Forest Ecology and Management 352 (2015) 35–46

Contents lists available at ScienceDirect

Forest Ecology and Management

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

Protective functions and ecosystem services of global forests in the past quarter-century ☆

Satoru Miura [a,*], Michael Amacher [b], Thomas Hofer [c], Jesús San-Miguel-Ayanz [d], Ernawati [e], Richard Thackway [f]

[a] Graduate School of Agricultural and Life Sciences, University of Tokyo, 1-1-1, Yayoi, Bunkyo-ku, Tokyo 113-8657, Japan
[b] Logan Forestry Sciences Lab, Rocky Mountain Research Station, US Forest Service, 860 N 1200 E, Logan, UT 84321, USA
[c] Watershed Management and Mountains, Forestry Department, Food and Agriculture Organization of the United Nations, Viale delle Terme di Caracalla, Rome 00153, Italy
[d] Unit Forest Resources and Climate, DG Joint Research Centre, European Commission, Via Fermi 2749, I-21027 Ispra, Italy
[e] Data and Information of Forest Management Unit and Land Preparation at Forestry, Ministry of Forestry, Block VII Floor V, Indonesia
[f] Planning and Environmental Management, School of Geography, University of Queensland, Brisbane St Lucia, QLD 4072, Australia

ARTICLE INFO

Article history:
Received 5 December 2014
Received in revised form 22 March 2015
Accepted 24 March 2015
Available online 7 September 2015

Keywords:
Sustainable forest management
Multiple functions
Forest conservation
Ecosystem value
Criteria
Indicator

ABSTRACT

The world's forests provide fundamental protection of soil and water resources as well as multiple ecosystem services and cultural or spiritual values. We summarized the FRA 2015 data for protective functions and ecosystem services, and analyzed increasing or decreasing trends of protective areas. The global forest area managed for protection of soil and water was 1.002 billion ha as of 2015, which was 25.1% of all global forested areas. Protective forests have increased by 0.181 billion ha over the past 25 years mainly because more countries are now reporting protective forest areas (139 in 2015 vs 114 in 1990). However, average percentage of designated for protective forests did not change significantly from 1990 to 2015. Global forest area managed for ecosystem services is also now at 25.4% of global total forest area and has changed little over the past 25 years. Among the twelve categories of protective forests, flood control, public recreation, and cultural services increased both in terms of percentage of total forest area and the number of reporting countries. Public awareness of the importance of forest resources for functions and services other than production continues to increase as evidenced by the increase of protective forest designations and reporting in many countries. Percentages of total forest area designated for both protective forests and ecosystem services show a dual-peak distribution of numbers of countries concentrated at 0% and 100%. This suggests a socio-economic influence for the designations. We examined five case study countries (Australia, Canada, China, Kenya, and Russia). The most dramatic changes in the past 25 years have been in China where protective forests for soil and water resources increased from about 12% to 28% of forest area. The Russian Federation has also increased percentages of forest area devoted to soil and water resource protection and delivery of ecosystem services. Australia is now reporting in more protective forest categories whereas Kenya and Canada changed little. These five countries have their own classification of forest functions and recalculation methods of reporting for FRA 2015 were different. This demonstrates the difficulty in establishing a universal common designation scheme for multi-functions of forest. Production of more accurate assessments by further improvements in the reporting framework and data quality would help advance the value of FRA as the unique global database for forest functions integrated between forest ecosystems and social sciences.

1. Introduction

The world's forests provide fundamental protection of soil and water resources and provide multiple ecosystem services as well as cultural or spiritual values. The Food and Agriculture Organization (FAO) of the United Nations reported in Global Forest Resources Assessment (FRA) 2010 that 8% of the world's forests had been primarily designated for protection of soil and water (FAO, 2010b). The public awareness of these forest functions has been growing over last few decades (WHO, 2005; Collaborative Partnership on Forests, 2014). The Earth Summit (United Nations Conference on Environment and Development, UNCED) in Rio de Janeiro in 1992 was a turning point in this awareness trend. The

☆ This article is part of a special issue entitled "Changes in Global Forest Resources from 1990 to 2015".

* Corresponding author. Tel.: +81 3 5841 8636; fax: +81 3 5841 8193.
E-mail address: a-miura@mail.ecc.u-tokyo.ac.jp (S. Miura).

http://dx.doi.org/10.1016/j.foreco.2015.03.039
0378-1127/

conference spurred people to promote a variety of activities for sustainable forest management. Chapter 11 of Agenda 21 (“Combating Deforestation”) is particularly relevant in this context. In the summary of this chapter, Keating (1993) writes: “forests are a source of timber, firewood and other goals. They also play an important role in soil and water conservation, maintaining a healthy atmosphere and maintaining biological diversity of plants and animals... there is an urgent need to conserve and plant forests in developed and developing countries to maintain or restore the ecological balance, and to provide for human needs”.

It is generally accepted that forests and trees, in undisturbed form, provide the greatest vegetative protection against erosion from rain, wind, and coastal waves (Broadhead and Leslie, 2007; Hamilton, 2008). Accordingly, they also significantly contribute to the reduction of downstream sedimentation (Fu, 1989). The root system of the trees creates increased soil strength (Greenwood et al., 2004; Reubens et al., 2007). Forests and trees contribute to the preservation of a good soil structure thanks to the protection against splash erosion (provided the litter layer and the understory vegetation are maintained) and maintenance of robust biological activity in the soil (Binkley and Fisher, 2013). In this context, forests and trees also contribute to the mitigation of risks of shallow landslides. However, deep-rooted mass movements triggered by tectonic events cannot be prevented by forests and trees (Hamilton, 1986; Government of Japan, 2002; Dolidon et al., 2009).

