# APPLICATION OF REMOTE SENSING IN STUDIES OF WATER QUALITY IN THE AMAZON REGION: A GENERAL VIEW.

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ABSTRACT

This paper deals with some basic considerations on the use of remote sensing techniques related to the limnological/water quality surveys in the Amazon Region, obtained from the literature. The main conclusions are: (1) the importance to use these modern techniques for detect problems before construction of new projects, that in some way, use water resources in the Amazon Region; (2) remote sensing focusing the water quality have to be strongly considered in Brazil's space program planning, to provide data for the correct water basin management.

Key words: Water quality, remote sensing, Amazon Region.

## 1. INTRODUCTION

Tropical forests are one of Earth's most valuable resources. From an ecological perspective, they play a major role in the hydrological cycle and in recycling atmospheric carbon dioxide. They stabilize soil and prevent excess runoff of silt and dissolved substances into streams. Their effects on climate through energy and water exchange with the atmosphere are not well understood but are expected to be very significant. Much of the Earth's species diversity is represented by the plants and animals which make up tropical forest biomes.

With 357 million hectares of forests, Brazil has probably made more extensive use of remote sensing than any other tropical country. In the early 1970s the Brazilian Government obtained the first estimates of the forest area in Amazonia from a special commissional comprehensive SLAR survey. SLAR, however, is too expensive for regular monitoring. Thus, in 1979 Brazil established a National Remote Sensing Programm to monitor the country's forest resources using satellite technology. The Program monitors the annual rate of deforestaion throughout Brazil and particulary in the Amazon Region, where change is most rapid.

The geographical location of the Amazon forest allows a near equatorial orbit which makes feasible to obtain new data with the convergence intertropical zone dynamics phenomena. The use of single or a small number of mission related equipments permits to choose a spacecraft platform for the mission needed thus optimizing cost and perfomance.

The monitoring of the natural resources and of the environment of the Amazon Region is a fundamental requirement for a rational exploration, what implies the use of remote sensing techniques. The Remote Sensing of the Amazon Region must provide information leading to the understanding of the Amazon as a system with a series of processes: hydrological, geographical, climatic, man activities, biological cycles, biogeochemical cycles, forest fires, soil wastes and water quality. The monitoring of these processes involves a large number of requirements which can only be fulfilled by numerous independent instruments and mission characteristics.

This paper presents an overview on the water quality monitoring in the Amazon Region and its relationship with the remote sensing studies, as a complementary tool to detect the spatial and temporal trends in the quality of the water under different anthropic pressures. It is very important to emphasize the use of remote sensing techniques before the decision for construction of new projects in the Amazon Region, as a fundamental tool to provide detailed informations to the Environmental Impact Assessment Reports.

## 2. RIVERS AND RESERVOIRS IN THE AMAZON REGION

To understand the processes that occur in major river basis such as the Amazon, is important not only locally but also when coupled with general circulation models to predict changes in global scale.
Outflow from the drainage system carries nutrient and sediment loads which are modified by the vegetation cover. In addition, chacracteristics of the soil and hydrological and biogeochemical transformations are expected to change with change in land use and with the construction of dams on major tributaries.

An important issue is to determine the appropriate time and spatial scales to integrate small basins studies with large

basin and global studies possible only with the integrated use remote sensing field measurements, and modelling techniques.

Amazonian waters were classified into three types (Sioli, 1984; Junk & Furch, 1985) according to their color as sensed by human eyes. The color of amazonian waters has been also empirically related to their productivity. The white waters are more productive then the black waters. So there is something to learn from the water color. It can be an index of water productivity.
Water color is related to the scattering and absorbing features of the water volume. The spectral ratio between scattering and absorption in each wavelength is related to the amount of energy which leaves the water/atmosphere boundary. It controls the water reflectance in each wavelength (Kirk, 1986). So the use of instruments for the spectral sensing of the water reflectance is potentially usefull for more accurate assessment of water properties.

The general objective of this paper is to describe the water quality studies developed in the Amazon region using remote sensing techniques and its relationships with the anthropic pressures in the Amazon Basin, based on informations from specialized literature.

