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Eco-archaeological regions in the Bolivian Amazon

An overview of pre-Columbian earthworks linking them to their environmental settings

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1 Introduction

Recent archaeological evidence of pre-Columbian complex societies in parts of Amazonia (Heckenberger et al. 2003; McEwan et al. 2001) has triggered a heated debate about cultural development and environmental constraints. Social complexity is understood as the combination of subsistence intensification, political integration and social stratification following population growth (Johnson & Earle 2000). While some scholars believe that large settlements and complex societies were limited to areas with favourable environmental conditions (Bush & Silman 2007; Meggers 2001), others argue that evidence of complex societies in the Amazon Basin demonstrates that culture evolved regardless of environmental constraints (Erickson 2006, 2008; Heckenberger et al. 2007). For these authors, environmental characteristics such as forest biodiversity, presence of savannas or soil fertility are primarily the result of human intentionality, rather than a pre-existent condition people had to adapt to.

However, the debate lacks important data as few studies have characterised the environmental settings in which archaeological sites are found.

North-eastern Bolivia, which comprises the Llanos de Moxos (LM) in Beni and the Department of Pando, is an ideal region to study past human-environment interactions as it contains an unusually large number of different kinds of pre-Columbian earthworks (Erickson 2008) and has a diversity of geo-ecological sub regions (Hanagarth 1993; Langstroth 2011; Plotzki et al. 2011). In recent studies, these earthworks have been interpreted as different elements of a unique landscape, which is thought to have been constructed by pre-Columbians in the LM between 900 cal BC and the arrival of the Spaniards (Erickson 2006, 2008). According to Erickson, mounds and anthropogenic forest islands hosted large sedentary populations that produced the food they needed by raised field agriculture. Raised fields were allegedly able to produce maize, manioc, sweet potatoes, peanuts, beans and squash on a continuous basis, without the need of fallow periods (ibid.). However, this reconstruction of the region's past overlooks the spatial distribution of the earthworks and the fact that different types of earthworks are found in different parts of north-eastern Bolivia, as was already documented by Plafker (1963) and Denevan (1966). This analysis also overlooks the diversity of geo-ecological regions in north-eastern Bolivia, consequently missing potential links which might exist between the different archaeological remains and their environmental settings. Detailed archaeological excavations of pre-Columbian settlements have been carried out only in a limited area of the LM (Prümers 2010; Prümers et al. 2005) and Pando (Arnold & Prettol 1988; Saunaluoma 2010). They have provided useful data at a local scale, such as the first pottery seriation for the region of Casarabe (Jaimes Betancourt 2010). The differences in the pottery styles suggest that different cultures inhabited different regions of the Bolivian Amazon at different times. However, the data is still insufficient to establish the spatial and temporal limits of these cultures, their migration history and the connections that may have existed among them and with other Amazonian cultures.

The aim of this paper is to present a first approximate description of the links that exist between the different types of pre-Columbian earthworks in the Bolivian Amazon and their environmental settings, based on an analysis of the spatial distribution of the earthworks and the hydrology and edaphology of the areas where earthworks are found. Did people adopt different strategies and build different earthworks to adapt to different environments? Was the level of social complexity achieved in the Bolivian Amazon conditioned by the local geo-ecology?

The scarcity of data on the archaeology and the geo-ecology of the LM and Pando makes it difficult to establish clear causal relations between environmental settings, types of earthworks and social complexity. Nevertheless, six distinct regions are identified in the study area, each with a specific combination of environmental characteristics and earthworks. Furthermore, among these six «eco-archaeological regions» a trend seems to emerge: in those regions where environmental constraints are fewer, there is some archaeological evidence of large and more complex pre-Columbian societies.

The present study draws on data from previous research published by the authors, bibliographic

research and GIS analysis. Geographic data was retrieved from Google Earth's coverage and the SRTM Version 4 dataset (http://srtm.csi.cgiar.org). The GIS analysis was performed with the software ArcGis 9.3. The description of the spatial distribution of the earthworks and their ecological settings is based on a review of the existing literature.

2 Pre-Columbian earthworks in north-eastern Bolivia

The range of earthworks types that have been documented in north-eastern Bolivia is big: agricultural fields, monumental mounds (MM), anthropogenic forest islands, canals, causeways, ring ditches and fish weirs (see examples in Fig. 1).

Several types of pre-Columbian agricultural fields have been described in the LM (Denevan 2001). The construction of agricultural fields brought about a rippled landscape in which the most elevated parts were cultivated. The shapes of raised fields vary considerably from low platforms separated by wide ditches (Fig. 1a) to high ridges closely packed together (Fig. 1b). The main reason behind the construction of Pre-Columbian agricultural fields in the LM was to improve the local drainage (see review in Lombardo et al. 2011).

