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The influence of forest definition on landscape fragmentation assessment in Rondônia, Brazil

Filip Colson [a,*], Jan Bogaert [b], Arnaldo Carneiro Filho [c], Bruce Nelson [c], Ekena Rangel Pinagé [d], Reinhart Ceulemans [a,1]

[a] University of Antwerp, Department of Biology, Research Group of Plant and Vegetation Ecology, campus Drie Eiken, Universiteitsplein 1, B-2610 Wilrijk, Belgium
[b] Université libre de Bruxelles, École Interfacultaire de Bioingénieurs, Service d'écologie du paysage et systèmes de production végétale, C.P. 169, Avenue F.D. Roosevelt 50, Campus Solbosch, Villa Capouillet, B-1050 Brussels, Belgium
[c] Instituto Nacional de Pesquisas da Amazônia, Ecology Department, Av André Araujo 2936, 69083-000 Manaus, AM, Brazil
[d] WWF-Brazil, Ecologia da Paisagem, SHIS EQ QL 6/8, Conjunto E 71620-430, Brasília, FD, Brazil

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ABSTRACT

Estimates of tropical deforestation and forest degradation are misleading, partly because different studies make use of different forest definitions. This paper investigates the influence of this confusion on the assessment of forest extent and its spatial distribution, by means of fine-scaled land cover maps and landscape metrics. The state of Rondônia, Brazil, located in the southwestern part of the Amazon basin and known for its fishbone-like pattern of deforestation, is used as a study area. A 1:250 000 vector data product from the Brazilian Geography and Statistics Institute (IBGE), describing the land cover type in a three-step hierarchy specifying canopy density, topography, and dominant life forms, was rasterized and analyzed. Forest subcategories were aggregated into a seven level gradient, ranging from a level that is very specific and only includes dense multi-layered rain forest, to less strict levels containing open forest systems, secondary vegetation, and tree savannas. We show that there is a consistent difference between the initial class aggregation level, and all other levels, which gradually broaden the forest definition and are characterized by very distinct ecological parameters, such as a higher mean patch size, increased levels of landscape connectivity and slightly more irregularly shaped patches. We recommend a harmonization of the major forest definitions in use today, while taking care not to lose the relevant ecological information that can be extracted from its most detailed classification level.

1. Introduction

Tropical deforestation is a diverse phenomenon caused by a wide variety of processes that vary in space and time (Lambin et al., 2003). Major direct drivers of tropical deforestation include large-scale timber extraction, agricultural expansion and infrastructure development, all of which have increased dramatically in many parts of the tropics over the past few decades (Geist and Lambin, 2002). The more recent attention given to tropical deforestation stems from concerns over its various consequences, including the massive loss of biological diversity, the loss of an important sink for atmospheric carbon dioxide, impacts on local, regional and global climate, and the negative effects on the livelihoods of people in tropical forests (Moran et al., 2000; Metzger, 2002; Börner et al., 2007). Deforestation can be described in several ways; a landscape ecological approach is mainly focused on the spatial process of fragmentation. This can be defined as the breaking up of continuous habitats into patches and thereby generating habitat loss, isolation, and edge effects (Bogaert et al., 2004).

The state of Rondônia in the Brazilian Amazon provides a unique study area to investigate the effects of human disturbance on the spatial patterns of a natural landscape. Rondônia has experienced tremendous landscape changes since the 1970s, and this trend is likely to continue under the pressure of population growth and migration (de Barros Ferraz et al., 2005). While in 1978, only 4200 km^2 (2%) of the state's primary forests had been deforested, by 2000 deforestation had eliminated 58 143 km^2 (24%) of the state's forest cover (Summers et al., 2004). Logging, shifting cultivation and cattle ranching, in this order, are considered the main drivers of land use change; they can be linked in a dynamic process creating a complex mosaic of land use and cover from mature forest to a deforested frontier (Lambin et al., 2001). Farmers typically settle on 100-ha rectangular lots along feeder roads that are spaced every 4–5 km, thus creating the well-known feather or fishbone pattern at landscape level (Goza, 1994).

* *Corresponding author*. Tel.: +32 3 820 22 82; fax: +32 3 820 22 71.
E-mail address: filip.colson@gmail.com (F. Colson).
[1] Tel.: +32 3 820 22 82; fax: +32 3 820 22 71.

