Ecological Modelling 384 (2018) 316–332

Contents lists available at ScienceDirect

Ecological Modelling

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

Spectral-temporal modelling of bamboo-dominated forest succession in the Atlantic Forest of Southern Brazil

Clara Greig[a,*], Colin Robertson[a], André E.B. Lacerda[b]

[a] Department of Geography and Environmental Studies, Wilfrid Laurier University, 75 University Ave. West, Waterloo, ON, N2L 3C5, Canada
[b] EMBRAPA Forestry – Brazilian Agriculture Research Corporation, Estrada da Ribeira, km 111, Caixa Postal 319, 83411-000, Colombo, PR, Brazil

ARTICLE INFO

Keywords:
Landsat time-series
Spectral-temporal modelling
Bamboo
Succession
Atlantic Forest

ABSTRACT

With access to collections of continuous satellite imagery over a 40-year period, spectral-temporal patterns extracted from multi-temporal imagery offer a potential new tool to model mechanisms of forest succession and monitor changes in forested landscapes. Specifically, spectral-temporal trajectories associated with successional forest change occurring over prolonged periods of time may enhance periodic 'snapshot' monitoring methods, especially for species that exhibit complex and non-linear dynamics. In this paper, Landsat time-series are used to examine the spectral-temporal signatures of bamboo-dominated forest succession occurring within the critically threatened Araucaria Forest, a pine-dominated subtype of the Atlantic Forest in southern Brazil. Alteration of canopy structure through ongoing anthropogenic disturbance has increased understorey light climate and given opportunity for native invasive bamboos to flourish, resulting in drastic reduction of tree regeneration and loss of biodiversity. We aimed to evaluate how spectral-temporal signatures could be used to (1) characterize stages of bamboo-dominated forest succession, (2) identify synchrony of bamboo lifecycle dynamics and (3) classify regions of bamboo-dominated forest. Changepoint analysis was performed using an extracted sample spectral-temporal signature and trajectories were fit to the resulting segments using linear regression. Based on slope values of the fitted segments, a novel description incorporating temporal information of bamboo-dominated forest succession was developed which identified four broad phases: pioneer predominance, mature bamboo, dieback and pioneer regeneration. To determine the spatial and temporal synchrony of bamboo-dominated forest succession, a hybrid model was developed by combining the modelled segments and compared to a 32-year Landsat time-series of vegetation indices by calculating root-mean square error between each pixel in the study area. The hybrid model proficiently classified regions of bamboo-dominance, achieving between 77% and 90% accuracy, which also indicated lifecycle synchrony of bamboo populations within the study area. To further assess the performance of the hybrid model, a time-weighted dynamic time warping model approach was used to determine synchrony and classify regions of bamboo. The time-weighted dynamic time warping classifier had lower overall accuracy (68%–82%), but is still considered a useful tool for automated classification purposes that take advantage of multi-temporal imagery. To compare classification performance between 'snapshot' and multi-temporal imagery classifiers, a maximum-likelihood classification was performed, which attained lower overall accuracies than the hybrid model (75%–84%). Overall, the use of spectral-temporal signatures offers a novel and effective approach to both describing and modelling bamboo-dominated forest succession (and forest successional processes more generally) on a landscape-scale.

1. Introduction

The Atlantic Forest, which is considered one of the world's twenty-five biodiversity hotspots (Myers et al., 2000; Mittermeier et al., 2004), has been reduced to less than 10% of its original area and is considered the most devastated and threatened ecosystem in the world (Leal and de Camara, 2003). The remaining forest is host to more than 8000 endemic species with over 530 species officially designated as threatened (Myers et al., 2000). As a subtype of the Atlantic Forest, the Subtropical Humid Forests of southern Brazil (FAO, 2005), locally known as Araucaria Forest (IBGE, 2012), has been subjected to intensive fragmentation, resulting in forest fragments of less than 50 ha which have been heavily altered (Lacerda, 2016). The degradation of the remaining forests has drastically altered canopy structure, allowing native bamboos to

* Corresponding author.
E-mail addresses: grei4780@mylaurier.ca (C. Greig), crobertson@wlu.ca (C. Robertson), andre.biscaia@embrapa.br (A.E.B. Lacerda).

https://doi.org/10.1016/j.ecolmodel.2018.06.028
Received 22 November 2017; Received in revised form 21 June 2018; Accepted 25 June 2018
0304-3800/ © 2018 Elsevier B.V. All rights reserved.

dominate the forest understorey forming dense clumps which exclude surrounding plant communities (Budke et al., 2010; Lacerda and Kellermann, 2017), contributing to further degrade the remaining Araucaria Forest fragments (Lacerda, 2016).

Merostachys skvortzovii is a pervasive bamboo species found throughout Araucaria forest. *M. skvortzovii* is characterized by a 31 to 33-year lifecycle (Pereira, 1941), during which it may dominate the forest understory continuously and terminate with a dieback event of synchronized mast flowering (Griscom and Ashton, 2006; Lacerda and Kellermann, 2017). Once *M. skvortzovii* populations establish themselves in the forest understorey, their monocarpic dieback events have been found to act as disturbance events by opening the canopy and releasing soil nutrients and space (Taylor and Qin, 1992; Abe et al., 2002; Taylor, 2004; Rother et al., 2009), enabling regeneration of pioneer specie to occur. Within Araucaria forest, *Mimosa scabrella*, a prominent pioneer species, will initially recruit and dominate the canopy, followed by secondary succession species *Vernonanthura discolor* and *M. skvortzovii* (Kellermann, 2011; Lacerda and Kellermann, 2017). Once *M. skvortzovii* recruits, it will continuously replace itself by clonal growth throughout its lifecycle, growing denser as it matures while simultaneously further suppressing regeneration. The way in which pioneer and *M. skvortzovii* population dynamics coincide is hypothesized to be a synchronized process which controls forest succession; due to similar lifecycle lengths of *M. skvortzovii* (31 to 33-years), *M. scabrella* (20 to 25-years), and *V. discolor* (30 to 60-years), gaps created by treefall from senescent pioneer populations enables incoming solar radiation to reach the bamboo-dominated understorey, increasing bamboo growth while impeding the development of tree species. This synchronized process has resulted in a perpetuated bamboo-dominance cycle which has been observed to arrest forest succession in the region (Lacerda and Kellermann, 2017), a phenomenon which has also been observed in the Amazon forest (Griscom and Ashton, 2006).

