# BIOMASS ESTIMATION OF FOREST AND SAVANNA TRANSITION VEGETATION ZONE BY JERS-1 AND SIR-C BACKSCATTER DATA

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Working Group VII/7

**KEY WORDS:** Tropical Rain Forest, Savanna, Biomass, Inventory, Microwave Data, Amazonia.

## ABSTRACT

The inventory and monitoring of transition zones between tropical rain forest and savanna formations in Brazilian Amazonia are an essential step for an accurate analysis of global change and biodiversity studies. The objective of this study is to analyse the empirical behaviour of the biomass from forest/savanna transition zones referring to backscatter signals of JERS-1 and SIR-C images. The complementary objective is to discriminate among vegetation types and to map the distribution of its' biomass using both sensors. The area under study is located in Mato Grosso State (Brazil), at the border with Rondônia State, representing a contact zone where typical botanical species of both formations are intermingled. The SIR-C and JERS-1 images were georeferenced, based on a bilinear method and the pixel resampling was made to get a spatial resolution of 25 m. Comments were made related to the physiognomic-structural details of vegetation types and spatial distribution of backscatter at primary forest, tall woodland, savanna woodland, tree and/or shrub savanna. The relationship between backscatter and biomass values is based on the analysis of their adequacy into a regression model where these variables were adjusted. Using the logarithm regression model, the results show that SIR-C data present the highest determination coefficient, specially the $L_{HV}$ band ($r^2$ = 0.8275) when compared to the $L_{HH}$ band of JERS-1 data ($r^2$ = 0.6791). Considering the same polarization ($L_{HH}$), the SIR-C data ($r^2$ = 0.7406) is also better than JERS-1 data. The methodological approach used in this study can be very useful to determine the dynamics of the biomass, taking into account the settlement of humans that occurred in the contact zones of forest and savanna in Amazonia.

## 1 INTRODUCTION

INPE, the Brazilian Institute for Space Research, which is related to the Ministry of Science and Technology (MCT), has got the mission to estimate the yearly gross deforestation rate, contributing to the Ministry of Environment (MMA), on the deforestation control. Considering a yearly deforestation rate of 17,000 $km^2$ /year, and that approximately 75% of this amount is located at the so-called "Deforestation Arch", it is evident that it a higher attention is necessary to control those forest/savanna transition areas, where there is the highest concentration of human activities. Besides the clear-cut of forest areas, in order to insert them in the agricultural or cattle raising production system of the country, the environmental degradation is also due to forest fires and to timber logging activities. All these actions contribute to the dynamics of biomass in this region.

Within this context, the objective of this study is to analyse the behaviour of the biomass at forest/savanna contact zones, considering backscatter signals of JERS-1 and SIR-C images. Statistical tests at regression models were used to improve the understanding of the empirical relation between field data (biomass) and those derived from radar images. The complementary objective of this study is to delineate the vegetation types and to map the distribution of its' biomass using data from both sensor systems. The concept of this study is inserted in the Scientific Cooperation Program Brazil-Germany (within the project "Multisensoral Remote Sensing Studies for Rainforest and Landuse Monitoring"), where research groups of INPE and DLR are evaluating different sensor products and testing new image processing techniques, aiming to use them for the inventory and environmental monitoring in tropical areas.

## 2 AREA UNDER STUDY

The area under study is located at the municipality of Comodoro (geographical coordinates W 59° 37' - 60° 11' and S 13° 02' – S 13° 48'), at the State border Mato Grosso/Rondonia, where an intermingling of species from both formations occurs (Figure 1).

The climate of this region, according to Köppen, is of Aw type, presenting a tropical rain season with a well-defined dry season, and an average annual rainfall of 1,700 mm.

