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Water Policy Reforms in South Korea: A Historical Review and Ongoing Challenges for Sustainable Water Governance and Management

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Abstract: This study aims to provide an opinion on the state-of-the-art of changes and reforms of water policies in South Korea, as well as the challenges along with their implications for sustainable water governance and management. In parallel with change in water resource characteristics generated by physical, environmental and socio-economic challenges such as: (1) uncertainties about climate change (flooding and drought) including seasonal and regional variation in precipitation; (2) significant increase in water use caused by rapid urbanization and population growth in industrialized urban areas; (3) inadequate water pricing mechanism which covers only around 80% of the production cost and makes it harder to maintain water systems; and (4) recursive water quality degradation and conflicts over water rights between regions resulting from non-point source pollution in highland versus lowland areas, Korean water policies have been developed through diverse reforms over 100 years. Nevertheless, new challenges for sustainable water management are continuously emerging. To meet those challenges we provide two ideas: (i) provider-gets-principle (payment for ecosystem services) of cost-benefit sharing among stakeholders who benefit from water use; and (ii) water pricing applying full-cost pricing-principle internalizing environmental externalities caused by the intensive water use. Funds secured from the application of those methods would facilitate: (1) support for upstream (rural) low income householders suffering from economic restrictions; (2) improvement in water facilities; and (3) efficient water use and demand management in South Korea's water sectors. We expect that this paper can examine the lessons relevant to challenges that South Korea faces and offer some implications on the formulation of new integration and further reforms of the institutions, laws and organizations responsible for managing water resources in South Korea.

Keywords: water policy changes and reforms; water challenges; provider-gets-principle; full-cost pricing; payment for ecosystem services

1. Introduction

Water systems are of vital importance for human well-being, providing many benefits to society in terms of water-related resources and services. For a long time, water policy has rapidly evolved in response to the ever-increasing demands that are being made on finite water resources in many parts of the world [1,2]. However, many countries worldwide still face significant challenges in managing their scarce water resources because of industrialization, urbanization, and the potential effects of climate change [3]. Due to population pressure caused by the industrialization and urbanization as the major factors for the economic growth, agricultural intensification with high external inputs of agrochemicals has been promoted, consequently leading to increasingly degraded water quality in many parts of the world [4], and climate change has increased spatial and temporal variations in water availability [5]. There are, in addition, many key water policies, institutions, and laws that are outdated and not effectively or equitably enforced [6]. Therefore, there have been many calls for water policy reforms in a number of countries [7], since current water governance systems fail to provide essential water services and to balance environmental, social, and economic concerns [8–11].

South Korea is no exception to these water management challenges. Over the last several decades, the country has gained a surprisingly high level of economic growth with an average annual rate of the Gross Domestic Products (GDP) of 8.5% [12]. However, the economic growth is achieved at the expense of the environment [13,14], such as water shortages and water quality degradation [15], which became severe during 1990s [16]. The rapid expansion of the economy has resulted in serious degradation of water supplies and ecosystems from municipal, industrial and agricultural pollution. Population and industrial growth have placed increased pressures on limited available water resources, creating water use conflicts between stakeholders [17]. Despite the fact that various water policy reforms have been undertaken, including the introduction of an additional water use charge in 1999 for lowland water users to pay for highland residents to reduce highland agricultural intensification, and that vast investments in water pollution treatment facilities have been made, water pollution problems are still encountered [18,19], indicating that the current water policy needs to be changed.

In order to provide policy makers and planners facing water management challenges in South Korea, this paper reviews the evolution of contemporary water policies in the country and the challenges along with their policy implications. Our review is an attempt to provide an overview and perspective on the history of water policy in South Korea and to discuss the drivers of water policy changes that have occurred. As stated by Moore et al. (2014) [20], understanding how policies change and the following effect on society is important as governments, civil society, and industry look to address growing water quantity and quality concerns. Increasing conflict associated with outdated or inadequate water allocation systems, and the need to consider the multiple interests of different water related stakeholders, coupled with the growing industrial, agricultural and urban demand for fresh water, are all driving an interest in water policy reform [21,22]. Hopefully, this paper is able to examine the lessons related to South Korea's challenges and provide recommendations on the formulation of new water policy in South Korea.

Our paper is structured as follows. After this Introduction Section, Section 2 examines physical, socio-economic and environmental characteristics of water resources. Section 3 reviews water policy reforms that have been undertaken since the colonial period started in 1910. Section 4 discusses the challenges and implications for water policy. Section 5 finally summarizes.

2. Characteristics of Water Resources in South Korea

2.1. Physical Characteristics

South Korea is located in East Asia on the south part of the Korean peninsula, which is surrounded by the three seas: the Yellow (West) Sea, the South Sea, and the East Sea. The longitude of the country lies between 124° and 132°. Its latitude is between 33° and 42°. This geographical location is a very significant part of determining the climate of the country which is classed as having four distinct seasons and a continental or temperate monsoon climate [23].

The country has a land area of around 99,596 km^2, and mountainous terrains which cover about 70% of the country's territory [24]. Most of the high mountains are located in the east area of the country and drop sharply to the East, while their height is gently lowered to the West and the South. That is why main four rivers run into the West (Yellow) Sea and the South Sea (see Figure 1) [23,25]. The Han River (length of 481.7 km, basin area of 26,018 km^2) is the largest one of South Korea and flows through Seoul (largest population) metropolitan areas including Inchon (third) to the West Sea. The Nakdong River (length of 506.17 km, basin area of 23,384 km^2) which is the longest one of the country flowing to the South Sea accommodates two metropolises: Busan (second) and Daegu (fourth) and several industrial cities. The Geum River (length of 394.79 km, basin area of 9912.15 km^2) begins from the central area of the country and ends in the West Sea. Daejeon and Sejong (fifth) belong to this basin. The Yeongsan River (length of 115.5 km, basin area of 3371 km^2) is a river in southwestern South Korean. It runs through Gwangju (sixth) and eventually flows into the Yellow Sea [23].

Figure 1. The four major river basins in South Korea.

As mentioned earlier, due to the Korean geographical situation in a temperate climate zone at the middle latitude of the Northern Hemisphere, the country has four different seasons (see Table 1). The winter (December to February) of the country is influenced by predominantly cold and dry northwesterly winds resulting from the Siberian high pressure system. Droughts in spring (March to May) are accompanied with northeasterly winds due to the influence of migratory anticyclones (Yangtze air mass), which brings clear and dry. In summer (June to August), the influence of the North Pacific high-pressure system brings hot and humid weather [23].

