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Review

The Inclusion of Forest Hydrological Services in the Sustainable Development Strategy of South Korea

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Abstract: In the last decade, the South Korean government has implemented an unprecedented series of plans and policy actions to promote sustainable development, including the National Strategy for Green Growth. Some of these initiatives were direct responses to the evolving challenges in the water sector, and put forest hydrological services into perspective. To a certain extent, water was managed within a wider environmental context through the combination of forest and water management. However, the efforts to enhance forest hydrological services did not correspond to the immense potential of forests for the achievement of sustainable water management. We present a comprehensive and current view of the major challenges and opportunities related to forest hydrological services in South Korea. We identify key forest hydrological services in view of the major biophysical, environmental, and economic challenges in the water sector. We propose guidelines for the enhancement of forest hydrological services and for a better inclusion of these services in South Korea's sustainable development strategy. An increased contribution of forests to the provision of high-quality water in sufficient, regulated amounts, and to the preservation of a safe environment in regards to natural hazards is imperative for the long-term development of South Korea.

Keywords: ecosystem services; green growth; forest and water management; Four Major Rivers Restoration Project

1. Introduction

The importance of forests for the provision of water-related benefits is continuously increasing [1,2]. In many parts of the world, forest hydrological services have significantly contributed to sustainable development, and measures for their preservation and enhancement have been included in national development strategies. In 2008, the Republic of Korea (hereinafter referred to as South Korea) defined sustainable development as one of its primary missions. The creation of the Presidential Commission on Sustainable Development and the subsequent Presidential Commission on Green Growth initiated the development of sector-based strategies, which resulted in the implementation of numerous initiatives for the sustainable development of the nation. The National Strategy for Green Growth implemented in 2009 is the most comprehensive environmental plan that South Korea has ever implemented [3]. The Strategy follows the international principles of green growth, and South Korea is innovating in this field [4]. The three main objectives of the Strategy are (i) to mitigate climate change and enhance energy independence; (ii) to create new engines for economic growth; and (iii) to improve the quality of life and enhance the international standing of the nation [5]. In the short-term, the Strategy aims at stimulating job creation and revitalizing the economy. In the mid- and long-term, it aims at achieving the sustainable management of the nation's natural resources. Two of the major sectors of the Strategy are forest and water. Although forests usually reduce the amount of water available for use by the process of transpiration, they can enhance water supply by the capture of precipitation, the regulation of water flow, and the preservation or improvement of water quality, among other processes [6,7]. In this sense, forests can play an important role in the sustainable management of water. Since forests account for 61.1% of the land cover of South Korea [8], their consideration and use for the achievement of sustainable water management is highly pertinent. We believe that this should be reflected in an adequate inclusion of forest hydrological services in the National Strategy for Green Growth.

Due to the increasing urbanization and industrialization of the country, to the high population density, to the mountainous topography, to the seasonal precipitation regime, to agricultural intensification in highland areas, and to an overuse of chemical fertilizers, the South Korean water resources have been under pressure. South Korea's rapid economic growth was achieved at a cost to the environment [9,10]. It is partly responsible for the aggravation of problems in the temporal regulation of water supply and the preservation of water quality. In fact, municipal, industrial, and agricultural pollution related to organic nitrates and phosphates has been identified as the most serious environmental issue [11]. The increasing concentration of these nutrients in rivers, lakes, and reservoirs has led to the eutrophication of surface and coastal waters [12,13].

The recent shift operated by the government from quantity-oriented growth to green growth has put forest hydrological services into perspective. To a certain extent, the nation has recognized the contribution of forests towards sustainable water management by including reforestation and forest management in projects such as the Four Major Rivers Restoration Project (FMRRP). This project was first implemented in the Han River basin, which is considered the heart of South Korea due to its population and the ecosystem services it provides to the population [14]. The supply of water by the Han River basin is an ecosystem service that is highly valued by a significant proportion of the South Korean population [15]. Nature and man have endowed the basin with many reservoirs, lakes, and rivers of which the watersheds are mostly covered by forests. These watersheds are the main sources of freshwater for the Seoul Capital Area. The basin provides additional services, such as food, erosion prevention, carbon sequestration and storage, habitat for species, local climate air quality, recreation, and tourism [16]. The Han River basin is a good example of a socio-ecological system, where agricultural production and the supply of high-quality water to downstream regions are highly valued and desired, but sometimes opposed [17,18]. Initiatives such as payments for ecosystem services have helped to improve the situation, not only in terms of environmental conditions, but also in terms of human health and wealth distribution [4,19]. Public engagement in sustainable development was solicited by the government, and the nation positively responded and acted at all levels [20].