In forested regions where canopy structure has been altered due to ongoing anthropogenic disturbances, it has been observed that increased understorey light climate has enabled native invasive bamboos to flourish, resulting in reduction of tree regeneration and loss of biodiversity (Lacerda and Kellermann, 2017). With increasing threat to ecologically sensitive regions, such as the Atlantic Forest of southern Brazil, increased knowledge regarding the impact of bamboo-dominance on surrounding plant communities will assist in improving current forest management techniques by emphasizing the need for silvicultural intervention to enable and promote the growth and regeneration of threatened and endangered plant species.

The use of Landsat time-series stacks has proven to serve as an effective tool to observe continuous change and improve understanding of ecological processes occurring at a landscape scale (Kennedy et al., 2007). Methods have been developed in recent years which exploit the use of spectral-temporal signatures to observe mechanisms of forest succession (Broich et al., 2011; Lehmann et al., 2013), identify distinct disturbance events and recovery rates (Huang et al., 2009; Vogelmann et al., 2009; Kennedy et al., 2010; Griffiths et al., 2014; DeVries et al., 2015; Senf et al., 2015) and classify various landcover types (Maus et al., 2016a). The premise of these methods is the underlying assumption that many natural systems exhibit a distinct temporal progression which can be observed in spectral-space (Kennedy et al., 2007). To analyze ecological processes of bamboo-dominated forests, we developed a semi-empirical spatially explicit hybrid spectral-temporal model (hybrid model) from a 32-year Landsat time-series to characterize the successional phases of bamboo-dominated forests and determine whether the perpetuated bamboo-dominance cycle is a synchronous process occurring on a landscape scale. While the lifecycle of *M. skvortzovii* has been only recently discovered on a local scale, research interest now centres on identifying the spatial scale and synchrony of these processes occurring across the landscape. Utilizing remotely sensed imagery to derive bamboo successional dynamics will support the development of synoptic mapping tools for the Atlantic Forest which will directly support conservation and adaptive management planning. Accordingly, this paper aims to:

1 Identify and characterize the spectral-temporal signature of bamboo-dominated forest succession
2 Determine whether the perpetuated bamboo-dominance cycle is a synchronous process occurring on a landscape scale by comparing a 32-year Landsat time-series stack to a hybrid model
3 Compare performance of the hybrid model to a time-weighted dynamic time warping model approach to assess the effectiveness of the hybrid model, and more generally spectral-temporal signatures, to determine bamboo lifecycle synchrony and identify regions of bamboo-dominance.

2. Materials and methods

2.1. Study area

The Embrapa Research Station in Caçador (ERSC) is a 1157-hectare research area located in Caçador, Santa Catarina, Brazil (Fig. 1). The study area is part of the Subtropical Humid Forest of the Atlantic Forest in Southern Brazil, locally known as Araucaria forest, which is a mixture of temperate and tropical floras (IBGE, 2012; Leite and Klein, 1990), occurring in subtropical highland climate (Cfb), with high annual precipitation of approximately 1400 mm. However, extensive colonization in the 19th century has reduced the biome to 5% of the original forest cover as primary forest, with 20–25% as secondary forest (Lacerda, 2016). The region is characterized by the predominance of the critically endangered late successional species, *Araucaria angustifolia* and *Ocotea porosa* (IBGE, 2012). ERSC is one of the most well-preserved remaining fragments of the Subtropical Humid Forest and has not received any silvicultural intervention in the past 20 years (Lacerda et al., 2012). Prior to that, the forests in the ERSC were subjected to selective logging, significantly reducing areas where the canopy is dominated by *A. angustifolia* (Lacerda, 2016). In 1948, ERSC was established as a forest reserve, although the east end continued to be heavily logged until 1974, which enabled the invasion of bamboo in the forest understorey in the area.

The ERSC has previously been classified into three forest types, which include (1) Araucaria predominance, (2) degraded forest and (3) bamboo-dominated forest (Lacerda, 2016). Araucaria predominance describes areas of forest where canopy is dominated by *Araucaria angustifolia*. Degraded forests are areas of the ERSC that experienced intensive logging in the past and may have been impacted by forest fires, resulting in significant alteration of forest structure and floristic composition. These forests are characterized by open canopies, which enables invasion of bamboo. Bamboo-dominated forests are areas within the ERSC that have been submitted to historical clearcutting in which bamboo populations are dominant with significant suppression of regeneration occurring in the understory (Lacerda et al., 2012; Lacerda and Kellermann, 2017). The landscape surrounding the ERSC is primarily farmland, commercial forest plantations and small forest fragments resulting from fragmentation or regeneration of abandoned agriculture land (Lacerda, 2016).

Download English Version:

https://daneshyari.com/en/article/8846018

Download Persian Version:

https://daneshyari.com/article/8846018

Daneshyari.com