

2. ABOVEGROUND BIOMASS QUANTIFICATION FOR NATURAL GRASSLANDS IN THE PAMPA BIOME

By: **Eliana Lima da Fonseca¹**; **Charles Tebaldi²**; **Adriana Ferreira da Costa Vargas³** and **Vicente Celestino Pires Silveira⁴**

2.1. Introduction and relevance of application

The Pampa biome has a unique kind of vegetation, characterized by C3 and C4 plants adapted to the transition from subtropical to temperate climates. The Pampa biome is situated in Brazil, Uruguay and Argentina and can broadly be classified as “grassland of the River Plate”. The biome is covering an area of approximately 700,000 km². This region is an important site for migrant birds in the American Continent and there are a quite number of vegetal species in danger of extinction.

The main economic activity in the region is cattle-raising (cows and sheep) based on the natural grasslands since the 18th century. This “free range” grazing system in natural pastures is compatible with the conservation of the Pampa environment. In the Rio Grande do Sul state (most southern Brazilian state) this continuous grazing has been existing for more than two hundred years, like a form of economic use of natural grasslands, with a low level of damage to the Pampa biome (Overbeck et al, 2007). Data from the Brazilian Ministry of Environment show that the Pampa biome in Brazil has been reduced by 54% of its original area due to agricultural activities and forestry (cellulose industry) during the last 30 years. These activities are the main reason of the loss of biological diversity as a result of the replacement of natural grasslands with other systems of production.

The monitoring of the aboveground biomass production of vegetation in this region will allow fitting cattle-raising activity with the actual biomass production, allowing an adjustment of the number of livestock per area to enable the economic exploitation of these areas jointly with the conservation of natural vegetation and of the environment.

The methodology adopted here can be applied in natural and cultivated areas to estimate aboveground biomass. The limitation for replication of this methodology is a good dataset with in situ measurements and knowledge about the phenology as well as about the vegetal species that are growing in the study area.

2.2. Objective

The main objective of this study is the quantification of the aboveground biomass production for the natural grassland of the Pampa biome using NDVI data calculated from images acquired by SPOT-Vegetation instrument.

2.3. Study Area

The study area is located in the “Environmental Protection Area (EPA) of Ibirapuitã” (see also figure 2.1), which is a region of 320,000 hectares. The objective of the EPA is to ensure the conservation of a significant portion of the biodiversity of the Pampa biome alongside other economic activities.

¹ Professor at Department of Geography - Universidade Federal do Rio Grande do Sul (UFRGS) - Brazil eliana.fonseca@ufrgs.br
(Corresponding Author)

² Bachelor Student at Department of Geography - Universidade Federal do Rio Grande do Sul (UFRGS) – Brazil

³ Agronomist at Fundacao Maronna - Brazil

⁴ Professor at Centre of Rural Science - Universidade Federal de Santa Maria (UFSM) - Brazil

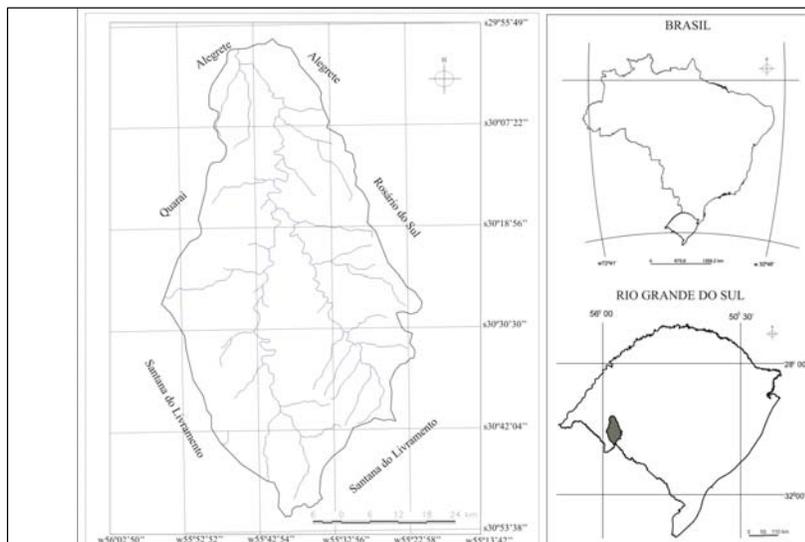


Figure 2.1 The location of study area.

