

# **The Sustainable Utilization of Water Resources for a Bioproductive Environment and the Role of Agro-Environmental Education in Korea**

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## **SUMMARY**

The sustainable utilization of the water resources has become an important national agenda in Korea. The great temporal and spatial variations of precipitation and stream flow cause frequent water shortage and floods. The water quality of rivers and lakes has been degraded significantly despite of the continuing investment for water quality improvement. Rapidly increasing water use has placed serious problems to reliable water supply, since the one-third of stream flow is now diverted for agricultural, domestic, and industrial uses. A national survey reported that 1.8 million m<sup>3</sup> of water will be short to meet the demands by 2011. Additional water resources have to be developed and the water demand controls and efficient water use need to be more extensively exercised. The basin-wide integrated flood controls are also important to the sustainable development. The concept of sustainability has been incorporated to the on-going efforts to the water related issues and policies.

Presently the two-third of paddy fields has been provided with the water from irrigation systems. Korean government has placed a high priority on the sustainable water use for paddy irrigation. The concept of 'sustainable development' has been reflected to many on-going national projects such as the reinforcement of existing irrigation dams, transboundary water use, automatic water management, telemetering/telecontrol systems, and water quality improvement projects. Drainage improvement projects for agricultural lands are also implemented to mitigate flood damages in paddy fields. The sustainable agriculture promotion act has given effects

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to improving water quality of paddy fields as well as to preserving the agricultural ecosystems.

This paper presents the overview of geography and agriculture, water resources, and water use for agricultural production in Korea. National agenda which concern the sustainable water use are presented. The on-going efforts for the sustainable use of agricultural water resources are introduced. A review on case studies of the integrated water management for more efficient water use and of an irrigation reservoir water quality improvement project is given. Results from the wastewater reuse for irrigation are also presented which may help restore the natural hydrologic cycle by reducing the over-exploitation of water from rivers. It is followed by the roles of agro-environmental education, which include the capacity building for interdisciplinary aspects of the sustainable water utilization in harmony with natural ecosystems. The importance of accredited curricula development is stressed for the future agro-environment education. The interdisciplinary research and development needs to be explored for the sustainable water use in agricultural production.

## INTRODUCTION

The Republic of Korea (Korea) like many other countries in the world has faced a serious challenge to sustainable water use. Here, the term 'sustainable' suggests an ability to maintain activity in the face of stress or shock. WCED (1987) defined the sustainable development as the ability of humanity to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own. In the context, the water for agricultural production needs to be developed economically and utilized efficiently and in harmony with natural environment, but should not be over-exploited to a degree affecting the future water supply.

The sustainable water use is particularly important to Korea. More than the one-third of the renewable water resources or the runoff from precipitation is now being diverted for the agricultural, domestic, and industrial uses. Yet, the projected water demands in 2011 is reported to be 37 billion m<sup>3</sup>, surpassing the existing water supply capacity by 1.8 billion m<sup>3</sup> (MOCT, 2000). Additional water resources need to be explored without adversely affecting the natural ecosystems. The water should be more efficiently used, water saving efforts should be promoted, and the water demands

should be controlled. The water quality of rivers and lakes should also be preserved. River environments need to be restored and conserved in harmony with natural ecosystems.

Another important water issues are flood control. Flood damages during the monsoon season and typhoon passes are increased significantly in recent years (MOCT, 2000). Flooding has been a real threat to the sustainable agricultural production. The Korean government has worked on the integrated flood control in a basin scale, along with the continuing investments on drainage improvement projects for agricultural lands.

This paper presents an overview of the Korea environment, water resources, and agricultural water uses. Efforts and initiatives for the efficient and sustainable use of water for agricultural production are discussed. The paper also presents the overall status of higher agricultural education and reviews the roles of agro-environmental education and research efforts for the sustainable water use.

## **OVERVIEW OF GEOGAPHY AND AGRICULTURE**

### **Topography, Climate, and Weather**

Korea is located in the southern Korean Peninsula and islands. It is about 400km long and 300km wide, and lies between 33° and 37° north latitude and 124° and 132° east longitude. The total area is 99,373 km<sup>2</sup>. About 70% of the land is mountainous with the main concentrations to the northern and eastern areas. Along the southern and western coast, the mountains descend gradually toward broad coastal plains. Most of the rivers flow from the north or east sides into the Yellow or South Seas.

Korea has a temperate climate with the four distinct seasons; spring, summer, autumn and winter. The contrast between winter and summer is pronounced: Winter is bitterly cold and is influenced primarily by the Siberian Air Mass, while summer is hot and humid affected by the Maritime Pacific High. The annual average temperature varies from 10 to 16 degrees Celsius except for mountainous regions. August is the hottest month with the mean temperature between 23 and 27 degrees. January is the coldest and the mean temperature ranges from -6 to 7 degrees.

