Six Ramsar remote sensing case studies were developed in 2002 as part of the NASA Socioeconomic Data and Application Center's (SEDAC) Ramsar Wetlands Data Gateway, developed in support of the Ramsar Convention on Wetlands of International Importance. That web service has been discontinued but the case studies are available from the documentation page for SEDAC's Sea Level Rise Impacts on Ramsar Wetlands of International Importance, v1 (2000–2010) data set at https://doi.org/10.7927/H4CC0XMD

Pantanal Tri-National GIS and Remote Sensing Pilot Project Case Study for Bolivia, Brazil, and Paraguay

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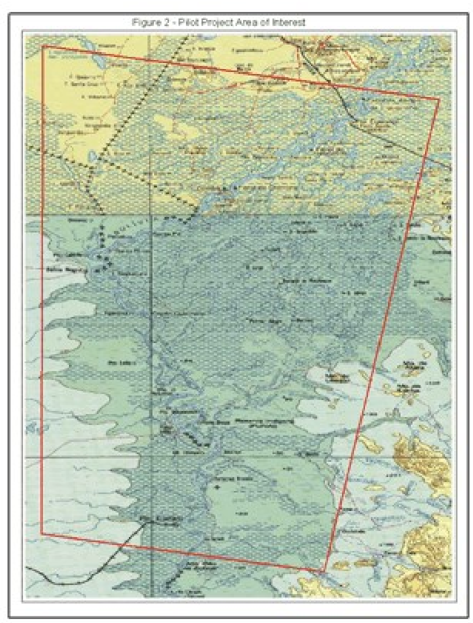
I. Introduction

The completion of the Pantanal Tri-national Pilot Project in October 2002 is the initial step in the development of a comprehensive GIS and remote sensing database for conservation planning and a data distribution network for the Upper Paraguay River Basin (UPRB). The pilot area covers the Otuquis in Bolivia (all of which is a newly designated Ramsar site), the Nabileque in Brazil (which is soon to be designated a Parque Estadual and a Ramsar site), and the Río Negro in Paraguay (partly included in the Río Negro Ramsar site) (Figures 1 and 2). Partners from governmental and non-governmental (NGO) agencies in Bolivia, Brazil, Paraguay and the United States have been collaborating on remote sensing and spatial data development tasks. Remotely sensed data was recognized as a vital application for studying inaccessible or remote areas at a regional scale and for change detection analysis. The data produced by the project will be used to model the effects of past, current and future land-use practices and to determine boundaries of future protected areas or prioritize action for restoration in the UPRB.

Figure 1 - Pilot Project Region

Figure 2 - Upper Paraguay Basin



The Pantanal is one of the world's richest ecosystems. Due to its location in the center of South America, it has fauna and flora typical of the Amazon, Chaco, Cerrado, Dry Chiquitania Forest, and Atlantic Forest ecosystems, which contribute to its high biological diversity. It includes more than 300 species of birds, 190 species of fish, 70 species of amphibians, and 50 species of large mammals (WWF 2002). It is especially important for migratory birds and provides habitat for populations of Giant River Otter, Marsh Deer, Tapir and Jaguar that are at risk in the region and elsewhere in the world (WWF 2002). The Pantanal is the world's largest continuous freshwater wetland, approximately the size of Honduras, Nicaragua and El Salvador combined, with an estimated area of 150,000 km^2 of which 110,000 km^2 are wetland (Scott and Carbonell 1986). Its boundaries extend across the borders of three countries: Bolivia, Brazil and Paraguay, but more than 70 percent of the Pantanal is located in Brazil (Dolabella 2000). All three countries protect discontinuous areas of Pantanal under different protection regimes such as the National Park Service, State Park Service and Forestry Reserves. Some areas have also been designated as Ramsar sites under the Convention on Wetlands of International Importance especially as Waterfowl Habitat (henceforth Ramsar Convention). However, much of this region is still unprotected and approximately 95 percent is under private ownership as cattle ranches (Crisman 2000). Primary threats to ecosystem health include road development projects, frequent uncontrolled fires, river channeling, and large-scale agriculture production, all of which can change the hydrology and water quality of the region.