2.4. Data sets used for the study

For this study two dataset are necessary, namely “*in situ*” measurements of the amount of aboveground biomass (kg/ha^{-1}) and satellite data recorded by the Vegetation Instrument onboard of SPOT 4-5.

2.4.1. Aboveground biomass data

The aboveground biomass dataset were collected in the field during a 12 month period (January to December 2002). The data was collected on a monthly basis on a plot using a methodology described by Fonseca et al. (2007). The “*in situ*” collected aboveground biomass values are provided for the purpose of the exercise. The plot where the aboveground biomass data was collected is situated at the following position: $30^{\circ}06'S$ and $55^{\circ}41'W$.

2.4.2. Satellite data

The NDVI data from the Vegetation instrument will be analyzed for the same months that “*in situ*” data of aboveground biomass are collected. Here NDVI images are used, the so-called VGT-S10 products, which are a ten-day Maximum Value Composite (MVC) synthesis for each pixel. The data can also be downloaded from the Vegetation website (<http://free.vgt.vito.be>). Here the images are available in ten predefined regions of interest. For this exercise it is necessary to select images from the South America region of interest. In order to match the field data and the satellite date it is necessary to choose the same ten-day MVC synthesis for each month that the field data were collected, e.g. when the field work was conducted on 3rd of April 2002 the NDVI image selected is for the first ten-day MVC synthesis of April 2002. In table 2.1 the selected period for each decade-month used in this study is presented.

Month	MVC decade selected	Month	MVC decade selected
Jan/2002	1 st to the 10 th days	Jul/2002	1 st to the 10 th days
Feb/2002	1 st to the 10 th days	Aug/2002	1 st to the 10 th days
Mar/2002	1 st to the 10 th days	Sep/2002	1 st to the 10 th days
Apr/2002	1 st to the 10 th days	Oct/2002	1 st to the 10 th days
May/2002	1 st to the 10 th days	Nov/2002	1 st to the 10 th days
Jun/2002	11 th to the 20 th days	Dec/2002	1 st to the 10 th days

Table 2.1 Dates selected for NDVI files used in this study

2.5. Methodology

The flowchart (figure 2.2) shows all the steps necessary in order to convert NDVI values in biomass values and to obtain an aboveground biomass map. First of all it is necessary to establish the relationship between the NDVI and aboveground biomass values collected in the field. This relationship can be expressed as an exponential equation using NDVI values as the independent variable. The next step is to calculate for each NDVI pixel the aboveground biomass values, using the equation established in the previous step.