However, in most parts of the country, problems of water supply and quality still emerge or have worsened from the effects of climate change and changes in land cover and land use [21,22]. The prospect of future increasing hydroclimatic variability stresses the importance of these problems in policy and scientific agendas. Further opportunities to regulate water supply and improve water quality through improved and expanded forest management are at hand [23–25]. Unfortunately, the increased pressure on water resources has fuelled conflicts between stakeholders [26]. Moreover, various stakeholders have raised criticism towards the motives, the content, and some of the results of the FMRRP [27]. We believe that this should be taken into account in the future development of policy and scientific agendas.

In the current article, we review the forest hydrological services in South Korea and their inclusion in the national sustainable development strategy. We rely on the wealth of articles, reports, and documents published in the recent past to derive a comprehensive view of the major challenges and current opportunities. This review concerns the following questions: (i) in South Korea, what are the most essential (i.e., key) hydrological services that can be provided by forests, and (ii) are these key forest hydrological services appropriately included in the sustainable development strategy? Our answers to these questions should provide information and suggestions to policy-makers, scientists, and other stakeholders engaged in the sustainable management of forests and water in South Korea. We also aim to promote reflection on the current issues.

2. Major Challenges in the Water Sector

The hydrological regime of South Korean water bodies displays a pronounced seasonality, as the climate of South Korea is characterized by cold and dry winters, and hot and moist summers [28]. More than 60% of the annual rainfall is concentrated in the summer months and related to the occurrence of the East Asian summer monsoon (EASM), of which the precipitation regime is characterized by heavy rainfall events [29]. The mountainous topography of South Korea also contributes to this pronounced seasonality, as water rapidly flows from steep slopes of short lengths and shallow soils to streams and rivers of short reaches and steep channels [28]. Although the annual rainfall of South Korea is ~60% higher than the global average, water availability per capita is only ~12% higher and is lower than the average for OECD countries [30–33]. This discrepancy can be partly explained by the complexity of water management in conditions of large flow magnitude. In fact, such conditions have resulted in relatively frequent floods and droughts in South Korea [32,34]. The severity of floods and droughts is highly variable, as the EASM exhibits a substantial interannual variability in intensity [35]. Eighteen droughts have occurred over the last 100 years, with severe droughts occurring in seven-year cycles since 1994 (Table 1). Over the last decade, the annual average damage caused by floods amounted to ~1.1 billion U.S. dollars (USD) (Figure 1).

Table 1. Droughts and associated damages since 1990 (from Ishiwatari et al. (2016) [32]).

Year	Damages
1994–1995	Limited water supply for 222,000 persons in 86 cities and counties
2001	Limited water supply for 304,815 persons in 86 cities and counties
2002	Limited water supply for 92,838 persons in 23 cities and counties
2008–2009	Limited water supply for 228,068 persons