South Korea has an annual precipitation of 1277.4 mm on average (1973–2007), which is 1.6 times more than the world's average precipitation of 807 mm. The annual precipitation per capita (2660 m^3) is, however, only one-sixth of that of the world (16,427 m^3) [26]. The 10-year average precipitation has shown a gradual increase by average 2.1% from 1103 mm in 1900s to 1350 mm in 2000s. The range of fluctuation in precipitation has been also growing such as minimum 754 mm in 1939 and maximum 1756 mm in 2003. More than half of the annual precipitation is concentrated during the rainy season including the summer monsoon and typhoons (June to September) which often result in flooding and damage to life and property. Only one-fifth, on the other hand, falls in a dry period (see Table 1) (November to April). This is mainly causing severe droughts and flooding [23,27]. During this period, there are also large differences in precipitation along regions and river basins due to rainfall patterns [28,29]. The annual precipitation ranges from 1100 mm to 1800 mm in the south and east areas around the Han River and Yeongsan River, while that of the central parts around the Geum River and the Nakdong River ranges from 1100 mm to 1400 mm [23,27].

Table 1. Korean seasonal weather distinction (1973 to 2007).

Season	Winter			Spring			Summer			Fall			Sum
Month	**Dec.**	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	
Weather	**Cold, Dry**			**Mild, Dry**			**Hot, Humid**			**Serene, Dry**			
distinction	**Snow**			**Clear**			**Typhoon, Heavy Rainfall**			**Clear**			
Monthly average precipitation (mm, %)	23.2 (1.8)	27.1 (2.1)	31.8 (2.5)	49.8 (3.9)	77.1 (6.0)	94.5 (7.4)	166 (13)	287.9 (22.5)	278.3 (21.8)	151.0 (11.8)	48.2 (3.8)	42.4 (3.3)	1277.4 (100.0)
Monthly average renewable water resources (billion m^3, %)	1.59 (2.1)	1.38 (1.8)	1.52 (2.0)	2.18 (2.9)	3.07 (4.1)	3.86 (5.1)	7.31 (9.7)	18.19 (24.2)	18.41 (24.5)	12.08 (16.1)	3.55 (4.7)	2.12 (2.8)	75.26 (100.0)

Note: The numbers in parentheses are the proportions of each contents, respectively.

Total amount of water resources of the country is 129.7 billion m^3, as shown in Figure 2 (100%). The renewable water resources are, however, estimated at slightly more than half (58%, 75.3 billion m^3). These are mostly discharged during the rainy period (June to September, 56.0 billion m^3). In particular, heavy rains of the summer monsoon and typhoons cause floods in downstream urban areas of the four major river basins (see Figure 1). For human activities, no more than 33.3 billion m^3 (26%) is used and 42 billion m^3 (32%) flows directly to the sea due to the steep slope of high mountains and shallow layers of topsoil. The remainder (42%, 54.4 billion m^3) is estimated to be lost by evaporation and transpiration (Figure 2) [26].

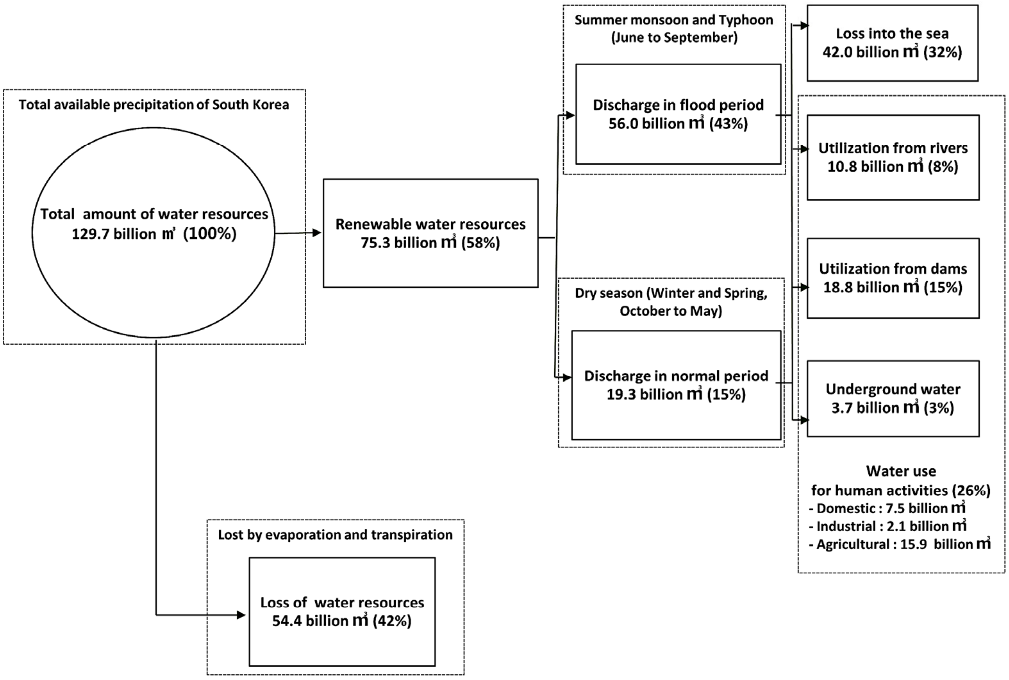

Figure 2. Utilization of water resources in South Korea. All the values are estimates from a 2007 base year.

2.2. Socio-Economic Characteristics

Figure 3 demonstrates that the nominal GDP of South Korea has increased from United States dollar (USD) 3.1 billion in 1965 to more than USD 1410.0 billion in 2014, with an annual average growth of 14.2% [30]. Along with the rapid economic growth, the country has faced considerable changes in industrial structure. For example, between 1960s and 1970s, total added value of the prime industry including agriculture to GDP had the highest ratio (28%). Through export-oriented industrialization and economic growth, its ratio significantly decreased to 2.8% in 2012. The ratio of that of the manufacturing industry such as heavy chemical and service industry inducing manufacturing business, on the other hand, increased from 16.9%, 40.4% in 1970 to 28.0%, 52.4% in 2012 respectively [31].

The population of South Korea is around 50.7 million in 2014 and its density is around 506 persons/km^2 [32], which makes it one of the world's most densely populated nations [33]. Between 1960 and 2010, the population increased with an annual average of 7.0% from about 25 million to 48.6 million. It is noteworthy that the population in urban areas has increased from 28.0% (7.0 million) of the total population in 1960 to 81.9% (39.8 million) in 2010. As shown in Figure 4, the Seoul (capital) metropolitan area, which covers only 11.8% of the nation's total land area, accounts for 49.1% of the total population (approximately 23.8 million) [32]. This remarkable population movement was promoted by industrialization and urbanization, which can provide better social and economic opportunities such as income and education [23].