Monumental mounds (MM), called locally «lomas», are planned, complex buildings that follow structural patterns and geometric rules (Fig. 2). Archaeological excavations have revealed the presence of differential burials, finely decorated pottery (Prümers 2007) and abundant use of maize (Bruno 2010). It has been shown that the MM were occupied continuously and simultaneously, approximately from 400 to 1400 cal AD (Jaimes Betancourt 2010). MM are often part of a more complex arrangement that includes several associated structures, such as canals, causeways and water reservoirs (Lombardo & Prümers 2010). Almost all the mounds are located along strips of forest that grow over the fluvial deposits of inactive rivers, often on the very edge of the paleo channel (Lombardo & Prümers 2010).

Forest islands (FI) is the term commonly used to refer to patches of forest that grow on slightly elevated locations in the savannah. FI normally cover less than one hectare, are less than one meter high and are sometimes surrounded by a moat-like ditch (Erickson 2008). Archaeological findings suggest that almost all the FI were used by pre-Columbian peoples (Erickson 2006; Langstroth 1996). However, the origin of FI is controversial. While some authors consider that a significant number of them are natural (Hanagarth 1993; Langstroth 1996), others believe that the great majority of FI are the result of human activity (Erickson 2006). Despite this controversy, it would appear that at least some of them are anthropogenic. The anthropogenic FI were probably built to gain dry land to establish settlements. However, in the case of the tallest anthropogenic FIs found in the San Ignacio area, which are up to 4 m high, they might have had a religious and/or political function too. Nevertheless, they should not be confused with the MM as they lack many of their structural characteristics and are far smaller.

Canals and causeways are quite common in the LM. It is often difficult to differentiate between them because when pre-Columbians built a causeway they also had to dig one or two adjacent canals and vice versa. Canals and causeways probably shared similar functions of communication and water management. Their construction did not require a great number of man-hours (Erickson 2000) but they are public works that probably indicate a certain degree of cooperation and political organization.

Ring ditches are earthworks that enclose pre-Columbian settlements (Fig. 1d). They are flanked, on one or both sides, by berms or earth walls. Ring ditches were mainly built on the relatively old, reddish soils of flood-free areas. Saunaluoma (2010) reports that ring ditches in Pando were occupied and re-occupied for short periods of time from 100 BC to 400 AD and from 1200 AD until the arrival of the Spaniards. The ring ditch of Bella Vista, in the LM, was occupied ca. 1300-1400 cal AD (Prümers et al. 2005). Why these earthworks were built is controversial. Many authors have interpreted them as defensive structures that included a palisade (Erickson 2010). However, no evidence of post holes or other kinds of defensive structures have been found in the ditches or associated berms in the area of Bella Vista (Prümers 2010). Other interpretations of ring ditches, which are not necessarily exclusive, are that they served ceremonial, ritual or monumental functions (Erickson 2010), delimited and marked the area of occupation (Saunaluoma 2010) and/or served as water reservoirs (Pärssinen et al. 2003). According to Saunaluoma (2010), the earthworks in the Pando area are less complex and diverse than those found in the central LM and in the State of Acre. In any case, it would seem that ring ditches required less labour for their construction than the other types of earthworks found in the LM (Arnold & Prettol 1988).

Fish weirs are zigzag structures of raised earth interrupted by funnel-like apertures which have been interpreted as fish traps (Erickson 2000, 2006). Since they were first reported by Erickson no further data has been published.

