LONG-TERM CHANGE DETECTION OF THE PURUS RIVER FLOOD PLAIN

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ABSTRACT

In this study, multiple decade classifications based on Landsat time-series scenes was adapted to map the Amazonian's Purus river floodplain borders along its 3,360 km extension using the Global Surface Water dataset associated to the Shuttle Radar Topographic Mission (SRTM) data. Despite some disadvantage for processing a large amount of image processing data. As a result, we obtained an accurate floodplain perimeter applicable to identify Union's indubitable lands which can be applied in other meandering floodplains in the Brazilian Amazon.

Keywords *— Amazon floodplain, meandering floodplain mapping, long-term changes, time-series classification.*

1. INTRODUCTION

Floodplains are wetlands which oscillate between terrestrial and aquatic phases. This makes them alternately suitable for aquatic and terrestrial organisms but makes utilization by humans difficult [1]. The Amazonian várzeas are the most extensive floodplain river system in the world covering about 64 million hectares [2]. These riverine ecosystems occurring at the confluence of terrestrial and aquatic ecosystems are typically considered as highly productive, sequestering large amounts of carbon in terrestrial phases, and potentially releasing carbon in aquatic phases. Nonetheless, the role of floodplains in local and regional carbon budgets is affected by major threats, including land use change, dam construction, exotic species invasion, and reclamation efforts [3].

In Brazil, the active flooding area (the river space) is considered as a Union's indubitable land. However, Brazilian's federal laws have different definitions and procedures in comparison to the North American understood of active flooding area. Although the North American concept considers it a perimeter based on the occurrence of, at least, one flood in the last 100 years using the probable maximum flood as measures, in Brazil instead, the imperial law 1.507/1867 [4] considers a 15,40 m buffer zone around the actual river course and, also, an older course up to 1867, using the average floodwaters as flooding measures.

This federal law of Union assets does not have a land conservation bias, nevertheless, guarantees the non-occupation of these lands within on this buffer zone around all rivers located at international borders or between two or more federated states. However, since the enactment of this law, no revocation or modification proposals has been conducted. In addition, the work of delimiting Union's indubitable lands includes surveying areas with few availabilities of cartographic and field research.

Remote Sensing offer potential to support the sustainable development and land as these problems related to the delimitation of the Union domain lands. The extent and inaccessibility of major floodplains make Remote Sensing the only practical method for monitoring inundation at the basin scale. However, measuring long-term surface changes remains a challenge, particularly in tropical regions, limited by their inability to penetrate cloud cover or dense vegetation canopies [5].

Although the mapping of water surface and main river structures as meanders and avulsions may seem simple, water is a highly variable target and its spectral properties at the wavelengths measured by any optical orbital sensor (as TM, ETM+, and OLI Landsat instruments) vary according to chlorophyll concentration, total suspends solids and colored dissolved organic matter load, depths and water-body bottom for shallow waters [6].

The mapping of long-term changes in global surface water occurrence, documenting multi-decadal trends and identifying the timing (to within a given month or year) of events such as lake expansion and retreat or river-channel migration provides insights into the impacts of climate change and climate oscillation on surface water distribution, and concurrently captures the impacts humans have on surface water resource distribution [7].

2. MATERIALS AND METHOD

2.1. Study area

The study area covers the Purus River, which flows from the Peruvian Andean slopes, near the 450 meters of altitude, crossing a sedimentary basin for about 3300 kilometers until the Amazon river at 10 meters of altitude, between the parallels 3°30' and 10°30' South latitude, and between the meridians 60°30' and 73°00' West longitude, as can be seen in the following Figure 1.

