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Global forest area disturbance from fire, insect pests, diseases and severe weather events ☆

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ABSTRACT

Reliable global data on forest degradation and disturbances due to fire, insect pests, diseases and severe weather are important to understand ecosystem health and condition, safeguard production of goods and services and avoid negative impacts on human livelihoods. This paper presents a global analysis of forest area affected by fire, significant insect pest outbreaks, diseases and severe weather reported by countries as part of the Global Forest Resources Assessment 2015. Between 2003 and 2012, approximately 67 million hectares (1.7%) of forest land burned annually, mostly in tropical South America and Africa. In a similar reporting period, in total 142 million hectares of forest land were affected by other disturbances than fire. Insect pests affected more than 85 million hectares of forest, of which a major part was in temperate North America. Severe weather disturbed over 38 million hectares, mostly in Asia. About 12.5 million hectares were reported to be disturbed by diseases, mostly in Asia and Europe. There were strong correlations between burned forest area and the area of partial canopy cover reduction, as well as between burned forest area and net forest loss. Partial canopy cover reduction is used as a proxy for forest degradation, although it also includes land under management that is not degraded. A decreasing trend in burned forest area was found, largely accounted for by decreased area burned within the last ten years in tropical South America. However, an increasing trend in burned forest area was found in the boreal climatic domain. The data on other disturbances was not suitable for determining any year on year correlations and should be improved in future data collection exercises.

1. Introduction

Forest disturbances are the environmental fluctuations and destructive events that disturb forest health and/or structure and/or change the resources or the physical environment at any spatial or temporal scale (FAO, 2005). Disturbances caused by agents such as fire, insect pests, diseases and severe weather are important influences on forest ecosystems.

Under normal circumstances, in healthy forests, disturbances by insect pests and diseases are an integral part of the forest ecosystem (Dajoz, 2000). However, catastrophic disturbances can have undesired impacts on forest ecosystems and can affect environmental functions, with consequences for biodiversity and livelihoods (Schowalter, 2012) and climate change impacts. Cochrane and Barber (2009), for example, describe incidence of catastrophic wildfire in Brazil during the El Niño years of 1997–1998 that destroyed nearly 80% of staple crops within a province. Chambers et al. (2007), using data from moderate spatial resolution satellites, estimated that damage caused to forest land in the United States from hurricane Katrina in 2006 resulted in carbon emissions to the atmosphere of between 50% and 140% the annual net carbon sink of all forests in the country.

Forest disturbance, deforestation due to land use change and climate change are interrelated and compound one another (Dale et al., 2001). Cochrane and Laurence (2008) describe how new deforestation due to land use change in the Amazon can lead to cascading effects including increased flammability of forests, increased burned area and more destructive fires. Climate change could have wide-ranging detrimental effects on the distribution and severity of forest insect and disease outbreaks; Ayres and Lombardero (2000) estimate that in the United States these could result in economic losses of over USD 1 billion annually. Accurate assessment of the size and scope of forest disturbances other than complete overstorey removal is therefore critical for monitoring the Earth's natural systems, especially in the face of a changing global climate (van der Werf et al., 2009).

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To assess the state and trend of forest disturbance globally, the Food and Agriculture Organization of the United Nations (FAO) has sought to aggregate information on forest disturbances in its periodic Global Forest Resources Assessment (FRA). FRA 2000 (FAO, 2001) revealed a lack of national data sources capable of generating global estimates of land and forest area burned. FRA 2005 (FAO, 2007) provided data on global and regional areas burned based on 12 regional working papers prepared within the Global Wildland Fire Network of the United Nations International Strategy for Disaster Reduction (UNISDR). In FRA 2010, FAO attempted to quantify the impacts of many factors that affect the health and vitality of forests by collecting data on the impact of fire together with insect pests and diseases and other biotic and abiotic factors.

Early attempts to assemble global-level information on forest insect pests and diseases included several international meetings held in the 1960s and 1970s (e.g. FAO, 1965, 1976), but since then most of the information available at the global level has been pest specific. As part of FRA 2005, FAO asked countries to report on area affected by insect pests, diseases and other disturbances. This information was supplemented by a thematic study reviewing forest pests in 25 countries (FAO, 2009). In FRA 2010, countries were again asked to report on the impact of insect pests and diseases. However, most countries were unable to provide reliable quantitative information because they did not systematically monitor these disturbances or had limited access to data (FAO, 2011). FRA 2015 responded by modifying the data request to indicate significant outbreaks only. This resulted in more precise reporting of important disturbance than in previous years.