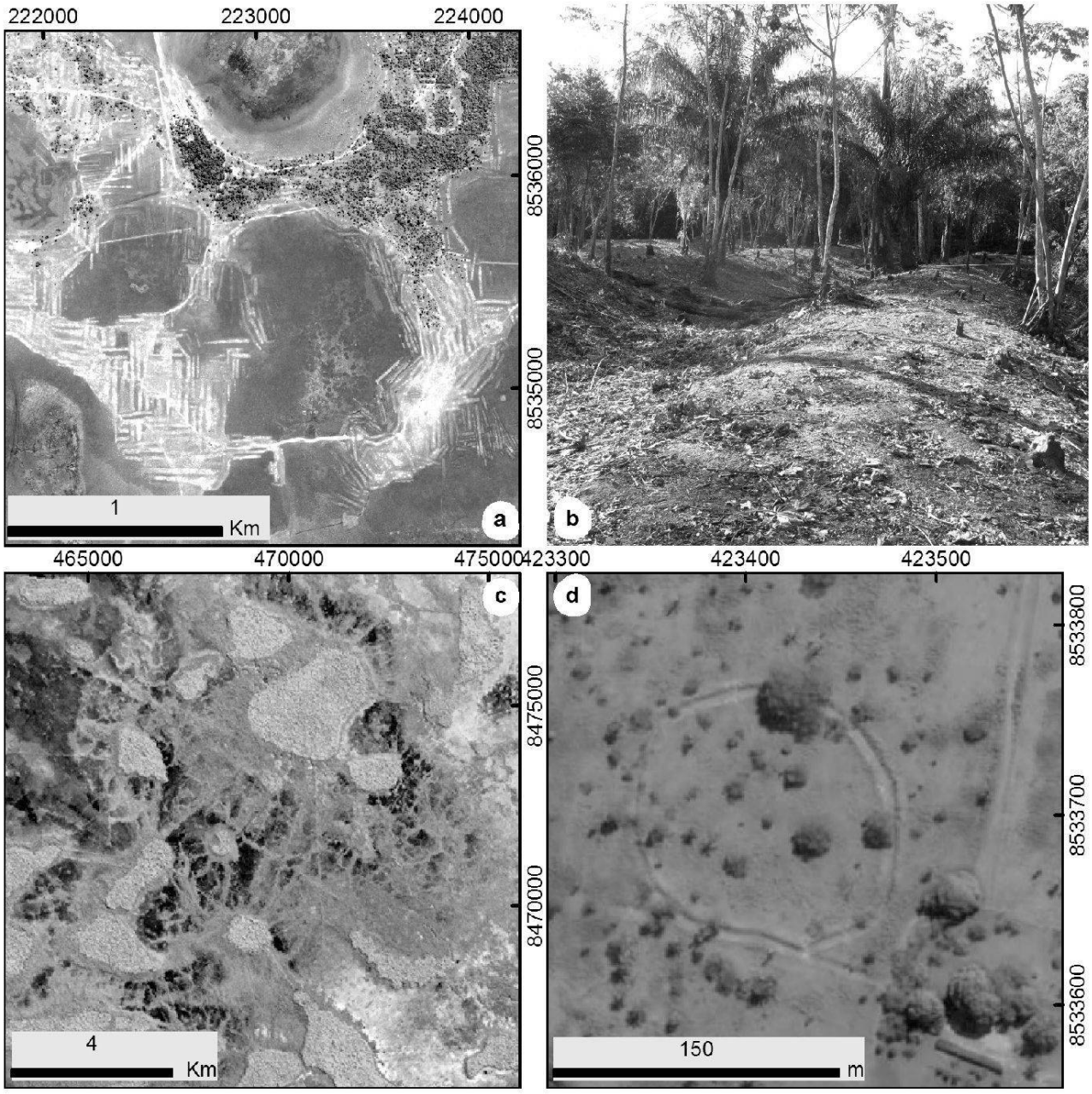

Fig. 1: Earthworks in the Llanos de Moxos (see fig. 3 for locations): a) platform fields in the north of Santa Ana; b) ridged fields close to San Ignacio de Moxos; c) causeways that connect forested areas south-east of Baures; d) ring ditch close to Bella Vista

Erdbauten in den Llanos de Moxos (zur Orientierung siehe Fig. 3): a) Hügelbeete (erhöhte Plattformen) nördlich von Santa Ana; b) Hügelbeete (Wall-Graben-Strukturen) in der Nähe von San Ignacio de Moxos; c) lineare Strukturen, die bewaldete Flächen miteinander verbinden (südöstlich von Baures); d) Ringstruktur in der Nähe von Bella Vista

Terrassements dans les Llanos de Moxos (voir fig. 3 pour les localisations) : a) champs surélevés au nord de Santa Ana; b) champs surélevés près de San Ignacio de Moxos; c) chemins reliant les zones forestières du sud-est de Baures; d) fossés circulaires près de Bella Vista