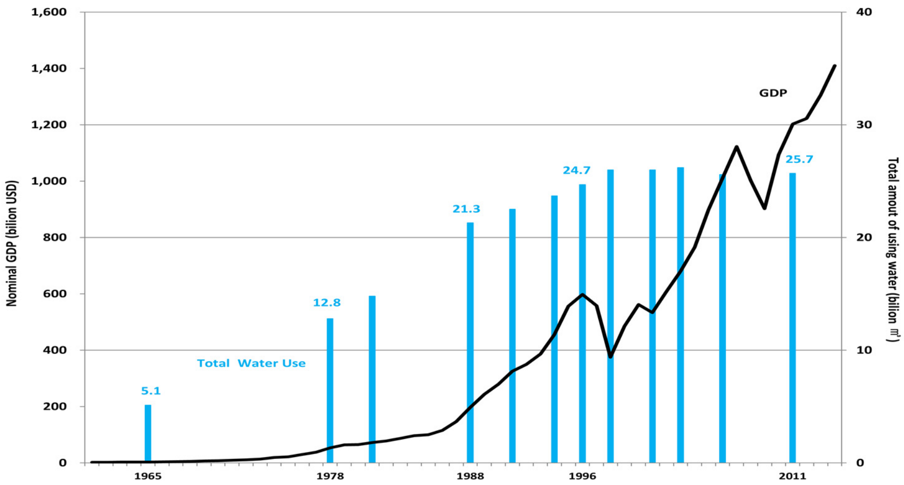

Figure 3. Trends in normal GDP and total amount of water use. Total amount of using water in 2011 is a value estimated by the Ministry of Land, Infrastructure, and Transportation based on current water consumption trends.

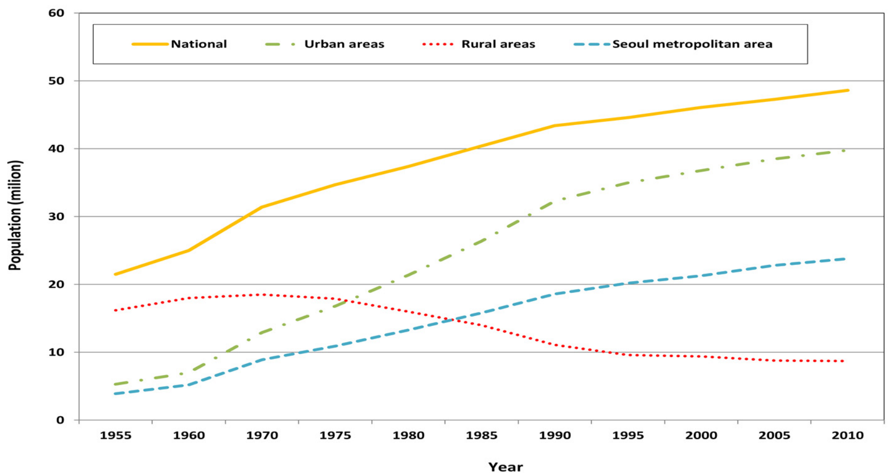

Figure 4. Population changes in rural and urban areas in South Korea. Urban areas are cities which have the population of more than 50,000. The Seoul metropolitan area includes Seoul city, Incheon city, and Gyeonggi province.

2.3. Environmental Characteristics

In South Korea, water quality degradation in river basins has been a main factor influencing policies for water resources in South Korea. The country is heavily dependent on river basins as the primary water source for human activities (around 90% dependency), which often causes the degradation of water quality [8], such as major drinking water contamination events in the early 1990s. Based on biochemical oxygen demand (BOD), indicating how fast biological organisms consume oxygen in water (good quality water in a low level, polluted water in a high level), change in water quality of the four main rivers is shown in Figure 5. Through intensive construction of treatment facilities in the mid-1990s, the water quality of the four river basins has improved. Water quality improvement has, however, slowed since the 2000s. The water quality in the Han River has been relatively stable below 1.5 mg/L of BOD concentration, while that in the Nackdong River and the Geum River have been even more variable. The level of water pollution in the Youngsan River has remained high [34].

Non-point source pollution has become main factors of making it harder to manage water quality in the river basins. In particular, there is a large difference in water quality between up- and downstream areas. Upstream areas of the main river basins have clean water (BOD concentration below 1 mg/L in general). There is a gradual decline in water quality from the midstream (BOD concentration in the range of 1.6 to 2.4 mg/L in general) to downstream areas (BOD concentration in the range of 1.7 to 2.9 mg/L in general) as presented in Figure 5 [27,34].

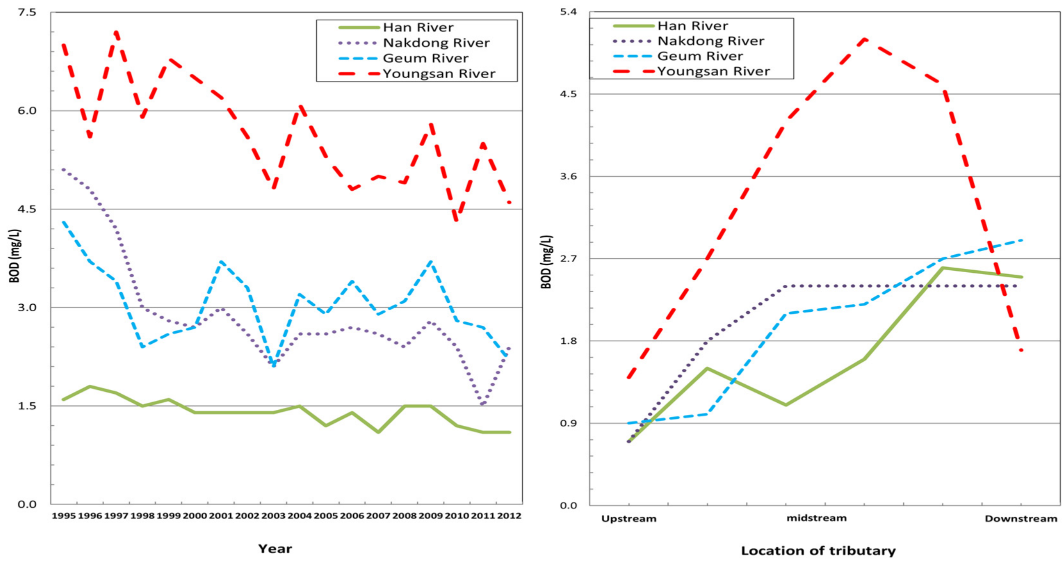

Figure 5. Change in water quality per year and change in water quality of 2012 between up- and downstream areas of the four major river basins.

3. Water Policy Reforms in South Korea

Due to those physical, socio-economic and environmental characteristics of water resources in South Korea, it is essentially needed for the country: (1) to mitigate flood risk; (2) to store water for uses in the other seasons; and (3) to protect or conserve water quality in the river basins. These feature in the fact that water policy has been the most important concerns all the time. The contemporary water governance of the country can be classified into the following periods: (i) the Japanese colonial period from 1910 to 1945; (ii) the postwar recovery period from 1945 to 1959; (iii) the modern river basin governance system development from 1960 to 1989; and (iiii) the comprehensive management of water resources: environment-friendly river basin development from 1990 to the present (Table 2).

Table 2. Historical water policy changes and reforms in South Korea.