The average annual precipitation ranges from approximately 770 to 1,640 mm, with the mean of 1,284mm. About two-third of the total precipitation (65%) is concentrated in summer, while precipitation in winter is less than 10% of the total. The monsoon front approaches the Korean Peninsula from the south in late June, moving gradually to the north. The rainy season, *Jangma* in Korean, normally continues for a month till late July. Two or three (3.1 in average) typhoons pass over the territory from July to early September usually with heavy rainfall (KOWACO, 2004).

### **Land Use, Population, and Agriculture**

The arable land is 18.3 thousand km<sup>2</sup> or 18.4 % of the total land, and consists of 11.5 thousand km<sup>2</sup> of paddy fields (11.2%) and 7.21 thousand km<sup>2</sup> of upland areas, orchards and other uses (7.2%). It has been steadily decreased from 23 thousand km<sup>2</sup> in 1970s as flat lands have been turned to urban and industrial zones (MAF, 2002).

The total population of Korea is 48,422 thousands. The population density is 475 persons per km<sup>2</sup>. The population in farm households is 3.9 million persons or approximately 8% of the total in 2004.

Rice is the staple food for Koreans and the most important sources of income for farm households, up to 37 percent of the gross farm receipts. Other crops being grown are soybeans, barley, and potato. Vegetables are also important cash crops for many farm households.

The agricultural contributions to the national GDP is about 2.7% in 2003, when forestry and fishery incomes are excluded. Average farm household income comes more from off-farm activities (60.7%) than farm business, but is 76.2% of the income of average urban households (MAF, 2004). The farm income is being threatened to be further cut down as the amount of imported brown rice is to be increased.

## **WATER RESOURCES**

### **Precipitation**

The average annual precipitation is 1,283mm, 1.3 times more than the average of the world of 973mm. The annual water resources from the precipitation per capita are only

2,705 m<sup>3</sup>, or approximately one-eleventh of the world average of 33,975 m<sup>3</sup>. Figure 1 shows the yearly variations of the annual precipitation from 1905 to 1998 (MOCT, 2000). It may be noticed that the annual precipitation varies significantly, and the variability tends to increase in 1990s. The spatial variability of annual precipitation is also significant in that the mid-eastern province, Kyungsangbuk-do has the mean precipitation of approximately 1,000mm, while it is over 1,700mm in the Jeju Island.

Figure 1 Variations of annual precipitation

The monthly precipitation varies greatly as may be seen in Figure 2. It is less than 60mm from October to next March. From June to September, it is equal to or greater than 150 mm. The total rainfall during July and August is 530mm, or 41.4% of the annual precipitation.

Figure 2 Monthly mean precipitation

Great variations of yearly, regional and seasonal variations of precipitation present serious problems and limitations in water resource management. In a year, drought prevails and causes damages to farming at some regions from mid April to mid June, and a week later the government flood control task forces open their offices to be ready for coming floods. Agriculture is a sector most vulnerable to and seriously affected by drought and floods. Thus, water resource development and flood control efforts are important to sustainable agricultural production.

## **Runoff**

The annual average runoff in Korea is 83.1 billion m<sup>3</sup> or 57% of the annual precipitation (MOCT, 2000). Since it varies with the amount of precipitation, the runoff also shows great fluctuations yearly and seasonally. The total number of streams and rivers is 3,893 and the length is 30.2 thousand km. Among the seventeen major river basins, the Han-gang (River) is the largest, having the drainage area of 25,954 km<sup>2</sup> (including the basin areas in North Korea) and the length of the river is 470 km. It passes through Seoul and drains 18.87 million m<sup>3</sup> of runoff to the Yellow Sea in a year,

As affected by the dry and wet seasons, the Korean rivers have very high flow

variations: The coefficients of the river regime, or the ratios of the maximum discharge to the minimum range from 300 to 400. The reasons for the unusual higher ratios include six months of the dry season, heavy storms during the monsoon season and typhoon passes, and the short and steep slopes of the river reaches. Such characteristics of the rivers cause serious problems to river management for flood control and water use.

## **Dams and Reservoirs**

Dams and reservoirs function to stabilize stream flow downstream and to ensure the water supply to planned users. The net water supply capacity of thirty-five multipurposed and other large dams is 14.7 billion m<sup>3</sup> (MOCT, 2000). Typical irrigation reservoirs and dams are small in the storage capacities; the total water supply capacity of about 18,000 irrigation reservoirs is 1.6 billion m<sup>3</sup>.

The largest dam in Korea is the Soyanggang-dam, which is 123m high and 530m long, and has the storage capacity of 2.9 billion m<sup>3</sup>. It is followed by the Chungju-dam, whose storage capacity is 2.75 billion m<sup>3</sup>. The two dams are instrumental to reliable water supply to the huge population of Seoul and the satellite cities.