Source: a) and d) Google Earth; b) photo by H. Veit; c) Landsat

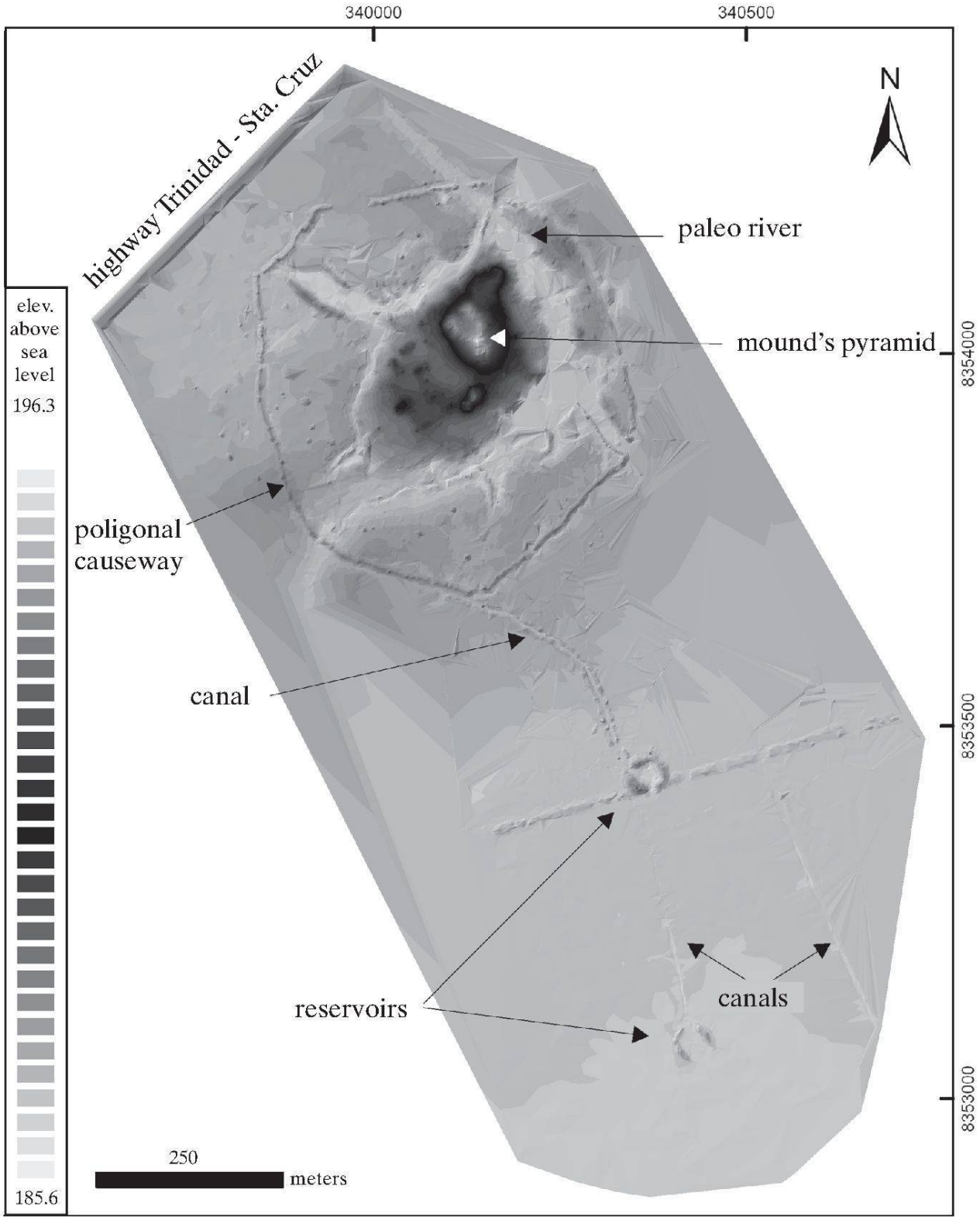

Fig. 2: Digial elevation model of Loma Salvatierra with annexed earthworks
Digitales Höhenmodell der Loma Salvatierra und der zugehörigen Erdbauten
Modèle numérique de terrain de Loma Salvatierra et de ses terrassements
Source: Lombardo & Prümers 2010

3 The eco-archaeological regions of Bolivian Amazonia

The study of the archaeological remains of Bolivian Amazona is still in its infancy and it is very hard to draw conclusions about past human-environment interactions based on the limited data available. However, as a first approximation, a certain degree of spatial overlap between specific types of earthworks and geo-ecological regions can be identified. Fig. 3 shows how, based on the spatial distribution of the earthworks and on the geo-ecology of Bolivian Amazonia, six distinct «eco-archaeological» regions can be defined.

3.1 Pando: Eco-archaeological region I

The Pando area is a very good approximation of the classical dichotomy between terra firme, where lateritic soils are dominant, and varzea, dominated by seasonally deposited white-river sediments (Navarro 2005). Here, settlements, surrounded by ditches (ring ditches), are placed on flood free «terra firme» sites that are in the vicinity of white-water rivers. This is the kind of optimal distribution predicted by Denevan's bluff model for pre-Columbian settlements (Denevan 1996). However, no evidence has been found either of continuous occupation of these sites, such as terra preta (Glaser et al. 2001), or of agricultural activities such as raised fields. This region probably offered opportunities for the seasonal utilization of floodplain playas, hunting and agroforestry, but there is no archaeological evidence of large, sedentary pre-Columbian populations here.