Period	Features	Problems
Japanese colonial period (1910–1945)	Construction of hydropower dams in North Korea for industrial development and irrigation dams in South Korea for land cultivation	Mainly focused on stable food and energy provision for the Japanese
Postwar recovery period (1945–1950s)	Lack of electric power provision due to North Korea's interruption to power supply after liberation from Japan	Limited effectiveness of the program and a single purpose development project at regional focus (low population density and predominance of small-scale industry)
	Establishment of a 5-year Electric Power Development Plan	
	Construction of 158 new irrigation dams - To stabilize energy supply, food production, and economic development	

Table 2. *Cont.*

Period	Features	Problems
Modern river basin governance system development (1960s–1980s)	Promulgation of River Basin Law focusing on water supply and flood control (1961)	Deterioration of water quality in all water basins (high-intensity use of river as a resource utilized for economic growth)
	Establishment of the Ten-Year Comprehensive Water Resource Development Plan(1966–1975) and Specific Multipurpose Dam Act (1966) - Foundation of the Korea Water Resources Development Corporation (1967) Adoption of the first comprehensive river basin development concept with attention to in-land navigation - Beginning of broad-scale river basin investigations into the four major river basins (Han, Nakdong, Keum, Youngsan)	
	Revision of the River Basin Law (1971)	
	Formulation of the Four Major River Basin Comprehensive Development Plan (1971–1981) - Securing sufficient water supply for urban areas and irrigation projects for rapid economic growth - Conversion from a single- to multiple-purposes dam construction - Contribution to the development of large urban centers	
	Establishment of the Comprehensive Long-term (1981–2001) Water Resource Development Plan (1980) - A sharp rise in water demand and an actual water shortage during 1970s due to rapid industrialization and population growth - Construction of additional 249 reservoirs	
Comprehensive management of water resources: environment-friendly river basin development (1990s–present)	Tap water contamination and other environmental accidents (Trihalomethanes in 1990, Phenol in 1991, etc.)	A growing need for improvement and reorganization of water management system and institutions Conflicts over water rights (water supply and quality) between local governments (high- and lowland areas)
	Establishment of a new Long-term Comprehensive Water Resource Development Plan (1991–2011) - First putting environment-friendly river basin restoration into water resource policy	
	Promulgation of the Natural Environment Conservation Act (1991) - Promotion from the Environment Agency to the Ministry of Environment in charge of tap water and sewage management (1994)	
	Revision of the Long-term Comprehensive Plan for Water Resources (Amended and Supplemented Plan of 1997–2011) - A growing concern about shortage of water supply and uncertainty from climate change (severe droughts and flooding) - Increase in importance for environment-friendly water resource development and management	
	Revision of the River Basin Law (1999) - Changing social demands and a broad diversification in water needs	
	Establishment of Water Vision 2020 (2001–2020) - A need for the vision of a new policy paradigm in water resource development, use and consideration	
	Establishment of the First Revision of Water Vision 2020 (2006) - The lowest springtime precipitation ever recorded in 2001 - Huge flood damage to property and lives by typhoons and torrential rains in 2002 and 2003 - Combination of water resource management interests of various government agencies (Ministry of Environment, of Agriculture, and of Industry and Resources) - Participation of expert groups from local community, civic, and technical organizations in the planning at an early stage	
	Revision of the River Basin Law (2007)	
	Implementation of river basin oriented national land renovation projects (four-river restoration project of 2008–2012) - A new national land development paradigm ("low-carbon green growth") Establishment of the Second Revision of Water Vision 2020 (2011) - A growing demand in conservation and restoration of riverine environments, riparian ecosystems, and riverfront parks (recreation)	

3.1. The Japanese Colonial Period (1910 to 1945)

During this period, Japan continued to introduce advanced techniques such as civil engineering for irrigation and hydroelectric dam construction from the US [35] and conducted an investigation on water resources in major river basins across the country. Based on the research of water resources in the river basins, many large-scale hydropower dams were built in the northern part of Korea to serve industrial development, while many irrigation dams were constructed in the southern part of Korea to support land cultivation. Under Japanese rule, South Korea's river basin development was based on securing a food supply by controlling floods and protecting agricultural lands through the river basin investigation and construction of irrigation dams in the river basins.

Along with the outbreak of the Second World War in the 1940s, industrial hydropower and consumable water supply became an important matter as the country became more industrially developed. However, in this period, the implementation of a water policy on the river basin development and management was often a short-term effort. Those efforts under Japanese rule were mainly determined by the need to supply food and heavy industrial manufacturing for their people and the army [36].

3.2. The Postwar Recovery Period (1945 to 1959)

Since Korean independence from the Japanese in 1945, in addition to food shortage, South Korea suffered from insufficient supply of electric power because North Korea stopped the electrical power supply to South Korea, which was about 50% of total power demand in South Korea at that time. To solve such urgent needs for food and power, a five-year Electric Power Development Plan was initiated and new 158 irrigation dams were constructed in river basins to stabilize energy supply, food production and economic development [27,37].

After the Korean War (1950−1953), the South Korean government also started to look into ways to consume as well as to control water. The effectiveness of the program considering both water control and water use, however, remained at regional focus and was characterized by a single-purpose river basin development project due to a low population density and a predominance of small-scale industries [36]. Nevertheless, this period may be viewed as a preparatory phase for the next period of comprehensive river basin development after the postwar recovery.

3.3. Modern River Basin Governance System Development (1960 to 1990)

An organized Korean water management policy framework was initiated with the promulgation of River Basin Law in 1961 [36]. In 1967, the Korea Water Resource Development Corporation established under the River Basin Law, was exclusively responsible for the implementation of the Ten-Year Comprehensive Water Resource Development Plan (1966–1975) and the Specific Multipurpose Dam Act of 1966 mainly aiming at constructing large-size dams for hydro-electric powers [36,38]. Unlike before 1960 characterized as peripheral and small-scale river basin development, in the 1960s, the comprehensive river basin development concept was first adopted in South Korea along with particular attention to in-land navigation [38], such as broad-scale investigations into the four major river basins, namely the Han, Nakdong, Keum and Youngsan Rivers [37].

The top priorities during 1970s were securing sufficient water supply for industrialization in urban areas and irrigation projects for stable food production [38]. This is because ensuring water supply for industrial and agricultural uses and reducing damages of floods and droughts became indispensable for facilitating more rapid economic growth [8,36]. The River Basin Law was, accordingly, revised in 1971 to formulate the Four Major River Basin Comprehensive Development Plan (Comprehensive Plan of 1971–1981). The Comprehensive Plan led to the conversion from a single- to multiple-purposes dam construction (a milestone in the contemporary history of water policy of South Korea) and the critical contribution to the development of the current large urban centres of the country [36].