In 1970s and 1980s, the Ministry of Agriculture and Forestry (MAF) had implemented the integrated agricultural development projects. A highlight of the projects was to construct estuary dams to irrigate paddy fields in lower lands along the west coast. Among the top ten largest rivers in Korea, the four rivers such as the Yongsan-gang, Geum-gang, Ansung-chon, and Sapgyo-chon have been closed with the dikes, and the two rivers, the Mangyung-gang and the Donjin-gang are being closed by the Saemangeum tidal reclamation project. The area of the six drainage basins is 23.5 thousand km<sup>2</sup>, or 23.7% of the total territory.

## **Groundwater**

The groundwater resources potentials are estimated to be 32.4 billion m<sup>3</sup> per year, among which up to 13.3 billion m<sup>3</sup> may be developed. The total number of groundwater wells is about 1.1 million, and 3.2 billion m<sup>3</sup> (24 % of the usable resources) is being used. It is well received that the present levels of groundwater utilization may be the maximum quantity to be developed feasibly (MOCT, 2000).

## Water Quality

Other imminent limitations imposed on water resources development are due to water quality degradation in rivers and streams. The water quality conditions of streams and rivers had been significantly degraded in 70s and 80s during the national economic development. Wastewater treatment projects have been placed at a high priority and have been implemented to some success. However, more efforts should be put to restore the water quality. Among 194 stream and river reaches which the Ministry of Environment (MOE) has divided and placed the target water quality considering the water use purposes, only 37% of the reaches showed acceptable water quality conditions in 2002 (OPM, 2003). Recently, MOE has promoted the total maximum daily load (TMDL) programs to major river basins. Under the programs, the targeted water quality should be met by all measures including the allocation of point and nonpoint source pollution loads within a river basin. It seems that the national target to improve water quality of rivers may not be easily achieved in the near future.

## Water Demand and Supply

The annual water demand is estimated to be 33.1 billion m<sup>3</sup> in 1998 as shown in Table 1 (MOCT, 2000). The domestic water use is 7.3 billion m<sup>3</sup> (22%), the industrial use 2.9 billion m<sup>3</sup> (9%), the agricultural use 15.8 billion m<sup>3</sup> (48%), and the in-stream demand 7.1 billion m<sup>3</sup> (21%). The in-stream demand is the minimum required statutory flow at a specific river reach which the River Act mandates to designate. The total off-stream use (excluding in-stream demand) is 26 billion m<sup>3</sup>, and 60% of that is used for agriculture.

Table 1 Estimated water uses (in billion m<sup>3</sup>/year)

Year	1965	1980	1990	1998
Total water use	51.2 (100%)	153 (100)	249 (100)	331 (100)
Agricultural	44.8 (88%)	102 (67)	147 (59)	158 (48)
Domestic	2.3 (4 %)	19 (12)	42 (17)	73 (22)
Industrial	4.1 (8 %)	7 (5)	24 (10)	29 (9)
In-stream	-	25 (16)	36 (14)	71 (21)

Figure 3 shows a schematic of the annual balance between water demand and supply. The annual water supply consists of 16.1 billion m<sup>3</sup> (49%) from stream flow, 13.3 billion m<sup>3</sup> (40%) from dams and reservoirs, and 3.7 billion m<sup>3</sup> (11%) from groundwater (MOCT, 2000). It may be noted that the off-stream water uses consist of 35.6% of the renewable water resources, which is defined to be the water to be renewed regularly and repetitively by rain or snow, or the difference between total precipitation and evaporation. The high rate of water use may present a great threat to the sustainable water use without seriously damaging fragile natural environment and ecosystems.

Figure 3 Annual water supply and uses of 1998 (Numbers above are in billion m<sup>3</sup>)

### **Policies for Water Resources Management**

The national policies towards better water resource management are based on three principles: Improving the soundness and reliability in water use, building up social infrastructures to cope with floods, and forming river environments to be harmonized with the nature (MOCT, 2000). The agenda for the sound and reliable water use include: 1) Water demand management, 2) efficient water use and water quality improvement, 3) new water resources development to ensure reliability of water supply, and 4) capacity building for drought mitigation.

The agenda for the flood control programs are: 1) Adopting basin-scaled integrated flood management plans replacing traditional river maintenance plans; 2) reducing the flood hazards and flood damage potentials; 3) promoting sustainable flood control projects; 4) reforming institutional structures and building up the capacities for better flood controls. Lastly, the four subtopics for river environment improvement are: 1) Promoting environmentally sound river maintenance projects; 2) implementing river rehabilitation programs; 3) promoting and recovering water related culture; 4) implementing projects for multi-use and multi-functionality of rivers.