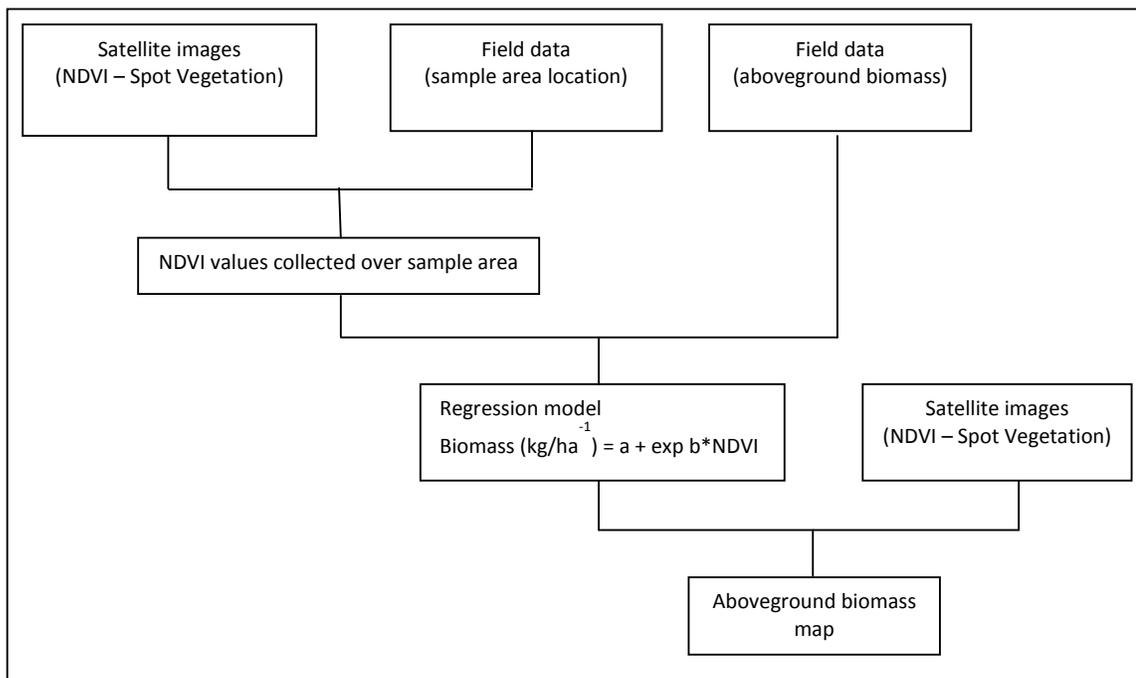


Figure 2.2 Flowchart of methodology adopted

2.6. Satellite image processing

2.6.1. Create the NDVI time series

The NDVI time series can be processed using the GEONETCast (GNC) Toolbox, available as plug in for ILWIS. In this toolbox it is possible to extract the files that contain the SPOT Vegetation NDVI maps of Latin America. The first step is to choose the date, according the format required by the toolbox. This step is repeated several times, for each of the files necessary for construction of the NDVI time series. In this study 12 NDVI images collected over the year 2002 were used (see table 2.1). After extraction of all files, 12 NDVI and Status maps are obtained. As example, extract a SPOT Vegetation NDVI of Latin America of the first decade of 2002 (note the date format: "20020101"), using the GNC-toolbox. Select from the ILWIS Operation Tree, "Geonetcast", "Toolbox", "SPOT VGT Products", "SPOT VGT Latin America", "NDVI". Specify the appropriate Date, here 20020101. Also select the appropriate input and output folders! The last one should be your active working directory! After extraction is completed display the map "ndvi20020101", using the "NDVI1" Representation. Add also the point map, called "insitu" to get an idea where the field observations have been collected. The results should resemble those of figure 2.3.

2.6.2. Create the "Sub map"

In order to calculate the operations only for the study area it is necessary to create a "Sub map". To create a sub map it is necessary to press with the right button over the "ndvi20020101" map and choose from the context sensitive menu the "Spatial Reference Operations => Sub Map". The details to select only the Environment Protect Area of Ibirapuitã are provided in the Figure 2.4 (left hand figure) and press "Show" to execute the operation.

