

### INFORMATION

#### Geography

The Republic of 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.

The country, including all its islands, lies between latitudes 33° and 39°N, and longitudes 124° and 132°E. Its total area is 100,212 square kilometres. The terrain of the country is mostly mountainous, most of which is not arable. Lowlands, located primarily in the west and southeast, make up only 30% of the total land area.

About three thousand islands, mostly small and uninhabited, lie off the western and southern coasts of the country. Jeju Island, about 100 kilometres off the southern coast of the Korean Peninsula is the country's largest island, with an area of 1,845 square kilometres. The highest mountain of the country, Hallasan, an extinct volcano in Jeju Island reaches 1,950 meters above sea level. The easternmost islands of Korea include Ulleungdo and Liancourt Rocks (Dokdo), while Marado and Socotra Rock are the southernmost islands of South Korea (Wikipedia.org (Geography of South Korea)).

#### Climate

South Korea tends to have 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  $-20^{\circ}\text{C}$  in the inland region of the country: in Seoul, the average January temperature range is  $-7$  to  $1^{\circ}\text{C}$ , and the average August temperature range is  $22$  to  $30^{\circ}\text{C}$ . 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  $30^{\circ}\text{C}$  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)).

#### Demographics

South Korea is noted for its population density, which is 497.1 per square kilometer as of 2011, more than 10 times the global average. Most South Koreans live in urban areas, because of rapid migration from the countryside during the country's quick economic expansion in the 1970s, 1980s and 1990s [131]. The capital city of Seoul is also the country's largest city and chief industrial center. Seoul had a population of 10 million inhabitants. Other major cities include Busan (3.5 million), Incheon (2.7 million), Daegu (2.5 million), Daejeon (1.5 million), Gwangju (1.5 million) and Ulsan (1.1 million) (Wikipedia.org (Demographics of South Korea), and Food, Agriculture, Forestry and Fisheries Statistics Yearbook, 2012).

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The population has also been shaped by international migration. After World War II and the division of the Korean Peninsula, about four million people from North Korea crossed the border to South Korea. This trend of net entry reversed over the next 40 years because of emigration, especially to the United States and Canada (Wikipedia.org (Demographics of South Korea)). South Korea's total population in 1955 was 21.5 million, and today it is 49,779,000 in 2011 (Food, Agriculture, Forestry and Fisheries Statistics Yearbook, 2012).

### **GDP and GNP**

The Korean national economy has been steadily developed since the 1960s. The Gross Domestic Product (GDP) was US\$ 480.2 billion in 1996, and dropped to US\$ 437.4 billion in 1997. Gross National Product (GNP) per capita decreased from US\$ 10,543 in 1996 to US\$ 9,511 in 1997. The economic growth rate was 8.7% in 1995, 6.9% in 1996, and 4.9% in 1997. The gross saving ratio in 1997 was 34.6%: 24.3% in the private sector and 10.3% in the government sector. Export volume increased sharply from US \$ 1.0 billion in 1970 to US \$ 63.0 billion in 1990, and it reached US \$ 136.2 billion in 1997. Based on 2013 estimation, Korea GDP (PPP) per capita is \$33,580 (26th) and GDP (nominal) per capita is \$25,051 (34th) (Wikipedia.org (South Korea)).

### **Water Resources**

Korea has 1,274 mm of average annual precipitation, which is estimated at 124.0 billion m<sup>3</sup> of water in volume. Out of 124.0 billion m<sup>3</sup> of water, 72.3 billion m<sup>3</sup> discharges to rivers and streams showing a 58% runoff rate and 51.7 billion m<sup>3</sup> evaporates or infiltrates as a direct loss. Total available surface and groundwater is estimated at 33.7 billion m<sup>3</sup> which includes 20.1 billion m<sup>3</sup> of river flows during the non-flood season, 17.7 billion m<sup>3</sup> of stored water in multipurpose dams and agricultural reservoirs and 3.7 billion m<sup>3</sup> of groundwater (National Water Plan (2006)).

