Journal of South American Earth Sciences 51 (2014) 28–44

Contents lists available at ScienceDirect

Journal of South American Earth Sciences

journal homepage: www.elsevier.com/locate/jsames

Remote sensing-based analysis of the planform changes in the Upper Amazon River over the period 1986–2006

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ARTICLE INFO

Article history:
Received 15 March 2013
Accepted 17 December 2013

Keywords:
Amazon River
Remote sensing
Channel change
Meandering
Multichannel
Anabranching

ABSTRACT

An analysis of the planform changes of the Colombian reach of the Amazon River was carried out over a period of 19.9 years. Remote sensing image processing techniques were applied to Landsat images acquired in 1986, 1994, 2001 and, 2006. These images were selected based on minimal daily water level variations, while providing the widest temporal span. Plan view river changes and geomorphologic characteristics were examined to identify which channel pattern classification best represents this large tropical river system. Discharge was also analyzed to determine whether changes in the river's plan view are a direct response to variations in discharge. The system had a depositional tendency between 1986 and 2006, with a period where erosion was more intense than deposition between 1994 and 2001. Percent change in the plan view area of the system (1.4% yr^{-1}) and the maximum migration rates (125 m yr^{-1}) suggest that this reach of the Amazon is less active than reaches upstream and the downstream reach between the confluences of the Jutaí and Japurá Rivers. Variations in discharge appear to be responsible for deposition and erosion dynamics observed after this remote sensing analysis in the Colombian reach of the Amazon River. Characteristics including multiple channels with vegetated islands developed from within-channel deposition, meandering planform, lateral activity of channel margins, and the absence of islands with saucer-like morphology suggest a multichannel, meandering pattern for this reach of the Amazon, that corresponds to a laterally active anabranching river.

1. Introduction

Large rivers are characterized in terms of their drainage basin, length, the volume of sediment transported and discharge (Potter, 1978). Depending on the criteria used, different approaches exist for categorizing these rivers (Inman and Nordstro, 1971; Potter, 1978; Meade, 1996; Gupta, 2007; Latrubesse, 2008; Ashworth and Lewin, 2012). It appears that relying solely on specific subjective, quantitative values for river definition is problematic in the case of large systems in general. Although it is difficult to define criteria for large rivers (Inman and Nordstro, 1971; Potter, 1978; Meade, 1996; Gupta, 2007; Latrubesse, 2008; Ashworth and Lewin, 2012; Nicholas, 2013), it is well established that such rivers are the major conveyors of sediments from the continents to the oceans. Syvitski et al. (2005) estimated that approximately 21 Gt yr^{-1} of sediments are supplied by large rivers to oceanic basins, mostly as suspended load. The transit of such amounts of sediments is also associated with the diversity of landscapes and fluvial facies. Large rivers are characterized by wide floodplains where sediment is stored temporarily and remobilized from time to time. These systems are also characterized by the presence of different channel patterns, from single sinuous channels to anastomosing reaches.

The Amazon River is the largest river in the world in terms of mean annual discharge (209,000 m^3 s^{-1}) and drainage area (6,100,000 km^2) based on estimations at the Obidos gauging station (Latrubesse, 2008). Additionally, a mean annual sediment discharge of 754 Mt yr^{-1} has been measured at the same gauging station (Martinez et al., 2009). The Amazon is more than 6000 km long and runs from the Andes in Peru to the Atlantic Ocean in Brazil (Fig. 1A). In Peru, the river is known as the Amazon as below the junction of the Marañon and Ucayali Rivers (Fig. 1B). In Colombia, the river runs for no more than 100 km and it is also known as the Amazonas. After entering Brazil the river is denominated Solimões and the name Amazonas is not used until the junction with the Negro River at Manaus (Fig. 1B). Here we refer to the Amazon as the entire fluvial system.

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0895-9811/$ – see front matter
http://dx.doi.org/10.1016/j.jsames.2013.12.004