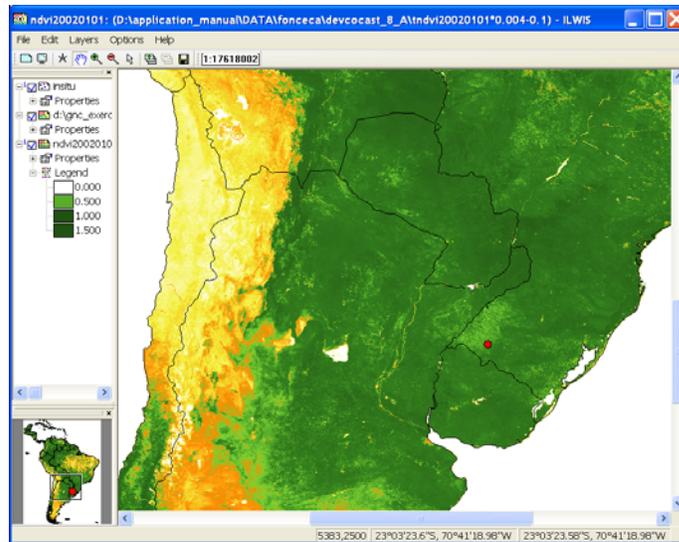


Figure 2.3 SPOT Vegetation NDVI, Latin America of 20020101

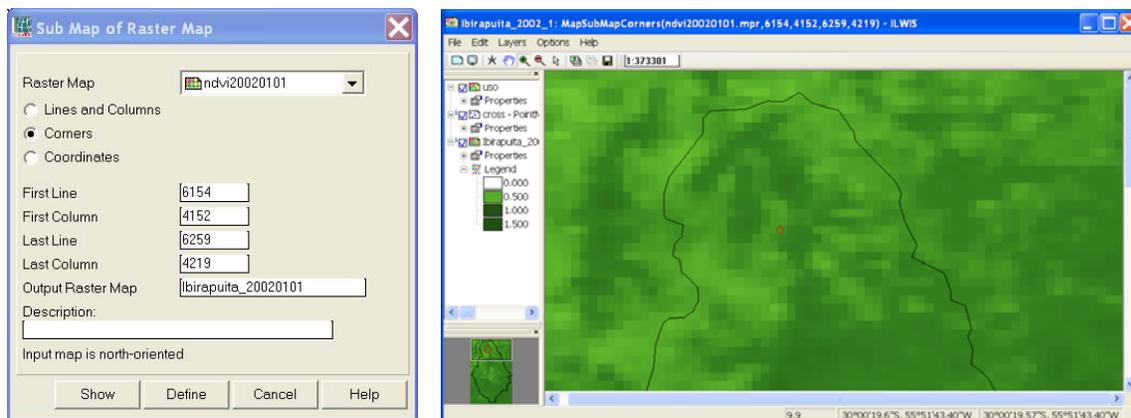


Figure 2.4 Options to create a Sub Map of the study area and resulting map obtained

To prepare the data for this exercise the above described import and subset routines have been used various times. In order to conduct operations and calculations using all 12 files at the same time it is necessary to create a “Map list”. Using the command “Create => Map list” available from “File menu”. All the 12 NDVI images used for this study have been selected to create this map list and sub maps have been created subsequently. In your active working directory you find a map list called “Ibirapuita_2002” with the NDVI maps of the study area only. Note that the sequential number at the end of the file name is indicating the month, e.g. the Ibirapuita_2002_3 is the NDVI sub map corresponding to the March 2002 NDVI image. All the NDVI time series maps over the Environment Protect Area of Ibirapuitã for the year 2002 are presented in Appendix 1.

2.7. Visualizing the study area over the satellite image

Open the map list “Ibirapuita_2002” and double click the “Ibirapuita_2002_1” map layer and display this map using a Representation called: “NDVI1”. In order to visualize the study area a vector file called “uso” can be draw over the Ibirapuita_2002_1. This operation can be performed by dragging this file over the window where the Ibirapuita_2002_1 image is shown. Unselect as Polygon Map Display Options “Info” and select the option “Boundaries Only” and press “OK”. Result of this operation should be identical to the right hand portion of figure 2.4. Note that the vector file called “uso” contains all the national protected areas of Brazil (MMA, 2011), but after

creating the sub map only the Environment Protect Area of Ibirapuitã region is visualized. You can display it over the NDVI map of Latin America.

2.8. Extract the NDVI values over the sample area

To extract the NDVI values over the sample area it is necessary to know the geographic coordinates that allow locating this area on the NDVI map. For this study the sample area where the field data was collected is located at the position: **30°06'S** and **55°41'W**. If not displayed already, once more open the “Ibirapuita_2002_1” map layer from the map list “Ibirapuita_2002”. Now add the point file called “insitu”, showing the location of the field measurement site.

By creating a graph over the “Ibirapuita_2002” map list is possible collect all the NDVI values over the sample area at the same time. The command for this operation is located under “Operations-List” menu from the main ILWIS window (“Operations menu => Statistics => MapList => MapList Graph”). The mouse should be clicked over the sample area (the sample area is located in line 19 and column 29). The result for this operation is visualized in figure 2.5.

To export the NDVI values to a spreadsheet, in order to establish the relationship between NDVI and the measured aboveground biomass values, it is necessary to click the button “Clipboard Copy” and then paste these values in spreadsheet programme or into an ILWIS table.

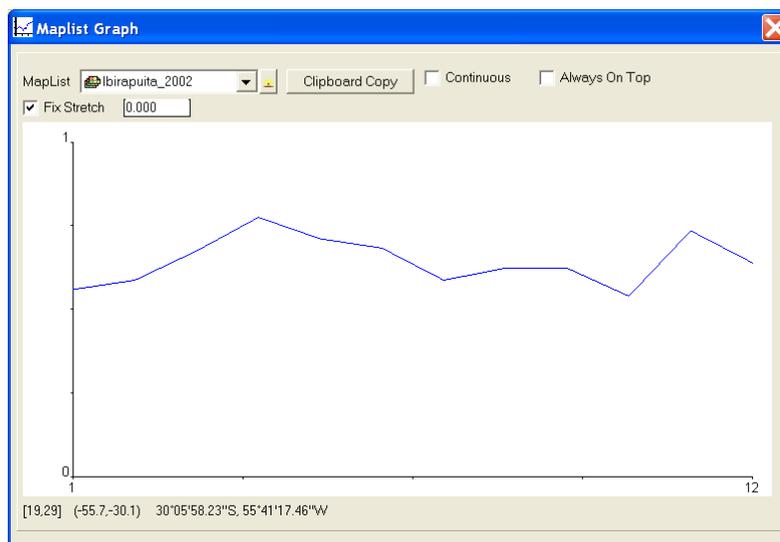


Figure 2.5 Graph of NDVI values collected over the sample area using “Ibirapuita_2002” map list

