2014 statistics. Among them, 60.1 % has the capacity to endure 10-yr return period of drought. However, by the 11 times droughts (2000, 2001, 2006, 2008, 2009, 2012, 2013, 2014, 2015, 2016, 2017) since after 2000, the agricultural reservoirs frequently fell far beneath the average in their original capacity at the right time of irrigation needs.

By the economic disadvantage compared to other industry reaching to limitation for hard-infrastructure development, environment priority over agriculture, and climate change attack for infra itself, the agriculture is placed in a dilemma between holding operations for the present organizations and making a breakthrough by new emerging technologies (for example, drone monitoring, self-driving tractor, big data computing etc.).

Now, the management organizations of agricultural water resources and watershed streams are separated to Ministry of

Agriculture, Food and Rural Affairs (MAFRA) and Ministry of the Interior (MOI). For the integrated water resources management (IWRM) in agricultural sector, we need the organization unification of water management function between MAFRA and MOI to keep the always flowing streamflow from watershed to streams and secure the reservoir inflows for irrigation water requirements.

3.0 The Participatory Irrigation Management (PIM) in South Korea

3.1 The need of PIM and its approach

As mentioned earlier, the irrigation responsibility was totally placed on the government agency, KRC in 2000 by national law. Since 2000, the irrigation water has been converted to free of charge and the management and operation expenses of KRC were totally supplied from the central government. Thus, the Participatory Irrigation Management (PIM) chance was almost disappeared since 2000 and the remaining things are the irrigation channel mainly for branch channels and lateral turnouts employing rural peoples by KRC.

With this kind of situations, the irrigation water was supplied by the farmers' requests from reservoir managed by KRC and local governments, and reuses the discharged water to the downstream by using pumping stations. Because of the free water and the low efficiency of irrigation water, the KRC has converted the earth canals to concrete canals and introduced the TM/TC irrigation control system to enhance the water conveyance efficiency. Even this kind of government investment efforts, there are still difficulties for managing the automated lateral turnouts because the farmers are struggling to supply water first to his/her field and eventually break the turnout function. This causes the low irrigation efficiency even though the government invested the modernization of irrigation system during the past couple of decades.

Since 1962, South Korea has focused on the self-supply achievement of rice as a national policy. By the reason, the irrigation system has been developed for rice paddies and the irrigation system for dry crops was not well developed by the reason of small cultivation areas and the difficulty for the water conveyance to hillslope areas from stream or reservoir. Thus, the dry crop areas are still remained as irrigation vulnerable areas especially for spring drought periods.

Thus, we need two tracks of PIM recovery for rice paddies irrigation and dry crops irrigation. For the rice paddy PIM among the many approaches, one of the South Korea customized PIM can be the introduction of incentive granting program for the good maintenance of turn out based on the affiliated farmers or district unit. For the dry crop PIM, the co-utilization of groundwater well can be one of the way. However, most of the dry crop farmers are small hold farmers, KRC need to develop the well, and the water supply system and almost the whole operation cost need to be supported by the government.

Now, the irrigation management transfer (IMT) from local government to KRC is an emerging social issue for better I&D service. The irrigation sector managed by local government has received relatively low quality of service by the insufficient financial support from local government compared to the KRC. Thus, there was a recent study (Choi et al., 2016) for the IMT with an extensive survey with structured questionnaires. The survey results showed that most of the farmers, KRC members, and local government officials agreed with the IMT from local government to the KRC. However, the transfer of assets revealed divided opinions for the farmers' contribution to the maintenance of canals, including clearing water weeds and dredging ditches. In addition, some actions have to be implemented to improve irrigation management by encouraging farmers' participation under the public irrigation management (PubIM) system. These actions include reorganization of the discarded water management committee to revive the concept of PIM and direct subsidies for loyal farmers as an incentive for their labour.

3.2 Water use efficiency and Cost recovery

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 Fig. 12. In addition, the use of ICT applications for agricultural water resources management is being made due to its benefits in terms of efficiency improvement and cost effectiveness.