### **National Issues**

Four most significant national issues for the development and management of the water for food and rural development are identified as follows:

The most significant issue is the development of agricultural and rural water resources under the spirit of environmentally sound and sustainable development. The construction of medium size multipurpose dams and irrigation reservoirs is recommended for supplying the increased water use. Enhancing existing reservoirs is advisable because of its fruitful merits. Linked operation of dams in a basin or transfer of water between different watershed areas is also the apparent method within some degree of limitations.

The second is water saving by a good water management and reasonable maintenance. The water saving is the most environmentally protective and sustainable conservation method for the sake of its advantages as well as its effectiveness on reducing the new construction needs to meet the increased water demand. The effective use of reservoir storage, water saving irrigation, construction of concrete ditch, and water management by a tele-monitoring and tele-control (TM/TC) system are the relevant methods fall into this category.

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The third is protection of water from pollution. Catchment management is essential. Pollutant sources should be regulated by prohibiting the discharge of themselves. Fundamental environmental protection facilities must be broadened and enhanced. Water quality monitoring system should also be strengthened. Groundwater should be conserved.

### Agriculture of Republic of Korea

#### Land resources and agricultural land use

The Republic of Korea had 100,148 km<sup>2</sup> of national land in 2012, which included 63,688 km<sup>2</sup> (64%) of forest, 16,980 km<sup>2</sup> (17%) of cultivated land, 19,479 km<sup>2</sup> of other types (19%). The average amount of cultivated land per capita was 0.034 ha and the average farm household had 1.46 ha including 0.82 ha of rice paddy and 0.64 ha of upland. The mountainous forest areas cover about two-thirds of the national land. The cultivated land is mainly composed of 7,381 km<sup>2</sup> of uplands and 9,599 km<sup>2</sup> of paddy fields. The cultivated land and forest have been shown to bear a sharp decreasing trend since the 1980s by being converted into roads, houses, industrial sites and other purposes.(Food, Agriculture, Forestry and Fisheries Statistics Yearbook(2012))

The cultivated land is utilized to grow food crops (1,054 thousand ha), vegetables (227 thousand ha), oil and cash crops (79 thousand ha), orchards (154 thousand ha), green house crops (93 thousand ha), and other crops (133 thousand ha). A total of 17,829 thousand ha of yearly land use indicates a 105 % land use rate by growing two or three crops on some parts of the cultivated land. The cultivated areas for food crops cover rice (854 thousand ha), barley and wheat (42 thousand ha), miscellaneous grains (28 thousand ha), pulses (88 thousand ha) and potatoes (43 thousand ha). (2012, Food, Agriculture, Forestry and Fisheries Statistics Yearbook).

#### Irrigated paddy fields

As a result of concentrated efforts in agricultural water resource development by Korean Government, about 800,000 ha of the rice production area was converted into irrigated paddy fields, which accounts for 80% of total rice production area. However, about 50% of the irrigated paddy fields are still subject to possible damage from the drought with 10-year frequency because of poor irrigation facilities. Besides these problems, 10,000 reservoirs (55% of the 18,000 existing reservoirs) do not function well due to this deterioration.

#### Physical and physiographic constraints

Major physiographic constraints are large mountainous areas, which are prone to erosion due to steep slopes and high intensity rainfall. These conditions limit development in the mountain area. Similarly the absolute shortage of flat plain area has led to the conversion of farming areas into industrial and urban areas. The recent development of industry as well as urbanization due to the increase of population is the major cause of the reduction in farmland.