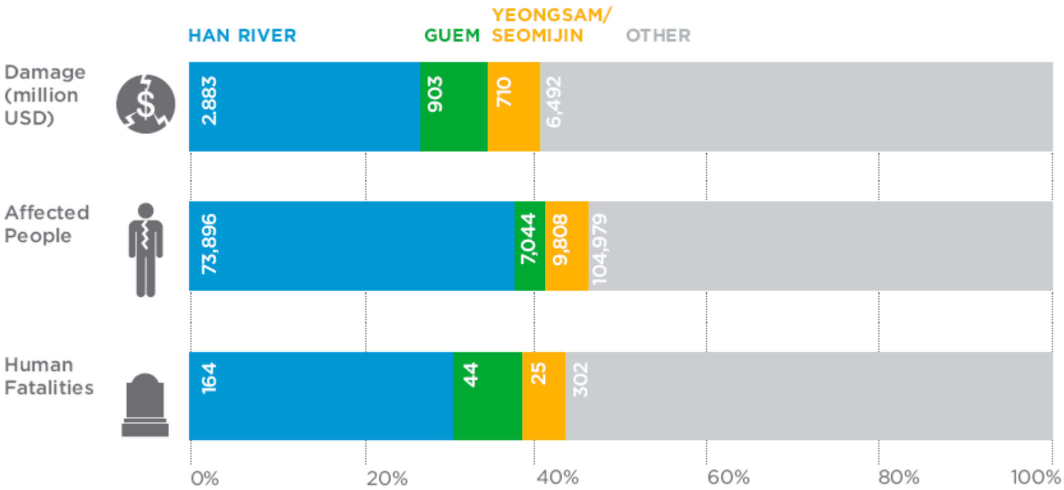

Figure 1. Flood damage over the last decade (from Ishiwatari et al. (2016) [32]).

In recent decades, changes in the climate of South Korea have been observed, namely an above-global-average increase in surface temperature, and a substantial increase in the frequency and intensity of heavy rainfall events [36–38]. From 1954 to 1999, surface temperature increased at a rate of 0.23 °C per decade, and from 2001 to 2010, at a rate of 0.5 °C per decade [35]. Choi et al. (2008) [39] reported that, in the region of the Lake Soyang watershed, the precipitation of extremely wet days increased by 61 to 80 mm per decade over the period from 1973 to 2007. The observed changes are predicted to intensify until at least 2100, along with an increase in the occurrence and severity of floods and droughts [40–43]. The United Nations has projected that, in terms of water availability, the Seoul Capital Area will be under very severe water stress by 2050 (<500 m^3 of freshwater per capita per year) [44].

South Korea is highly dependent on its ~18,000 reservoirs for its water supply. In recent decades, increasing trends of sediment load, nutrient load, and consequent sedimentation and eutrophication of some of the major reservoirs have been observed. These trends are related to increasing rates of soil erosion and nonpoint source pollution [21,45]. In 2003, between 42.4% and 68.7% of the total pollutant load of the four major rivers originated from nonpoint sources (based on data of biological oxygen demand (BOD)) [46]. As a matter of fact, the development of agriculture in highland areas has been a major factor in the increase in sediment and nutrient loads. In these areas, steep slopes prevail and a change in land cover from forest to agricultural field, concurrent with the tilling of the land, is usually followed by a substantial increase in the average rate of soil erosion [47]. In addition, the high levels of fertilizer application practiced and the production of animal manure result in the massive input of nutrients to water bodies. There is a strong seasonality in the input of nutrients and sediment to reservoirs, as rates substantially increase in response to heavy rainfall events of the EASM [21,48,49]. Accordingly, changes in the water balance components of watersheds from the aforementioned increases in extreme hydroclimatic conditions have also contributed to the increase in sediment and nutrient loads [50]. The combined effects of changes in land cover, land use, and climate have had and are predicted to continue having considerable and negative impacts on the South Korean water resources [51–53].

Highland agricultural intensification has not only caused water pollution but also led to increasing water use conflicts between stakeholders of highland and lowland areas. The public distrust of national and local governments has also been increasing [54]. A water use charge was imposed in 1999 on downstream users to pay for upstream farmers to preserve water quality. The charge was increased with time, from 80 KRW/m^3 in 1999 to 170 KRW/m^3 in 2012, but upstream farmers have declared that the payments do not correspond to their efforts. Meanwhile, downstream users have claimed that, due to water quality problems, upstream farmers should not be compensated. Downstream users have also raised concern that money raised by the charge has not been used in an efficient way by national and local authorities [26,54]. Another issue is the water pricing mechanism. It has been claimed that South Korean water is priced without a complete overview and consideration of all costs and environmental externalities [54]. The average national price of tap water has increased on average by 5.4% per year, from 211 KRW/m^3 in 1991 to 660 KRW/m^3 in 2013, and the production costs have increased by an average of 5.6% per year, from 260 KRW/m^3 in 1991 to 849 KRW/m^3 in 2013 [54]. Thus, the average price in 2013 covered only ~80% of the production costs. This underpricing mechanism has resulted in an excessive use of water, which increases pressure on the resource. In fact, the South Korean daily water use per capita is 1.2 times higher than that of the United Kingdom, 2 times higher than that of France and Germany, and 2.5 times higher than that of Denmark [54].