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There is considerable controversy over the statistics that emanate from governments, international agencies and non-profit organizations on the extent of forest and the rates of tropical deforestation (Fearnside, 1993; Hoare, 2005). The United Nations Food and Agricultural Organization (FAO) figures are widely used in spite of highlighted internal inconsistencies arising from the difficulties in standardizing national data obtained from different countries (Matthews, 2001). The Intergovernmental Panel on Climate Change has pointed out that deforestation estimates are very uncertain for tropical countries and could be in error by as much as 50% (Watson et al., 2000). This uncertainty may be due to differences in methodological approach used to arrive at periodic figures on the extent of tropical forest in different countries (Fairhead and Leach, 1998). In addition, definitions of forest may vary considerably, as shown by the following examples.

FAO uses the term closed forest to represent a land area of more than 0.5 ha with a tree canopy cover of more than 40% and the trees should be able to reach a height of 5 m (Forest Resources Assessment 2000, report available online at http://www.fao.org/forestry/fra2000report/en/); forests with 10–40% cover are classified as open forest. This definition includes both plantations and natural forests. As a result of this broad FAO definition, a wide range of forest-like ecosystems are probably included within the category of forest, from dense humid forests to open woodlands and woody savannas. The definition used by the International Geosphere Biosphere Program for evergreen broadleaf forest includes lands dominated by woody vegetation with a cover of more than 60% and a height exceeding 2 m (Loveland et al., 2000). The Tropical Ecosystem Environment Observations by Satellites project (TREES, funded in the 1990s by the Joint Research Centre of the European Commission), used again different definitions: areas with more than 70% canopy cover are classified as dense forest, and those with 40–70% cover – which FAO classifies as dense – as fragmented forest (Achard et al., 2002). The overabundance of forest definitions in use has been shown by Lund (2005) who listed over 890 different meanings.

These divergent definitions and subsequent thematic resolutions of mapped data lead to confusion and disagreement on tropical forest extent and its spatial distribution (Bailey et al., 2007; Buyantuyev and Wu, 2007). For instance, Giri et al. (2005) found important differences in forest distribution between two prominent land cover products, namely the GLC2000 product (Global Land Cover 2000, available online at http://www-gvm.jrc.it/glc2000/; Bartholomé and Belward, 2005) and the MODIS (Moderate Resolution Imaging Spectrometer) land cover product prepared by researchers at Boston University (Friedl et al., 2002). Analogously, FAO estimated that there was 5.466×10 km^2 of forest in Brazil in 1995 (FAO, 1997), while the United Nations Environment Program (UNEP) estimated that there was only 3.62×10^6 km^2 of closed forest (with a canopy cover of more than 40%) for the same year (UNEP, 2001). The 30% difference in these two estimates is largely accounted for by cerrado vegetation (Hoare, 2005), which is a regional term that includes all the subtypes of savanna, including the densely wooded savanna cerradão and park savanna.

Table 1
Overview of the aggregation scheme of forest subcategories, using as a starting point the detailed classification from the Brazilian Geography and Statistics Institute (IBGE) (Veloso et al., 1991). Level A contains only the ombrophilous multi-layered rain forest with dense canopy cover. Equivalent to savanna woodland (F) the term cerradão can be used. Ranges of the forest land cover definitions of the Food and Agricultural Organization (FAO), the International Geosphere Biosphere Program (IGBP), and the Tropical Ecosystem Environment Observations by Satellites project (TREES) are approximated by marked verticals.

LAND COVER AGGREGATION LEVEL	INCLUDED IBGE LAND COVER CLASSES	OTHER FOREST DEFINITION RANGES
A	Dense Rain Forest (Floresta Ombrófila Densa)	TREES
B	Open Rain Forest (Floresta Ombrófila Aberta)	TREES
C	Secondary Vegetation (Veg. Secundária)	FAO closed, IGBP
D	Semi-deciduous Forest (Floresta Estacional Semidecidual)	FAO closed, IGBP
E	Rain Forest/Savanna Ecotone (Contato Floresta Ombrófila/Estacional/Savana)	FAO closed
F	Savanna Woodland (Savana Florestada/Arborizada)	FAO open
G	Park Savanna (Savana Parque)	FAO open