Figure 4 A conceptual view of basin-scaled flood control

The above national agenda target the sustainable development of the Korean society through achieving the sound water use and restoring the safe and friendly water environments. They have been well reflected to the national plans for long-term water



resources development, called 'The Korea Water Vision 2020', which consist of water use, flood control, and river environment programs (MOCT, 2000).

## **WATER USE FOR AGRICULTURE**

### **Irrigation Development**

Rice has long been the staple food for Korean. The crop has been grown by supplemental irrigation for reliable crop production. Based on the discovery of carbonized rice and remains of paddy fields in many places, it was reported that rice was eaten as early as in Bronze Age in the Korean Peninsula (MAF, 2004). Historical records showed that rice was cultivated in the first Century (16 A.D). As early as 157 A.D, earthen embankments were constructed to divert water for irrigation (MAF and KARICO, 2002). The excavated remains of the earthen embankment, Byukgol-ge (dike) were constructed in 330 A.D. The length was over 3,000 meters long and the irrigated area was over 10,000 hectares. Many historical records show that diversion weirs, presumably in temporal structures, were built and used for paddy rice irrigation. The oldest still existing embankment, the Eorip-ji (pond) was built in 504 A.D and is being used as an irrigation water resource. Tidal land reclamation was firstly done in the 13<sup>th</sup> Century, which may reveal rice irrigation in a large scale was practiced.

Following the remarkable invents of rain and stream level gages by the great King Sejong (1418-1450 A.D), historical records revealed that a ministry level officer was appointed to administer irrigation projects and to inspect irrigation facilities at provincial levels in the 15<sup>th</sup> Century. In 1729, the total number of earthen embankments was 3,527. Other historical records of worth noting are in that a local governor appealed a minister to discourage rice transplanting culture, reasoning that the practices were vulnerable to drought damages when not enough water was available. This document may suggest that rice transplantation was widely practiced in the 16<sup>th</sup> Century.

Modern irrigation systems were initiated after the proclamation of Irrigation Association Act in 1906. Reservoirs and weirs were built and used to supply irrigation water. As of 1945, the irrigated paddy acreage was 335 thousand hectares.

Recent advancement in irrigation systems was initiated since 1960s. Groundwater Development Corporation was founded in 1965 to develop deep wells for irrigation, which was later merged to now Korea Agricultural and Rural Infrastructure Corporation (KARICO). KARICO is the main institution for agricultural water management. National budget and international loans were invested to develop large scaled agricultural development projects.

The total acreage of irrigated paddies reached the peak, 987.9 thousand ha in 1991, and has been declined to 880 thousand ha (76.6% of paddy fields) by 2003. The decreases in the irrigated paddy fields were due to the land conversions to urban and industrial sectors. The total water use for agriculture was estimated to be 15.8 billion m<sup>3</sup>, approximately 49% of the total water use. The acreage does not include some paddy fields to be privately irrigated. When all acreage is added up, it is believed that most of paddy fields are being irrigated at least partially.

Figure 5 An irrigation reservoir

MAF has implemented the agricultural water resources development projects. Targeting the irrigated paddy fields up to 82% of the total paddy fields, MAF has prepared the 3<sup>rd</sup> Rural Water Development and Management Plan (2005~2014) (MAF, 2004). The upland consolidation projects have been also practiced, in which the groundwater resources for upland crop and vegetable irrigation are developed. Many vegetable growers have relied on private irrigation systems for their farming. It was reported that at least 25% of upland farming was being equipped with irrigation systems of some kinds.

### **Irrigation Facilities and Management Organizations**

Table 2 shows the irrigation facilities and irrigated paddy areas (MAF and KARICO, 2001). Major irrigation water resources are reservoirs, pumping stations, and weirs. Groundwater is used only for 54 thousand ha.

Table 2. Paddy field areas by irrigation facilities and the reliability of drought mitigation (MAF and KARICO, 2001)

Irrigation facilities	No. of facilities	Irrigated areas (ha)	Irrigated areas by frequency of drought (ha)				
			Normal year	3 years	5 years	7 years	Over 10 years
-Reservoirs	17,913	516,783	127,038	74,844	29,294	37,466	248,141
-Pumping stations	5,937	123,634	8,887	8,734	3,447	7,931	94,635
-Pumping & drainage stations	119	30,045	959	37	211	8,879	19,959
-Drainage stations	490	1,189	340	381	302	-	167
-Weirs	18,350	102,499	30,393	22,433	7,207	6,749	35,717
-Groundwater wells	21,734	54,441	9,728	13,341	8,830	1,187	21,355
-Other facilities	-	51,853	48,039	1,687	804	230	1,093
Total	64,543	880,444	225,383	121,457	50,095	62,442	421,067

A major reform in irrigation water management frameworks was implemented in 2000, when KARICO was founded to be a primary institute to manage larger irrigation systems. Farmland Improvement Associations (FLIA) used to be in charge of the operations and management of local irrigation facilities before. Three agencies including FLIA and their Federation, and the Agricultural Development Corporation were merged to establish KARICO. KARICO is responsible for the operation and management (O&M) of 12,295 irrigation facilities, covering 520 thousand ha (59% of irrigated paddy fields). The remaining small facilities of 52,248 are operated by the water associations under the auspice of local governments.