To summarize, South Korea is faced with evolving challenges in the water sector. These include, among others: (i) the biophysical and environmental challenges of a monsoon climate, a mountainous topography, and climate change; (ii) increasing rates of water pollution due to changes in land cover and land use (related to the rapid economic growth of the country); and (iii) an inefficient water policy framework for water pricing and water use. It should also be noted that many hydrological services are considered public services, which implies nonrivality and nonexcludability [55]. The exclusion of these principles can lead to the underestimation of service value, to free-riding, undersupply, over use, and finally, to exploitation and environmental damage.

3. Key Forest Hydrological Services

Forests can provide a plethora of hydrological and other ecosystem services. These services are not independent of each other and their relationships may be highly nonlinear [56,57]. Attempts to enhance a single service often lead to gains (synergies) or losses (tradeoffs) in other services [58]. Nevertheless, in order to establish priorities and define targeted policy actions, key (i.e., most essential) forest hydrological services must be identified. In view of the major challenges and the persistent public demands for a greater improvement of environmental conditions [59], we consider that the key forest hydrological services in South Korea are (i) water supply; (ii) the preservation of water quality and the purification of water; (iii) the regulation of water flow; and (iv) the prevention and moderation of natural hazards (Table 2). Except for water supply, which is considered a provisioning service, these are defined as regulating services [60]. The specific benefits associated to these services fill the most urgent needs in terms of improvement in the water sector, and relate mostly to the first and third objectives of the National Strategy for Green Growth (refer to Section 1).

The provision of these key services is directly related to certain forest functions (Table 2). Water supply and quality can be influenced by both the aerial and underground parts of forests. The influence of the canopy is greatest through the interception of rainfall and solar radiation as well as through transpiration. The interception of rainfall and the process of transpiration reduce the amount of rainfall transferred to soils and groundwater, directly influencing water supply. Rates of interception and transpiration usually vary with forest type and forest density. For example, interception losses are usually much less in a well-thinned deciduous stand than in a dense coniferous stand. The interception of solar radiation can influence water supply by lowering air temperature below the canopy, which consequently reduces rates of evaporation. Rates of snowmelt are also usually reduced by the presence of a canopy, thus regulating water flow in spring. The presence of a canopy can also influence the water quality of streams by regulating the process of eutrophication through the lowering of water temperature. It also reduces the kinetic energy of rainfall, which consequently decreases erosion rates and improves water quality. This is also the case for the presence of an organic layer and debris. The influence of forest soils and the root system of forests is also significant. By creating a network of soil micro- and macropores, the root system increases soil infiltration capacity. This can enhance soil water storage and the recharge of groundwater, which are both closely related to the regulation of water flow. A higher soil infiltration capacity usually results in lower rates of surface runoff, and hence in a reduction in erosion. Erosion can also be reduced by the soil stabilization effect of the root system, especially in riparian and mountainous areas. Improvements in water quality can be achieved by the fauna of forest soils, as bacteria and other organisms enhance nutrient cycling. This can also reduce the leaching of nutrients to groundwater [61]. Concerning natural hazards, their prevention and moderation by the presence of forests has been widely reported [62]. Chang et al. (2009) [63] reported an association between increasing flood damage and deforestation in a mountainous province of South Korea.

In summary, we consider that in South Korea, forests can greatly contribute to the provision of high-quality water in sufficient, regulated amounts, and the preservation of a safe environment in regards to natural hazards.

Table 2. Key forest hydrological services associated to forest management measures.