3.2 North of Santa Ana de Yacuma: Eco-archaeological region II

This is a transitional region from the «terra firme» to the alluvial plains of the LM (Josse et al. 2007). It is not lateritic, as is region I, but the combination of old, weathered soils and severe waterlog makes this a poor region for agriculture, as indicated by the presence of cerrado-like vegetation (Langstroth 2011).

This is probably the region in the LM where the greatest amount of earth was moved by pre-Columbian people to create raised fields and where the transformation of the landscape is most evident today (Fig. 1a). There are also a few earth platforms that served as settlements. Radiocarbon data from two settlements associated to platform fields shows that both sites were occupied for approximately 200 years, one 446-613 cal AD and the other 1311-1446 cal AD (Walker 2004). With the exception of the exploratory test pit performed by Walker, no other archaeological excavations have been carried out in this region. The vastness of the cultivable area in region II favours the idea that there were many people living here in pre-Columbian times (Erickson 2006). However, if it is taken into account that the fields were built over a period of 900 years then it is theoretically possible that a relatively small group of people could have been responsible for all of the agricultural earthworks in Santa Ana. There is no evidence that this region hosted a complex society.

3.3 Bella Vista/Baures: Eco-archaeological region III

The Baures region is made by late quaternary sediments and it is more or less under the same hydrological regime as the rest of the eastern LM. However, this region is characterized by a great number of large natural forest islands (NFI) formed by tertiary outcrops. While the NFI are well above the floods all year round, the surrounding savannah is seasonally flooded. Settlements (ring ditches) were situated on top of the NFI. Agricultural ditched fields were built on the well drained gentle slopes that border the NFI towards the savannah (Lombardo et al. 2011). Ditched fields improved the agricultural potential of the land. The limited archaeological data available suggests that this region was occupied for a short period just before the arrival of the Spaniards. The absence of monumental earthworks also suggests that pre-Columbians did not reach high levels of social complexity here.

3.4 South-east of Baures: Eco-archaeological region IV

The savannah in the south-east of Baures is almost enclosed by the pre-Cambrian Brazilian shield, which strongly limits drainage and is probably the main source of sediments. There are no studies on the soils of this region. The area is covered by Amazonian black water flooded vegetation (Josse et al. 2007). As in region III, tertiary FI are also common here (Fig. 1c). Earthworks in this area include canals, causeways and fish weirs. Natural FI were probably used for slash and burn agriculture. Fish weirs suggest that people employed extractive techniques that involved cooperation, while the presence of public works such as canals and causeways suggests some level of coordination among the people who built them, hence a certain degree of social complexity. Although Erickson (2000) suggests that the natural productivity of the fish weirs region is possibly equal to that of an abandoned river channel, there is insufficient data to estimate the productivity of the area with any accuracy.

3.5 San Ignacio de Moxos/San Borja: Eco-archaeological region V

Soils in the south-western part of the LM are quite young. They range from loams or silty loams along overbanks of active and abandoned river to very fine soils where clay content can be as high as 85% (Boixadera et al. 2003). Riverbanks are relatively elevated forested areas that are better drained and more fertile than the savannahs. In the savannahs, severe flooding