2.9. Establishing the relationship between NDVI and aboveground biomass values

In order to establish the relationship between NDVI and aboveground biomass values a table has been prepared, called “insitu_measurement”, containing four columns, map_name, month, NDV and Measured respectively (see also figure 2.6). Double click the table to open it and to check if there is a relationship between the measured biomass and obtained NDVI, select from the menu “Columns”, “Statistics” and as Function, select “Correlation” (see also figure 2.6). The two columns to be selected are “Measured” and “NDVI”. Is important to note that a low correlation coefficient is obtained ($R=0.517$). For this kind of vegetation (natural grasslands) one does not expected high correlations (Fonseca et al., 2007) because these are non-homogeneous areas, since the Pampa biome support very high levels of biodiversity (Overbeck et al., 2007). This behaviour is also observed for other non-homogeneous areas when the NDVI is used to estimate aboveground biomass (Wessels et al.; 2006).

Having observed that there is a positive correlation, the next step is to express the relationship in the form of an equation to transform the NDVI into above ground biomass. According to Gamon et al. (1995) the relationship between these two variables is exponential. First select from the Table menu the graphics icon , and from the “Create Graph” menu, select as X-axis “NDVI” and as Y-axis “Measured”. Press “OK” to display the graph. You

can modify the Graph properties by selecting the items in the left hand graph legend. E.g. unselect “Legend” and for the item ”NDVI*Measured”, by double clicking with the mouse on the item name, use as “Color” “Red”. Also change the Min-Max settings of the graph axis (X: from 0 to 1, interval of 0.2 and Y: from 0 to 1400, interval 200). Proceed from the active Graph window, select from the menu “Edit”, “Add Graph” and select “Least Square Fit”. Select as X-column “NDVI” and as Y-column “Measured”, use as Function “Exponential” and press “OK”. From the Graph legend, select the item: “NDVI*Measured-Exponential”, change the Color to “Black” and set the Line Width to “0.2”. Also note the regression formula, which is given on the lower left hand of this menu. Press “OK”. Your results should resemble those of figure 2.6.

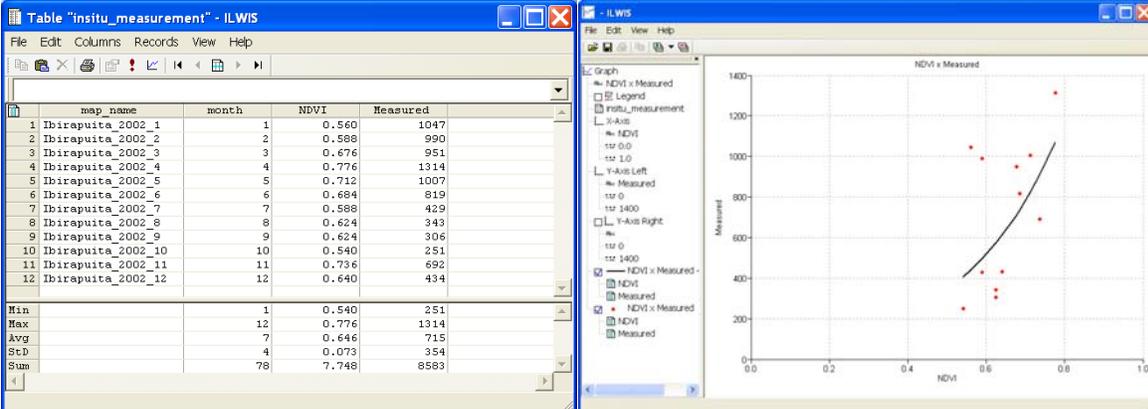


Figure 2.6 Table with insitu measurements and scatter plot showing relationship

Close the graph window, eventually save the graph (or select from the graph menu the option File and Save). Activate the table “insitu_measurements” again and from the table Menu select “Column”, “Least Squares” and for the X-column select “NDVI” and the Y-column “Measured”, specify as output column “Calculated”. Use as function “Exponential” and press OK to execute the operation. In the column properties window select the option “Additional Info”, here the function is given that needs to be used later to transform the NDVI maps to aboveground biomass maps. The derived function should resemble the one given in figure 2.7, leave the other options as default and press OK. A new column, called “Calculated” is now added to the table. Check also the results obtained in the table.