Forest Hydrological Services	Specific Benefits	Forest Functions	Forest Management Measures
Water supply	- Domestic, agricultural, and industrial use - Enhancement of energy independence with hydropower	- Recharge of groundwater due to high soil infiltration capacity	- Avoid soil compaction - Favour well-thinned, deciduous stands in order to reduce interception losses
Preservation of water quality and purification of water	- Reduction in sedimentation and eutrophication of reservoirs - Reduction in water treatment costs - More equal distribution of wealth by payments for ecosystem services	- Erosion prevention by reduction of surface runoff, reduction of the kinetic energy of rainfall, and stream bank stabilization - Nutrient cycling - Water temperature regulation - Reduction of nutrient leaching to groundwater	- Avoid detrimental soil disturbance in order to maintain a continuous cover of organic matter - Favour the development of understory strata and the accumulation of debris - Buffer strips along streams - Buffer zones around wetlands - Favour dense, coniferous stands in order to increase interception
Regulation of water flow	- Reduction in costs of water management measures - Mitigation of floods and droughts	- Water storage in soil - Recharge of groundwater due to high soil infiltration capacity - Reduction of water velocity by percolation through soil - Reduction of snowmelt rate	- Measures to increase soil formation rates - Avoid soil compaction - Buffer strips along streams - Buffer zones around wetlands
Prevention and moderation of natural hazards (e.g., landslides and mudflows)	- Reduction in the number of victims - Reduction in damage - Reduction in restoration costs	- Soil and stream bank stabilization - Reduction of water velocity by percolation through soil	- Reforestation of highland areas - Buffer strips along streams - Avoid soil compaction

4. Combination of Forest and Water Management

Forest management can greatly influence the capacity of forests to provide hydrological services (Table 2). In South Korea, the Forest Act requires the government to produce a National Forest Plan for the management of forests every 10 years. Accordingly, the Plans reflect the views, visions, and strategies of succeeding governments over time. During the 1960s, the government focused on afforestation and forest restoration. Until this decade, forests were degraded because of war, illegal harvest, and uncontrolled shifting cultivation. During the 1980s, it focused on increasing forest stocks to ensure timber supply [64]. As a result, the national forest cover increased from 55% in 1963 to 64% in the 1990s and until today [65]. From 1960 to 2010, the growing stock increased by about 13 times, from only 10 m^3/ha in 1960. However, even though the growing stock increased, the forested area decreased (Table 3). Since 2000, the national percentage area of forests and wooded land has been decreasing by an annual average of 0.1% (Figure 2).

Table 3. Forested area, stock, and growing stock over time (from Lee (2012) [66]).

Year	Area (1000 ha)	Stock (1000 m^3)	Growing Stock (m^3/ha)
1960	6700	63,995	9.6
1970	6611	68,772	10.4
1980	6567	145,694	22.2
1990	6476	248,426	38.4
2000	6430	387,758	60.3
2010	6369	800,025	125.6

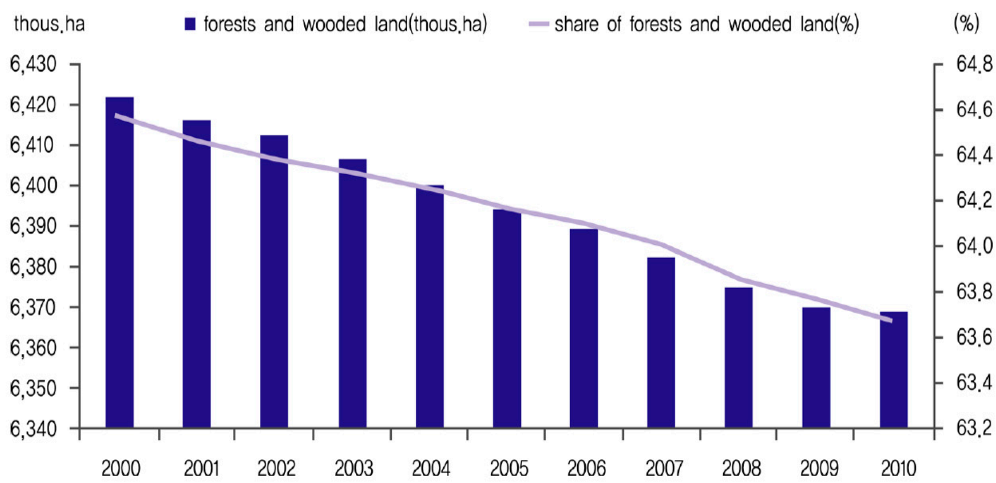

Figure 2. Total area and national percentage area of forests and wooded land over time (from Statistics Korea (2012) [67]).