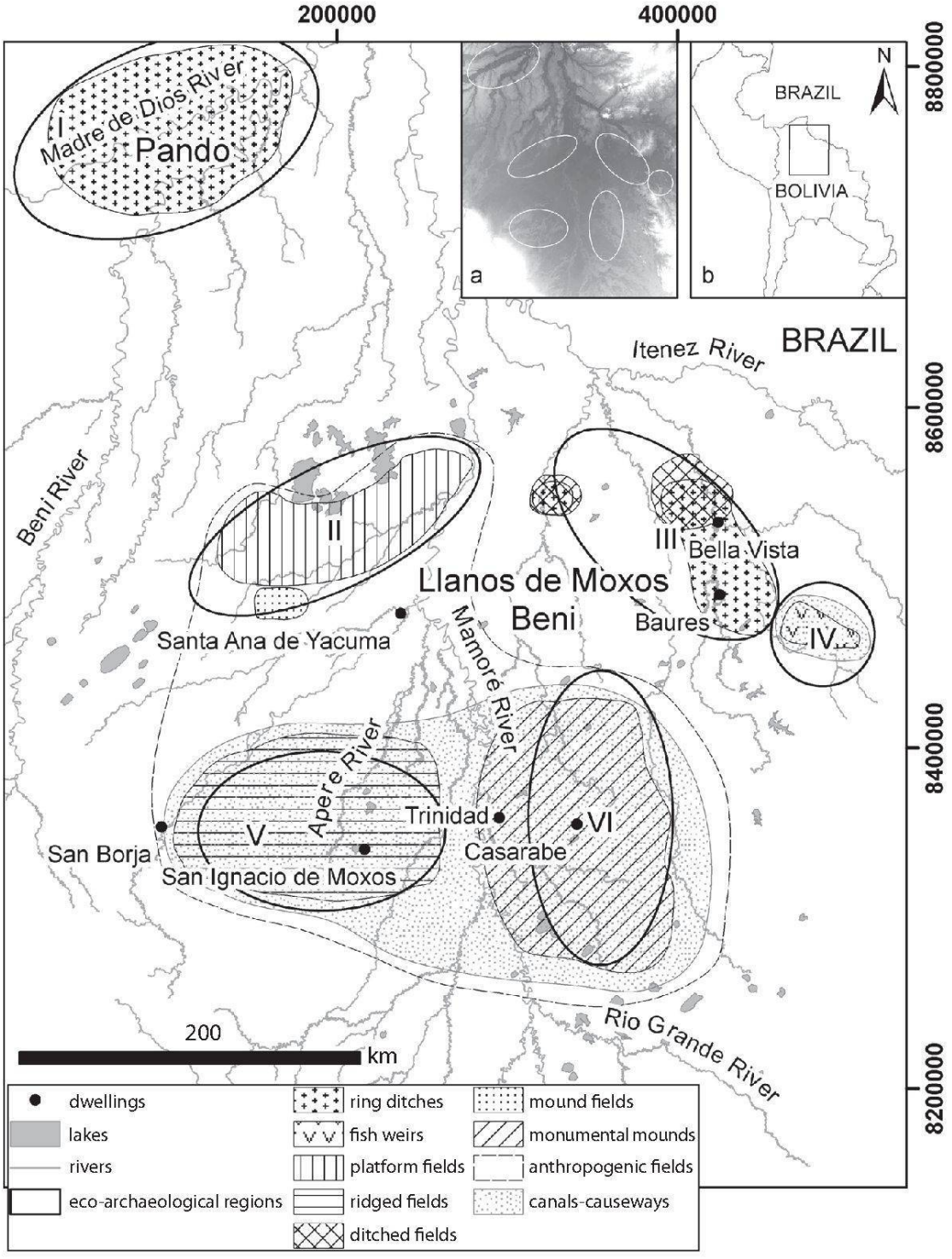

Fig. 3: Map of eco-archaeological regions of NE-Bolivia: pre-Columbian earthworks and their environmental settings. Inset a) digital elevation model: dark grey 130 m a.s.l., light grey 250 m a.s.l. Inset b) location of the study area
Karte der öko-archäologischen Regionen Nordost-Boliviens: präkolumbische Erdbauten und ihre Umweltbedingungen. a) Digitales Höhenmodell: dunkelgrau 130 m a.s.l., hellgrau 250 m a.s.l. b) Lage des Untersuchungsgebietes
Carte des régions éco-archéologiques du nord-est de la Bolivie: terrassements précolombiens et leurs conditions environnementales. Encart a) modèle numérique de terrain: gris foncé 130 m a.s.l, gris clair 250 m a.s.l. Encart b) localisation de la zone d'étude
Source: U. Lombardo, based on Denevan 1966, Erickson 2000, Lombardo and Prümers 2010

and the high content of clay in the soil are the main constraints for agriculture. This region is characterised by the presence of ridged fields, canals, causeways and anthropogenic FI. Here, anthropogenic FI can be up to 4 meters high, indicating some degree of monumentality. Ridged fields and causeways are the most impressive earthworks in the area and were mainly built along the white-water Apere River. Anthropogenic FI are often associated with ridged fields; canals and causeways seem to have both communication and hydrological functions (Erickson & Walker 2009). The majority of the anthropogenic FI and ridged fields are located on fluvial deposits where the loamy soils offer the highest agricultural potential. The presence of public earthworks and of some degree of monumentality of the anthropogenic FI suggests that here the level of social complexity in pre-Columbian times was higher than that of regions I, II, III and IV.

