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Improving the monitoring, control and analysis of the carbon accumulation capacity in *Legal Reserves* of the Amazon forest

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ABSTRACT

The Amazon forest is host for a large number of deforestation activities caused by artisanal mining and mainly by agriculture and livestock businesses. In order to regulate these activities and relieve the environmental impacts, local authorities have been trying to guide them towards more responsible operations. This paper describes the initiative of monitoring forest areas located near deforestation regions since fundamental elements such as biomass and carbon accumulation of trees may be adequately controlled and monitored against occasional disturbances brought by these activities. The current standard approach in the Amazon is to monitor all trees in the forest within an area called *transecto*, in order to keep a rigorous record of their behavior and growth. However, these control activities are restricted to controlling portions that are located in strategic areas, therefore they do not represent the entire region to be monitored. This research exploits a new methodology based on geostatistics, aimed at optimizing sampling, and allowing the extension of the study to much larger forest areas, while keeping unitary utilization of human resources unchanged and at the same time, increasing the studied areas footprint and the precision of the results. The proposed methodology also allows the selection of the *Legal Reserve* (RL) area to be made according to the actual carbon-accumulation distribution on the property's contained forest, allowing the determination of a location target for the RL, what is not possible with the current used methodologies that rely simply on a percentage area utilization for the RL, inside the property. This methodology was applied using the available data set in this paper in order to optimize the samples and to monitor the capacity of the forest to store carbon at Tapajós National Forest, in Pará, Brazil. It is expected that this methodology will contribute to an overall cost decrease per unit area of the monitoring activities, increase the precision for the RL location and simplify the needed procedures through the application of a user friendly toolkit, that can be developed using the proposed methodology, whose complexity is totally transparent to the land and business owners, regulators, environmental scientists and workers involved. This, if correctly applied could ultimately contribute to the sustainable development of the affected regions.

1. Introduction

The Brazilian legislation is majorly concerned with preserving the Amazon forest, thus, it has created the so-called *Legal Reserve – RL*, where 80% of the property located in rural areas must be preserved and notarized as RL, allowing the exploration of 20% of the area. However, there is no concern as to determine what would be the most appropriate area in which this RL should be located, and this decision is entirely up to the landowner.

This paper proposes:

1. A methodology that is based on geostatistics, optimizing sampling, and allowing to extend the study to much larger forest areas
2. A propose of methodology allows the selection of the RL area to be made according to the actual carbon-accumulation distribution on the property tropical forest

The shrub and arboreal-pattern plants are the ones that offer the longest carbon-stocking cycles in nature since photosynthesizing

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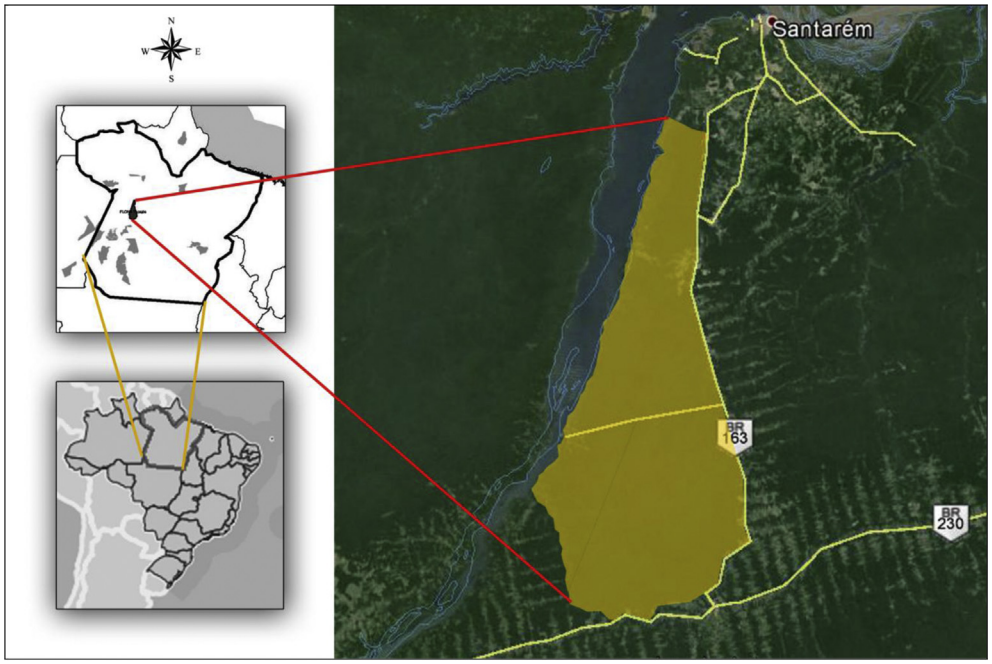