The challenge was to develop common, landscape-level data sets for tri-national natural resource planning. During the 7th Meeting of the Conference of the Contracting Parties to the Ramsar Convention in Costa Rica (May 1999), Ducks Unlimited. Inc. (DU) and the USDA Forest Service organized a Geographic Information System (GIS) seminar to present DU's work with GIS on wetland and watershed protection over the last 20 years. After consultation with participating government agencies, research institutions and individuals from the three countries, it became apparent that there was no comprehensive GIS database in place for the UPRB. Subsequently, a scoping meeting was held in Campo Grande, Mato Grosso do Sul, Brazil in April 2000 with the objectives of determining standards and guidelines for delivering a GIS and remote sensing database, evaluating land-use and conservation planning needs with natural resource management staff for the region, identifying a pilot project area, establishing data priorities, and formulating institutional partnerships.

Funded with seed money from the USDA Forest Service International Program, the role of DU has been one of facilitation and capacity building as well as coordinating fundraising efforts. DU and the USDA Forest Service are aware that a tri-national project can be complex and time consuming, but the success of a project can only be guaranteed in the long term if the direct users of the results are involved and actively participating in the process.

The partnering organizations holding project agreements and those who have been actively involved in data development for the pilot project are listed alphabetically by country in Table 1.

Bolivia	Brazil	Paraguay	USA/Canada
World Wildlife Fund (WWF Bolivia)	Ecotrópica Empresa Brasilera de Pesquisa Agropecuaria (EMBRAPA) (agreement pending) Fundação Estadual de Meio Ambiente (FEMA-MT) Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA) (agreement pending) Instituto de Meio Ambiente Pantanal (IMAP-MS) Universidade Católica Don Bosco (UCDB)	Fundación Moisés Bertoni (FMB) Guyra Paraguay	Ducks Unlimited Inc Ducks Unlimited Canada Land Information and Computer Graphics Facility, University of Wisconsin University of Memphis US Geological Survey USDA Forest Service

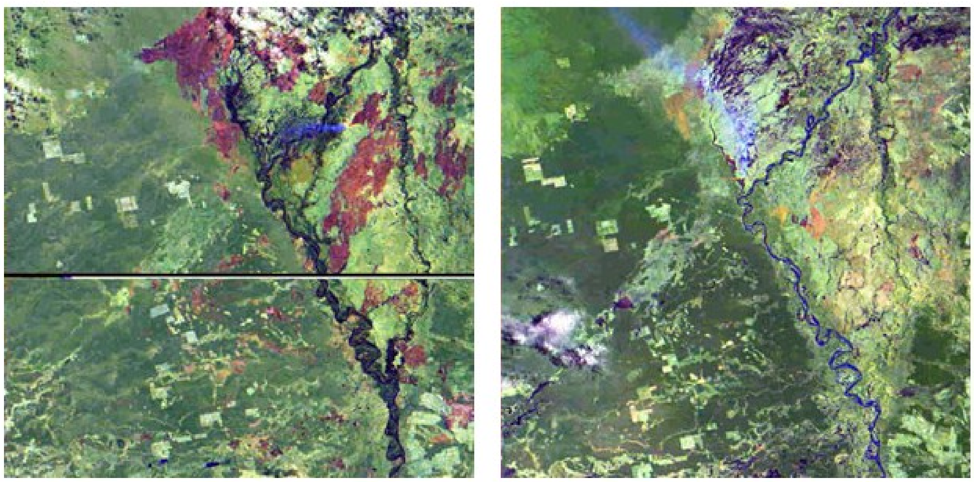
Table 1. Members of the Pantanal GIS Consortium

2. Methods and Results

The first step in the study was to develop a change detection analysis for the pilot area. One of the purposes of the change detection analysis was to determine landscape level changes, both natural and human-induced, for the Pantanal pilot project area so cross-border analyses could be made and common methods could be applied for planning, monitoring and managing the basin. In the past, each country has completed many projects that have generated important spatial information for the Upper Paraguay River Basin. However, each used different classification schemes and a variety of formats, even within their own country, making data sharing and transfer extremely difficult. To counter this challenge, the Pantanal Pilot GIS project partners decided to start with several analyses that are important for conservation. Several approaches were used to identify temporal change in the following areas:

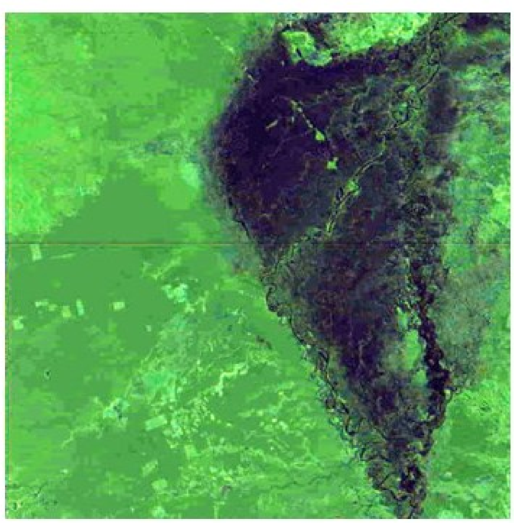
- Hydrology (Figure 3 & Figure 4)
    - Seasonal Flooded Area/Water Level Changes (Max/Min flooded area)
- Historical Land-Use and Land-Cover Change (Figure 5)
    - Human-Induced (NDVI/Vegetation Change)
    - Naturally Occurring (fires and regeneration) Burn Scars
- Roads Data Update (Figure 6)

Figure 3 - Changes in Seasonal Flooding



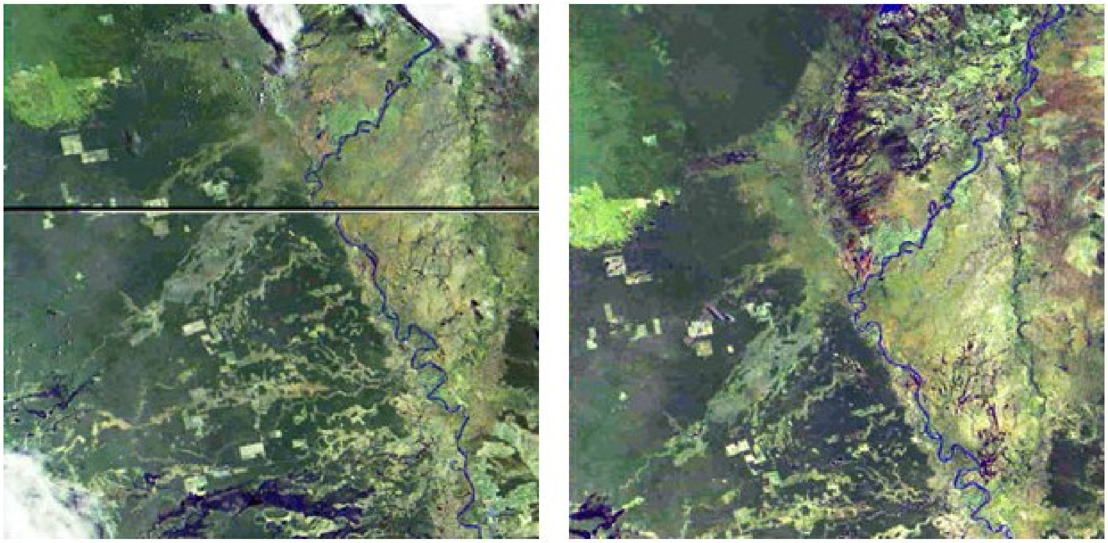
August November

Figure 4. Area of Maximum Flood Extent



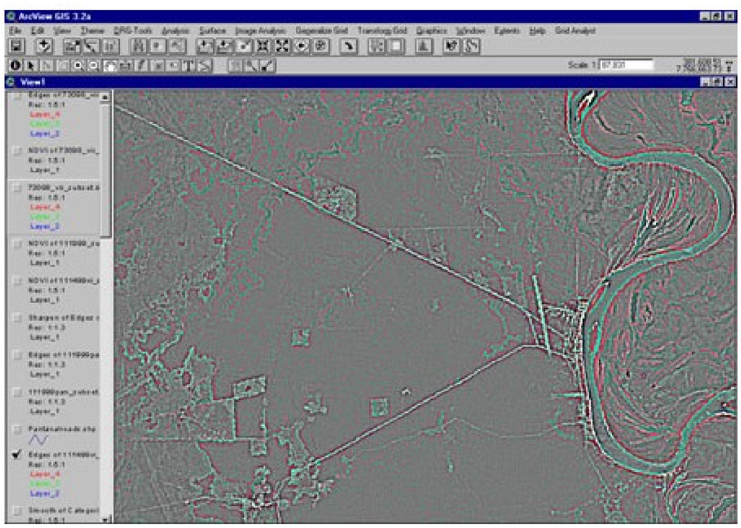
June

Figure 5. Historical Change



January 2000 January 1986

Figure 6. Updated Roads Coverage using Arcview Image Analysis – Edge Detection

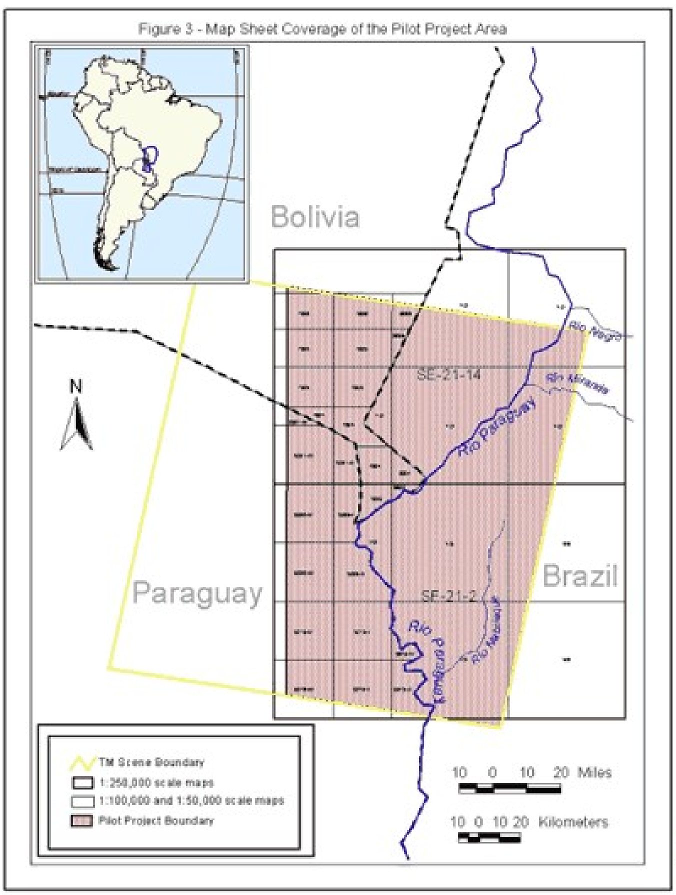


The group also decided to use ERDAS Imagine image processing software and ESRI's GIS products, including ArcView 3.2, ArcView Spatial Analyst, ArcView Image Analysis to develop a long-term solution that will unite the three countries in their desire to protect and manage the Pantanal and the UPRB.

The use of Landsat TM (Thematic Mapper) and Landsat ETM+ (Enhanced Thematic Mapper) satellite imagery was a logical choice for monitoring and evaluating environmental threats in the pilot project area (Figure 7) and eventually the entire Upper Paraguay River Basin for the following reasons:

- Each image covers a large regional area (185 x 170 km).
- The 30 x 30 meter spatial resolution provides sufficient detail for landscape studies
- Scenes are captured frequently and archived.
- Multi-spectral characteristics allow features such as vegetation, moisture and inundation to be extracted from the data.
- The use of this technology provided a cost-effective method for landscape scale analysis.