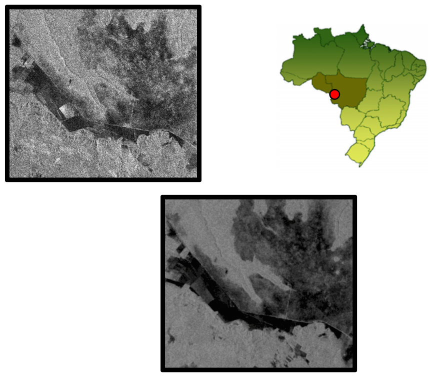

Figure 1. Section of the area under study: JERS-1 and SIR-C scenes

## 3 DATA ACQUISITION AND METHODS

The JERS-1 image of path/row 410/323 of May 22nd '96 was obtained in the frame of NASDA's Global Rain Forest Monitoring Project (GRFM), through an agreement with INPE, to perform this study. The references of the digital SIR-C image acquired by DLR are: DT 14.71, GMT at image center 07:52:59.8 (1994/274). A TM-Landsat scene at bands 3 (red), 4 (near infrared) and 5 (middle infrared), referring to path/row 229/69 from July 9th '97, in digital format, was also used as a complementary source of information related to the landscape characterization and to support the extraction of the backscattering values on the selected sampling areas at both radar images. Both JERS-1 and SIR-C scenes were processed using respectively the ENVI and ERDAS package. Figure 2 shows the flow diagram of the methodology used, whose detailed description can be found in Xaud (1998), Santos et al. (1998) and Krämer (1999).

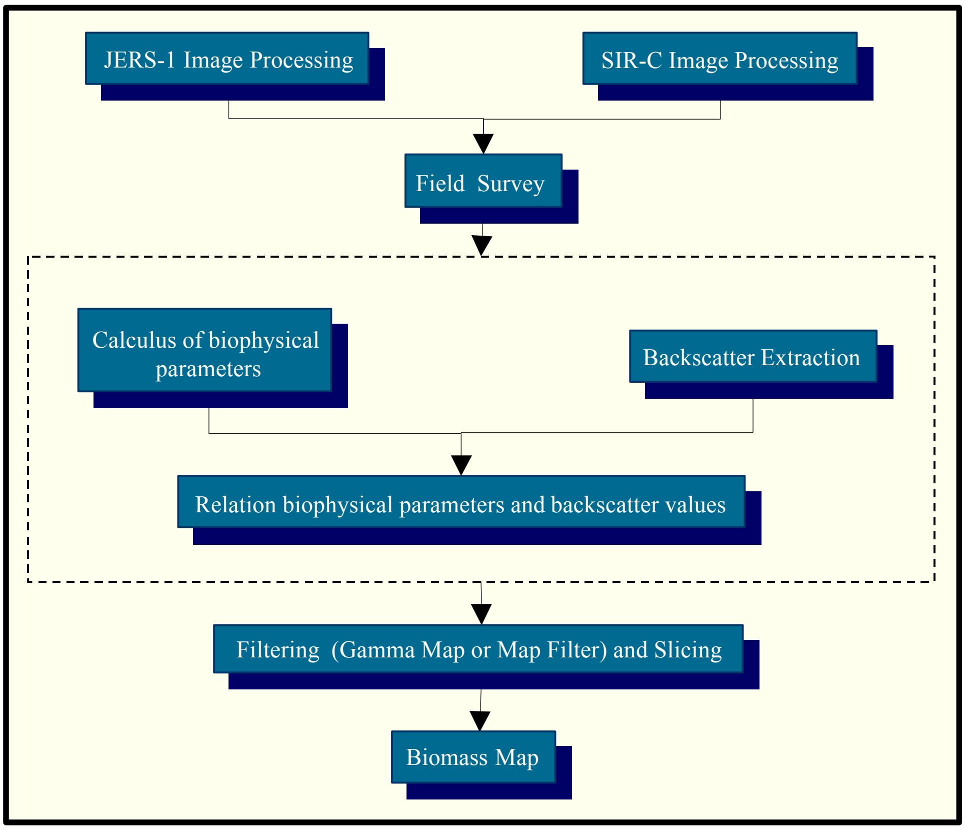


Figure 2. Methodological steps of JERS-1 and SIR-C data processing.