Information on the spectral properties of Amazonian inland waters will help to answer the following questions: how many wavebands are needed to cope with the variety of optical conditions of those aquatic systems? Which are those wavebands? Are the number and spectral region affected by the type of water mass? How different components affect band selection? How multiviewing capability can be used to improve the algorithms for water variable estimates?

Reservoir construction and hydropower development are a key issue in Brazil considering ecological, economical and social aspects. In a country with abundant water resources, reservoir construction has been one of the major development strategies for the last 20 years. There is a large dependency of the economic development in Brazil related to hydroeletricity. The reservoirs changed considerably the ecology of several river basins causing ecological problems, social problems, and economic changes in the regional systems.

The reservoirs already in operation are subject to heavy pollution, eutrophication thus hampering possibilites of multiples uses, by rapid and severe changes in water quality. The use of remote sensing techniques for monitoring the changes verified during the construction and operation phases in the Amazonian reservoirs, and its relationships with the "ground truth", can help to decide the the correct way for monitoring the surrounding areas.

## 3. WATER QUALITY STUDIES AND REMOTE SENSING TECHNIQUES IN THE AMAZONIAN REGION

Since 1960s, satellite-based remote sensing revolutioned the assessment of land and water uses, as well as the consequences of human activities on ecosystems.

Remote sensing techniques as an additional source of information for water management and for limnological studies were recently introduced. The fundamental idea is to relate the reflectance of the water in the spectral classes with the limnological characteristics of the water masses in order to combine thematic maps with the "ground truth". The calibration of the water quality properties with the satellite images will introduce an important qualitative technique to reservoir and water management. Frequency and distribution of blooms, spatial distribution of aquatic macrophytes and suspended matter can be better determined by these techniques.

In the Amazon Region, several aquatic systems have been studied by many authors using remote sensing techniques: Braga (1988), Novo & Pires (1990), Novo et al. (1990), Pereira Filho (1991).

Mere & Braga (1988) used images of the years 1976, 1979, 1984, 1985 and 1986 to historically represent the construction of the Tucurui Dam, the supporting infrastructure and consequently the anthropic action in this region. By supervised classification of the five mentioned dates, the authors were able to establish the changes (increase and decrease) of the planted areas, deforested, natural forests, borrow areas (material for the dam construction) and the urban areas mainly in Tucurui city and in the residential villages.

Batista et al, (1988) studied the land uses in the Amazonia, focusing three subjects: the study of the terrestrial phase of the hydrological cycle, the study of the impact of deforestation on the hydrological balance on a yearly basis, and the study of the relationship of human occupation with water quality.

Braga (1990) showed the results of a preliminary analysis of the chlorophyll surface distribution in Tucurui Reservoir; data were obtained during the 1989 dry period, simultaneously to TM/LANDSAT overpass, in July, 16th, and, August, 1st. Information about quality

water parametrs (surface temperature, Secchi depth, total chlorophyll content, total suspended solids and nutrients) were collected in 15 sampling sites in the first data, and in 30 sampling sites in the second one. Digital data were extracted from TM bands 1, 2, 3, 4 and 6 corresponding to the same sampling sites. Simple Linear Correlation Analysis was applied to both sets of data to access phytoplancton primary producitivity over all the reservoir water body.

Novo et al. (1990) studied a previuos classification of Tucurui water masses using TM/LANDSAT data to locate the best sampling sites. The area encompassed by limnological stations in the upper and central portions of the reservoir presented a strong gradient between the turbid Tocantins river water and the deep clear reservoir water. This gradient can also observed through TSS concentration which drops from 8.92 mg/l at the upper portion to 4.29 mg/l at the central portion during the dry season (June). During the rainy season the concentrations are higher but the gradients are lower ranging from 31 mg/l (upper portion) to 23 mg/l (central portion) (January).