#### Agricultural Productivity

The climatic conditions in Korea allow one harvest of most crops except some vegetables and food crops. The agricultural productivity of major crops is relatively high with high inputs of fertilizers and chemicals, applying advanced farming skills, intensive extension and farm mechanization. The yields of paddy rice, barley, wheat, potato, maize and pulse in 2011

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recorded 6,590 kg, 4,280 kg, 3,350 kg, 23,210 kg, 4,650 kg and 1,660 kg per ha, respectively. (2012, Food, Agriculture, Forestry and Fisheries Statistics Yearbook)

The yield of rice in Korea is the highest among all the food crops and indicates a high level in the world as well. Chinese cabbage is the most widely grown among the vegetables and yields 109,480 kg per ha for 2011 fall season. Apples are one of the major fruits and harvests are 12,180 kg per ha. (2012, Food, Agriculture, Forestry and Fisheries Statistics Yearbook).

### **Agricultural Water Resources and Use in Korea**

Statistics in this section mainly referred from Statistical Yearbook of Land and Water Development of Agriculture (2010)

Korea, located in Far-East Asia, has a long history of paddy farming and rice is the staple food for Korean. Since 1960, Korea government has quite concerned for food-self-sufficiency especially for rice and developed a number of agricultural water resources for paddy farming. Those efforts for paddy farming has resulted in achieving rice self-sufficiency and caused rice overproduction problem these days. Korea has about 1,00,000 ha paddy rice field and about 80% of irrigated paddy fields with over 63,000 agricultural water resources structures. Reservoir is the main water resource for paddy fields and other structures including pumping station and diversion weir share about half of agricultural water supply. Aged and a large number of irrigation facilities have been burdened for operation and maintenance of sound management for agricultural water resources and it requires a breakthrough to solve the cost and labor.

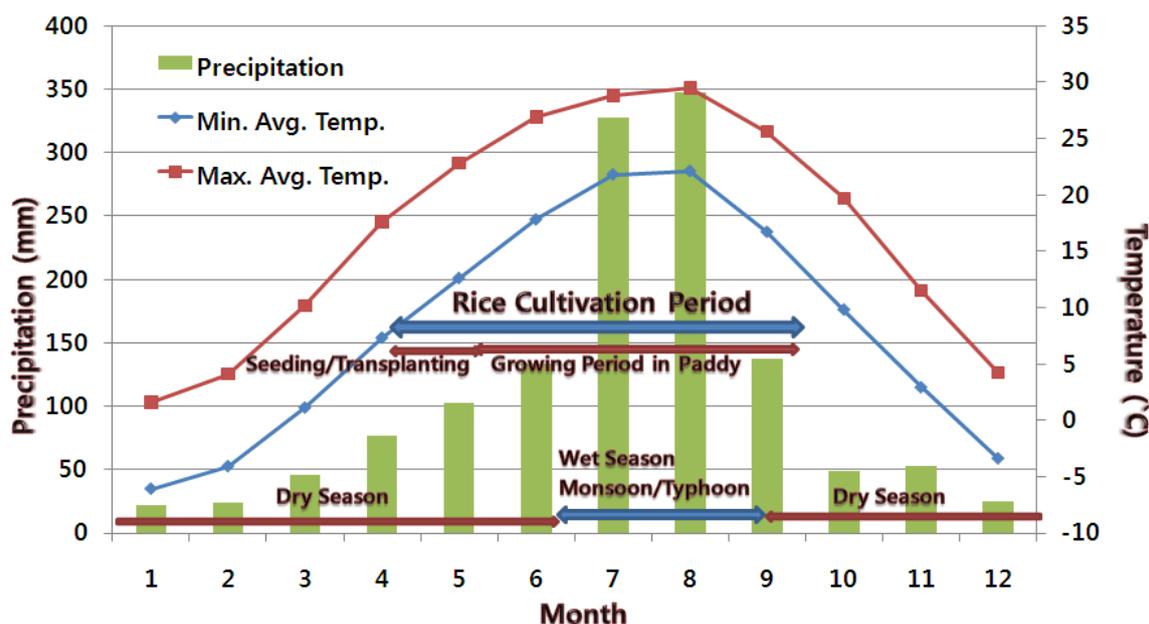
Agricultural water use is typically concentrated during end of April to early June for rice transplanting. Rice transplanting has to be accomplished before starting wet season, usually begin with monsoon, so that every agricultural reservoirs have to store the water for rice transplanting during dry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

From the national water plan (2003), agriculture consumes 160 billion ton/year as a major water use among industrial sectors with 47 % water use ratio, about double of municipal water use

### **Agricultural Water Resource Facility Problems in Korea**

Agricultural dams for reservoirs and pumping stations are the typical main water resource 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. A large scale pumping stations are generally operated for water uptake from lakes which were formed by sea dike for tidal land reclamation.