Since the beginning of the millennium, a gradual shift in forest policy and management towards the provision of multiple ecosystem services has been operated. In order to respond to the major challenges in the water sector, the South Korean government defined a series of policy actions in its National Strategy for Green Growth [5]. Some of the policy actions are directed towards the management of water within the wider context of environmental conservation, including reforestation, forest management, and the protection of forests. Such policy actions, combining forest and water management, were also defined in the Fifth National Forest Plan (2008–2017) [68], the Comprehensive Water Management Plan for the Four Major Rivers [46,69], and the Water Environment Management Master Plan (2006–2015) [70].

The Fifth National Forest Plan was designed for the promotion of sustainable forest management (SFM) through the local-scale application of criteria and indicators of SFM, the expansion of forest management certification, the development of a national certification system, and the use of a forest sustainability index. Directly related to forest hydrological services is the SFM indicator of protected forests. Prior to the Plan, between 1990 and 2007, the area of forests protected for soil erosion control decreased from 8968 to 1653 ha. Over the same period, the area of forests protected for the conservation of watersheds increased from 160,634 to 292,472 ha, while the area of forests for the protection of water sources remained stable at ~125,000 ha [68].

The Comprehensive Water Management Plan for the Four Major Rivers was established as a new system of watershed management for the improvement of water quality. It consisted in the development and implementation of water and watershed management policies, and the establishment of decentralized watershed management bodies. In addition to the funding of projects of stream protection and restoration, it introduced a buffer zone system to reduce nonpoint source pollution. Buffer zones were designated around the major reservoirs as well as along a few other rivers and streams, and a policy to restrict development within the zones was implemented. In 2007, these buffer zones covered a total area of 113,056 ha [68]. Furthermore, the Plan established a land purchase system in which the owners of land located within the buffer zones can voluntarily sell their land to the government. The land is to be managed by the government and land cover is to be converted to forest. In 2005, the area of purchased land totalled 1653 ha [70].

The Water Environment Management Master Plan was developed to meet the public demands of an ecologically healthy water environment. It expanded some of the systems introduced by the Comprehensive Water Management Plan for the Four Major Rivers, and promoted projects of ecosystem restoration and water quality control. Among other measures, the Plan aimed to restore 21,800 km of non-natural streams into natural streams, and improve the management of buffer zones. It also aimed to convert 30% of the purchased land into forested riverine ecobelts in order to enhance the connectivity between and within water bodies and buffer zones. An assessment of the progress in reaching the targets set for water quality revealed that, in 2013, 80.7% of the rivers and 12.2% of the lakes met the targets [71].

Some of the policy actions of the National Strategy for Green Growth were first implemented in the Four Major Rivers Restoration Project (FMRRP; 2009–2013) [69,72]. The FMRRP followed the shift in management structure realised by the Comprehensive Water Management Plan for the Four Major Rivers, and was implemented through the first Five-Year Plan of the Strategy. The budget of the Five-Year Plan corresponded to ~10% of the 2009 gross domestic product (GDP), and the government estimated the production induced by the Plan to ~20% of the 2009 GDP [73]. The FMRRP was attributed 14.2% of this budget, and included projects revolving around five core tasks. It introduced a Water Quality Forecasting System at the sixteen weirs that were built on the four rivers, in order for the nation to adapt to extreme conditions and to mitigate their impacts on communities [74]. Through the FMRRP, the construction of hydropower generators by K-water (a governmental company) was promoted, which contributed to energy independence, created employment, and boosted the economy [75,76]. The government also aimed to ecologically restore 1667 km of streams from 2011 to 2017 through efforts of reforestation in riparian areas [71]. Water quality was improved, as a substantial decrease in BOD was reported following the restoration of streams [77]. To increase the flood-control capacity of the country, 147 wetlands were established for a total area of 12.5 km^2 [29]. These efforts were part of the Strategy's policy action of adaptation to climate change [5]. The positive coupling between environmental management and the operation of the newly built hydraulic structures was highlighted by Ahn et al. (2014) [78]. Park et al. (2014) [79] reported a strong positive relationship between the water quality of reservoirs and the proportion of forested area of watersheds. Furthermore, simulations showed an improvement in the regulation of water supply from the combined effects of the measures, taking the effects of climate change into account [80,81].