Clean water is becoming more recognized as one of the most important environmental services provided by forests and trees (FAO, 2013). At least one third of the world’s largest cities draw a significant proportion of their drinking water from forested areas (FAO, 2013). It is also well established that forests play a crucial role in the hydrological cycle. Forests influence the amount of water available and regulate surface and groundwater flows while maintaining high water quality (Aust and Blinn, 2004; Hamilton, 2008). Forests and trees contribute to the reduction of water-related risks such as floods and droughts and help prevent desertification and salinization (FAO, 2013). However, there is sufficient scientific evidence that forests are not able to prevent or even reduce medium to large scale floods (FAO and CIFOR, 2005; Hofer and Messerli, 2006; Hamilton, 2008). Policy makers have voiced concern about the effectiveness and limitation of these regulating and provisioning services of forests (Cubbage et al., 2007; Collaborative Partnership on Forests, 2014).

In the context of climate change and the resulting increased incidence of natural hazards, the soil and water protection function of forests and trees is becoming increasingly important. For the maintenance and sustainability of this function, forest management through a watershed (landscape) approach is very important (Kammerbauer and Ardon, 1999; Postel and Thompson, 2005). Watershed management includes the management of all available natural resources (including forests) in a comprehensive way and makes the link between natural resources management and the improvement of livelihoods. It provides a framework to organize different land-uses (forestry, pasture, agriculture) in an integrated way (Turner, 1989). Watershed management contributes to the reduction of risks of natural hazards, such as landslides and local floods, and creates local resilience against climate change as well as adaptation options (FAO, 2006b, 2007).

The soil and water protection function of forests and trees offers significant scope for the establishment of payment for ecosystem services (PES) schemes. PES has been developing rapidly under the framework of the Convention of Biological Diversity (CBD) supported by Millennium Ecosystem Assessment and environmental economics (ex. Costanza et al., 1997; Kumar, 2010). In the context of large economic losses by floods and sediment disasters, the calculation of ecosystem values of services related to soil and water protection provided by forests and trees is getting increased attention and importance. FAO (2008) conducted an interesting practical experience of compensation mechanisms for water services provided by forests in Central America and the Caribbean, however its calculation remains a challenge (FAO, 2004b). Recent advances in Clean Development Mechanism (CDM) and Reducing Emissions from Deforestation and Forest Degradation (REDD) in the 2000s under the UN Framework Convention on Climate Change (UNFCCC) also require a reliable reporting of objective forests (REDD Research and Development Center, 2012). Demand for reporting multiple functions of forests has increased in importance based on these rising social concerns in the field of environmental economics.

FRA, the only statistical forest database covering the whole globe, has attempted to assess the extent of protective forests in the world. The inclusion in FRA of the protective function of forests gradually developed in parallel with the increasing importance for the global community assigned to this function. FRA first introduced a concept of ‘protective function’ of forest as non-wood benefits in FRA 1990 only for developed countries (FAO, 1995) and made the first comprehensive report of protective functions of forest in FRA 2005 as “More than 300 million hectares of forests are designated for soil and water conservation” (FAO, 2006a). In the report of FRA 2015, FAO created separate main categories for protective functions and selected ecosystem services since 1990 (FAO, 2012). An initial evaluation of the status and trend of forest protective functions over the past twenty-five years can provide the basis for further detailed analysis of the importance of these forest functions to the international forestry community and other related environmental sciences.

In this paper we analyze the FRA reported data in two main categories of protective functions and selected ecosystem services. In addition, we analyze the status and trend data in several protective forest sub-categories. We tested the effects of sub-regional, latitude-affected climatic, and socio-economic differences and temporal changes on the main category and sub-category protective forest variables according the FRA reporting framework (FAO, 2014a). The trend analyses are based on percentages of total forest area or total land area and not on absolute forest area. We also discuss, as case studies, the status and trend of protective forests in selected countries located in different regions and climatic domains. Finally, we discuss key findings and future recommendation to FRA for improving the reporting of protective functions and ecosystem services.

2. Methods

2.1. Data source and compilation

The FRA 2015 dataset (http://www.fao.org/forestry/fra/fra2015/en/) is described by MacDicken (2015). We used FRA 2015 data submitted by countries in response to the question “How much forest area is managed for protection of soil and water and ecosystem services?”

There are two main categories and ten sub-categories of protective forests designated for specific purposes of providing protection against events that damage forest resources as well as for providing various types of ecosystem services. The main categories are protective forests for soil and water resources and protective forests for delivery of ecosystem services. Within the soil and water resource protection category are protective forests for the sub-categories of (1) clean water, (2) coastal stabilization (3) desertification control, (4) avalanche control, (5) erosion and flood control, and (6) other control. Within the ecosystem services category are protective forests for the sub-categories of (1) public recreation, (2) carbon storage, (3) cultural services, and (4) other services (excluding Table 6 for conservation of biodiversity).