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

Unit: 0.1 billion Ton

Year	1965	1980	1990	1994	1998	2003
<b>Total Water Resources</b>	1,100	1,140	1,267	1,267	1,276	1,240
<b>Total Use</b>	51.2	153	249	301	331	337
<b>Municipal</b>	2.3(4%)	19(12%)	42(17%)	62(21%)	73(22%)	76(23%)
<b>Industrial</b>	4.1(8%)	7(5%)	24(10%)	26(8%)	29(9%)	26(8%)
<b>Agricultural</b>	44.8(88%)	102(67%)	147(59%)	149(50%)	158(48%)	160(47%)
<b>Environmental</b>	-	25(16%)	36(14%)	64(21%)	71(21%)	75(22%)

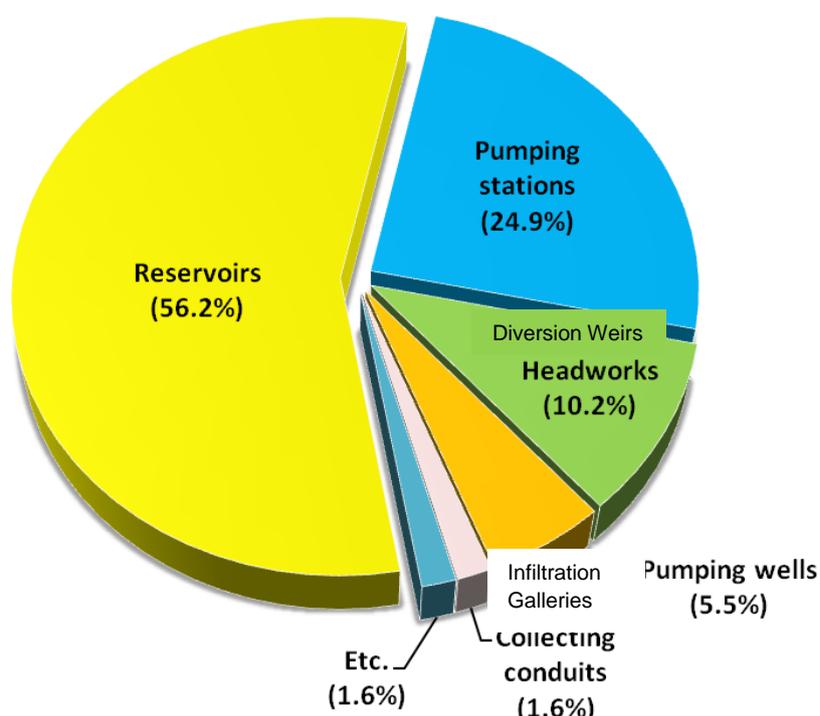
**Figure 2.** Water use statistics about the industrial sectors (National Water Plan, 2006)

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Total number of irrigation facilities in Korea is 69,323 in 2009. The number of pumping wells is 23,478 (33.9%) showing which is the most popular facility for paddy irrigation, though the irrigation area is smaller than reservoirs, pumping stations and diversion weirs. 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 3). During two decades from 1990 to 2009, the number of irrigation facilities is increased from about 57,600 to 69,324 with 11,724 facilities construction (20.4%) decreasing the number of reservoirs, diversion weirs and infiltration galleries, and increasing pumping stations and wells.

