# LANDSCAPE CHANGE DETECTION USING FUZZY DECISION MAKING AND GRFM JERS-1 DATA CLASSIFICATION ON WETLANDS IN THE CENTRAL AMAZONIA, BRAZIL

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## 1. ABSTRACT

This abstract presents an approach for oil spill environmental sensitivity evaluation in landscape modifications within half hydrological cycle over the wetland in the Western Amazonia, Brazil, using JERS-1 SAR seasonal classified images and a fuzzy logic method. A pair of multitseasonal set of JERS-1 images (1995 - low water season and 1996 - high water season) obtained in The Global Rain Forest Mapping (GRFM) Project in Western Amazonia, Brazil, presented the identification of large extension of wetlands in a region characterized by the high sensitivity to oil spill [1][2]. The oil spill hazard information derived from JERS-1 SAR data is straightforward to interpret and constitutes a representation of the original Environmental Sensitivity Index (ESI) product conceived by PETROBRAS [3].

The GRFM data set is organized in semi-continental synthetic aperture radar image mosaics with a 100 m nominal resolution. The global, continuous and weather-independent coverage provided by the SAR system onboard the JERS-1 satellite enable end users to monitor rapidly changing conditions in cloud-covered, rain forest regions. Potential applications for environmental protection in Amazonia include the understanding and the management of flood hazards.

The basis for the definition of a sensitivity index to oil spills in Western Amazonia is the relationship between physical and biological characteristics of the fluvial environment. These habitats were used to rank the overall sensitivity of fluvial areas in Western Amazonia to spilled oil as part of the Environmental Sensitivity Index (ESI) [3]. The most sensitive fluvial environment for oil spills was given an index of 10b, the least sensitive, an index value of 1. Visual inspection of the high flood GRFM JERS-1 SAR mosaic indicates a widespread occurrence of double bounce reflections of flooded forests that is characterized by a strong radar return. Such a backscatter mechanism occurs when the JERS-1 SAR beam reflects off both the tree trunks and the smooth reflective surface of the water (Figures 1A and 1B). JERS-1 SAR images therefore demonstrate that the study area was extensively covered by flooded forests in May 1996, which is the most oil-sensitive habitat (ESI Ranking = 10b).

Because of its ability to deal with imprecise, uncertain or ambiguous data or relationships among data sets, fuzzy logic methods has been applied in a wide range of ecological and environmental issues, including environmental impact evaluation.

The objective of this paper is to present an approach to extract membership values of environment sensitivity in regional scale directly from dual season GRFM SAR image mosaics using the Unsupervised Semivariogram Textural Classifier (USTC) [3] and the membership function of Fuzzy c-Means (FCM) algorithm.

The USTC has been applied to discriminate and map cover types associated with the following scattering mechanisms [1]: (1) specular reflection mostly associated with open water, but also pasture, clear cuts and airstrips; (2) double bounce mostly flooded forest but also with urban areas; (3) diffuse backscatter associated with upland forest; (4) and predominantly forward scattering associated with flooded vegetation with low to intermediate values of biomass above water (Figures 1C and 1D). Flooded forest and flooded vegetation correspond to the most oil-sensitive habitat.

The combination of the USTC classification of low and high seasons enabled sixteen different classes of change detection and consequently, the identification of the LHH backscatter coefficient center value of each class. The following procedure consisted on calculating the membership values of pixel combination (low and high water backscatter images) to each center using the fuzzy membership function defined by the FCM algorithm. The results consist on sixteen different membership values maps predicting the likely extent of the combination of LHH backscatter coefficients of low and high flood pixels for each center class. Each fuzzy membership map was computed and implemented within a geographic information system (GIS) to formalize expert knowledge about the temporal changes occurring within the study area. The membership results successfully identified different ambiguity regions within each change detection class and likely changes between different landscapes identified in USTC classification.

For example, the class assigned as upland forest in low flood season presents an average backscatter coefficient of -7.11 dB and -5.54 dB for flooded forest in high flood season. In Figure 1E, this class is represented by red color and the flooding extension attains a distance of 43 km which presents the same ESI rank within this entire region. The application of membership fuzzy approach showed to be able the identification and ranking of different sensitive environments take into account the backscatter coefficient distance from the center class described before. Consequently, this entire region acquires different values that represent the membership degree to belong to the flooded region (Figure 1F).

The application of the proposed fuzzy decision making approach improves the knowledge–based system and thematic classification procedures providing membership degrees in regions characterized by the same oil spill environment sensitivity. Also the fuzzy set theory revealed to be a promising method to manipulate sensitivity environments using LHH SAR image dataset. The information provided by this method is relevant for example, in contingency plans to guide the protection of large regions with subtle sensitivity differences to oil spills.