5. Inclusion of Key Forest Hydrological Services in the Sustainable Development Strategy

The objectives of the National Strategy for Green Growth are in line with those of previous and concurrent environmental plans [59]. However, even though South Korea has committed to a green growth model, the current degree of "greenness" remains debatable. In the face of evolving challenges in the water sector, it is believed that the measures implemented through the FMRRP were not adequately coupled to the long-term objectives of the Strategy, and that the possible contribution of forest hydrological services to sustainable water management was underestimated. According to various stakeholders, the operations of the FMRRP of dredging sediment, installing riverbed filtration facilities, and installing weirs and dams did not entirely follow the principles of green growth, neither at the environmental, nor at the economical, nor at the political level [82–86]. Park (2010) [87] stated that the FMRRP likely induced some habitat destruction. Lee et al. (2016) [88] observed important changes in groundwater flow systems following the construction of weirs, and anticipated gradual changes in groundwater chemistry. A risk assessment at the Nakdong River basin resulted in little future effect of the FMRRP in certain flood-prone regions [89]. In spite of the successes of the FMRRP, the government has been criticized for focusing too much on growth and overlooking the green aspects. In other words, the continued preference for market-driven growth prioritized the economy over the environment [90,91]. In order to ensure long-term beneficial effects of the FMRRP, forest management for the enhancement of hydrological services (Table 1) should have been done at a much wider scale, as UNEP (2010) [3] proposed. It should be better integrated into the National Strategy for Green Growth as well as expanded within the Strategy, in order to realize the full potential of forests for the provision of these services. We agree that this may be much more complex than the construction of infrastructure, but are convinced of the willingness of the nation and the capacity of the government to advance in this direction. Also, in order to promote the second objective of the Strategy (refer to Section 1), the government could complement the economic growth generated by infrastructure construction with economic growth generated by forest management.

Choi (2011) [92] provided a very good example of the significant effects of forest management on the long-term water balance of forested catchments (Table 4). Over a period of 28 years, the runoff coefficient of a catchment mostly covered by a coniferous plantation was lower than that of a similar catchment covered by a deciduous forest. This was attributed to the greater rainfall interception capacity of the coniferous plantation. This capacity increased with the age of the plantation, as crown closure also likely increased. In 1996, the coniferous plantation was thinned and crown closure was reduced. This resulted in a notable but temporary increase in the runoff coefficient of the catchment. These observations demonstrate the possible effects of forest management on water quantity and ultimately water management, as well as the dynamic nature of these effects.

Table 4. Runoff coefficient for designated periods in a coniferous and a deciduous forested catchment (from Choi (2011) [92]).

Period	Runoff Coefficient Coniferous (%)	Runoff Coefficient Deciduous (%)
1982–1986	48.6	63.7
1987–1996	42.4	62.2
1997–2005	61.3	61.6
2006–2009	51.0	66.9

The successful measures of reforestation have been a flagship of the National Strategy for Green Growth [66]. Nevertheless, we consider that a proper balance in the enhancement of forest ecosystem services has not yet been achieved. The Fifth National Forest Plan was designed with a focus on "low carbon, green growth" to emphasize and enhance the capacity of forests for carbon sequestration and storage [66]. This followed a period of 16 years during which the national greenhouse gas emissions almost doubled (1990–2005) [93]. We believe that this focus was partly derived from the will to enhance the international standing of the nation. To our knowledge, the enhancement of forest hydrological services was not specifically targeted by any of the strategies and action plans presented in the National Forest Plan [68]. In fact, it is stated that a more systematic and practical management of protection forests (for the conservation of soil and water resources) is needed. It is also stated that all protection forests should be defined according to their functions. As Kwon et al. (2008) [94] proposed, the classification of forest functions and the analysis of their spatial arrangement could improve the planning of forest management. In any case, the expansion of protection forests (for the conservation of soil and water resources) would very likely contribute to enhance the key forest hydrological services. It would also likely lessen the consequences of the future predicted forest cover change on the capacity of forests to provide these services [3].