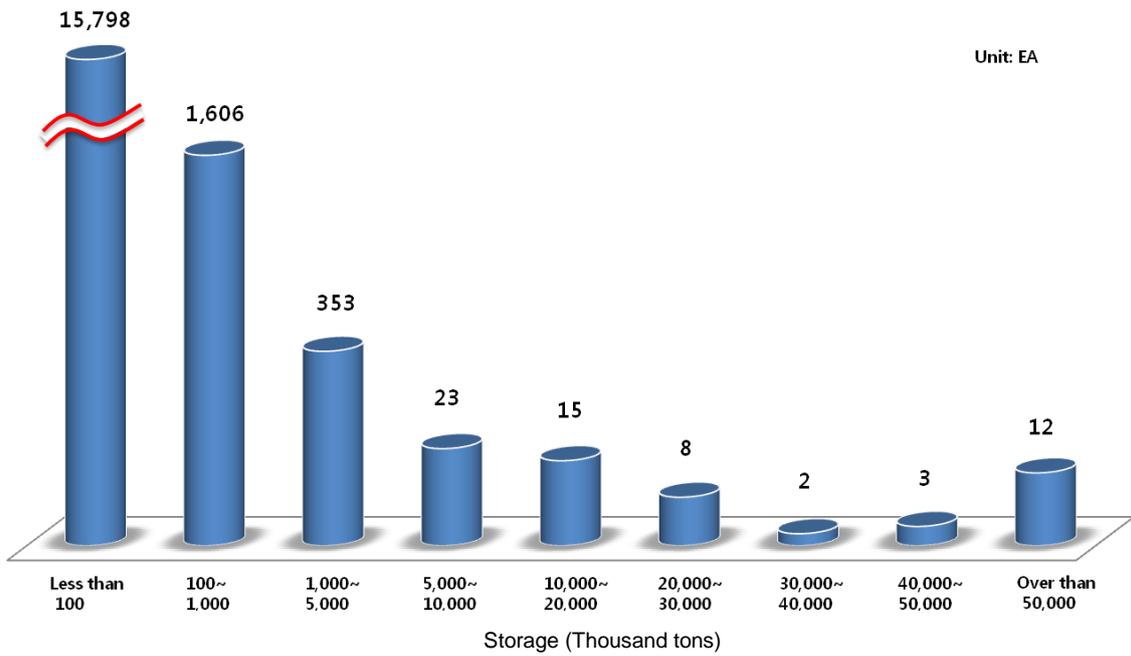
Agricultural reservoirs are the main irrigation facilities in Korea supplying more than half of the agricultural water to 453,000 ha paddy fields (56.2 %) with 17,569 reservoirs showing that reservoirs are the main agricultural water source structure. However, 52.1 % of the agricultural reservoirs were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

For paddy field irrigation, the large number agricultural dams have constructed comparing to multi and hydropower dams, but the most agricultural reservoir capacity is smaller than 100,000 cubic meters demonstrating in Figure 4. It explains that large number of small irrigation facilities is operated for small irrigation area.