Figure 7. Scene Coverage for Pilot Project Area



Based on river gauge and precipitation information gathered from several sources in South America, Landsat TM and ETM+ scenes and dates were selected for the pilot area. River height and/or discharge data was evaluated to determine the optimal timing for the satellite imagery. The Pantanal has widely variable water flooding regimes both seasonally and annually within the basin. It is very important to understand this variability when selecting imagery for change detection analysis. Precipitation data is important for the same reasons. Timing of rainfall in the pilot area sub-region must be well understood to apply it to the selection of imagery.

The following imagery dates were used for this study and represented high, medium, and low water periods as well as high fire seasons:

- Landsat TM - November 23, 1988
- Landsat TM - June 9, 1997
- Landsat TM - July 7, 1998
- Landsat TM - November 19, 1998
- Landsat TM - December 24, 1999
- Landsat ETM+ - November 14, 1999

Utilizing ERDAS Imagine and ESRI software, partners from Bolivia, Brazil, Paraguay and the United States have been working together on image processing and GIS data development tasks such as edge detection, normalized difference vegetation index (NDVI) differencing (Figure 8), flood extent analysis (Figure 9), multi-temporal burn scar data layers (Figure 10) and updating digital roads data. Satellite imagery and aerial photography can also be used in conjunction with wildlife surveys and other GIS feature data for habitat assessments. The data produced by these assessments can be used to model the effects of current and future land-use practices and determine, for example, boundaries of future protected areas or areas of priority action for management and restoration. It can also be used to make management decisions at sub-catchment levels and it offers planners and decision-makers the tools necessary to provide sustainable alternatives to development projects.

Figure 8. Normalized Difference Vegetation Index (NDVI): increases (green) and decreases (red) of greater than 15 percent