Rapid industrialization and urbanization, high population growth and agricultural intensification during 1970s led to a sharp increase in water demand, which caused an actual water shortage. In 1980, the Long-term Comprehensive Water Resource development Plan (1981–2001) was, therefore, commenced: (1) to expand the current dam networks to increase water supplies; and (2) to restore river basins to reduce natural disasters [36]. An additional 249 reservoirs were constructed to fulfill the rise in water demand and the ratio of restoration of the river basins increased from 48.3% in 1979 to 55.4% in 1989 [27]. Since the 1970s, the river basin development including the construction of multi-purpose dams significantly contributed to modernization of the four major river basins [36].

3.4. Comprehensive Management of Water Resources: Environment-Friendly River Basin Development (1990 to Present)

In South Korea, the construction of multi-purposes dams during the last period provided an adequate water supply and contributed to expanding water distribution systems in the 1990s [36]. Simultaneously, the most visible negative impact during this period is the deterioration of water quality in all water basins in the country due to the high-intensity use of river as a resource utilized for economic growth [38]. Contamination in tap water source and other environmental accidents such as detection of trihalomethanes in 1990, phenols in 1991, heavy metals and poisonous pesticides in 1994, and high levels of bacteria in 1993 and 1997 have raised many concerns and led to the reluctance of tap water as a drinking water source [39]. The massive uses of chemical fertilizers, insecticides, and pesticides resulted from agricultural intensification in highland regions also contributed to accelerate the problems [13]. Water pollution was identified as one of the most serious environmental issues in South Korea [40] during this period. This led to a new paradigm of the river basin management policy [8].

Due to a variety of development projects promoted after the establishment of democratic regime in early 1990s, there were frequent conflicts between local governments over water quality deterioration. It sharply increased concerns about environmental issues. Consequently, a new measure for water resource management was required, resulting in a call for environment-friendly river basin restoration [38]. A new Long-term Comprehensive Water Resource Development Plan (1991–2011) was adopted in 1990, which made the environment-friendly river basin restoration into the water resource policy for the first time [8]. The Environment Administration was, accordingly, promoted to a ministerial level (Ministry of Environment) in 1994 and took charge of tap water and sewage management [37,41]. The first introduction of the environment-friendly river basin restoration concept, which is completely different from those between 1960s and 1980s, means a lot to South Korea's water policy reform. At the planning stage of river basin restoration projects in this period, however, local authorities rarely considered improvement of ecological values of the river [38].

In 1994, the National Land Use and Management Act facilitating land development around the Paldang Lake of the Han River basin, which is the main source of water supply for the Seoul metropolitan area considerably accelerated water quality deterioration [18,42]. Despite subsequent efforts of the Korean government to control water quality and quantity, the unsatisfactory results were continually derived [43]. The Han River Law was established in 1999 to improve water quality and manage drinking water sources and to support communities in highland areas of the Han River Basin for compensation as an economic incentive to reduce the amount of chemical uses. This led to the introduction of an additional water use charge that downstream residents have to pay [33]. Water users of downstream areas such as Seoul city, Incheon city, and 25 districts of Gyeonggi-do, who were supplied with raw or purified water from upstream water conservation zones in 11 districts of Gyeonggi-do, Gangwon-do, and Chungcheongbuk-do, pay for this charge to compensate upstream communities and their people for regulating economic activities (e.g., housing and highland agriculture).

Due to uncertainty about climate change, e.g., possible severe droughts and/or flooding which would inhibit economic growth, and the growing importance of environment-friendly river basin restoration, the Long-Term Comprehensive Plan for Water Resources (Amended and Supplemented Plan of 1997–2011) was revised in 1996 [36]. The 1999 revised River Basin Law envisaged an overall improvement in national developmental planning. Nevertheless, the policies were implemented with skepticism, continued concerns about the safety of tap water, and conflicts over water rights along the river basins [37].

In 2000, new water policy strategies and specific plans were required to implement the vision of a new policy paradigm in considering the river basin development, use and conservation [36]. Revision of the River Basin Law in 1999 confronted changing social demands and a broad diversification in water needs. Accordingly, the Water Vision 2020 (2001–2020) was established in 2001 with the contents of allowing efficient river basin restoration to deal with unusual droughts and floods, limited water resources, and water pollution [27,36]. Based on the River Basin Law revised in 1999, the Comprehensive Long-term Water Resource Plan, which is established every 20 years and reviewed every five years, became the water policy with a top priority in securing stable water resources and efficient use, development, and preservation of river basins [27]. However, river basin restoration projects involving too much emphasis on engineering of water flow (dam-oriented construction), and ignoring stakeholder participation in decision-making, were still dominant during this period [38]. This, as a result, led to conflicts over the environmental suitability of dam construction and the decision-making process for national water resources plans [44].

Rapid environmental, social and economic changes after the turn of the century triggered changes in the Water Vision 2020 even as early as in 2001. The lowest springtime precipitation was ever recorded in 2001, leading to severe droughts that were unprecedented in history. Secondly, the typhoons and torrential rains in 2002 and 2003 resulted in extensive flood damage in terms of property and lives around the country. Strong demand for adequate water resource management forced the Water Vision 2020 to be revised in 2006. The long- and mid-term water resource management concerns of various government agencies in the Ministry of Environment, Ministry of Agriculture, and Ministry of Industry and Resources, were to be combined. Furthermore, expert groups from local communities, civic, and technical organizations were able to participate in the river basin restoration planning at an early stage [36]. In spite of many regional river restoration projects with diverse forms of partnership, it was rare to find a special ordinance to define the role, structure, organization, and finance [38] which plays a vital role in the water resource management [23]. There was also a limit to a bottom-up approach to creation of a vision which not only shows what the regional water policy might look like and how it can work for the community [45], but also motivates local residents to participate in water project voluntarily [38].

Since the mid-2000s, climate change has been the most urgent issue in water management. With the River Basin Law revision in 2007, national efforts to ensure stable supply of water resources despite climate change have been addressed in the Long-term Comprehensive Water Resource Plan. The Korean government conducted river basin oriented national land renovation projects (four-river restoration project) along with a new national land development paradigm (low-carbon green growth) [27]. As life quality improves with higher standards of living, a growing demand has arisen for the conservation of riverine environments, restoration of riparian ecosystems, and recreation which is being provided in riverfront parks. Based on this growing water demand, the Water Vision 2020 was second revised in 2011 [36].

Nevertheless, there are still growing challenges for improvement and reorganization of water management system and institutions to mitigate or resolve conflicts over water quality and supply between local governments.

Despite Korean continuous water policy changes and reforms over 100 years, those physical, environmental and socio-economic challenges such as uncertainty about climate change (flooding and droughts), rapidly rising water use and water scarcity due to economic growth (industrialization and urbanization) impede sustainable socio-economic development and accelerate water quality deterioration, consequentially increasing the vulnerability of ecosystems (agricultural intensification in highland areas) in the river basins. Forming an integrative water resources management system at the river basin is, thus, crucial for ensuring the sustainable development (water use efficiency) and ecological security (conservation or improvement of ecosystem services) of river basins (Figure 6).