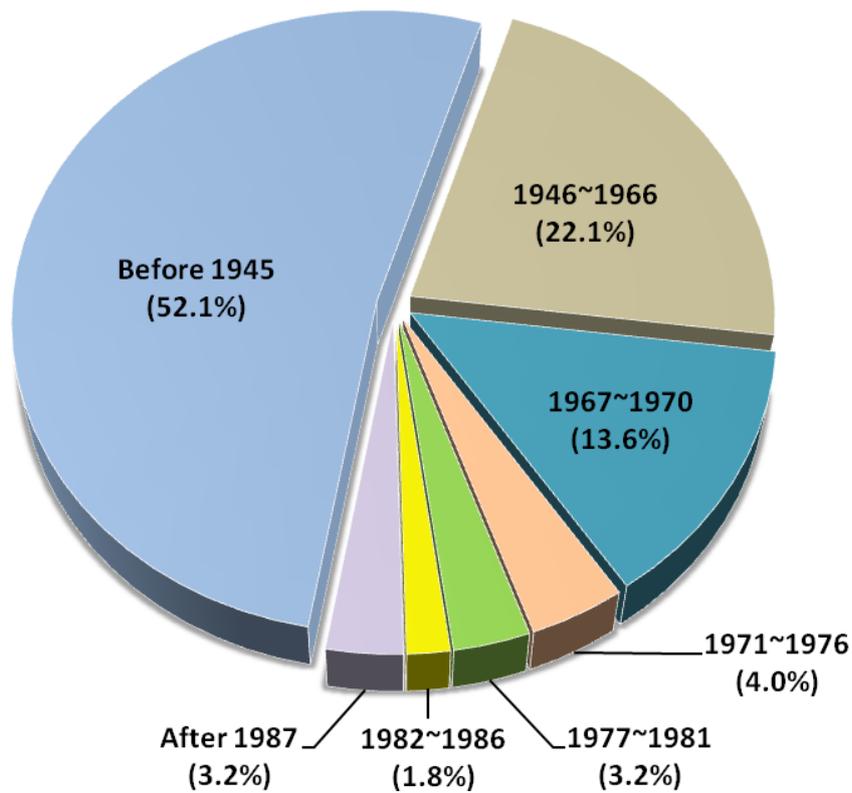


**Figure 3.** Ratio of irrigation area depending on the different water source facilities

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**Figure 4.** Number of agricultural reservoirs by effective storage



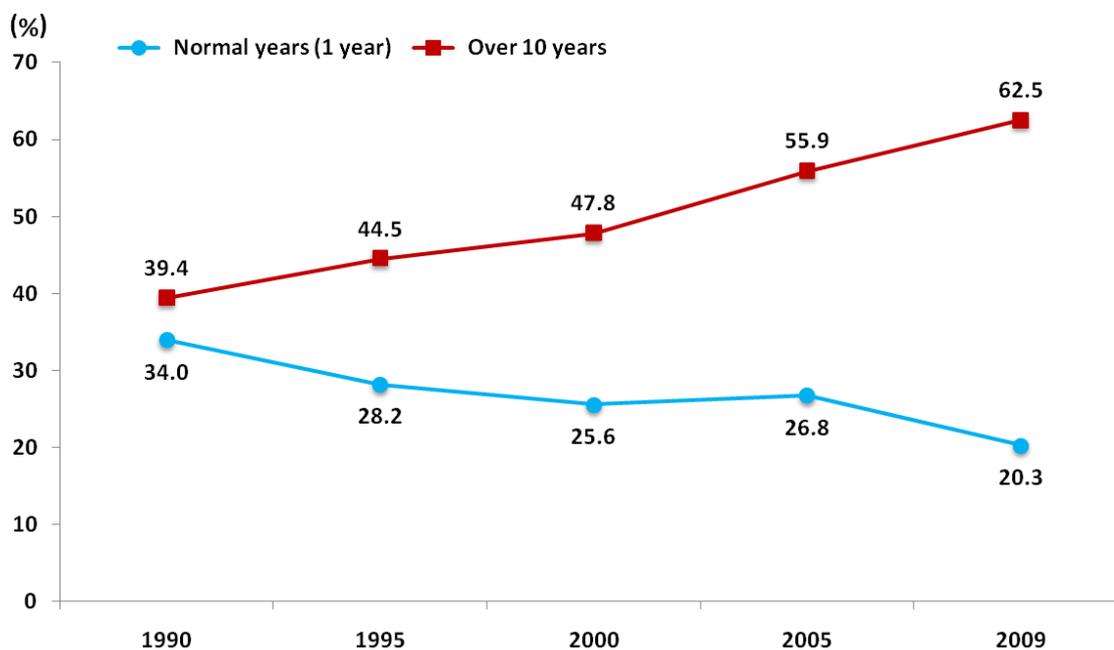
**Figure 5.** Ratio of number of reservoirs by construction year

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Drought resistant capacity of water resource facility is quite important because the structures have to supply irrigation water during drought period. In Korea, agricultural water resource structures are designed to overcome 10-year or more return period drought. The ratio of irrigation facilities that can resist 10-year or more return period drought is increasing as shown in Figure 6. The percentage of number of facilities that can irrigate during 10-year drought is 62.5 % in 2009 from 39.4 in 1990 increased 23.1 % due to large scale structure construction and maintenance efforts.

