Ecosystem Services 29 (2018) 40–46

Contents lists available at ScienceDirect

Ecosystem Services

journal homepage: www.elsevier.com/locate/ecoser

Economic viability of the national-scale forestation program: The case of success in the Republic of Korea

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ARTICLE INFO

Article history:
Received 20 July 2017
Received in revised form 25 September 2017
Accepted 2 November 2017

Keywords:
National forestation
Disaster risk reduction
Water yield
Soil erosion
Carbon sequestration
Economic viability

ABSTRACT

The forests in the Republic of Korea (ROK) successfully recovered through the national forestation program as did the ecosystem services associated with them. With this positive experience, it is instructive to investigate the economic viability of the forestation program. In this study, we estimated the changes in the key ecosystem services (disaster risk reduction (DRR), carbon sequestration, water yield enhancement, and soil erosion control; 1971–2010) and the monetary investment of the forestation (1960–2010) in the ROK, at a national scale. These benefits and costs were estimated by biophysical and monetary approaches, using statistical data from several public organizations, including the Korea Forest Service and the Korea Meteorological Administration, combined with model simulation. All monetary values were converted to the present value in 2010. The net present value and the benefit-cost ratio of the forestation program were 54,316 million $ and 5.84 in 2010, respectively, in the long-term. The break-even point of the extensive investment on the forestation appeared within two decades. In particular, the enhancements of DRR and carbon sequestration were substantial. This economic viability was ensured by the subsidiary implementations (e.g., participation of villagers, shifting energy source, and administrative regulation). Early and extensive investment in forestation is recommended for economic viability and successful implementation of the program. Our study is expected to provide a scientific rationale for implementing forestation program in other countries.

1. Introduction

Forest ecosystems can provide a substantial amount of ecosystem services, which consist of provisioning, regulating, habitat or supporting, and cultural services (TEEB, 2010). Global society has paid attention to these forest ecosystem services, which approximately account for 125–145 trillion US Dollar yr^{-1} (Costanza et al., 2014). Deforestation activities, however, have threatened the forest ecosystem services and conflicts of interest always exist between conservation and utilization (DeFries et al., 2010; TEEB, 2010; Mutoko et al., 2015). Given the substantial value of forest ecosystem services, forestation activities are potentially highly beneficial to human society. In this context, estimating the value of these services can aid in internalizing the benefits for forestation. The internalization might be also help to support ecosystem-based financing for environmental policies (de Groot et al., 2010; Campbell and Tilley, 2014; Baral et al., 2016). Thus, valuation of forestation through its ecosystem services is a timely topic for supporting the implementation of forest management policies.

The Republic of Korea experienced severe deforestation after the Korean War, when more than half of the forests were destroyed. The Korean government implemented the national forestation program from the 1960s and the Korean forests successfully recovered during the subsequent decades (Korea Forest Service, 2014; Park et al., 2017). Subsequently, the mean stand volume density (m^3 ha^{-1}) increased from 9.55 in 1960 to 145.99 in 2015 (Korea Forest Service, 2016). The success of the program is especially unique for the following reasons: (1) the Republic of Korea is one of only four countries which succeeded in post-war forest rehabilitation and (2) the Republic of Korea is the only developing country among these countries (the others being Germany, the UK and New Zealand, Gregersen, 1982). This positive experi-

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https://doi.org/10.1016/j.ecoser.2017.11.001
2212-0416/© 2017 The Authors. Published by Elsevier B.V.

ence of forestation can be instructive to examine which ecosystem services benefitted from the national forestation. In particular, assessing the economic viability of the national forestation program in the Republic of Korea can provide a reliable scientific rationale of forestation program in other countries where the forests have been suffered from deforestation.

Monetary valuation directly links the ecosystems and the societies they serve, providing numerical measures of ecosystem services (Seppelt et al., 2011; Campbell and Tilley, 2014; Häyhä et al., 2015; Ruckelshaus et al., 2015). To be reliable and scientifically credible monetary valuation needs a strong basis of biophysical-based modeling, which can be based on look-up tables and simulation models (de Groot et al., 2010; Seppelt et al., 2011; Bagstad et al., 2013; Campbell and Tilley, 2014). Despite the data requirements and technical difficulties, biophysical methodologies can provide realistic estimates of forest ecosystem services (Seppelt et al., 2011; Baral et al., 2016).

In this study, we evaluate the changes in the ecosystem services (disaster risk reduction (DRR), carbon sequestration, water yield enhancement, and soil erosion control) and the monetary investment and associated other costs of the national forestation program in the Republic of Korea. All ecosystem services (biophysical and monetary value) and the investments in the forestation program were estimated through a combination of statistical data and modeling approaches. Following on from that we determined the economic viability of the national forestation program, which can be crucial information to other countries in the world looking into forestation options.