This paper updates the state of knowledge on global forest disturbances from fire, insects, diseases and severe weather. It analyses the status and trend of these various disturbance agents and events as reported by countries for FRA 2015. Total land area burned annually is included, but the analysis and discussion focuses, as much as possible, specifically on disturbed forest area. First presented are the aggregated results of the areal extent of forest disturbances globally, by broad climatic domain and by region. The article describes the trend in burned forest area over time and compares the amount of forest area burned with net deforestation. Further, a new disturbance-related variable in FRA 2015, called partial canopy cover reduction (PCCR), is introduced and analyzed as a proxy indicator of forest degradation. PCCR is summarized by climatic domain and region and related with burned forest area and net forest loss for each.

2. Data and methods

2.1. The Global Forest Resources Assessment

The results presented in this paper are based on data from FRA 2015. FRA relies on responses to a standardized questionnaire submitted by countries through a network of official national correspondents. For the history and details of the FRA reporting process see MacDicken (2015). National correspondents were asked to respond to questions in the following six categories relating to the type, number and areal extent of forest disturbances in their countries: number of fires per year; total land and forest area burned per year; area affected by insect outbreaks; area affected by disease outbreaks; area affected by severe weather events; and area of forest with reduced canopy cover. Where possible, countries were asked to report on specific types of pests, diseases and weather disturbances as well as on the species or forest type affected.

The target reporting years for FRA 2015 were 1990, 2000, 2005, 2010 and 2015. Disturbance variables, however, were not requested specifically for these years because they are by nature episodic. Countries were asked to report annual figures for number of fires and area burned from 2003 to 2012. The area of forest affected by insects, diseases and severe weather was reported non-systematically according to the year the disturbance was detected. The area of forest with reduced canopy cover was calculated on an annual basis, but annual figures were summed to produce a single statistic representing the total area affected between 2000 and 2010.

National reporting of burned area and PCCR was supplemented through the use of remote-sensing data (see Section 2.2). Remote-sensing based values for total burned area, burned forest area and PCCR were provided to the countries as pre-filled variables, and country experts were asked to accept, reject or modify the supplied area estimates with better quality, nationally derived data where available (MacDicken, 2015). This was done in an attempt to make global estimates of burned area more consistent. PCCR was summed for all the years between 2000 and 2012. Thus there is no time series of estimates to determine changes in rates or locations of PCCR.

2.2. Derivation of pre-filled data for burned area

Burned area estimates for FRA 2015 were derived from the Moderate Resolution Imaging Spectroradiometer (MODIS) Collection 5 Burned Area product (MCD45A1) (Roy et al., 2008) distributed as part of the MODIS fire products suite (Justice et al., 2002). The MODIS sensor is aboard the AQUA and TERRA satellite platforms and is capable of imaging nearly the entire Earth's surface daily with a pixel size of up to 250 m. The algorithm for mapping burned areas is based on the spectral, temporal and structural changes that characterize the land surface after a fire occurs (Roy et al., 2005). It detects the approximate date of burning at 500 m by locating the occurrence of rapid changes over a long time series of daily land-surface reflectance observations.

Estimates of burned forest area were obtained by spatially intersecting the burned area with forest area. Forest areas were determined using Collection 4, Version 3 (Hansen et al., 2006) of the MODIS Vegetation Continuous Fields (VCF) product (MOD44B) (Hansen et al., 2003). The VCF product is a globally consistent depiction of per-pixel percent cover for three types of vegetative cover – woody vegetation, herbaceous vegetation and bare ground – with a pixel size (spatial resolution) of 250 × 250 m. VCF data have been produced annually since 2000. Forest was distinguished from non-forest by applying a 30% threshold to the continuous VCF values for woody vegetation. Values of less than 30% were considered non-forest, and those of 30% or greater were considered forest. It should be noted that this threshold is different than the 10% used for FRA 2015 and that the MODIS definition of woody vegetation includes areas that are not forest using the FRA forest definition.

2.3. Derivation of pre-filled data for partial canopy cover reduction

Partial canopy cover reduction (PCCR) was defined as a detectable modification of canopy cover, at the 250 × 250 m MODIS pixel size, that resulted in a partial loss of tree cover relative to a predetermined reference time period, in this case the year 2000. Partial loss was determined on the basis of a change in per-pixel percent tree canopy cover as estimated from the annual VCF time series. Pixels with PCCR between 2000 and 2012 were identified using three main criteria: an initial VCF value greater than 30%; an overall decrease in percent canopy cover greater than 20% between 2000 and 2012; and a negative slope (>−1) of the line formed by the linear regression of the VCF percent tree cover over the period from 2000 to 2012. Pixels where VCF values dropped and stayed