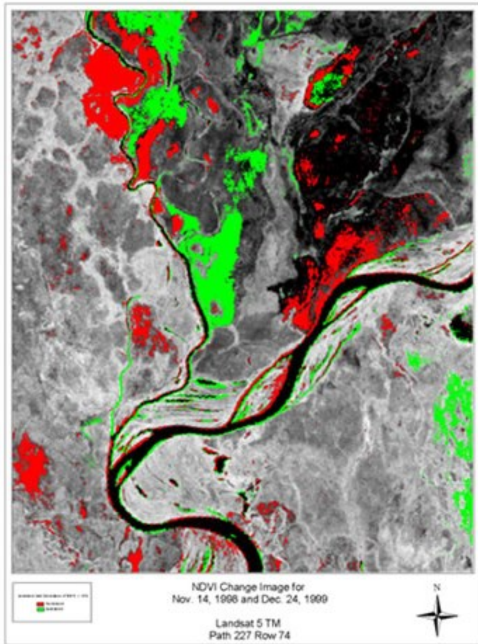
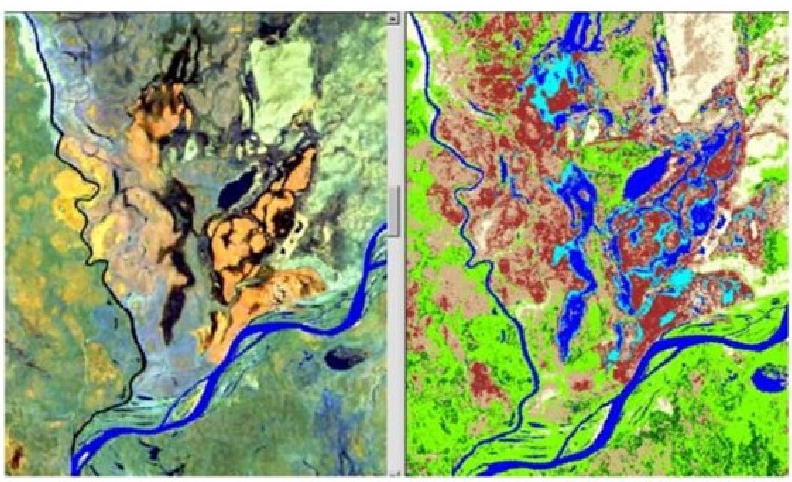
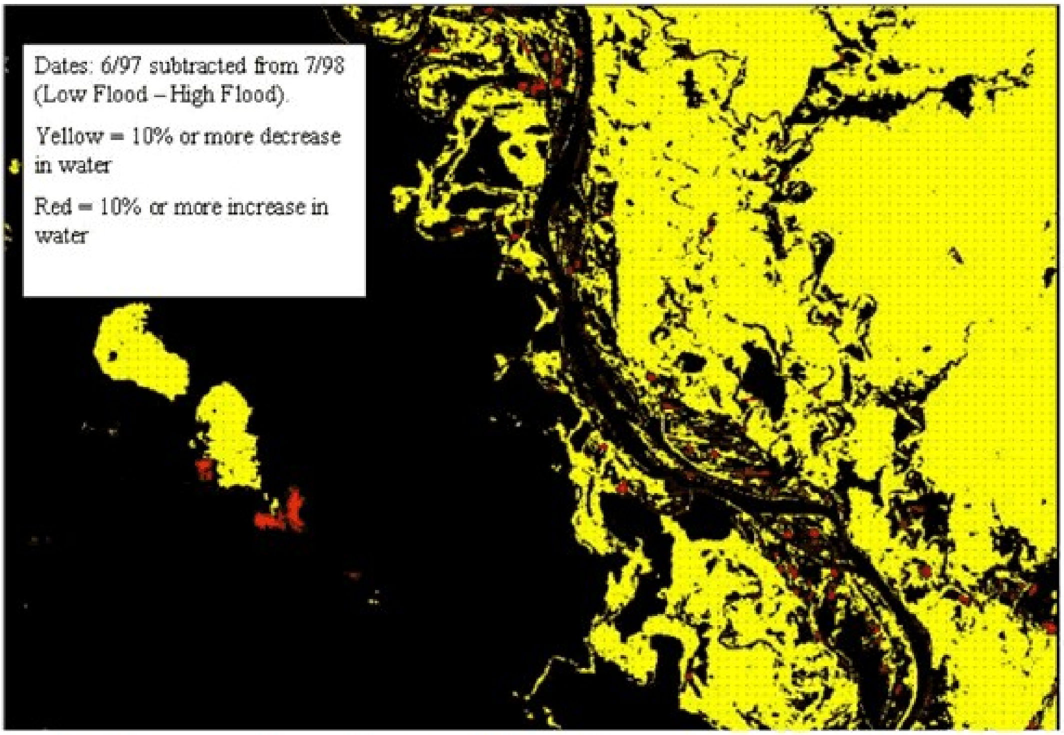


Figure 9 - Direct Multi-date Classification



All dates of imagery are classified (unsupervised) and then target features extracted (i.e. flooded area was used as an example). The image is recoded as binary file representing target features.