3.6 Casarabe: Eco-archaeological region VI

In the south-east of the LM the landscape is formed by savannahs interwoven with strips of forests that grow on levees of paleo rivers. In this region the soils are young and fertile, similar to those of the San Ignacio area (region V) but less hydromorphic. Floods here are less severe because the few rivers that cross the region are fed by local precipitations alone and the Mamore floods do not reach this area. The region is characterised by the presence of anthropogenic FI, canals, causeways and MM. The different kinds of earthworks are very well integrated at local and regional spatial scales (Lombardo & Prümers 2010). This is the only region in northern lowland Bolivia where industrial agriculture has developed today. Archaeological excavations and settlement analysis studies suggest that this is the region in the Bolivian Amazon where pre-Columbian people reached the highest level of social complexity.

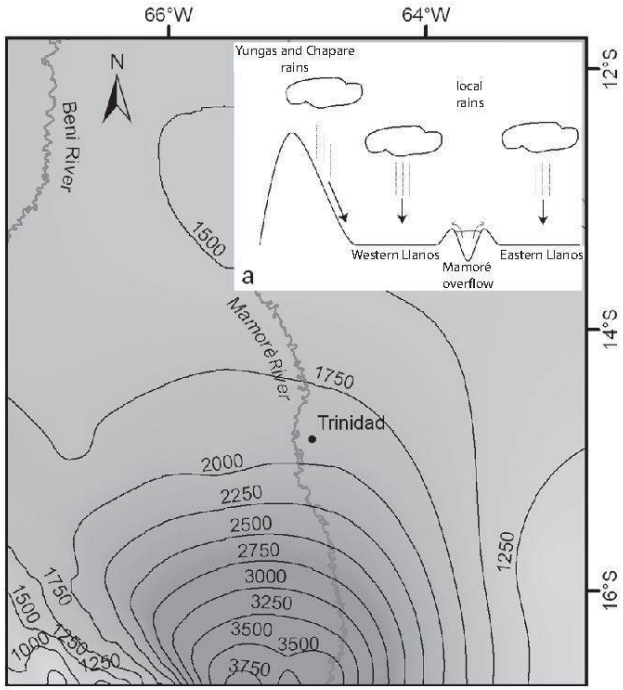

Fig. 4: Annual precipitation map for the study area (after Hijmans et al. 2005) and sketch of the hydrology of the LM (Lombardo et al. 2011)
Karte des Jahresniederschlages im Untersuchungsgebiet (nach Hijmans *et al. 2005) und hydrogeographische Skizze der LM (*Lombardo *et al. 2011)*
Carte des précipitations annuelles moyennes de la zone d'étude (d'après Hijmans *et al. 2005) et croquis de l'hydrologie des LM (*Lombardo *et al. 2011)*

4 Discussion

Based on the study of the spatial distribution of the earthworks and its geo-ecological diversity in north-eastern Bolivia, at least six distinct eco-archaeological regions can be identified. A detailed analysis of these eco-archaeological regions and the causal links between each specific environment and the way humans adapted to it must be left for future studies as the archaeological and geo-ecological data available is still too limited. Nevertheless, some general trends are apparent. The key environmental constraints today and in the past seem to be soil fertility and soil drainage. Soil fertility is closely linked to the age of the soils and to the source of the sediments: it is very low for old, weathered soils formed on the Brazilian shield and it is higher for younger soils formed on fluvial sediments from the Andes. Therefore, the first general trend to emerge is a decrease in soil fertility from the south (Andes piedmont) to the north (Pando).

The second constraint, soil drainage, depends on both the general hydrology, as determined by precipitations and river networks, and on the local topography created by fluvial levees and splays. The regional hydrology is not the same on the eastern and western sides of the Mamore River. The precipitation map (Fig. 4) shows that the western part of the Llanos receives more rain than the eastern part. Moreover, as shown in the sketch in Fig. 4a, the western part receives water not only from local precipitation but also from rainfall in the Andes. Thus, the second general trend to emerge is a decrease in flood risks from the west to the east. Local drainage also depends on the gradient and permeability of soil, which are relatively high on fluvial levees and splays. It is not possible to identify a clear trend in drainage patterns across the territory studied, but favourable local drainage conditions are present in regions III, IV and

VI. This suggests that «suitability» for human development in the study area increased from the north/north-west to the south-east. This idea seems to be reinforced by the archaeological findings: evidence of past social complexity appears to increase following a line drawn from the north-north-west region of Pando, where there is no evidence of long, continuous occupation of pre-Columbian settlement sites, to the south-eastern MM region, where the highest level of social complexity seems to have been reached.

It is possible that similar links between the environment and patterns of human occupation exist in other parts of the Amazon basin. In order to establish the role that environmental constraints and opportunities played in the development of complex societies in the region, further research is needed that combines archaeological data with the study of local edaphology.