Table 4 shows the transition of irrigation water fee from farmers and Table 5 shows the constitution of irrigation management cost from water fee, subsidy from government, and revenue from FLIA (Farmland Improvement Association) before 2000. Since 2000, after the farmers' water fee was exempted, the O&M costs were provided by the central government and KRC. The O&M cost increased from $214 million in 2000 to $339 million in 2013. The cost share in 2013 was 36.6% for government and 63.4% for KRC. The KRC requests more government funds with the maintenance cost share between central government: local government: KRC: farmer of 4:3:2:1. According to a survey conducted by the KRC in 2007, 39% of farmers were willing to pay water fees of $60 per ha, which was about 10% of the total maintenance cost (Lee and Kim, 2011).

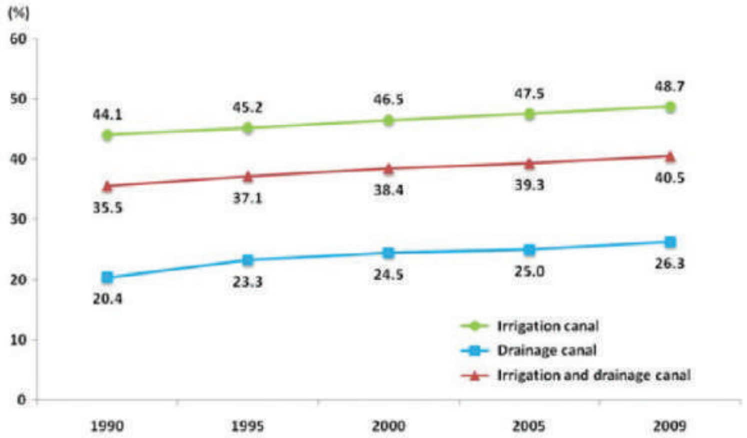


Fig. 12. Changes of structured canal during 1990~2009 (MAFRA and KRC, 2012)

Table 4. Transition of irrigation water fee from farmers (Lee and Kim, 2011)

Classification	Year	Irrigation fee
Before 1987 (Non Subsidy by Government)	1908~	- Establish Irrigation Association - **Collet Irrigation Association member fee(IAF)**
	1917~	- **Enactment for IAF** (Farmers say not IAF but Irrigation tax)
	1952~	- Permission parallel payment of IAF(Cash, Goods)
	1983	- **Setting maximum of IAF** Reservoir beneficiary area 25kg/10a Pumping station 30kg/10a Pumping & Drainage station 35kg/10a
After 1987 (Subsidy by Government)	1987~ 1989	- **Rejection and abolition demand by water user(farmer)** - **Rapidly reduction of IAF** ('87 25kg => '88 10kg => '89 5kg)
	1997	- Change to Cash(6 USD/10a)
	2000	- Abolition of IAF

Table 5. Constitution of irrigation management cost before 2000 (Lee and Kim, 2011)

Classification		1987	1988	1989	1999	2000
Standard of IAF (per 10a)		**Rice 26kg**	**Rice 10kg**	**Rice 5kg (89~95)**	**6USD (96~99)**	**-**
Irrigation management cost	**Irrigation fee**	**66%**	**23%**	**13%**	**8%**	**-**
	Subsidy by Government	7%	45%	61%	21%	30%
	Revenue by FLIs	27%	32%	26%	71%	70%

4.0 Challenges

4.1 Water Accounting and Auditing

The water accounting in agricultural sector of South Korea has not been properly treated. Since 2001, the MAFRA (Ministry of Agriculture, Food and Rural Affairs) and the government agency KRC (Korea Rural Community Corporation) has invested in reservoir water level monitoring project, which targets at nationwide 1,570 agricultural reservoirs having effective storage above 0.1 million ton in order to watch reservoir flow, alert flood and control storage water for drought in real time (https://rawris.ekr.or.kr). KRC also has updated and modernized irrigation practices by introducing TM/TC (tele-metering & tele-control) technology. The project has been completed at 37 irrigation districts since 2001 will be invested until 2021 with total $0.5 billion. Recently during 2009 to 2015, total 113 agricultural reservoirs were rehabilitated to secure 0.28 billion tons of water for flood and drought prevention including stream management flow as part of four major river restoration project ($2.7 billion).