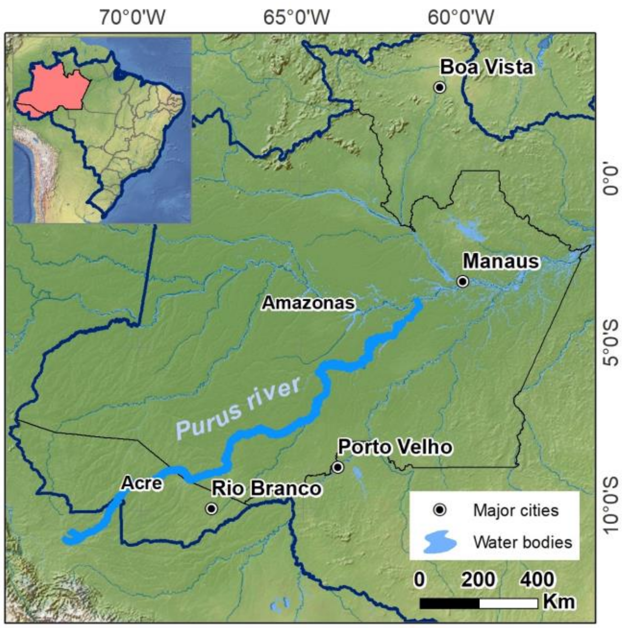

Figure 1. Study area location

2.2. Data

Four different datasets are used in this study. First, the Global Surface Water [7] freely available from https://global-surface-water.appspot.com/, which extends previous work by using the entire multi-temporal orthorectified Landsat 5, 7 and 8 archive spanning the past 32 years to map the spatial and temporal variability of global surface water and its long-term changes.

Second, the Shuttle Radar Topographic Mission (SRTM) data [8] freely available from https://lta.cr.usgs.gov/SRTM1Arc, which allows extracting the Purus river floodplain altimetric characteristics as the contour lines, slope and aspect and, especially, channels abandoned for more than 32 years and not easily recognized on orbital scenes.

Third, fluviometry data from 15 monitoring stations located along the Purus river to calculate the ordinary floods according to the ON-GEADE 03/2001 [9]. These data are freely available at Brazil's Hydrological Information System (HIDROWEB) [10] from http://www.snirh.gov.br/hidroweb/publico/apresentacao.jsf.

Finally, as a reference map we recovery the map results from the first well-documented survey exploration of the Purus river conducted by William Chandlless and published by 1866 [11]. Despite the ineluctable precision errors, it's a valuable historical document which allows reconstructing the course of the Purus river from that period.

2.3 Procedures

Here we adopt an approach [7] that applies a consistent algorithm to all 32 years of the Landsat observations to produce a validated data set that documents global surface water dynamics with new levels of spatial detail and accuracy. This information is linked to complementary datasets, such as satellite altimetry measurements (as SRTM), would produce fresh estimates of surface water volumes, river discharge, and even sea-level

The next step is calculating the ordinary floods values for each 15 monitoring stations selected. According to the ON-GEADE 03/2001 [9], to calculate the arithmetic mean of ordinary floods, the annual maximum levels for floods with a recurrence period of between 3 and 20 years were considered, and floods with a recurrence period of fewer than 3 years and equal to or greater than 20 years were discarded.

Considering, for instance, a 12-meter arithmetic mean ordinary flood in the last 20 years, this value is added to the altimetry of a certain reference station. If a particular station has 200 meters of altitude, then the Union's undoubted lands domain reaches 212 meters, besides the river itself and the connected meanders.

Then, a mosaic of SRTM arc-30 second scenes [8] was analyzed to extract the flat regions of an Aspect image analysis and to extract the correspondent contour lines to the ordinary flood arithmetic mean values. The SRTM scenes have also an important for visual interpretation and hands-on job. As illustrates the previous Figure 2, is notorious how the Purus river meandering system constructs and left river avulsions.

The fluviometry data and the arithmetic mean ordinary flood has also function to validate the image analysis result among the Global Surface Water and SRTM scenes. The Purus river map published by William Chandlless [11] has a complementary function to validate the reconstruction of the Purus river channel by 1866-1867, a period of the enactment of Brazil's Federal Law 1.507, 26 September 1867 [4].

3. RESULTS

The combined use of SRTM elevation data and Global Surface Water dataset supported the delimitation work of approximately 17,203 km² along the Purus river flood plain. As can be seen observed in the following Figure 2, the Union's indubitable lands do not necessarily correspond to the whole floodplain, but in fact to the active river area.

The Global Surface Water dataset is categorized in five different datasets: 1) Surface water occurrence 1984-2015; 2) Surface water occurrence intensity 1984-2015; 3) Surface water recurrence 1984-2015; 4) Surface water seasonality 1984-2015; 5) Transitions in surface water class 1984-2015.

There is no difference in water bodies dimensions among each one of these five Global Water Surface datasets, however, it condenses the relative information about the migration of meandering river channels in the floodplain.