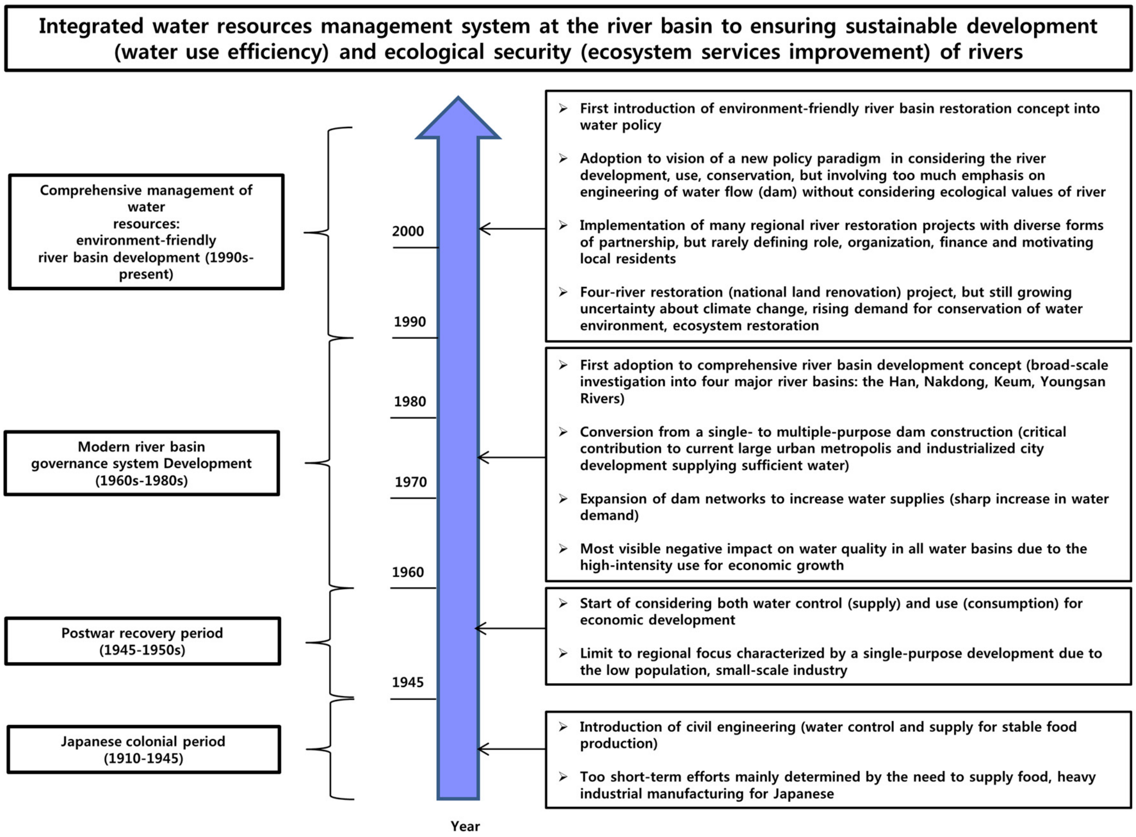

Figure 6. South Korea's water policy reforms and their implications for future water policy making.

4. Challenges for Water Policy in South Korea

The challenges in managing water resources are neither homogenous nor constant over time [46,47]. While many risks and uncertainties are predictable, it is hard to derive the exact magnitude and reliable implications in terms of water management and other associated impacts [48]. Although many changes in water policies have been undertaken in South Korea, and other countries, there are still many challenges that need to be solved. These include environmental, physical, socio-economic, etc. challenges.

4.1. Environmental and Physical Challenges

4.1.1. Damage to Water Quality and Ecosystems of River Basins

The seasonal and regional characteristics of water resources in South Korea such as the concentration of approximately 69% of the annual precipitation in the middle of summer monsoon and typhoon [27] and large differences in precipitation along river basins [28,29] represent environmental challenges to make the country highly vulnerable to seasonal oscillation between floods and droughts, which make water quality worse and threaten ecosystems.

Moreover, the renewable water resources of South Korean is at 1553 m^3 per person per year which accounts for around 72.9% of that of China (2130 m^3) and around 48.1% of that of Japan (3232 m^3), and considerably lower (18.5%) than that of the global average (8372 m^3) [26]. This result shows that despite abundant precipitation, Korean water conditions are still poor due to dense population in its limited land space. Concentration of the population in large cities, including the Seoul metropolitan area, together with the regional variations in precipitation has often led to severe regional differences in renewable water resources per person per year. The Han River basin accommodating the Seoul metropolitan area has the lowest volume of local renewable water resources per person (annual average 907 m^3 of renewable water resources during 1968–2007) compared with the other three major river basins [23].

Since 1999, chemically contaminated and turbid water problems have continuously occurred along the Han River Basin due to heavy rains. For example, the heavy rains during Typhoon Ewiniar in 2006 led to the export of massive quantities of sediments to the Soyang Lake and, in turn, led to long-term turbid water discharge problems along the Han River Basin [19] when high soil erosion occurred in mountainous agricultural areas. Consequently, it has caused frequent conflicts over the responsibility for water quality management among up-, mid-, and downstream along the river basin.

In South Korea, floods and droughts appear to be intensified over time and occur more frequently due to environmental and physical challenges caused by climate change. This, thus, causes serious socio–economic losses, environmental damages, and difficulty in managing water resources systems which result in changes in the hydrologic cycle and water availability [49]. In particular, regional and seasonal variations in precipitation have had negative impacts on water quality and the ecosystems in river basins. The damage to water environments causes conflicts over water rights between up- and downstream areas [19,50].

4.1.2. Regional Water Use Conflict

Due to the seasonal and regional variation in renewable water resources in South Korea, dam construction was adopted as the prime means for flood control and water supply and was planned particularly in the upstream areas of main rivers for water delivery to support the expansion of downstream urban and industrial areas [23]. The multi-purposes dams have contributed to urban and industrial water supply (10.9 billion m^3, 32.7%) of the total water supply capacity (33.3 billion m^3), and flood control (2.2 billion m^3, 3.9%) of the total discharge (56.0 billion m^3) is held back during the flooding period (Table 3) [27].

Table 3. Current status of dams in South Korea.

Classification (million m^3/Year)	Number of Dams	Total Water Storage	Flood Control	Water Supply
Multipurpose	15	12,588.9	2197.6	10,883.1
Hydroelectric	12	1793.8	266.0	1335.0
Water supply	19	609.0	23.5	880.5
Estuary	12	1258.3	0.0	2930.0
Irrigation	6	2801.8	19.0	2742.0
Irrigation reservoir	17,643	2457.0	0.0	2457.0
Flood control	1	2630.0	2630.0	0.0
Total	17,708	24,138.8	5136.1	21,227.6

Nevertheless, recent trends in precipitation variability along with economic growth intensify vulnerability to water pollution as well as damage from natural disasters, and lead to an increased need for a new water quality management system [51]. Moreover, conflicts over water-related issues, in particular frequent disputes between local governments in up- and downstream areas about the effectiveness of water use charges for water quality improvement shows that existing water quality management policies which the Korean government implements are facing challenges [19,29].