4.2 Engineering challenges

South Korea is now preparing the forthcoming 4th industrial revolution (4IR) age by strong soft-infrastructure building. As already mentioned, the keyword in private sector is 'smart' by introducing summarized ICT. Since the technological foundation of the fourth Industrial Revolution is ICT, it is required to reestablish nationwide ICT policy driving system or ICT governance. Since the technological foundation of the fourth Industrial Revolution is ICT, it is required to reestablish nationwide ICT policy driving system or ICT governance. Since the technology foundation of 4IR is ICT and pursues hyper-connection mutually, it is required to reestablish nationwide information linkage between a sector and other sectors. This means that the government side needs to reform or link the institutional and organizational structures in irrigation sector and the related sectors. South Korea has central government organizations for irrigation water management by KRC (Korea Rural Community Corporation, http://eng.ekr.or.kr/Kenpub/index.krc), crop water management by RDA (Rural Development Administration, http://www.rda.go.kr/foreign/ten/), agricultural product distribution by aT (Korea Agro-Fisheries & Food Trade Corporation, http://www.at.or.kr/home/apen000000/index.action), and local government institutions at each city and provinces for providing agricultural technology and information (http://agro.seoul.go.kr/, http://nongup.gg.go.kr/). If they are linked each other, they can provide alive information and knowledge contents from farming irrigation to food supply to personnel (from watershed agricultural water resources-water production-water supply-water consumption-crop yield-food delivery-food safety-to people's welfare) (Fig. 13).

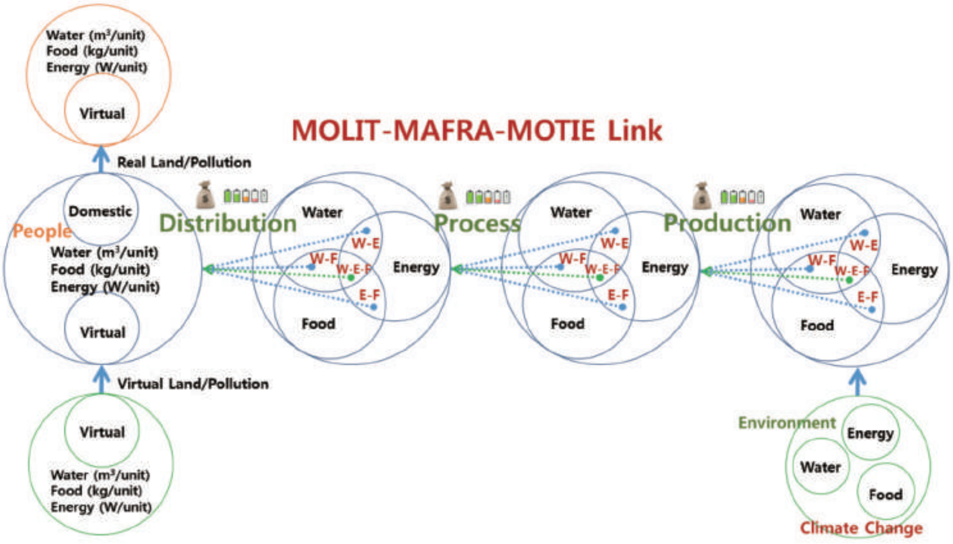


Fig. 13. Concept of Water–Food–Energy Nexus
MOLIT: Ministry of Land, Infrastructure and Transport
MAFRA: Ministry of Agriculture, Food and Rural Affairs
MOTIE: Ministry of Trade, Industry and Energy

4.3 The direction of Public Private Partnership (PPP) in South Korea

The irrigation management system of South Korea has been revolutionarily changed by the law in 2000 from private (PIM; Participatory Irrigation Management) to public (PubIM; Public Irrigation Management). From this change, there were positive and negative aspects for the water supply and use. The positive effects by PubIM were the stable investment of new I&D facilities and repairs, the systematic operation of I&D facilities, and the risk management for drought event by KRC. The negative effect were the full dependency of water supply from central and local governments. This resulted in the weakened and limited participation for irrigation works, and the abuse of water as a result with still less than 40% irrigation efficiency even though the O&M and branch channels have been modernized.

