Forest Ecology and Management 352 (2015) 109–123

Contents lists available at ScienceDirect

Forest Ecology and Management

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

Assessing change in national forest monitoring capacities of 99 tropical countries ☆

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ARTICLE INFO

Article history:
Received 28 November 2014
Received in revised form 29 May 2015
Accepted 1 June 2015
Available online 7 September 2015

Keywords:
Tropical forests
Forest cover change
Monitoring systems
Carbon reporting
Capacity building
REDD+

ABSTRACT

Monitoring of forest cover and forest functions provides information necessary to support policies and decisions to conserve, protect and sustainably manage forests. Especially in the tropics where forests are declining at a rapid rate, national forest monitoring systems capable of reliably estimating forest cover, forest cover change and carbon stock change are of vital importance. As a large number of tropical countries had limited capacity in the past to implement such a system, capacity building efforts are now ongoing to strengthen the technical and political skillsets necessary to implement national forest monitoring at institutional levels. This paper assesses the current status and recent changes in national forest monitoring and reporting capacities in 99 tropical countries, using the Food and Agriculture Organization of the United Nations (FAO) Forest Resources Assessment (FRA) 2015 data, complemented with FRA 2010 and FRA 2005 data. Three indicators "Forest area change monitoring and remote sensing capacities", "Forest inventory capacities" and "Carbon pool reporting capacities" were used to assess the countries' capacities for the years 2005, 2010 and 2015 and the change in capacities between 2005–2010 and 2010–2015. Forest area change monitoring and remote sensing capacities improved considerably between 2005 and 2015. The total tropical forest area that is monitored with good to very good forest area change monitoring and remote sensing capacities increased from 69% in 2005 to 83% in 2015. This corresponds to 1435 million ha in 2005 and 1699 million ha in 2015. This effect is related to more free and open remote sensing data and availability of techniques to improve forest area change monitoring. The total tropical forest area that is monitored with good to very good forest inventory capacities increased from 38% in 2005 to 66% in 2015. This corresponds to 785 million ha in 2005 and 1350 million ha in 2015. Carbon pool reporting capacities did not show as much improvement and the majority of countries still report at Tier 1 level. This indicates the need for greater emphasis on producing accurate emission factors at Tier 2 or Tier 3 level and improved greenhouse gases reporting. It is further shown that there was a positive adjustment in the net change in forest area where countries with lower capacities in the past had the tendency to overestimate the area of forest loss. The results emphasized the effectiveness of capacity building programmes (such as those by FAO and REDD+ readiness) but also the need for continued capacity development efforts. It is important for countries to maintain their forest monitoring system and update their inventories on a regular basis. This will further improve accuracy and reliability of data and information on forest resources and will provide countries with the necessary input to refine policies and decisions and to further improve forest management.

1. Introduction

About one third of the earth's land surface is covered by forests which store about 45% of the world's terrestrial carbon in wood, leaves, roots and soil. Almost half of this area consists

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

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http://dx.doi.org/10.1016/j.foreco.2015.06.003
0378-1127/

of tropical forests, which, on average, can store 50% more carbon in the trees than other types of forests (Houghton, 2005; Bonan, 2008). In addition to playing a critical role in regulating the world's climate, forests provide a variety of functions for people and the planet, including ecological, economic, social and aesthetic functions (Miura et al., 2015). Moreover, forests contribute largely to livelihood security and provide fuelwood and charcoal, which are major energy sources in developing countries (FAO, 2014a).

Humans are continuously changing the land use to get access to the planet's resources through clearance of forests for agricultural activities and urban expansion. Land use and land cover change have a climate forcing effect and play a major role in changing the world's climate (Pielke, 2005; Hosonuma et al., 2012). Deforestation is a global threat, not only because it causes habitat fragmentation and loss of biodiversity, but it also degrades environmental conditions and has an impact on global greenhouse gas emissions (GHG) by releasing CO_2 to the atmosphere. This causes changes in the global carbon cycle and alters the surface energy and water balance. As a consequence, the release of carbon affects climatic patterns and causes changes in environmental conditions and ecosystems (Cramer et al., 2004; Foley et al., 2005). Avoiding deforestation could reduce GHG emissions significantly. Forest management, including reducing and preventing deforestation is an important climate mitigation strategy and helps to secure the different forest functions (Bonan, 2008; Salvini et al., 2014). Numerous studies used global remote sensing data to highlight the fact that during the last decades forests in the tropics have been rapidly declining (DeFries et al., 2002; Achard et al., 2004; Hansen et al., 2010, 2013; FAO and JRC, 2012). FRA 2015 data show that the annual rate of net forest loss in the tropics has decreased compared to the 1990s (9.5 M hectare per year) and 2000s (7.2 M hectare per year). Recent estimates indicate a decline of 5.5 M hectare of forests per year between 2010 and 2015 in the tropics (Keenan et al., 2015).