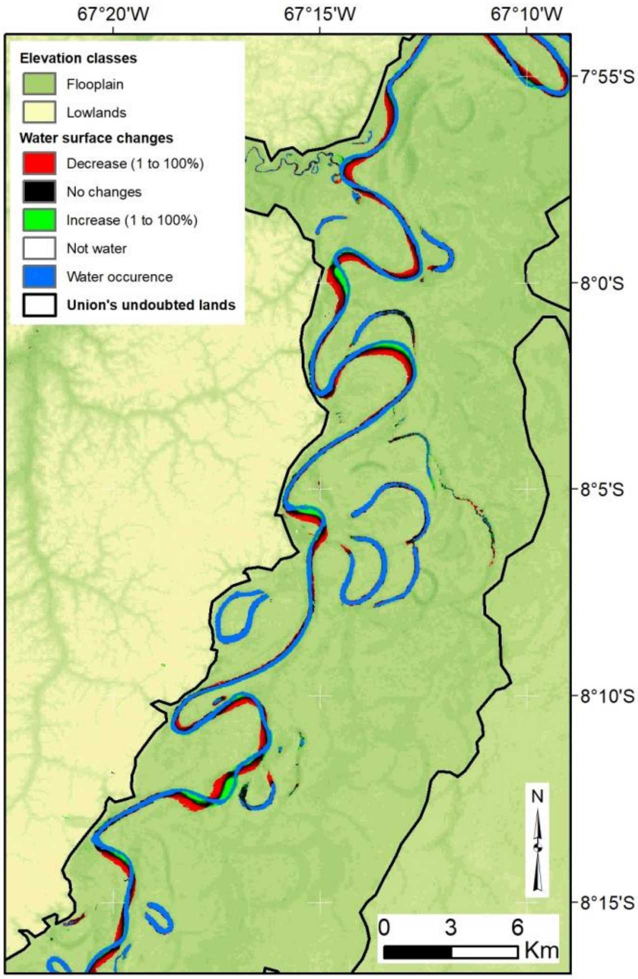

Figure 2. Water surface changes over a Purus river section in the southern Amazon State

In Figure 2 above, river decreasing areas are underlined in red and new river increasing areas are colored in green. The river decreased areas are now new sand point bars, while the green indicates the river cut banks. No other great differences are observed in the Purus river floodplain, except the oxbow lakes formed over 30 years ago and therefore not contemplated in this data.

The comparison with SRTM data suggests that flow-path selection is not random, but instead in a compensatory way driven by the alluvial ridge width. The William Chandlless map [11] reinforces this interpretation. Unfortunately, this map is not adequate enough to compare with each river meander, nevertheless, revealed that in 152 years the changes in the Purus river are restricted to the formation of oxbow lakes and decreasing/increasing of river meanders; no river directions changes were verified.

The following Table 1 illustrates the direct relationship between the ordinary flood high and the alluvial ridge width. The smaller the width, equally smaller is the flood height.

Table 1. Fluviometry and flood data from 15 monitoring stations

Station Code	Lat	Long	Altitude	Ordinary Flood	Altitude + Flood
361000	-3.90	-61.37	14	13.95	28
462001	-4.74	-62.15	17	13.72	32
563002	-5.72	-63.51	30	12.75	43
462002	-4.86	-62.87	33	12.52	46
564001	-5.58	-64.34	39	12.07	51
564002	-5.95	-64.32	48	11.21	59
13880000	-6.54	-64.39	48	11.21	59
765001	-7.53	-65.35	59	9.73	69
765000	-7.72	-66.06	85	7.96	93
766001	-7.72	-66.98	92	7.45	100
867002	-8.25	-67.37	97	7.1	104
867001	-8.74	-67.40	100	6.9	107
13710001	-8.65	-67.38	100	6.9	107
968001	-9.04	-68.58	124	5.2	129
869000	-8.88	-69.27	146	3.17	149
13169000	-9.57	-70.59	213	1.9	215

Source: Adapted from ANA-HIDROWEB [9]

4. DISCUSSION

Identify the Union's indubitable lands it's a complex job, and this approach can provide detailed and precise information never build with traditional thematic approximation before. Traditionally based on cartographic surveys, this job can be improved using thematic mapping products with information about relief, soil, floods, rainfall or land cover.

If these thematic mapping products are published by a recognized public, educational or scientific institution, it brings valuable information for decision-makers constitutes proof of the unequivocal domain of the Union.

These thematic products may be validated through fields surveys or comparison to reference products, collecting coordinates and other elements that help in the definition of the area. If there are already maps of the own floodplain, prepared by a recognized public, educational or scientific institutions, such products can constitute proof of the unequivocal domain of the Union.

5. CONCLUSIONS

The findings reported here highlight the importance of analyzing multitemporal data to change detection studies and applications. On one hand, Landsat multispectral scenes have no complex preprocessing procedures, nevertheless, the segmentation accuracy is related to spectral measures and indexes. On the other hand, synthetic aperture radar products as SRTM data, with best accuracy results.

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