In order to understand the physiognomic-structural characteristics of vegetation cover, two procedures of data collection were used during the field survey. In those areas covered by savanna, the biomass estimation was made by cutting and weighting the woody and foliar material of different strata, considering size plots of 200 or 500 $m^2$ each (11 samples) according to the physiognomy of the savanna; all individuals of bush and/or arboreal features were identified botanically. As for the herbaceous strata, sampling to collect biomass and data on the percentage of soil coverage were also performed in at least 5 sections with $1m^2$ size for each sample area. In those areas covered by forest formation (6 samples), including the transition areas, the following measurements were made: DBH, height, percentage of crown cover as well as the botanical identification of individuals with DBH > 5 cm for areas of secondary succession and DBH > 10 cm for areas of primary forest, at sample areas of 1,000 $m^2$ and 2,500 $m^2$ respectively. The estimation of biomass values was modeled by dendrometric parameters into allometric equations. At the biomass inventory a larger amount of samples was effectively obtained during the field survey, totaling 37 samples. The precise location of each field plot in the respective radar database was identified using the GPS system.

During the SAR data processing, a Gamma Filter (window size 5x5) was applied to the JERS-1 image, and a MAP Filter (window size 3x3) was applied to the SIR-C image, to reduce the speckle noise of the image. The georeferencing of both SIR-C and JERS-1 images (including also the TM/Landsat image) was based on a bilinear method, with pixel resampling to a spatial resolution of 25 m. It was considered adequate to extract the digital number (DN) values of each radar image from previously selected sample areas inventoried in the field survey. The DN values were converted to dB values by appropriated equations (Rosenqvist, 1997; Krämer, 1999) considering the offset calibration factor of each sensor. The backscatter coefficient of the vegetation cover is a function of sensor parameters (wavelength, incidence angle and polarization) as well as of the geometric and dielectric characteristics of the vegetation type, according to the seasonal effects acting over this area.

The empirical relation between backscatter (y) and biomass (x) values is based on the statistical analysis of their adequacy to a regression model, where these variables were adjusted. Diagrams showing the physiognomic-structural details of the vegetation types and the spatial distribution of the backscatter at primary forest , tall woodland, savanna woodland, tree and/or shrub savanna were made. After the definition of the appropriate equation for each sensor type, images were sliced in dB values found for each pixel, and the result was the definition of biomass intervals and its' spatial distribution.

## 4 RESULTS

In a brief description, the forest typology section of Comodoro is included in the semi-deciduous category, where the climatic conditions are conceptually defined as seasonal (4 to 6 dry months or 3 months below $15^oC$), with xerophytic/hydrophytic physiology, including alic and distrophic soils (FIBGE, 1992). Within the common arboreal species identified, there are those of families Lauraceae, Burseraceae, Chrysobalanaceae, Euphorbiaceae, Anonaceae, Guttiferae and Sapotaceae, where one could find 570 individuals per hectare (DBH > 10 cm), with an average height of 16 m. The estimated forest biomass of the sections inventoried is of 205.81 ± 54.4 ton/ha (dry weight). As for the savanna formation, there is a variability on the content of estimated biomass, being generally 58.11 ton/ha (dry weight) for tall woodland (a forest-like physiognomy of savanna), 12.29 ton/ha for savanna woodland (cerrado *strictu sensu*) and 7.13 ton/ha for tree and/or shrub savanna (facies where grass stratum predominates, with sparse arboreal and/or bush strata). It is important to point out that the acquisition period of images, as well as of the time of field data collection should be concomitant, due to the strong effect of changes during the yearly seasons of this type of savanna, specially those where the grass stratum dominates.

Based on the ground truth database related to the typical structure of forest and savanna formations, it is possible to show the empirical behavior of the backscatter derived from both sensors against biomass values (Figure 3). Using the logarithm regression model, the analysis shows that $L_{HH}$ band of SIR-C data presents a little higher determination coefficient ($r^2$ = 0.7406) when compared to JERS-1 data ($r^2$ = 0.6791). Considering the $L_{HV}$ band, the SIR-C data (y = 3,3731 Ln (x) - 29,59 , with $r^2$=0.8275) is already more significant, according to a separated analysis which was also performed. It is well known that cross polarization allows a better comprehension on the signal interaction with the complex structure of trunks, branches, twigs of distinct forest features.