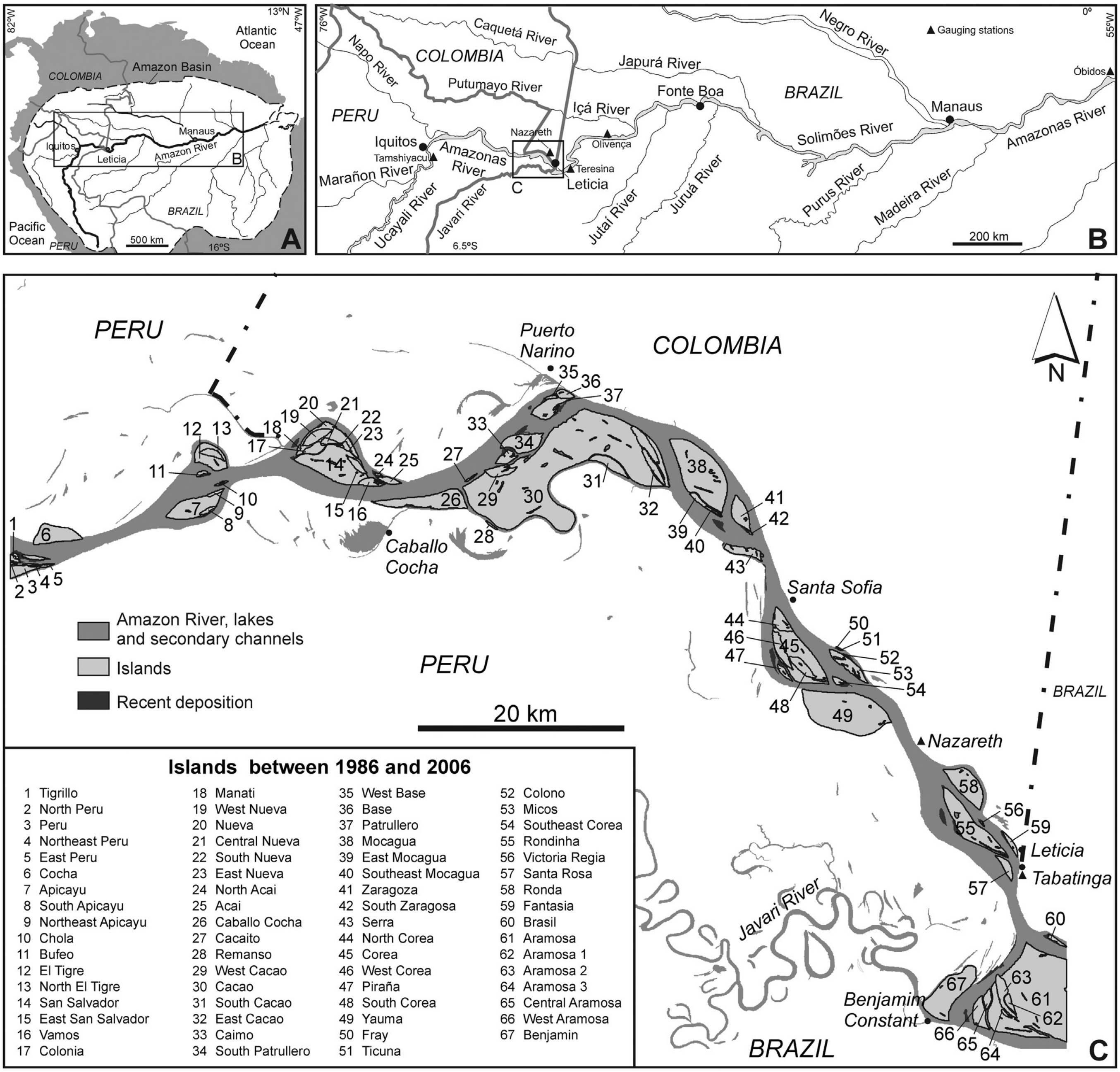

Fig. 1. Colombian Amazon River location map. A) Amazon Basin. B) Regional map of the Amazon River between Iquitos, Peru and Manaus, Brazil. We refer to the Ucayali-Amazonas-Solimões system as the Amazon River. Locations of gauging stations from which data was obtained for the discharge analysis are indicated. C) Studied reach of the Amazon River. This map was generated based on the Landsat image June 24 2006. Islands not present at that time were added to the map in order to show the location of all islands under study.

The stability of the Amazon River follows a generally increasing trend between the Içа and Madeira Rivers (Fig. 1B) (Mertes et al., 1996). River stability has been evaluated using satellite images and based on the percent change in the plan view area per year. Plan view area changes of 2% yr^{-1} and 0.2% yr^{-1} were observed at the confluence with the Jutaí River and the confluence with the Negro River, respectively (Mertes et al., 1996). Recently, change in the plan view area of the Amazon have been estimated at 1.8% yr^{-1} at the confluence with the Japurá River (Peixoto et al., 2009) and at 0.6% yr^{-1} between the confluences of the Negro and Madeira Rivers (Rozo et al., 2012). These values are in agreement with the general trend of increasing stability demonstrated by Mertes et al. (1996). Differences between estimates are related to the use of more accurate remote sensing tools and to the longer time periods analyzed by Peixoto et al. (2009) and Rozo et al. (2012). Maximum migration rates estimated for different reaches of the Amazon River similarly reflect a trend in increasing stability from upstream to downstream. Migration rates of 400 m yr^{-1} (Kalliola et al., 1992) and 213 m yr^{-1} (Rozo and Soto, 2010) have been reported in the Upper Amazon River in the Iquitos area (Peru) and near Leticia (Colombia), respectively (Fig. 1B). In the Brazilian Amazon River, rates of 140 m yr^{-1} (Mertes et al., 1996) and 60 m yr^{-1} (Rozo et al., 2012) were reported for the reaches near Fonte Boa and Manaus, respectively (Fig. 1B).