Novo & Pires (1990) studied Total Suspended Solids (TSS) gradients derived from water samples along three limnological stations, and compared to different dates in the Tucurui Reservoir; the preliminary results indicate that the spectral radiance detected by TM/Landsat data are sensitive to changes in TSS greater than 4 mg/l. This difference represents the average TSS concentration between two adjacent limnological stations (in the upper portion of the reservoir) in the dry season. Hydrodynamical factors are controlling a high rate of sediment deposition at the reservoir entrance and/or the submersion of Tocantins denser water towards the methalimnion.

Abdon & Meyer (1990) studied the LANDSAT/TM data to identify the occurrence of aquatic macrophytes within the Tucurui reservoir, Pará state, Brazil. Images of the dry period were used in the consecutive years from 1986 to 1989. The classification of the macrophyte areas was done by slicing vegetaive index imagery derived from applying the normalized ratio between LANDSAT/TM bands 3 and 4. Those classes were used as training sites to implement a maximum likelihood classification on the remaining study area.

Pereira Filho (1991) studied the effect of Tucurui reservoir's catchment basin features on water quality. Abiotic features were represented by soil texture and terrain dissecation level. Anthropic features were defined as the deforestation rate between 1986 and 1989. Water quality changes along time were indicated by the rate of macrophyte infestation and TSS concentration. TM/LANDSAT-5 images were digitally classified using Digital Processing System . The forest, deforestation, and macrophyte areas mapped from TM digital data were integrated to geomorphological and soil classes to build a georeferenced data base for the area. Each class represented an information plane in the Geographical Information System (GIS). TSS data were correlated to bands 1 to 4 digital number to generate an empirical model to estimate water properties from satellite data. Results were not satisfactory because of low TSS concentration in the studied area. The integration of information derived from multidate satellite data and conventional ground information into a GIS proved to be an efficient tool to assess the environmental impact of land use and physiography on the water quality of Tucurui reservoir.

Juras (1991) recommended the use of remote sensing techniques as a preliminary diagnostic of Amazonian waters (rivers and reservoirs), coupled with limnological and water quality field surveys to provide data for the correct water basin management.

As proposed by Ahern et al. (1990) the drainage networks and standing water can be studied under the following appropriate sensors: LANDSAT/TM, SPOT/HRV, RADARSAT Standard.

## 4. FINAL CONSIDERATIONS

The physico-chemical conditions of water are associated with the agricultural productivity. When combined, this information facilities the planning for agricultural activities of upland and humid areas, and through these activities the rational utilization of the available resources in the Amazon Region.

The following parameters are important to be detected in water bodies: suspended inorganic matter, TSS gradients, and their consequences to the equilibrium of the aquatic system; occurrence of aquatic macrophytes, analysis of the chlorophyll surface distribution, land use dynamic (runn-off).

The land use detection and monitoring, using remote sensing techniques will provide information to planning the occupation management in the influenced area by the projects, and to detect the sources of water pollution.

The use of orbital imagery led to positive results related to the delineation of the surface drainage and the delineation of the watershed.

Satellite sensing has some disadvantages: in the humid tropics, satellite sensors

are frequently "blinded" by clouds; satellites can overfly large areas of the Brazilian Amazon twice a month for years and never get a cloud-free image. This constraint applies to aerial photography as well, but another aerial method (side-looking airborne radar "SLAR") can "see" through dense cloud cover, at a higher resolution than satellite sensing.
Satellite-based methods also require substantial instruments in supplementary hardware and software, such as receveing stations, computers, display devices, training, and "ground truthing".

Considering the global coverage of remote sensing systems and their data and the ever increasing interdependende of economic, environmental and political systems, international cooperation is essential.

The future growth for remote sensing may depend largely upon educating the potential buyer because many potential buyer do not yet know how to use the data nor do they appreciate its applicability. For developing countries, the obstacle are worse in terms of education due to the costs and lack of training in the use of the data. Remote sensing data, however, are particularly pertinent for their economic development as well as for the support of the world's ecological balance.

The main conclusion is that Amazon Region remote sensing focusing the water quality have to be strongly considered in Brazil's space program planning, to provide data for the correct water basin management, before, during and after of the projects implementation.

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