Taking into account an isolated analysis of JERS-1 data for the savanna, one can perceive that the largest backscatter values represent the class "tall woodland" (-6.9 dB), followed by -9.1 dB for "savanna woodland" and -10.5 dB for a "tree and/or shrub savanna". All these savanna physiognomies occupy the space of attributes mentioned above, with values of ± 0.5 dB around these average values. In the specific case of SIR-C ($L_{HH}$) the backscatter values are -9.1 dB, -12.0 dB, and -15.8 dB for the same topologic sequence found, presenting only a variability of ± 1.0 dB around the average values. This can demonstrate a higher sensitivity of the SIR-C, compared to JERS-1 to discriminate small variations of inherent characteristics of each one of these classes. The same can be affirmed for the class "semi-deciduous tropical forest", with average backscatter values of -7.2 dB and -8.1 dB for JERS-1 and SIR-C ($L_{HH}$ band) respectively.

Luckman et al. (1997) comment that L band systems may be used to derive information about biomass density up to a limit of approximately 60 ton/ha. Furthermore one can observe that this regression function shows a high sensitivity of the model for values below 80 ton/ha, that corresponds to -7.73 dB (JERS-1 image) and -9.26 dB (SIR-C image), which is the space of attributes where different types of savanna, secondary forest or degraded forests are normally located.

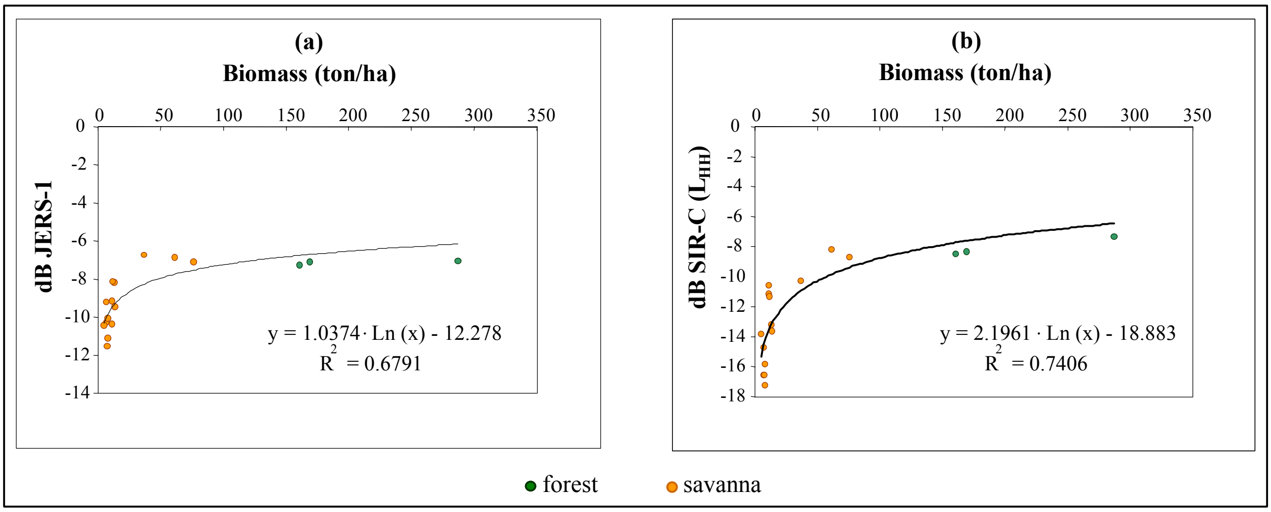


Figure 3. Correlation between biomass and JERS-1 (a) or SIR-C/$L_{HH}$ band (b) backscatter values for forest and savanna formations.

After a synoptic analysis of Fig. 3, one can perceive that SIR-C data presents a higher space on y axis, in order to reach the turning point of the curve, which reflects the signal saturation due to the biomass increase.

Based on backscatter values, a slicing of both radar datasets was made. The mapping of biomass with class intervals is presented at Figure 4. The analysis of statistical attributes of radar images (i.e. grey level frequency) shows that the SIR-C products have grey level amplitudes that allow a higher performance of thematic class delineation. The result is a textural and homogeneous image segmentation, compared to the JERS-1 image which is less homogeneous. An intensive field survey with 137 georeferenced observations of different vegetation features (Krämer, 1999), support the significance of the biomass distribution map.