2. Materials and methods

2.1. Study area

The study area was the Republic of Korea. The Korean forests cover approximately 64% of the Korean territory (6,368,843 ha) in 2010 (Korea Forest Service, 2016). The mean annual temperature and precipitation from 1905 to 2016 were approximately 11–14 °C and 800–1900 mm, respectively (Korea Meteorological Administration (https://data.kma.go.kr/cmmn/main.do)). The forest types consist of coniferous forests (32.1%), deciduous forests (39.0%), and mixed forests (28.9%) (NIFoS, 2011). The forest soils mainly consist of Entisol and Inceptisol in the Republic of Korea (Brady and Weil, 2008). The Korean forests has been mainly managed by tending work and protection. Most of the forests are located below the elevation of 600 m.a.s.l (NIFoS, 2011). The forest area with steep slope (>30°) accounts for approximately a half of the total forest area (NIFoS, 2011).

2.2. The investment on the national forestation program

The monetary investment of the forestation (1960–2010) was estimated by using the annual budget of Korea Forest Service (including plantation, protection, operation, research, and monitoring) in order to consider the cost of the initial as well as the subsidiary measures for the forestation program. The nominal value of annual investment on the forestation program was converted into a real value in 2010 Dollars by a combination of the purchasing power parity (PPP) exchange rate (Korean Won: US Dollar) and the gross domestic production (GDP) deflator, which were provided from World Bank. Finally, a constant real discount rate (i.e., net of inflation) of 3%, which is typical for forestry-type projects, was applied to this converted value in order to calculate the present value (PV) in 2010 (Treasury, 2003; Valatin, 2010; Markandya, 2015). As the information on the budget is lacking before 1981, only the direct cost of the forestation was used during the period 1960–1980. Owing to the lack of the statistical data during 1960–1972, the extrapolation was conducted by multiplying the annual planted area during 1960–1972 (65,089–454,903 ha; provided by Korea Forest Service) by unit cost of planting ($ ha^{-1}) in 1973.

2.3. The benefit of carbon sequestration, water yield enhancement and soil erosion control with modeling approach

A Korean-specific forest carbon model, the Forest Biomass and Dead organic matter Carbon (FBDC) model, was developed to simulate annual carbon dynamics (Lee et al., 2014). This model already quantified the carbon dynamics in various forest ecosystems (Lee et al., 2014, 2016, 2017). In particular, Lee et al. (2014) estimated annual total forest carbon stocks from 1954 to 2012 at a national scale with the FBDC model and these estimates and methodologies were also verified externally. Accordingly, the modeling methodologies in Lee et al. (2014) were directly used to simulate the annual carbon sequestration at a national scale in this study. Meanwhile, the annual monetary benefit of carbon sequestration (1971–2010) was estimated by multiplying the national carbon sequestration by the social cost of carbon (31 $ ton^{-1} CO_2; US government, 2016). The annual benefit was then converted to US Dollar PV in 2010 by applying a discount rate of 3%, which was also used in the previous section. Then the benefits in 1971 (baseline) were subtracted from the annual benefits during 1971–2010 to partition the net effect of forestation on enhancement of carbon sequestration.

The Integrated Valuation of Ecosystem Services and Tradeoff (InVEST) model was applied to quantify ecosystem services in a spatial unit (Sharp et al., 2015). In particular, the InVEST Water Yield (InVEST-WY) model is able to estimate annual amount of water supply by land cover (Song et al., 2015). InVEST-WY requires data on annual precipitation, potential evapotranspiration, depth-to-root restricting layer, plant's available water content, land use and watersheds, and biophysical table. The seasonality factor should be also adjusted to study region. This parameterization process followed the methodologies in Kim et al. (2017), which already simulated the annual water yield in the Republic of Korea with the verified methodologies and model estimates.

Following this, the net effect of forestation on water yield enhancement was estimated by a comparison of annual model projections under two scenarios: a forestation scenario and a no forestation scenario. In the forestation scenario, the change in forest area through the forestation program and other factors were reflected. In contrast, the no forestation scenario excluded the change in forest area by the forestation program. The difference in water yield between these two scenarios was the net effect of the forestation on water yield enhancement. The annual benefit of water yield enhancement by the forestation (1971–2010) was estimated by multiplying the amount of annual water yield enhancement (the difference in water yield under the two scenarios) by the unit production cost of water (0.92 $ m^{-3}; considering the PPP exchange rate in 2010), announced by the Ministry of Environment in the Republic of Korea. The annual benefit was then converted to US Dollar PV in 2010 by applying a discount rate of 3%.

The Soil and Water Assessment Tool (SWAT) is a semi-distributed model and a hydrological model, which is able to simulate amount of soil erosion with a basis on hydrologic response unit (HRU) (Gassman et al., 2007). The Modified Universal Soil Loss Equation (MUSLE), a module of the SWAT model, was used to estimate soil erosion in the SWAT model. The MUSLE is widely used to simulate soil erosion around the world (Williams, 1975). It has an advantage in reflecting the energy flow of surface runoff. In this equation, factors such as rainfall, slope, vegetation, and conserva-