Forest hydrological services should also be enhanced by monetary incentives. In this regard, a primary factor to consider is the ownership of forests. In South Korea, forests can be divided into national forests, public-owned forests, and private-owned forests. National forests account for ~23% of the total forested land and are managed by the Korea Forest Service. Public-owned forests are possessed by local governments and public organizations, and account for ~8% of the total forested land. The rest of the total forested land belongs to private entities. Ownership has changed over the last 20 years with a distinct decline in private-owned forests, and a steady increase in national forests (public-owned forests remained stable). Private-owned forests are still dominant, and 90% of the ~19 million owners own less than 10 ha of forests. The management of these private-owned forests is still very much oriented towards timber production [95]. To change the scheme, payments for the provision of hydrological services should rival with the profits of timber production. Criticism has been raised towards the fact that this is not the present situation [96]. A possible solution would be the identification of spatial priority areas, in order to provide compensation to areas in a situation of urgency and with high potential for improvement. Kong and Lee (2014) [97] and Nguyen et al. (2013) [98] both realized such an analysis for a region of Vietnam, and concluded that the improved distribution of compensation would likely result in a significant enhancement of forest hydrological services. In particular, Nguyen et al. (2013) [98] reported that increases in the normalized forest cover of a catchment resulting from adequate payments for forest hydrological services would likely be accompanied by important decreases in overland flow and soil sedimentation, as well as important increases in soil-retained water and in the longevity of a reservoir dam (Table 5).

Table 5. Changes in hydrological variables and dam longevity with increasing normalized forest cover in comparison to a scenario of null forest cover (from Nguyen et al. (2013) [98]).

Normalized Forest Cover (%)	Δ Overland Flow (million m^3 y^{-1})	Δ Soil Sedimentation (million t y^{-1})	Δ Soil-Retained Water (million m^3 y^{-1})	Δ Dam Longevity (y)
30.8	−842	−17.3	2112	34.9
35.0	−920	−19.9	2309	40.5
40.0	−1015	−21.2	2546	48.3
45.0	−1109	−23.4	2783	57.2
50.0	−1204	−25.5	3021	67.5
55.0	−1298	−27.7	3258	79.7

6. Summary

We presented a comprehensive and current view of the major challenges and opportunities in the South Korean water sector in relation to forest hydrological services. Biophysical, environmental, and economic challenges were described, based on a review of the recent literature. We identified key forest hydrological services, to which we associated forest management measures. The most relevant and recent environmental plans were assessed in terms of the combination of forest and water management, and guidelines were proposed for the enhancement of forest hydrological services.

The challenges that South Korea is now faced with require a well-thought set of measures taking into account the vulnerability of water resources and the key hydrological services. The Four Major Rivers Restoration Project targeted these challenges, and, over a short period of time, achieved progress in sustainable water management. However, the completion of the core tasks of this project requires additional efforts [99]. We firmly believe in the immense potential of forests to at least partly overcome the challenges and contribute to the achievement of sustainable water management. Yet, this potential can only be fully realized by a better inclusion and enhancement of forest hydrological services in South Korea's sustainable development strategy. This could be achieved by (i) forest and water management measures better reflecting the long-term objectives; (ii) a balance in the enhancement of forest ecosystem services; and (iii) improvements in payments for the provision of hydrological services. In addition, a better alignment of policy and scientific agendas would likely be beneficial, as well as an increased participation of scientists in the establishment of watershed management schemes [100].

The link between human well-being and the provision of water-related benefits by forests is widely documented [101–106]. In South Korea, the implementation of adequate solutions to the problems of water supply and quality would likely result in a greater provision of water-related benefits to future generations, and is imperative for the long-term development of the nation [100].

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