Fig. 1. Location of the Tapajós National Forest. Source: INPA.

organisms are majorly responsible for the atmospheric CO_2 sequestration, and plants are responsible for stocking two-thirds of the carbon on Earth (Totten, 2000).

Several ecological studies reveal that most, if not all, communities are spatially structured, and that the sampling methods need to be robust in order to detect different levels of spatial autocorrelation.

The most used form of sampling is the transect, that aims to characterize the transition areas (ecotone) or areas in different successional stages (Brower and Zar, 1984), the transect lines are widely used by ecologists fauna, characterized by the establishment of ranges of known lengths (Garcia and Lobo-Faria, 2009). Transect belts are used for better representation of the composition of the area (Brower and Zar, 1984). For the detection and prediction of the spatial structure is best described with samples plots (Oda-Souza, 2009). The sampling methodology allows parcels in the repetition of the methodology in a large community, allowing adequate representation of local diversity (Garcia and Lobo-Faria, 2009).

Geostatistical analysis was chosen because it allows the evaluation of the spatial distribution of the samples, uniquely associating the dependency degree between samples with the spacing measurements among sampled points and it may be associated to the kriging method, which generates values for non-sampled locations (Matheron, 1971). Thus, in addition to the geostatistical analysis of the carbon accumulation, we may also optimize the forest sampling, which is currently exhaustively performed, that it, it is performed in the entire area, sampling species by species.

For this study, the carbon accumulation was analyzed based on geostatistics, establishing a relationship between the samples of georeference arboreus species, in order to provide carbon accumulation models in tropical forest areas located near the artisanal mining regions, with the purpose of monitoring such carbon accumulation, offering grounds to determine the most appropriate location for the RL area. Sampling was performed at the Tapajós National Forest, in the state of Pará.

1.1. Tapajós National Forest

The Tapajós National Forest, who was created by decree no. 73,684 from 02/19/74. Art 1: It is instituted, in the State of Pará, the Tapajós National Forest (Fig. 1), under the jurisdiction of the" Chico Mendes Institute for Biodiversity Conservation" – ICMBio, a federal agency under the Ministry of the Environment of Brazil, responsible for the management, monitoring and protection of 312 units of existing nature conservation in Brazi. This forest has an estimated area of 600,000 ha (six hundred thousand hectares), within the following boundaries and confrontations: West – Tapajós River; East – Cuiabá Road - Santarém; North – A line that goes through the 50 (fifty) kilometer mark of the Cuiabá-Santarém Road and through a point with latitude equal to 2°45′S (two degrees and forty five minutes South), at the right bank of the Tapajós River; South - Cupari River and its affluent, Santa Cruz, also called Cupari Leste, up to its intersection or axis prolongation, with the Cuiabá – Santarém Road.

The soils occurring are, according to the American classification, Oxisolos clay with low organic matter content, acidic pH, low cation exchange capacity (CEC) and high aluminum saturation (Chavel, 1982; Parrota et al., 1995; Ferraz et al., 1998; Telles et al., 2001) according to the classification Brazilian oxisols are called red yellow distróficos. The vegetation is classified as rainforest dense terra firme (Higuchi et al., 1997; Clark and Clark, 1996). The study area is located on a large plateau with water very deep water table, sometimes to more than 100 m deep.

1.2. Deforestations activities

Reducing the size of natural forests around the world has occurred as a result mainly of fires, cuts trees for commercial purposes, devastation of land for agricultural use, or even natural phenomena (Arraes et al., 2012). According to Ruviaro et al. (2012) in recent years, the debate about environmental sustainability has broadened to include the impact of agricultural production. In addition to deforestation, agriculture causes many environmental