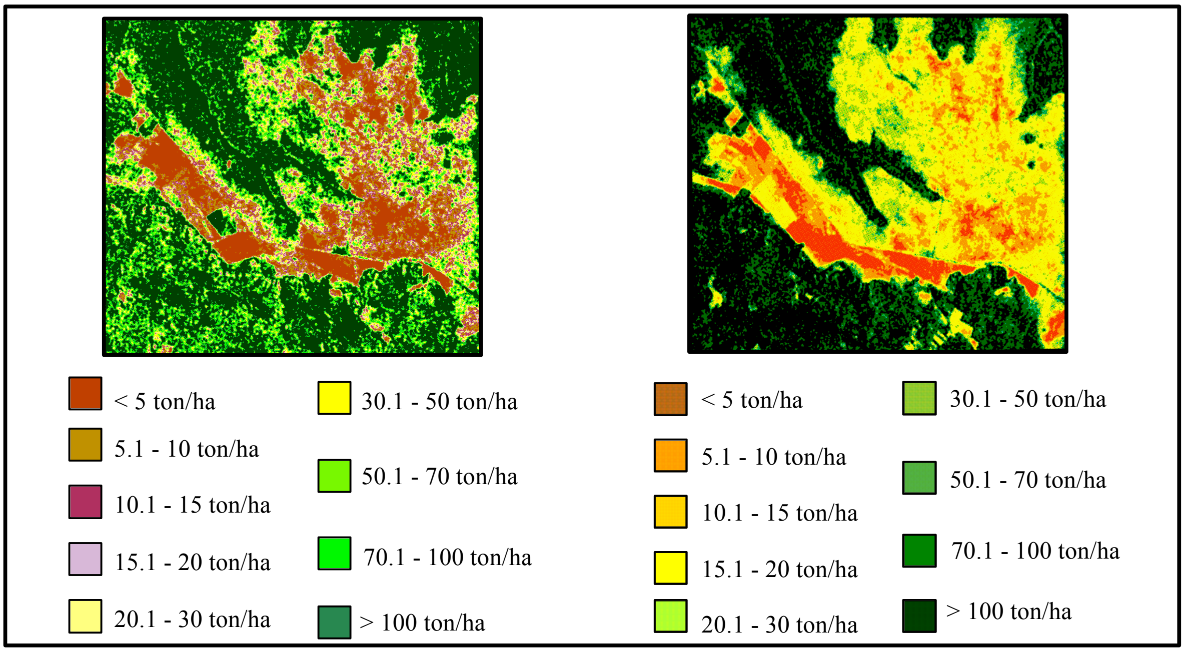


Fig. 4 - Biomass distribution map by class intervals, for a section of test-site Comodoro (MT) in forest/savanna contact zones. JERS-1 (a) and SIR-C (b).

The evaluation of biomass in tropical regions is an important input variable in the regional and global change models. The use of JERS-1 and SIR-C datasets presents limits to the stratification of biomass, specially for those areas covered by “mature tropical forest”. More detailed biomass intervals (> 100 ton/ha) cannot be defined due to the saturation of the radar signal in such forest environments with structural complexity.

## 5 CONCLUSIONS

The methodological approach presented, based on JERS-1 and SIR-C data has been very useful to determine the land cover changes due to human settlement that has occurred in Amazonia and more recently in the contact zone between forest and savanna formations. It is an important challenge to use these images to evaluate and to stratify the vegetation cover found in this region, in order to demonstrate the capacity of the sensor, and also to better understand the techniques for the extraction of information. The final goal of all this effort is to improve monitoring of the biomass dynamics by a multi-sensor approach, as well as the landscape changes, due to human action in this very large brazilian tropical environment.

## ACKNOWLEDGMENTS

This project was conduced under the Bilateral Cooperation in Scientific Research and Technological Development (WTZ) between Germany and Brazil. The authors acknowledge: CNPq (process 300677/91, 381246/97-3, 380597/99-3) and logistic support by INCRA/Vilhena (RO).

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