Deforestation of the Brazilian savanna biome (locally called Cerrado) has been rapid and extensive: more than 66% of the original 2,000,000 km² has been converted to pasture and agriculture since 1960. Land cover changes lead to important changes in the hydrologic, geomorphic, and bioclimatic states of river systems: decreasing evapotranspiration on land, increasing river discharge, erosion and sediment flux, and altering river and floodplain morphology. The Araguaia River (Figure 1) offers a unique opportunity to evaluate the impact of deforestation on a large tropical river.

- The drainage area has undergone a rapid conversion from native Cerrado.
- Continuous discharge measurements have been recorded at numerous sites since deforestation began.

Here we present evidence of changes to the land cover, channel morphology, sediment flux, and discharge of a 120,000 km² area of the Araguaia River basin and quantify the role that deforestation has played in these changes. The results represent one of the more spectacular examples of rapid large-scale hydrological and geomorphic response to deforestation in a large tropical fluvial system.

**Land Cover:**

23 CBERS II - CCD, 20m spatial resolution images (China Brazil Earth Resource Satellite) acquired August and September of 2006 (dry season), were used to map the remnant Cerrado and forested areas of the Araguaia basin. The images were made available by the Brazilian Space Research Institute (INPE) (see http://www.dgi.inpe.br/CDSR/).

The CBERS scenes, geocoded and mosaiced, were spectrally enhanced via a normalized difference vegetation index (NDVI) transformation, followed by the slicing of the resultant NDVI image into three thematic classes: 1) remnant vegetation, 2) converted areas, and 3) water bodies (Figure 2).

A summary of the classes shows that 38% of the 120,000 km² land area is in native Cerrado vegetation, while 62% has some kind of environmental disturbance, ranging from major converted areas to local use by small holders. About 45% (or 6,353 km²) of the area within a 100 m buffer of major streams is already converted from its native state.

**River morphology:**

LandSat MSS, TM 5, and ETM+ images from many years, SLAR mosaics from 1973, topographic charts, aerial photographs from 1965, and fieldwork were used to quantify the changes to stream morphology that have occurred since 1965, such as variability in the number and size of islands, type and size of sand bars, channel width, and number of secondary channels.

The results indicate relatively small changes when comparing the 1965 data with 1977 data.

- Islands are relatively stable, with only small changes (Figure 3C).
- Large lateral bars and an increasing number of middle channel bars are present (Figs 3A & C).

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**In summary:** With increased conversion of the landscape to agriculture, there has been a very large increase in the amount of sediment in the river. The river has responded to this increase quickly: the river is storing more sediments by infilling secondary channels, creating the more stable lateral bars, and eliminating some obstacles such as the smallest islands, which means that the river, that formerly had a multi-channel pattern is in the process of opening a central corridor to more effectively transport the increased sediment supply.

**Discharge:**

We analyzed discharge data collected for the period 1970-2000 at the 77,000 km² Aruanã watershed, as collected by Agência Nacional de Águas (ANA).

- Mean annual discharge at Aruanã increased by 26% from 1970-1979 to 1231 m³/s for the decade 1990-1999 (Figure 6A).
- Discharge increased in all months except November (Figure 6A), by about 30% in the core of the wet season (Jan-Mar) and dry season (April-Aug).

The land surface model IBIS was used with the river transport model THMB to evaluate the influence of historical deforestation on the discharge of the Araguaia River.

The river discharge was simulated for the entire basin for two land cover scenarios:

- An estimate of the natural and agricultural landscape in the 1970s, in which about 30% of the basin is in agriculture.
- An estimate in the 1990s, in which about 55% of the basin is in agriculture (Figure 7).

The simulations were run with identical climate data for the period 1970 to 2000 and the decadal mean discharge for the 1990s and 1970s were compared. Because all other aspects of the simulations are identical, any differences in the simulated river discharge between the two scenarios are a result of the land cover changes alone.

The results show the impact of land cover changes:

- Moderate 1970s land cover constant, mean discharge increased 10% by the 1990s due to increased precipitation (Figure 6B).
- Allowing both land cover and climate to change from the 1970s to the 1990s, mean discharge increased by 23% (Figure 6C), which agrees with the observed 26% increase.
- Therefore, land use change contributed about 1/2 of the increase in river discharge over 3 decades.

**CONCLUSIONS**

Satellite observations, extensive fieldwork and numerical modeling studies were used to quantify the Araguaia River system that have occurred in the last 40 years.

Fundamental changes to the terrestrial and aquatic environments include:

- As of 2006 62% of the land has been converted to agriculture.
- Sediment flux within the Araguaia River increased by 26%.
- The river is re-organizing its physical structure to accommodate the increased sediment; with a central channel being carved from what was once a multi-branched river.
- Discharge since the 1970s has increased by 26%.
- Simulations indicate that more than 1/3 of change in discharge is attributable to changes in land cover.