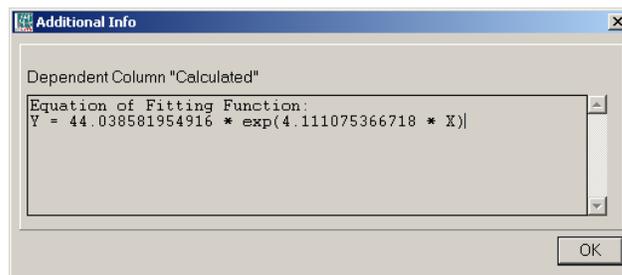


Figure 2.7 Exponential function derived

2.10. Generate the aboveground biomass map

2.10.1. Calculate the aboveground biomass

To generate a set of aboveground biomass maps, the equation that expresses the relationship between this variable and the NDVI needs to be applied to each pixel for the “Ibirapuita_2002” Map List. To perform this operation select the option “MapList calculation” available from the “Operations => Raster Operations” menu. The symbol “@1” in the equation represents the “Ibirapuita_2002” Map List. The results are express in a dataset of new output

maps, called “Above_biomass_2002” Map List. The options to conduct this operation are shown in figure 2.8. Press “Show” to execute the operation.

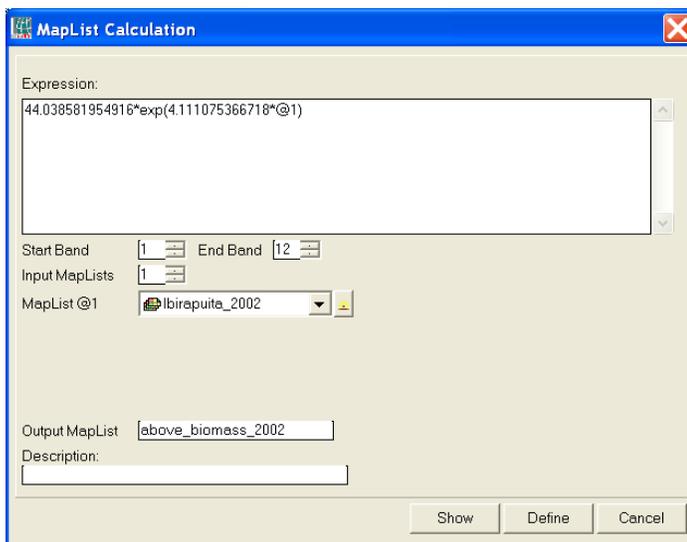


Figure 2.8 Options to generate the set of aboveground biomass map

2.10.2. Visualizing the results

All the aboveground biomass maps calculated for each month in 2002 can be visualized like a slide show, or individually like a map. Since the range of “Aboveground_biomass_2002” Map List value is between 260 kg/ha and 1070 kg/ha, is necessary build a new colour representation that allows one to visualize the aboveground biomass variations. To do this select “New Representation” available from the “Operation-List” menu. For visualizing the Pampa aboveground biomass the colour representation made for this exercise is called “biomass_pampa”, which is presented in figure 2.9.

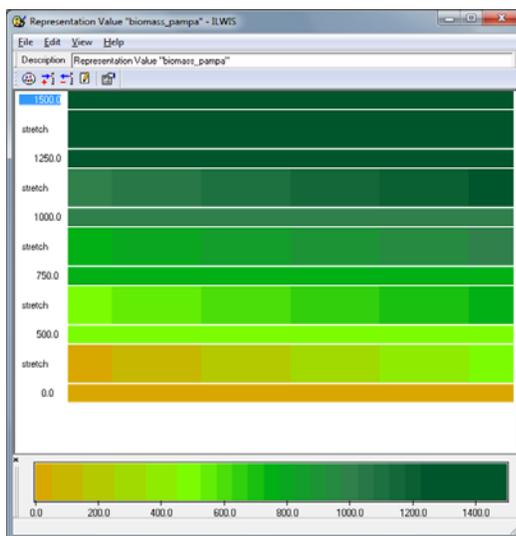


Figure 2.9 The colour representation for the Pampa aboveground biomass

An example of aboveground biomass map for January 2002 is presented in figure 2.10. The entire set of aboveground biomass maps over the Environment Protect Area of Ibirapuitã for the year 2002 is given in Appendix 2. Display an aboveground biomass map calculated using the “biomass_pampa” Representation. Browse with the mouse cursor over the map, keep the left mouse button pressed to see the values.