KARICO is supported with the budget fully by the government for the O&M of the irrigation facilities. Water fees from farmers at KARICO irrigation districts have been waived. Yet, farmers of local water associations have to pay the O&M costs. The controversial institutional structures have been being debated, and no resolutions have been foreseen in the near future.

Over 15 thousand irrigation facilities were more than 60 years old, and many of them do not function well enough to supply water to irrigated areas during a long drought span. 48% of the irrigated paddy fields are estimated to be supplied water from

irrigation water resources for a drought of the return period of 10 years (Table 2). More than half of the acreage is vulnerable to drought. The lack of the reliability is one of the major issues concerning irrigation systems in Korea.

### **Irrigation Water Quality**

The overall water quality of irrigation reservoirs appears to be alright to meet the national water quality standard class IV of 8 mg/L of chemical oxygen demand (COD). Less than 0.4~0.6% of total irrigation reservoirs fails to meet the standard (MAF, 2004). Some polluted stream flow is being diverted to paddy fields. Untreated or inappropriately treated animal wastes in upstream areas are a major source of pollutants to those streams. The eutrophication of estuary dams is also a major concern. Unlike upstream waters, the water quality improvement for the estuary dams is a real challenge and hard to achieve without substantial investment for basin wide water quality improvement efforts.

### **Irrigation Efficiency**

It has been recognized that the efficiency of paddy irrigation is very low. The efficiency depends on many factors such as irrigation facilities, types of canals, scheduling, and on-farm water management. Theoretically, the efficiency increases when the water supply is equal to the demand or on-farm requirements at individual fields over entire irrigated area. Delivery efficiency is reported to be about 75 to 95 % depending on canal types. Field efficiency, which is defined to be the ratio of the water use on farm to the diverted water, varies with water management on a farm. A recent survey by the author showed that about 20% of irrigated water drained to stream (Im et al., 2000). Nearly 20% of irrigated water returned to stream in a form of groundwater releases. This may suggest the overall irrigation efficiency to be less than approximately 50%. The uniformity of water supply to irrigation district was also low: Upstream zones enjoyed more than enough water supply while lower zones were irrigated with secondary water diversion structures. Efforts are being made to convert open canal systems to pipeline systems, which may significantly improve the overall irrigation efficiencies as compared to the conventional.

### **Flood Control for Agricultural Lands**

Flood controls for farmlands are one of major projects which MAF places a high priority on. A recent national survey showed that 235 thousand ha of low lands need drainage facilities for flood control and improving farming operations. 36% of the target areas have been completed as of 2000. Over 83 thousand ha remains to be the flood prone paddy fields.

## **SUSTAINABLE UTILIZATION OF IRRIGATION WATER**

### **National Policies**

The national policies concerned with the sustainable water use for agriculture may be categorized to the three (MAF, 2004): 1) Measures to assure food security or keeping threshold levels of food production, 2) measures for efficient and sustainable use of irrigation water, and 3) measures to preserve paddy field ecosystems soundly. The total grain production has fallen to a level that the self-sufficiency ratio of grains is 30.4%. Only rice production yields 107% of the domestic needs in 2002, not because the gross production increases greatly but because the rice consumption per capita drops steadily. Yet, nearly 14 thousand ha of farm lands are converted to urban and industrial zones each year. In order to keep the self-sufficiency of rice production, the agricultural development projects are justified, which include the rural water resources development, tidal land reclamation, redevelopment of arable lands, and drainage improvement.

MAF has prioritized highly the efficient and sustainable use of irrigation water resources. On-going efforts include: 1) Repair and reinforcement of existing irrigation dams and canals which have been aged and deteriorated, 2) networking of water resources for trans-boundary water allocation, 3) automation of water management, 4) installing telemetering and telecontrol (TM/TC) instrumentation systems for water resources operation and management, and 5) management of irrigation water quality. They aim to more efficient use of water, or to improve water quality, while maintaining the high levels of agricultural production.

Figure 6 TM/TC control center

The Sustainable Agriculture Promotion Act was established in 1997, which provides a sound ground for environmentally friendly farming. It promotes cultural practices

for minimal chemical fertilizer and pesticide applications. The agricultural products from such farming practices have been well received by consumers who are willing to pay more for the high quality foods.