Conflicts over water rights between up- and downstream areas in South Korea have increasingly occurred despite governmental implementation of diverse measures for water quality improvement, e.g., a water use charge based on the beneficiary (or user) pays principle [18,50]. In particular, the inflow of agro-chemically contaminated turbid water caused by heavy rain at highland dry fields to the Han River Basin has exacerbated water quality problems [19,24,52]. The water use charge gradually increased from South Korean won (KRW) 80 per m^3 in 1999 to KRW 170 per m^3 in 2012 and has been maintained at this level up to now in 2016 [18,53]. The residents in downstream areas argues that the water use charge should be reduced or abolished, while upstream residents insist that overlapping regulations in the upstream areas should be eliminated and compensation for water quality improvement in the Han River basin should increase [18].

There is, accordingly, a growing need for a new allocation system of costs and benefits related to water supply and quality improvement. However, an important obstacle to attain the goals around the world has been the failure to adequately address financial challenges such as the costs of attaining goals, how to achieve lower costs and more efficiency, matching costs with available resources, which framework for and how to implement the cost-benefit sharing [54]. It is obvious that economic instruments based on economic analysis of water uses such as water pricing play a vital and very effective role in financing water resources management. However, additional issues caused by applying the economic instruments such as the role of private sectors (all stakeholders) and how to elicit benefits from water services that are not traded in real markets should be considered in a practical approach on a case-by-case basis.

In South Korea, the Han River basin is a major drinking water source and provides many tangible and intangible benefits to its mid- and downstream (the Seoul metropolitan) areas. Based on the benefits provided by the basin, the mid- and downstream areas have been economically developed while the upstream areas have not. Despite the implementation of the water use charge to support communities and their people in the upstream areas, some problems regarding equal distribution of the benefits of using water resources between river basin stakeholders remain [55,56]. It is necessary to pay close attention to upstream areas' roles as a provider of water services such as protection or conservation of water resources and ecosystems, along with provision of a safe and stable water supply to the mid- and downstream areas. These opportunity costs that the upstream areas lose by the regulations should be compensated [55] based on the provider gets principle, i.e., payment for ecosystem services [57,58]. To minimize negative effects caused by conflicts over water rights between local communities, it is obvious that a broader stakeholder involvement is needed in planning and decision-making of policies related to water rights [38].

4.2. Socio-Economic Challenges

4.2.1. Rapid Rise in Water Use as Economic Growth

Rapid industrialization, urbanization and population growth in urban and industrial areas around the four major river basins contributed to not only changing water environment such as intensive construction of water service systems to support the expanding Seoul metropolitan areas and industrial cities, but also deepening the socio-economic gap between urban and rural areas [33].

In particular, the striking population shift from rural to urban areas has been very significant for notable changes that have occurred in the socio-economic structure of South Korea. In particular, the high population density in relatively small areas results in extremely high local demand for water, that is, one of the crucial infra-structural inputs, which enhances the productivity of capital, labor, and other factors necessary for socio-economic development [59,60], with substantial influence on the planning for flood control and necessitating special measures to supply water year-round. It increased the need for construction of new water supply systems [50]. As a result, industrialization, urbanization and population growth triggered a sizeable increase in total water use by five times (5.1 billion m^3 in 1965 to 25.7 billion m^3 in 2011) (Figure 3) and have influenced strikingly the amount of water resource consumption and its pattern [60,61].

According to the second revised version of the Water Vision 2020 (2011–2020) [27], the total amount of water being used will continue to increase by an average of 1.2% per year based on current water consumption trends. Therefore, the stabilization of water demand would be one of the main drivers of the policy change and reform of South Korea's water sector, causing shift from the development of new water resources to water demand control [23]

4.2.2. Inadequate Water Pricing Mechanism

During the recent decades, the national average water charge has risen on the average by 5.4% per year, from KRW (South Korean won) 211 per m^3 in 1991 to KRW 660 per m^3 in 2013, in proportion to the tap water by 5.6% per year, between KRW 260 per m^3 in 1991 and KRW 849 per m^3 in 2013. Nevertheless, the average water charge, which is different among domestic, industrial, and other uses, covers only part (77.8% in 2013) of the production costs as shown in Figure 7. Water is priced without considering a full cost recovery principle, and environmental externalities are not taken into account. In particular, the domestic water use during a year of 2013 accounted for 63.5% (3.26 billion m^3) of the total tap water consumption (5.13 billion m^3), which is the highest proportion in use, while the rate of recovering production costs via the domestic water charge (KRW 482.8 per m^3) is the lowest (56.8%) [62].

More seriously, the proportion of recovered production costs in the water utility bills has decreased on average by 1.2% per year, from 89.3% in 2003 to 77.8% in 2013. On the other hand, the daily water use per capita has increased from 265 L in 1998 up to 282 L in 2013 as illustrated in Figure 7 [62]. As stated in Kim (2013) [63], the Korean daily water use per capita is 1.2 times higher than that of the UK, 2 times than that in France and Germany, and 2.5 times than that in Denmark. The Korean low average water charge is most likely to result in excessive water use. Park and Choi (2006) [64] recently estimated the price of elasticity of water for domestic use using data from 176 local governments. As a result, the price coefficients ranged from −0.048 to −0.052, which means, if the price rises by 10%, water demand falls by around 0.5%. This value is lower than those of previous studies such as Jeon et al. (1995) [65], Kim (1996) [66], Gwack et al. (2002) [67]. Nevertheless, the water price can apparently contribute to managing water demand. First, it is true that a rise in the water price has an effect on water saving. Annual domestic water use is around 7.0 billion m^3. Based on the price elasticity of −0.05, around 3.5 hundred million m^3 per year can be saved through the price increase. Despite the low price coefficients, considering attributes of water resources for which there is no substitute and recent continuous increase in water supply (production) costs, the water price would be a significantly effective tool to manage water demand. Conversely, the low water price can contribute to increasing water use continuously and eventually has negative impact on water quality in the rivers [63].

Along with the dam development for water distribution between regions, the Korean government has continued investment in the multi-regional water supply system, resulting in increase in the water supply ratio (percentage of the population who has running water) from 16.8% in 1960 to 98.5% in 2013 (Figure 7) [63]. A continually rising water demand as well as outdated water management facilities in South Korea is, nevertheless, expected not only to intensify the imbalance between water supply and demand under the influences of climate change, but also to cause difficulties in mitigating uncertain water quality changes.