Figure 10. Multi-temporal Analyses



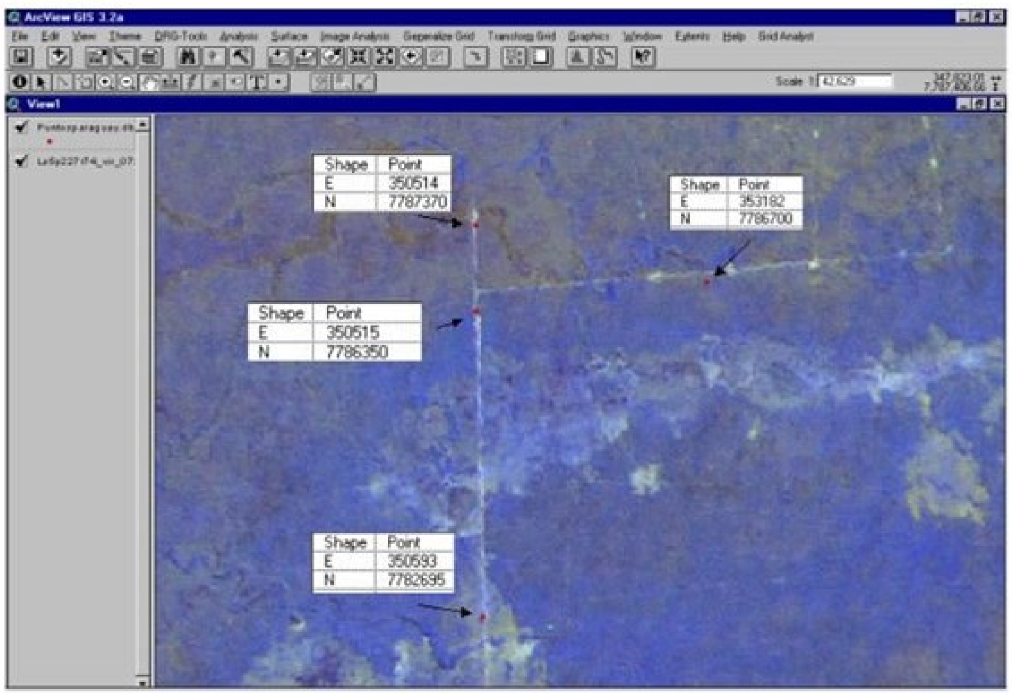
Use ERDAS Imagine's Change Detection Utility to difference the binary file for different dates. A highlighted "change file" is produced. Dates: 6/97 subtracted from 7/98 (Low Flood - High Flood)

As a result of coordinated software training and brainstorming at various workshops and field data collection efforts between and within the three countries, the following pilot project deliverables were developed and presented in draft format for review at a meeting in Cuiabá, Brazil in August 2002:

- GIS data and satellite imagery inventory for the pilot area.
- An imagery-based change detection dataset depicting areas with significant change in the last 10+ years (1) Seasonal Flood Extent, (2) Vegetation/NDVI, (3) Multi-date burn scar data layers.
- Analysis and map production at a landscape level.
- Updated roads coverage for the pilot project portion in each country.
- Land cover maps and other existing topographic maps for each country have been compiled, reprojected and compiled as a mosaic where scale and format permitted.
- Compilation of existing georeferenced historical aerial photography for portions of the pilot area and acquisition of new aerial photography with GPS coordinates for Bolivia, Paraguay and Brazil.

- Fieldwork producing ground control points (GCP's) for georeferencing of imagery (Figure 11).
- Quality check of the data that has been conducted to ensure that the three countries have compatible file formats, projections, and attributes.
- A standardized metadata format has been completed for all datasets.
- A report and power point presentation documenting procedures and the contents of the database is in the final stages of development.
- A team of local organizations with GIS capacity in Bolivia, Brazil, and Paraguay will continue to develop and maintain the integrated database for the entire Upper Paraguay River Basin.

Figure 11. GPS Fieldwork Data Used to Verify Imagery



In addition to the above contributions to the development of the Pantanal GIS database, the project has also produced the following benefits:

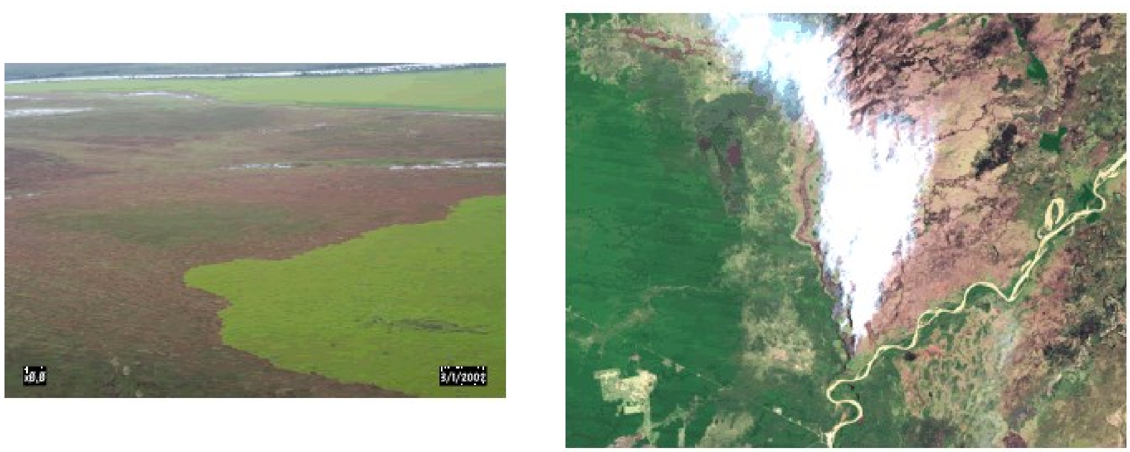
- Establishment of a technical network of professionals, specialized in GIS, remote sensing, and spatial data development;
- Development of a PantanalGIS email discussion list with more than 200 members for posting messages and updates related to the Pantanal GIS project and other projects related to the Pantanal;