### **Case Studies**

The Sangju Integrated Central Water Management System which was completed in 1998 may present a successful application of TM/TC systems to improve irrigation efficiency and to save water for domestic use (MAF, 2004). The Sangju-dam has the storage capacity of 40 million m<sup>3</sup>, and provides irrigation water to 35.3 km<sup>2</sup> of paddy fields and also supplies domestic water of 8,800 m<sup>3</sup> per day. After water diversion schemes were optimized to yield a better allocation, the saved water is being used for expanded paddy fields nearby while enhancing the reliability of domestic water supply.

A case study to improve the water quality of an irrigation reservoir having the storage capacity of 1.7 million m<sup>3</sup> has been implemented since 2001. A sedimentation pond and artificial wetland systems were installed and operated, with a favorable result that the average COD was reduced from 12.5 mg/L to 8.5 mg/L. More projects are being planned to improve irrigation water quality at heavily eutrophicated reservoirs. For further information about case studies related to sustainable agriculture, MAF (2004) should be referred.

### **Wastewater Reuse for Irrigation**

Wastewater reuse is defined to be the beneficial use of the treated water. Reclaimed wastewater from domestic sewer treatment plants has been used in many countries. It has not been practiced in Korea, since rice farmers prefer 'good water'. The author has worked on the wastewater reuse for paddy irrigation during the past five years. Effluent from the Suwon municipal sewer treatment plant is reclaimed through filtration and disinfection systems and used for irrigating rice and vegetable crops. The results showed that rice yields increase 25% more than the control plots which were irrigated with groundwater. Other advantages using reclaimed wastewater for paddy irrigation include: 1) Wastewater reuse eases new irrigation water resources development since effluent from sewer treatment plants is nearly 7.5 billion m<sup>3</sup> a year, 2) crop yield increases with little side effects on crop growth, 3) it helps save fertilizer application rates by a half, 4) it reduces the pollutant loads by at least two-thirds because of the

natural purification effects at paddies; 5) it does not significantly adversely affect soil and water environments; and 6) it is one of better practices to help sustainable water use for irrigation.

Figure 7 A test plot for wastewater reuse

MAF and MOE have promoted wastewater reuse projects (Park, 2005). Three pilot projects are now being planned for wastewater reuse. One of the pilot projects is now implemented for the paddy fields of 85 ha adjacent to the Suwon sewer treatment plant as shown in Figure 7. We have surveyed that the maximum amount of feasible wastewater reuse for paddy irrigation is over 150 million m<sup>3</sup> a year. We will publish technical references on wastewater reuse for paddy irrigation, and offer training to water managers.

### **ROLES OF AGRO-ENVIRONMENTAL EDUCATION**

Forty-three universities (20 national and 23 private universities) establish the colleges of agriculture, agro-business, or related disciplines in Korea. In 2004, the total number of students enrolling at agricultural colleges is 11,386, or 0.62% of the total. Among them, less than 1% of the graduates have worked as farmers since 1994. In 2004, 596 graduates or 0.5% have begun their careers as farmers. A recent survey on the educational background of farmers showed 4.8 % of them have earned college degrees (Lee and Na, 2005). This trend may continue for some times as the contribution of agricultural production to the national gross domestic product (GDP) decreases to less than 5%.

A recent study showed, however, that GDP from new-defined agro-business sectors are actually 1.7 times more than that of all manufacturing sectors (Lee and Na, 2005). It was assumed that the agro-business is not only the traditional agricultural production business, but includes the related industrial and service business associated with food production, processing, and services. Lee and Na (2005) cited an early reference in which total number of employees in fields of the agro-business was approximately 25% of all employees in manufacturing business in 2000, and that the future job opportunities would be increased. It does not seem to clear, however, what roles of agricultural college education should play on the whole agro-business.

Continuing debates have been brought up whether the present roles of educational programs of agricultural colleges are appropriate and effective (Lee and Na, 2005). Some experts challenged that the majority of college education programs failed to provide with practical knowledge and training for potential job opportunities. More challenges of the same kinds may follow as more college graduates remain to be not permanently employed for a longer period. However, drastic reforms in the educational programs and curricula have not yet been observed.

Agro-environment disciplines have been a major concentration of educational programs which many national colleges have put more emphasis on. For instance, Seoul National University established the National Institute Center for Environmental Management (NICEM) in 1992, which has become a leading institute in areas of agricultural environment. The success of NICEM may be able to show that agro-environmental disciplines have a bright future as has been observed in many developed countries.

Accredited educational programs in agricultural water engineering and sciences are important to the capacity buildings for future engineers and scientists for the sustainable water resources development and management. The sustainable water utilization requires multi-disciplinary backgrounds, many of which may not be satisfied by traditional undergraduate and graduate programs. New curricula in environmental sciences and ecology need to be added to the programs. It is also important to establish an accreditation program for qualified engineers such as internationally received registration for professional engineers.