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

Irrigation and drainage canal improvement is steadily implemented to increase irrigation efficiency. Earth, lined and flume canals are quite typical water way 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 7.



**Figure 6.** Ratio of irrigation facilities by drought resistant

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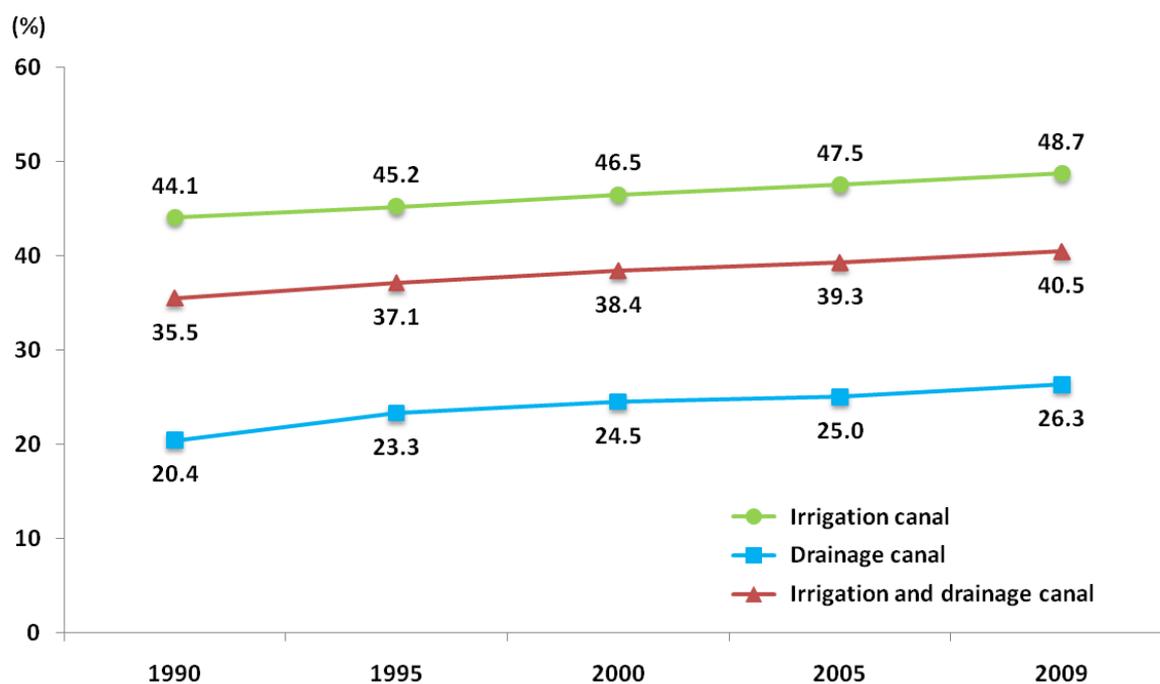


Figure 7. Ratio of structured canal during last 20 years

### Vulnerability of agricultural water resources in Korea

Climate change will effect on Korean Peninsula as well as other region. IPCC (Intergovernmental Panel on Climate Change) report in 2006 described that the rainfall amount will be increased and frequency is going to be decreased implying each storm event has more rainfall amount and no rainy days will be longer than past. Therefore, the agricultural water resources structures can be vulnerable in facing to future rainfall pattern because agricultural water resources structures, as mentioned above, have several problems in terms of operation and maintenance. Those problems can be summarized into five issues

- Large number of facilities
- Aged and deteriorated facilities
- Varied sizes and capacities
- Scattered location
- Mixed of different types of facilities.