- Building of alliances between institutions and countries sharing stewardship of the Upper Paraguay watershed;
- Coordination and standardization of applications and procedures among the three countries for the development, maintenance and use of the comprehensive Upper Paraguay River Basin GIS database;
- The preliminary results of a proposed tri-national land cover classification for the UPRB;
- The project has been documented in journals and newspapers and presented at several professional meetings.

Initial findings show that time-series NDVI and NDVI differencing appeared to produce the best results for visually detecting landscape-scale, clear-cut and burned areas in forest and heavily vegetated areas. A decrease in the infrared coupled with an increase in red leads to a large decrease in the calculated NDVI for a burn scar compared to that of unburned vegetation. The rationale of this procedure is that it highlights areas showing a change in time, normally associated with fire damages and vegetation re-growth. The decorrelated data produced through this process were of great value in enhancing regions of localized change in NDVI.

Results of the pilot project have prompted partners such as WWF in Bolivia, Guyrá in Paraguay and EMBRAPA in Brazil to apply methods, data and/or results of the pilot project to specific cases on the ground in each of their countries. For example, extensive burn scars mapped from 1999 analyses in the Bolivian pilot area prompted discussions with the Bolivian Park Service (Figure 12).

Figure 12 - Field verified photo showing burn scar (left) and Landsat imagery with smoke plume (right)



The completion of the pilot project leads to the next phase of GIS database development which includes (1) web-enabling the pilot project data inventory, (2) expanding the project to other areas in the UPRB and (3) confirming a location and organization responsible for establishing, maintaining and serving the database. Satellite imagery will continue to play an essential role in the development of key datasets and identifying priority areas of monitoring, evaluation, and planning. At present, a communication and dissemination strategy is being developed to ensure that these data may be made available to both technicians and planners. An effective way to share the pilot project results and attract more users of the database is via the Internet. There are three main Internet-based components:

- Create a Metadata (data description) Clearinghouse: This will soon be served through the US Geological Survey site http://130.11.52.184/servlet/FGDCServlet where the general public will have access;
- Develop a GIS data and literature inventory: A data inventory and bibliography was compiled in Access at DU and will be served via a web-enabled data catalogue created and maintained by Ducks Unlimited, Canada. General public will soon have access; and
- Compile the database for ftp access and Internet: Develop, test, and establish an initial central location for all project-related GIS and imagery data and documents. Mirror sites may be developed later. General public will soon have access.

3. Conclusions

The methods and standards established during the pilot project will be transferred to the broader Upper Paraguay River Basin Tri-National GIS project. The image processing methods may vary slightly for each country depending on software availability, landscape characteristics, hydrology, and other factors that make various portions of the Pantanal unique. We look forward to new partners joining the project and incorporating new technical capabilities and software/hardware availability. Many suggestions were made during the pilot project on how to expand on some of the image processing and GIS tasks. Communication between partners via meetings and the technical discussion list will continue to be pivotal to the development of the project. If your organization is interested in subscribing to the list serve, please enroll via email at the following address: pantanalgis@yahoogroups.com.

The completion of the pilot project leads to the next phase of GIS database development that includes:

- Expanding the project to other areas in the Upper Paraguay River Basin UPRB
- Web-enabling the pilot project data inventory for the general public, and
- Confirming the location(s) and organization(s) responsible for establishing, maintaining and serving the database.

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