Like in many engineering disciplines, research and development programs are important to the technical advancement in sustainable water utilization. It is believed that multi-disciplinary research and development (R&D) programs produce a fruitful achievement for sustainable water use. For instance, the integrated irrigation management systems based on TM/TC technology has been developed at a university, and is now a national project. Projects on the wastewater reuse for agriculture are now being implemented as the pilot projects by MAF and MOE as discussed in a previous section. Other examples include the multi-functionality of rice culture which contributes to the justifications of the environmentally friendly agriculture promotion. It is suggested that continuing R&D efforts be needed to promote the advancement of



our understandings and the improvement of technologies for sustainable water utilization in Korea and beyond.

## CONCLUSIONS

The sustainable utilization of water resources for agriculture is important to Korea which has to keep up with the continuing economic prosperity in harmony with natural ecosystems. More than one-third of the renewable water resource is now being used, and yet more is needed to satisfy the future water demands. The more water is used, the more adversely affected are the hydrologic cycle, the water quality of rivers and lakes, and the ecosystems. The over-exploitation of water resources for the present use may significantly impact on future generations to come. Thus, it is a right course of actions to take measures to control water demands, to use water more efficiently, and to develop alternative water resources like wastewater reuse. Some of case studies have proven that such actions contribute to water saving and more efficient water use for agriculture.

Wastewater reuse for irrigation may be an important step to normalize the natural hydrologic cycles and to offset the over-exploitation of freshwater from streams and rivers. It also helps improve the water quality. A well-planned reuse would minimize significantly adverse effects on crop growth, environments, and most of all human health hazards.

Flood control is also an important issue to the sustainable development of agriculture. Flood damages have been increased recently in Korea, and agricultural lands are most vulnerable. Basin-wide integrated flood control plans are being established to minimize damages from heavy storms. Continuing farmland drainage improvement projects need to be implemented sooner and more extensively.

Other aspects of the sustainable water use are to improve water quality and to preserve agricultural ecosystems. The water quality of irrigation reservoirs and estuary dams has been a major concern, because of the high degrees of eutrophication resulting from improperly treated domestic and animal wastes. More attention should be given to maintain the water quality of rivers and lakes to be intact. Though some water quality improvement projects for irrigation reservoirs have been successful, a better way of improving the water quality is to control and reduce pollutant loads at the sites or

nearby where they are being generated. Environmentally friendly farming has also helped preserving agro-ecosystems.

Agricultural colleges are facing a serious challenge toward the roles for their future programs as the contributions of agriculture to the nation economy are decreasing drastically in a rather short period of time. And a recent reform in a college to emphasize the educational programs on biotechnology and agro-environment has been proven to be a success. Accredited curricula development appears to be needed for college programs. And interdisciplinary approaches to the research and development are important to the sustainable development in agriculture.

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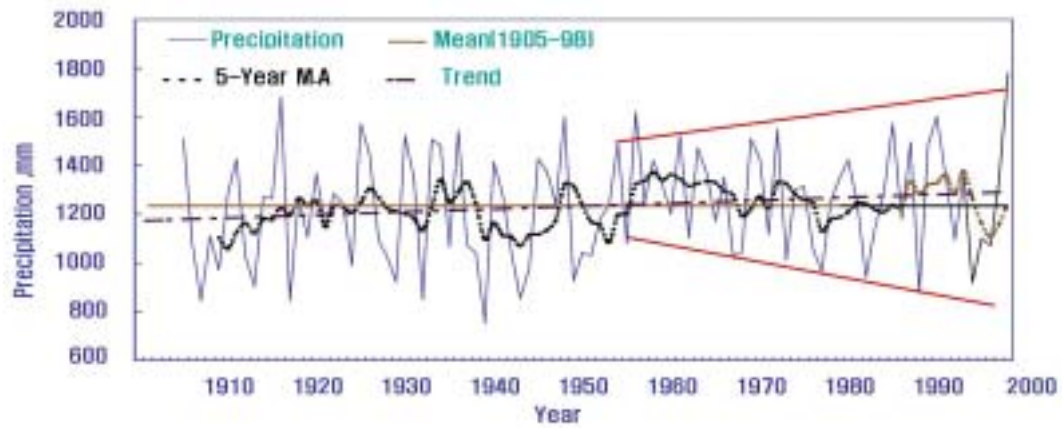