5 Conclusions

This paper offers a first approximate description of the links that exist in north-eastern Bolivia between different types of earthworks and diverse geo-ecological settings. Although available data is insufficient to establish clear causal relations between environment, type of earthworks and social complexity, six eco-archaeological regions have been tentatively identified. In order to establish the relation between the earthworks and the environment, more data is needed about soil properties and hydrology at the very local scale of the earthworks. In order to establish the relation between earthworks and social complexity, more archaeological data is needed. Archaeological evidence is also needed to establish the spatial and temporal limits of the different cultures that inhabited the area. Once it is clear which areas were colonized or abandoned and which were occupied continuously, a clear link between environmental constraints and social complexity can be established or, as some historical ecologists propose, rejected. Meanwhile, the analysis herein seems to indicate that such a link does exist. Evidence of social complexity appears to increase as environmental constraints decrease following a line from the north, north-western region of the study area towards the south-east. Unveiling the causal relations between local ecological settings and past human adaptation strategies is going to be among the most interesting scientific challenges for those involved in the reconstruction of the Amazon's past.

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Abstract: Eco-archaeological regions in the Bolivian Amazon. An overview of pre-Columbian earthworks linking them to their environmental settings
The discovery of extensive pre-Columbian earthworks in north-eastern Bolivia has been seen as evidence that Amazonia was once densely populated by complex societies. This has led some scholars to believe that culture evolved in Amazonia regardless of environmental constraints. However, this view does not take the diversity of earthworks and geo-ecological regions into account, nor their uneven distribution. This paper offers an initial explanation of the possible links that exist between the different types of earthworks in north-eastern Bolivia and their environmental settings and identifies six distinct eco-archaeological regions. Results show a spatial overlap between those areas with greater evidence of past complex societies and areas where environmental constraints were fewer. This suggests that local hydrology and soils influenced the development of pre-Columbian societies in the region.

Keywords: human-environment interactions, landscape archaeology, Amazon Basin, Bolivia, social complexity

Zusammenfassung: Öko-archäologische Regionen im bolivianischen Amazonasgebiet. Ein Überblick über präkolumbische Siedlungsspuren und ihre Umweltbedingungen
Die Entdeckung weit verbreiteter präkolumbischer Siedlungsspuren in Nordost-Boliven wird in der Literatur vielfach als Hinweis auf eine ehemals hohe Bevölkerungsdichte und komplexe Gesellschaften im Amazonasgebiet gedeutet. Dies führt zu vereinzelten Annahmen, dass die Kulturentwicklung in Amazonien unabhängig von naturräumlichen Einschränkungen erfolgt sei. Vertreter dieser Ansichten über-

sehen jedoch die Vielfalt der regional unterschiedlich ausgeprägten Erdbauten und der geoökologischen Rahmenbedingungen. Im vorliegenden Beitrag wird erstmals versucht, die verschiedenen Siedlungsspuren in Nordost-Bolivien vor dem Hintergrund der jeweiligen lokalen Umweltbedingungen zu sehen. Sechs öko-archäologische Regionen können unterschieden werden. Die Ergebnisse zeigen eine räumliche Übereinstimmung von Gebieten komplexerer Kulturentwicklung mit günstigeren Umweltbedingungen. Dies weist darauf hin, dass lokale hydrologische Bedingungen und Bodeneigenschaften die Entwicklung präkolumbischer Kulturen beeinflusst haben.

Schlüsselwörter: Mensch-Umweltbeziehungen, Landschafts-Archäologie, Amazonasbecken, Bolivien, soziale Komplexität

Résumé: Régions éco-archéologiques de la Bolivie amazonienne. Un aperçu des terrassements précolombiens et de leurs conditions environnementales
La découverte de terrassements précolombiens très étendus dans le nord-est de la Bolivie a été considérée comme une preuve que l'Amazonie avait été autrefois densément peuplée par des sociétés complexes. Certains auteurs pensent actuellement que la culture a évolué en Amazonie sans relation avec les contraintes environnementales. Cependant, cette approche a souvent négligé la diversité des terrassements et des régions géo-écologiques et le fait que les terrassements sont inégalement répartis dans l'espace. Cet article présente une première description des liens possibles entre les différents types de terrassements dans le nord-est de la Bolivie et leurs conditions environnementales et identifie six régions éco-archéologiques distinctes. Les résultats montrent un recouvrement entre les zones présentant des preuves de la présence de sociétés complexes aujourd'hui disparues et les zones de plus faibles contraintes environnementales, ce qui suggère que les conditions hydrologiques et pédologiques locales ont pu influencer le développement précolombien dans la région.

Mots-clés: interactions entre homme et environnement, archéologie du paysage, bassin amazonien, complexité sociale

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