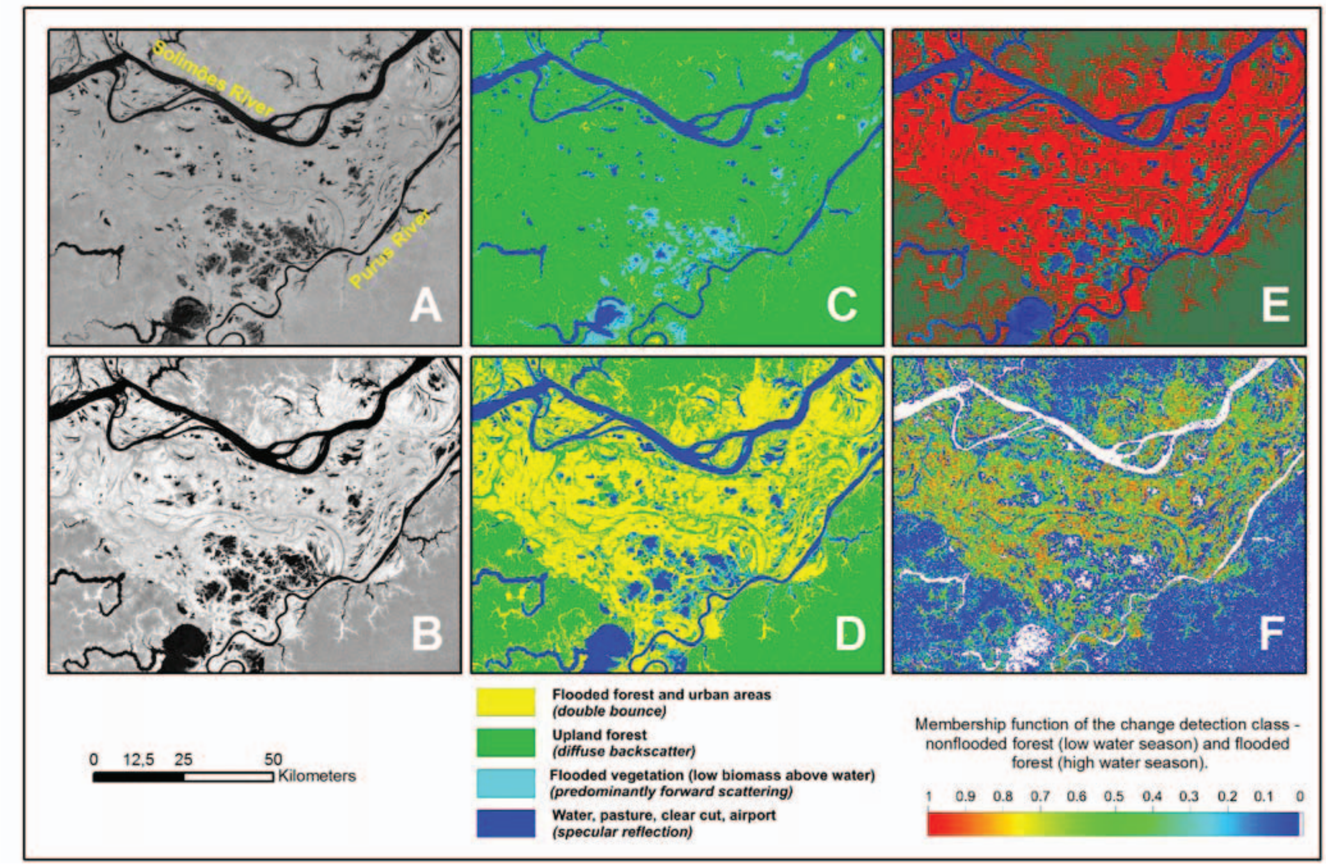


Figure 1. (A). Low Water GRFM JERS-1 SAR Mosaic (October 1995) at the wetland region of Solimões and Purus rivers; (B) High water mosaic (May 1996); (C). USTC Classification of low water GRFM JERS-1 SAR mosaic (October 1995); (D) USTC Classification of high water mosaic (May 1996); (E) Change detection map showing in red only the class of nonflooded forest in low water season and flooded forest in high water season; (F) Membership function map.

## 2. REFERENCES

[1] C.H. Beisl; F.P. Miranda; A.G. Evsukoff; and E.C. Pedroso. "Assessment of environmental sensitivity index of flooding areas in Western Amazonia using fuzzy logic in the dual season GRFM JERS-1 SAR image mosaics". In: *International Geoscience and Remote Sensing Symposium*, 2003, IEEE Toulouse., 2003

[2] L.L. Hess, J.M. Melack, E.M.L.M Novo, C.C.F. Barbosa and M. Gastil, "Dual-season mapping of wetland inundadtion and vegetation for the Central Amazon Basin," *Remote Sensing of Environmental*, Elsevier, (87), pp. 404-428, 2003.

[3] S.I. Araújo, G.H. Silva, and D. Muehe. 2002, Adaptação do Índice de Sensibilidade Ambiental a Derramamento de Óleo da NOAA às Feições Fluviais Amazônicas, PETROBRAS-CENPES Internal Report, Unpublished