Monitoring forests over time allows countries to observe changes. Regular and accurate monitoring of forest cover, forest cover change and drivers of change provides the necessary information to support policies and management practices to protect, conserve and sustainably manage forests and to ensure the different functions of forests (Mayaux et al., 2005; Achard et al., 2007; MacDicken, 2015). Consistent information on forest resources is needed for developing these policies and monitoring should be done at a national scale to properly assist localized land management decisions. At the global level, the importance of monitoring forest cover change and forest functions is reflected in environmental conventions such as the United Nations Framework Convention on Climate Change and the Convention on Biological Diversity.

Main focus of forest observation systems is on monitoring forest area and changes in forest area and on monitoring forest carbon stocks and changes. Earth observation has a key role in monitoring tropical forests. It should be noted that different studies use different definitions of forests and earth observation may provide varying estimates of "forest area" depending on the definition and method that is used. For example, the FRA (FAO, 2015) uses a forest land use definition. The JRC/FAO Remote Sensing Survey (FAO and JRC, 2012) uses a forest cover definition, while Hansen et al. (2013) measures tree cover change. This results in varying estimates of forest extent for a similar area. A detailed explanation on this matter can be found in Keenan et al. (2015).

Several papers discuss the technical requirements for implementing national forest monitoring systems in the context of REDD+ (Mayaux et al., 2005; Achard et al., 2007; DeFries et al., 2007; Herold and Johns, 2007; De Sy et al., 2012). Earth observing satellite data analyses, together with field-based national forest inventories provide data on forest cover and forest cover change at national scale. At least a time series of Landsat-type remote sensing data with 30 m spatial resolution should be used for national deforestation monitoring. An example of operational national and regional remote sensing monitoring is Brazil's PRODES system for monitoring deforestation in the Brazilian Legal Amazon region. This system uses Landsat, DMC and CBERS satellite data at 20–30 m resolution (GOFC-GOLD, 2014). National forest inventories provide data that are needed to estimate the carbon content of different forest types. India has a long history of national forest inventories. The new national forest inventory, established in 2001, generates national level estimates of growing stock at similar time intervals as the biennial forest cover assessment which is based on 23.5 m resolution IRS P6 satellite imagery. Using a sampling design, estimates of growing stock are developed for 14 physiographic zones based on physiographic features including climate, soil and vegetation. Every two years different districts are inventoried (GOFC-GOLD, 2014).

Remote sensing technologies are continuously in development and new available satellite and airborne sensors, analysis and methods are emerging at a constant pace (De Sy et al., 2012). Evolving technologies include the use of LIght Detection And Ranging (LIDAR) and Synthetic Aperture Radar (SAR) observations for forest characterization and biomass estimation. These techniques can help to overcome the challenge of cloud cover in the tropics. Unmanned Aerial Vehicles (drones) can be used for local scale validation studies. New techniques for acquiring, processing and managing vast amounts of satellite remote sensing data include cloud-based databases and data processing platforms which offer space for large datasets and computational resources for processing (GOFC-GOLD, 2014). An example of new and forthcoming initiatives includes the Copernicus program with a constellation of earth observation satellites (Sentinels) and in-situ sensors for monitoring the earth.

Capacities of tropical Non-Annex I countries to monitor forests and forest cover change were limited in the past. However, through capacity building efforts capacities are strengthening at technical, political and institutional levels (Herold and Skutsch, 2011; Romijn et al., 2012). A few Non-Annex I countries like Mexico and India have well developed national forest monitoring systems. Other countries are in the process of developing capacities and are at various stages of development; they need considerable capacity improvements before they are able to produce accurate estimates of forest area, forest area change and carbon stock change (Tulyasuwan et al., 2012).

The aim of this paper is to assess the capacity status and the changes in national forest monitoring and reporting capacities in 99 tropical Non-Annex I countries for the years 2005, 2010 and 2015, using the FAO FRA data. The specific objectives are to explain the change in forest monitoring and reporting capacities and to investigate the effectiveness of capacity building initiatives for improving national forest monitoring systems. Additional objectives are to assess the effect of increased capacities on the area of tropical forest that is monitored with accurate and reliable data and methods, and to assess the effect of increased capacities on reported FRA numbers of net change in forest area for similar time periods.

2. Materials and methods

2.1. Data

This study focuses on 99 tropical Non-Annex I countries. These include countries that are located in the sub-tropical or tropical domain, as defined in the FRA 2015 datasets (FAO, 2015) and