Assessing on estimates of biomass in forest areas

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Abstract

The objective of this paper is to assessing on estimates of biomass in forest areas using: a direct approach, through measures in the field; and an indirect approach, through processing of remote sensing products. Two study areas were used for the direct and indirect biomass estimates for the monitoring of natural regeneration of riparian forests, on the banks of the Uruguay River, in the border between the states of Santa Catarina and Rio Grande do Sul, Brazil. Results showed that the average biomass of representative class showed an increased biomass growth following the growth stage of forest. It was observed that the permanent preservation areas near the reservoirs had a significantly higher variation in the NDVI values compared to other areas not preserved nearby. Looking at the average change in NDVI values between the years of 2005 and 2012 for these land use classes, it was found an increase in the index for all classes of coverage analysis. In this scenario, when assessing the total production of biomass for these study areas, it was noted that there was a positive increase of biomass, since the forest classes showed a significant increase in their biomass and the class of grazing - a decrease. This increase can be classified as positive even with a significant decrease in average forest stage of succession, since this decrease, possibly also means an increase in forest classes in early and advanced stages of succession.

Keywords: NDVI, SAVI, Biomass Estimates, Riparian forests.

1. Introduction

Information on estimates of biomass in forest areas is of great importance for different application areas. This information usually serve as subsidies related to the conservation of natural resources; quantification of nutrient cycling; and evaluation of natural regeneration of riparian forests. Although there is an enormous literature on the remote sensing of biomass including the use of standard spectral indices, none of them is motivated to objectively state the accuracy of used techniques and how this can be extrapolated to other regions.

The objective of this paper is to assessing on estimates of biomass in forest areas using: a direct approach through measures in the field; and an indirect approach, through processing of remote sensing products.

2. Study Area

Two study areas were used for the direct and indirect biomass estimates for the monitoring of natural regeneration of riparian forests, on the banks of the Uruguay River, in the border between the states of Santa Catarina and Rio Grande do Sul, Brazil.

Figure 1: Study area location map.

3. Material and Methods

For all the experiments, four predominant vegetation classes were considered of interest for the years of 2005 and 2012: Grassland, Forest in - early, intermediate, and advanced - stages of successions.

In this survey, biomass estimates were obtained initially in the field using a non-destructive approach. Database of the vegetation heights and diameters were obtained in experimental plots, previously selected from 16 m^2 (4m x 4m) and were used in equations to estimate biomass (BA) from each individual in the plot. The procedure used in order to estimates biomass was proposed by EMBRAPA (Arevalo *et al*., 2002), expressed as Equation (1):

$$BA = 0{,}1184 \times DAP^{2{,}53} \quad (1)$$

Where, DAP is the tree diameter at 1.5 meters from the ground.

From the sum of biomass of all individuals, it was possible to obtain estimate values for the distribution of biomass in the plots expressed in tone per hectare.

It was also performed an indirect biomass estimation using vegetation indices, through the processing of satellite imagery for the areas on the banks of Ita and Machadinho reservoirs, between 2005 and 2012.

Visible and infrared Ikonos bands were used to generate these indices. It was used the ERDAS Imagine and ArcGIS systems in order to carry out the processing of these images and spatial analyzes, respectively.

In order to estimate indirectly the increase of biomass in the study area, many vegetation indices were tested. Most vegetation indices can be influenced by soil reflectance, the atmospheric path radiance and/or by varying the substrate under the canopy.

Thus, it was also tested vegetation indices that are able to minimize these effects. Initially, it was used the NDVI - Normalized Difference Vegetation Index, and subsequently other vegetation indices were also tested: TVI - Transformed Vegetation Index, SAVI - Soil Adjusted Vegetation Index (Qi *et al*., 1994), ARVI - Atmosphere Resistant Vegetation Index (Kaufman and Tanré, 1992), GEMI - Global Environment Monitoring Index (Pinty and Verstraete, 1992) and EVI - Enhanced Vegetation Index.

Among the indices studied experimentally, It was shown the best performance for the study areas where the NDVI and SAVI indices were tested (Baret and Guyot, 1991).

3.1 NDVI – Normalized Difference Vegetation Index

The NDVI index was initially proposed by Rouse *et al.* (1973), in order to quantify a vegetation growing and accumulated biomass. Its value varies from -1 to +1. As high as is its value, greater is vegetation vigour (Rouse *et al*., 1973). This NDVI index is used to reduce the influence of soil, atmosphere as well as the Sun inclination angle.

The NDVI index can be determined by the subtraction of the gray scale from an infrared band (IVP) by a band from the region of red (V), on the electromagnetic spectrum, divided by the sum of these two bands. This can be expressed using the Equation (2):

$$NDVI = \frac{\mathrm{IVP} - \mathrm{V}}{\mathrm{IVP} + \mathrm{V}} \quad (2)$$

3.2 SAVI – Soil Adjusted Vegetation Index

The Soil Adjusted Vegetation Index (SAVI) is used to reduce the soil effects into different cover densities, through an addition of a constant L to a generic red band (V) versus its infrared band (IVP) (Huete *et al*., 2002). O SAVI index can be obtained by Equation (3):

$$SAVI = \frac{(\mathrm{IVP} - \mathrm{V})}{(\mathrm{IVP} + \mathrm{V} + \mathrm{L})}(1 + \mathrm{L}) \quad (3)$$

Where L is a constant which minimizes the soil effects and could vary from 0 to 1.