Figure 1 Variations of annual precipitation

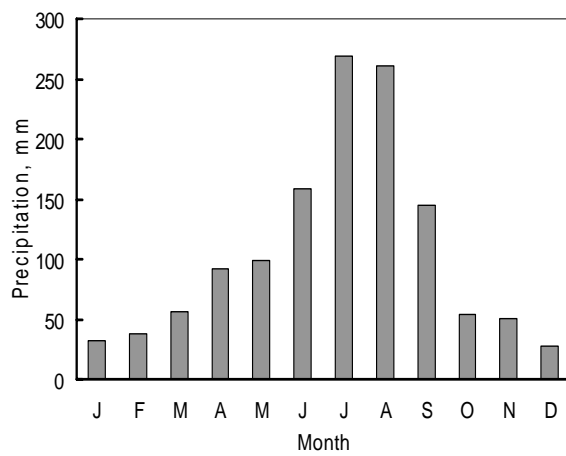


Figure 2 Monthly mean precipitation

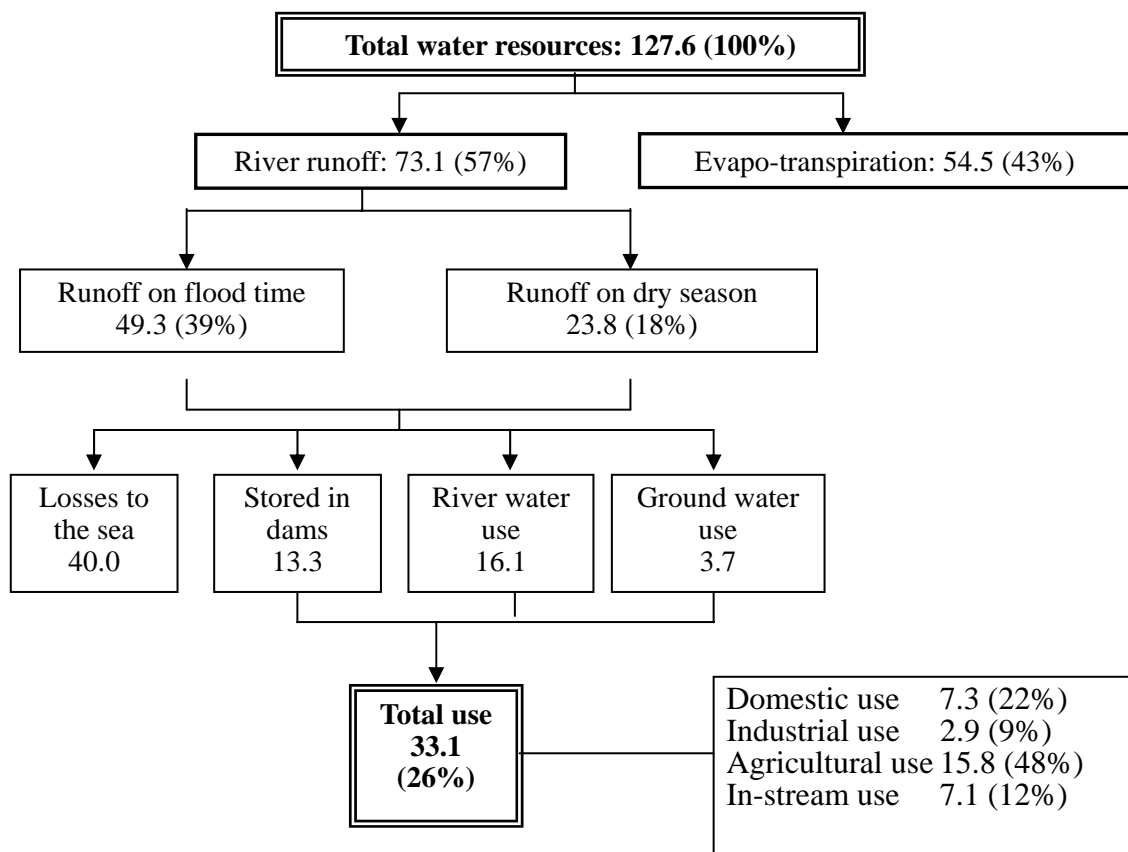


Figure 3 Annual water supply and uses as of 1998 (numbers above are in billion m<sup>3</sup>)

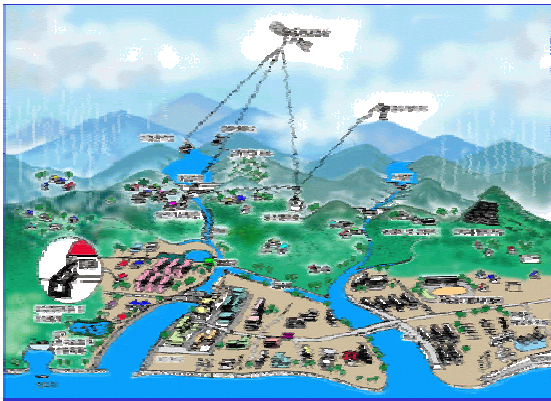


Figure 4 A conceptual view of basin-scaled flood control



Figure 5 An irrigation reservoir



Figure 6 TM/TC control center



Figure 7 A test plot for wastewater reuse