Therefore, we need to recover the partnership acceptable and executable with farmers for water saving and environmental conversation of their private controlled areas. For the farmers' participation, the government needs to give incentives for the farmers' efforts of saving and conseravtion, and financial supports for the new WUG (Water Users Group) organization and activities. For the partnership restoration between public and private, the KRC needs to to give more rights and duties to the board of representatives in the KRC and government decision making processes. Among the rights and duties to be given and recovered, the most important and first thing is the reorganization of WUGs to revive the concept of PIM through the autonomously reinforced new type of WUGs. The second thing is that KRC needs to recover the rights of collecting water fees from the farmers for the better irrigation service adjusted by PPP between WUGs and KRC.

5.0 Recommendations

As described above, the PIM and the PPP concepts of South Korea were broken and could not be operated well by the government legal action of unification from 3 organizations (ALU, ALUF, and RDC in Fig. 8) to government agency, KRC in 2000. After that, the irrigation management has been dependent on public side. Thus, we, first of all, should recover the function of PIM and PPP by reorganizing WUGs with decision making rights and water price duty for better water sharing and service.

Agricultural water management is so complex because it concerns different spatial and temporal scales and multiple stakeholders with varying goals. Information on the spatio-temporal variability of environmental parameters, their impacts on soil, crop, water, and other components of farming play a major role in formulating the farmers' strategy. Today, farmers and water-related stakeholders can utilize the convergence of several technologies including in-field sensors, geographic information system (GIS), remote sensing (RS), crop and water simulation models, prediction of climate and advanced information processing and wire/wireless communications (Panchard et al., 2006). As already mentioned, the information and communications infrastructure in South Korea is now well equipped for irrigation management applications between government and farmers. Thus, as the future irrigation water management of South Korea, it is necessary to build the bi- or multi-directional synchronous linkage of shared information for irrigation management. This is the direction of 4th industrial revolution preparation in agricultural activities.

The big problem to solve is the adaptation and mitigation of climate change impact on sustainable irrigation. The future climate trend certainly goes to become hotter and drier resulting in the difficult irrigation water management. Despite increased stress on agricultural water resources, many water users and managers are still unaware of practical, cost-effective irrigation water efficiency improvements they can make. Strategies or plans for irrigation water efficiency are largely lacking, both in the public and private sectors. The PPP for enhancing the irrigation water use efficiency in supplying and cultivation processes are very important. The irrigation water efficiency should be the indicator between the amount of water required for irrigation purpose and the amount of water used or delivered for irrigation (Vickers, 2001).

References

- Choi SM, Yoon KS, Kim JS. 2016. Irrigation management transfer between public organizations and the role of participatory irrigation management under public irrigation management in Korea. Irrigation and drainage 65: 69 – 75
- Jung CG, Park JY, Kim SJ, Park GA. 2014. The SRI (system of rice intensification) water management evaluation by SWAPP (SWAT-APEX Program) modeling in an agricultural watershed of South Korea. Paddy Water Environment 12(1): 251-261
- Korea Rural Community Corporation (KRC), Korea National Committee on Irrigation and Drainage (KCID). 2014. Agricultural Development in Yeongsan River Basin, Korea. KRC: Republic of Korea
- Lee SH, Kim TC. 2011. Encouraging farmers' participation in Public Irrigation Management in Korea. In: Proceedings of ICID 21st International Congress on Irrigation and Drainage, Iran, Tehran; 181-191. October 15-23
- Ministry of Agriculture, Food and Rural Affairs (MAFRA), Korea Rural Community Corporation (KRC). 2012. Statistical Yearbook of Land Water Development for Agriculture 2012. MAFRA and KRC: Seoul, Republic of Korea
- Ministry of Agriculture, Food and Rural Affairs (MAFRA), Korea Rural Community Corporation (KRC). 2016. Statistical Yearbook of Land Water Development for Agriculture 2012. MAFRA and KRC: Seoul, Republic of Korea
- Panchard J, Rao S, Prabhakar TV, Jamadagni HS, Hubaux JP. 2006. COMMON-Sense Net: Improved water management for resource-poor farmers via sensor networks. International Conference on Information and Communication Technologies and Development, Berkeley, CA; 22-33
- Vickers A. 2001. Handbook of Water Use and Conservation. WaterPlow Press: Amherst, MA