According to Huete (2002) the best L values are:

L = 1 (for areas with low vegetation density)

L = 0,5 (medium density of vegetation)

L = 0,25 (high vegetation density)

Finally, in order to identify the areas that had increased biomass, it was performed a subtraction of information layers containing these indices for the year 2012 compared to 2005, and analyzes the average change in NDVI for each land use class.

4. Results, Discussions and Conclusions

The grassland class is the one with the highest spatial distribution in both study areas for the years of 2005 and 2012. However, there was a decrease of 4.49% in regions covered area of pasture. Whereas, an increase of 2.13% in area of forests in the range between 2005 and 2012 was found. Analyzes showed that there were differences in average biomass per hectare of all vegetation classes studied. In general, the average biomass of representative class showed an increased biomass growth following the growth stage of forest. The average variation of NDVI for areas on the banks of Ita and Machadinho reservoirs in the period between 2005 and 2012 was approximately 0.101 and 0.027, respectively, representing an average increase in the value of NDVI for the area of interest on the banks of these two reservoirs.

It was observed that the permanent preservation areas near the reservoirs had a significantly higher variation in the NDVI values compared to other areas not preserved nearby. Looking at the average change in NDVI values between the years of 2005 and 2012 for these land use classes, it was found an increase in the index for all classes of coverage analysis.

The increase in NDVI values for the class "Forest in Early Stage of Succession" reinforces the hypothesis of an evolution of the vegetation, as previously established classes of pastures tend to migrate to this early stage of succession.

Although it was observed that classes with more advanced phenological stages, tend to have a less rapid growth. In this scenario, when assessing the total production of biomass for these study areas, it was noted that there was a positive increase of biomass, since the forest classes showed a significant increase in their biomass and the class of grazing - a decrease (Table 1). This increase can be classified as positive even with a significant decrease in average forest stage of succession, since this decrease, possibly also means an increase in forest classes in early and advanced stages of succession.

Table 1: Biomass Total Estimates.

Predominant Classes in 2005			
Vegetation Types	**Area (ha)**	**Direct Estimates ($t.ha^{-1}$)**	**Total Estimates (t)**
Grassland	35.945,67	23,74	853.350,37
Forest Early Stages	11.617,46	78,84	915.920,74
Forest Intermediate	16.387,06	135,71	2.223.888,25
Forest Advanced	15.627,47	458,44	7.164.257,80
Total	**112.836,74**		**11.157.417,17**
Predominant Classes in 2012			
Vegetation Types	**Area (ha)**	**Direct Estimates ($t.ha^{-1}$)**	**Total Estimates (t)**
Grassland	30.603,48	23,74	726.526,61
Forest Early Stages	11.916,07	78,84	939.462,95
Forest Intermediate	12.713,29	135,71	1.725.320,58
Forest Advanced	21.538,29	458,44	9.874.013,66
Total	**108.883,19**		**13.265.323.82**
Biomass Difference between 2006 and 2012			
Vegetation Types	**Total Estimates (t) 2006**	**Total Estimates (t) 2012**	**Differences (t) (2006-2012)**
Grassland	853.350,3767	726.526,6152	- 126.823,76
Forest Early Stages	915.920,7435	939.462,9588	+ 23.542,21
Forest Intermediate	2.223.888,2518	1.725.320,5859	- 498.567,66
Forest Advanced	7.164.257,8052	9.874.013,6676	+ 2.709.755,86

By correlating the data obtained by direct estimation of biomass with the indirect estimation - using NDVI, may infer that where there is the class of grassland vegetation with range values of 0.124 NDVI, biomass production is about 23 tons per hectare

(Figure 2). For forest already in early succession stage, presenting range NDVI values of 0.232 the equivalent biomass production is approximately 78 tons per hectare, and so on.

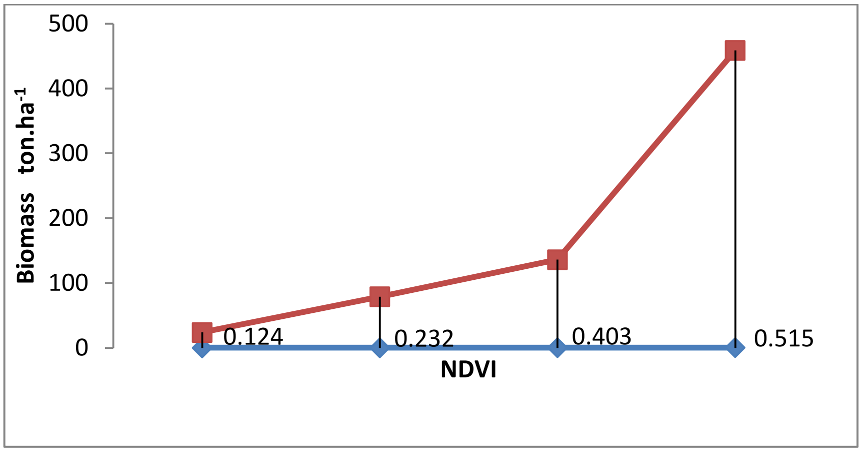

Figure 2: Correlation between NDVI Values versus Biomass. The NDVI values of Grassland (0.124), Forest in – early (0.232), intermediate (0.403) and advanced (0.515) - stages of successions.

Such interpretations can still be extrapolated to the averages of other vegetation classes. Yet, it has been possible to verify that there is a growing trend in both NDVI values, as well as the values of biomass, assuming an almost exponential relationship for these study areas.

Acknowledgments

We would like to thank Tractebel S.A Company for support this research and VisãoGeo Company for this partnership.

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