Rational water pricing for the effective use and management of water in South Korea, e.g., water saving and environmental conservation, has become a key social and political issue due to the effects of climate change. The water charge, in particular, remains below the production cost [63]. Additionally, there is resistance of many Koreans to an increase in the water charge due to deep perception of water as a public good and of more governmental responsibilities for water distribution and use [68]. Experiences from other countries indicate that it is needed for South Korea to have a better water pricing system. The funds secured through appropriate water utility billing should then be used to support the water welfare of low income households as well as stakeholders in upstream areas where economic activities are restricted to ensure water quality protection in large reservoirs. Furthermore, support is required to invest in and improve water-related infrastructure, e.g., upgrading water processing facilities. Rational water pricing, which fully considers the cost of supply is critically necessary not only to obtaining funds for maintenance and development of water-related facilities, but also for saving water and effectively improving water quality in general [63] (Table 4).

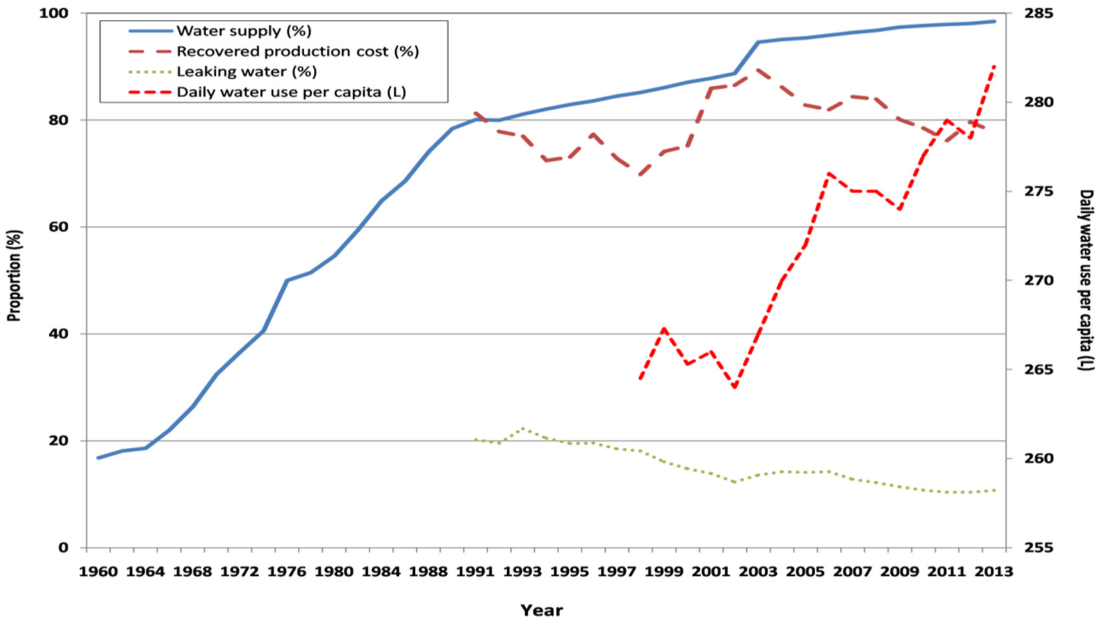

Figure 7. The proportion of water supply (percentage of the population who has running water), recovering production costs via the water utility bills, the amount of water leaking from outdated water pipe networks, and per capita daily water use of South Korea.

Table 4. Challenges and implications of Korean water policy.

Challenges	Implications
Conflicts over water quality and supply between local governments in high- versus lowland areas	Need for a new sharing criterion of benefits and costs from water quality policy (e.g., water use charge) between high- and lowland areas Application of the provider gets principle considering provision of environmental services (payment for ecosystem services)
Inadequate water pricing mechanism (outdated water facilities, inefficient water demand and quality management)	Rational water pricing recovering the production costs based on the full cost recovery principle to effectively use and manage water Supporting low income households and the upstream areas damaged from dam construction and economic restrictions that result in the process of water quality protection Improving outdated water facilities and strengthening efficient water use and demand management (water saving, environment conservation)

5. Concluding Remarks

Monitoring and development of water resources have been important considerations in South Korea for over 100 years from the Japanese colonial period up to now. The characteristics of water availability and supply have been influenced by environmental changes as well as long-term shifts in social-economic factors. South Korea has developed water management policies through continuous response to such surrounding conditions above and must be viewed as a series of stepwise reforms. Nevertheless, persistent and new water challenges emerge, including a growing demand for water due to economic growth, the need for an acceptable water quality in many regions, insufficient and ineffective practical implementation of the water management system, and uncertainties due to climate change. As noted by Juliet et al. (2011) [6], the water management reforms in some foreign countries (South Africa, Australia, European Union countries, and Russia) have introduced innovative approaches to better cope with their water challenges, emphasizing soft-path water solutions that address inequitable water policies which are influencing ecosystems and the natural resource base. These include efficient water use and conservation, rational water pricing, provider gets principle (payment for ecosystem services), and additional aspects of public participatory water management.

Examining the characteristics of water resources in South Korea, we demonstrate that South Korea is facing four major challenges in the water management policy and should reassess management approaches. First, water resource policy must confront the risks and uncertainties associated with climate change. Regional and seasonal differences in precipitation and in renewable water resources have resulted in droughts during the dry season (winter and spring, November−May) as well as flooding during the rainy season (summer monsoon and typhoon, June−September). Second, rapid industrialization, urbanization and population growth, particularly in the Seoul metropolitan area, have resulted in remarkable changes in the socio-economic structure and pattern of water consumption. To provide adequate supply, many dams were constructed in the upstream areas of main river basins to store water for flood control, to generate electricity, and to stabilize water supply to the mid- and downstream areas. However, the supply has an upper limit and negative externalities, e.g., loss of riparian habitat, submergence of usable valley land, and water quality deterioration due to the need for highland farming on mountain slopes, have not been adequately compensated. Thus, a third need, namely maintenance of the system as well as compensation for externalities, is not appropriately supported by water use charges and water utility charges, which covers only about 80% of the production cost. Finally, water quality improvement in the four major river basins has slowed in recent years despite continuous investment in environmental treatment facilities after the environmental crises that occurred in the early 1990s. Non-point source pollution, such as the inflow of contaminated turbid water caused by heavy rain in the upstream highland dry fields has become a main cause of water quality degradation and has caused conflicts over water rights between local governments in highland versus lowland areas.

In agreement with measures taken in other countries, we suggest that rational water utility pricing must be applied based on the full cost recovery principle to effectively use and manage water. The funds secured by recovering the production costs should be used: (1) to support low income households and the upstream areas damaged by dam construction as well as the economic restrictions that result in the process of water quality protection; (2) to improve outdated water facilities; and (3) to strengthen efficient water use and demand management. Secondly, there is a need for a new sharing criterion on benefits and costs of water quality policies (e.g., water use charge) between up- and downstream areas based on the provider gets principle considering provision of environmental services (payment for ecosystem services).

Long-term problem solutions require greater investments, more technology, higher human capacities and intensified co-operation between countries, sectors, organizations and different societal strata. Therefore, plans to address the risks, uncertainties and conflicts over water will require new integration and further reforms of the institutions, laws and organizations responsible for managing water resources in South Korea.

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