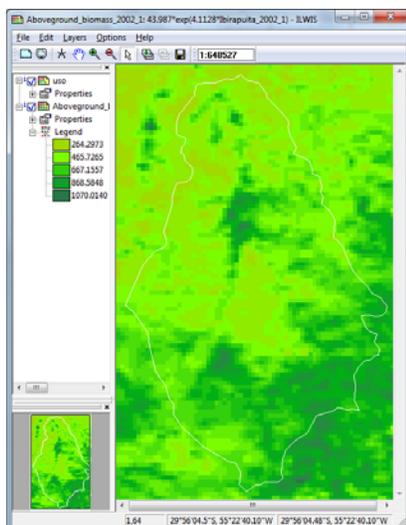


Figure 2.10 Aboveground biomass map for January 2002

2.11. Verification of the results

The calculated aboveground biomass can be compared with the “*in situ*” aboveground biomass in the table. Since the vegetation of the Pampa biome is non-homogeneous, the distribution of the points does not fit as straight line, having a 45 degree angle. This is expected for this kind of vegetation. Consult once more figure 2.6 to see the distribution of the points and the relationship used.

Open the table “insitu_measurements” again and type in the Command line the following expression:

Residual:=Measured-Calculated

Press enter and leave all options default in the newly opened Column Properties dialog box and press “OK”. A new column is obtained, called “Residual”. Make a new graph and use as X-axis the column “Month” and as Y-Axis the column “Residual”. Display the graph and from the graph legend uncheck the item “Legend”. Your results should resemble those of figure 2.11. As can be observed from this figure the residual analysis shows clearly a time dependency. The high residuals are associated with the beginning of the year. During the start of 2002 the El Nino phenomena resulted in above average rainfall in this region (CPTEC, 2011) and this may have affected the quality of satellite information.

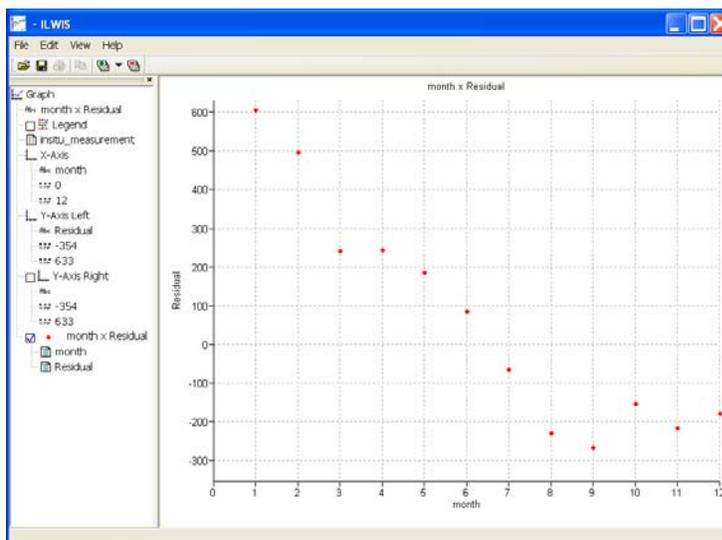


Figure 2.11 Residual analysis

2.12. Conclusions

The data obtained from the Spot-Vegetation instrument can be used to derive estimates of aboveground biomass. The satellite observations can be converted into NDVI maps and this in turn, using an equation - mathematic model, can be converted into biomass. This kind of information is useful to monitor the Pampa biome and it is necessary in order to preserve the natural vegetation in association with economic exploration done by the traditional people.

Model calibration for each kind of vegetation cover, also considering the local weather, will allow one to make more realistic models, which are more useful at local conditions and at regional scale when it is compared with global scale models. To develop a global model to estimate the aboveground biomass some generalizations are made, like for the Brazilian Cerrado and the African Savannas. These generalizations are necessary to build a global scale model but it can be an obstacle to apply the results for the purpose of local planning and monitoring.

The results of the analysis presented here can be improved with a larger dataset of “*in situ*” measurements for different plots and collected over a longer period of time for analysis.

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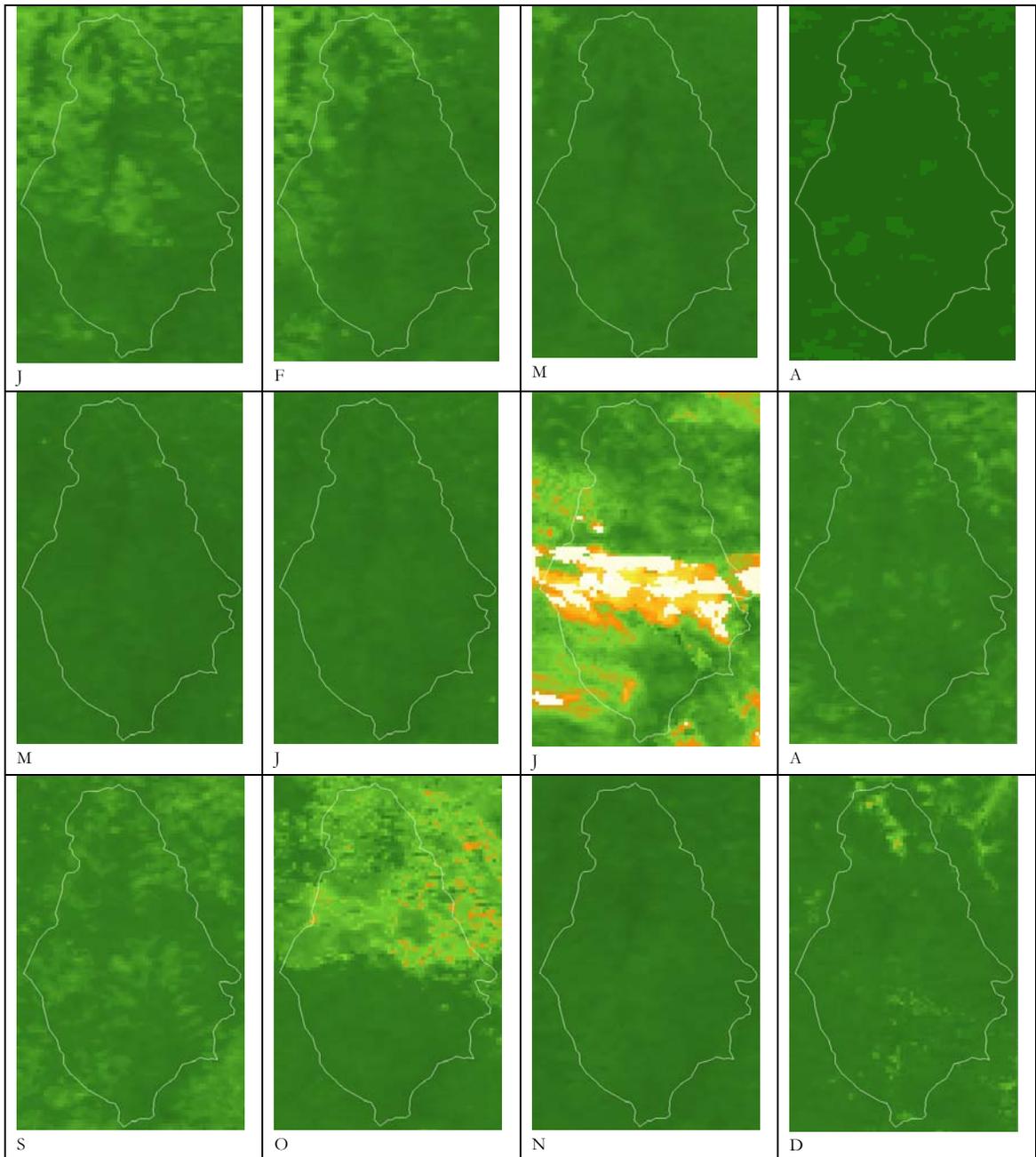
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Appendix 1 NDVI time series over the EPA of Ibirapuitã for the year 2002



Appendix 2 Aboveground biomass map time series over the EPA of Ibirapuitã for the year 2002.

