Catena 172 (2019) 21–39

Contents lists available at ScienceDirect

Catena

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

Anthropogenic soils from Llanos de Moxos (Bolivia): Soils from pre-Columbian raised fields

Jaume Boixadera[a,b], Irene Esteban[c,d], Rosa M. Albert[d,e], Rosa M. Poch[a,*]

[a] Dept. Medi Ambient i Ciències del Sòl, U. de Lleida, Spain
[b] Dept. Agricultura, Ramaderia, Pesca i Alimentació, Generalitat de Catalunya, Spain
[c] Evolutionary Studies Institute and School of Geosciences, University of the Witwatersrand, Johannesburg, South Africa
[d] ERAAUB, Dept. de Prehistòria, Història Antiga i Arqueologia, Universitat de Barcelona, Spain
[e] ICREA Research Professor, Spain

ARTICLE INFO

Keywords:
Soil fertility
Maize cultivation
Redoximorphic features
Soil classification
Soil micromorphology

ABSTRACT

Raised field cultivation (*camellones*) is a Pre-Columbian technique, now abandoned, which is very extensive in the Llanos de Moxos (Bolivia). The objectives of the research were to understand the effects of human actions on the morphology, genesis and characteristics (especially redoximorphic features and chemical properties) of these soils on ridged fields and their past use. We studied five representative raised field (anthropogenic) soils and other non-anthropogenic soils around San Ignacio de Moxos and along the transect Trinidad-San Borja.

The non-anthropogenic soils are acidic, show a wide range of clay contents and different degrees of human activity according to their available phosphorus content. Soil-forming processes are related to fine fraction mobility and alternating redox conditions. Contrarily, the soils of the raised fields show a distinct pattern of redoximorphic features from ridge to channel. Moreover, ridges tend to be less acidic and have lower aluminium saturation than channels. Nevertheless, they have neither artifacts nor charcoal, and their colour and P content is similar to those of surrounding soils.

The raised fields appear to have been built to improve the drainage conditions. Chemical soil fertility was not the main issue and they were used for cultivation including maize. The set of characteristics encountered (differences in pH, and drainage status at a microscale) should be used to improve the classification of these anthropogenic soils.

1. Introduction

After the seminal work of Sombroek (1966) there has been increasing evidence of the extensive influence of humans on the soils of what was once thought to be a pristine Amazonian environment. The best known of these human-influenced soils are the "*terra preta do índio*" or Indian Black Earth, a dark-coloured anthropic epipedon usually rich in nutrients (Lima et al., 2002). Much less attention has been paid to the soils of the raised fields: ridge and bed fields with channels between them, a system of wetland cultivation.

Very extensive Pre-Columbian earthworks exist in the Llanos de Moxos (Bolivia), one of the largest wetlands in the world: mounds (*lomas*), causeways (*terraplenes*), channels and ditches (Erickson, 1995), the most striking ones being the raised fields, so called *camellones* (large beds) Nordenskiöld (1924) was the first author to note their presence in Los Llanos. Later on Plafker (1963) and especially Denevan and Turner (1974) gave a full account of them, providing a first overview of their presence in Amazonia. They also gave information about raised fields from the chronicles of the first Spaniards. Many other authors in the Amazonian region from Bolivia to Santarem (Denevan, 2006; Valdez, 2006) also mentioned raised fields. Other places where they occur are in the Orinoco headwaters (Colombia, Denevan, 1970), Venezuela (Zucchi and Denevan, 1979) Central America (Turner and Harrison, 1981) and in the Andes (Ecuador, Wilson et al., 2002; Villalba-Sevilla, 2009) especially in Tiwanako (Erickson, 1996), although their overall extent is not yet known.

According to Erickson (1995), raised fields in Moxos were built in the seasonally inundated savannahs. They occur under herbaceous vegetation but also under forest, although the latter remain largely unknown. They have been dated from 300 BCE to 1400 CE (Erickson, 1995; Rodrigues et al., 2015) using several techniques, especially radiocarbon. The marks of ancient land use in the form of earthworks have been almost unnoticed in the area until now due to the dense vegetation. They are clearly man made and there are no grounds to

* Corresponding author.
E-mail address: rosa.poch@macs.udl.cat (R.M. Poch).

https://doi.org/10.1016/j.catena.2018.08.007
Received 23 June 2016; Received in revised form 2 August 2018; Accepted 9 August 2018

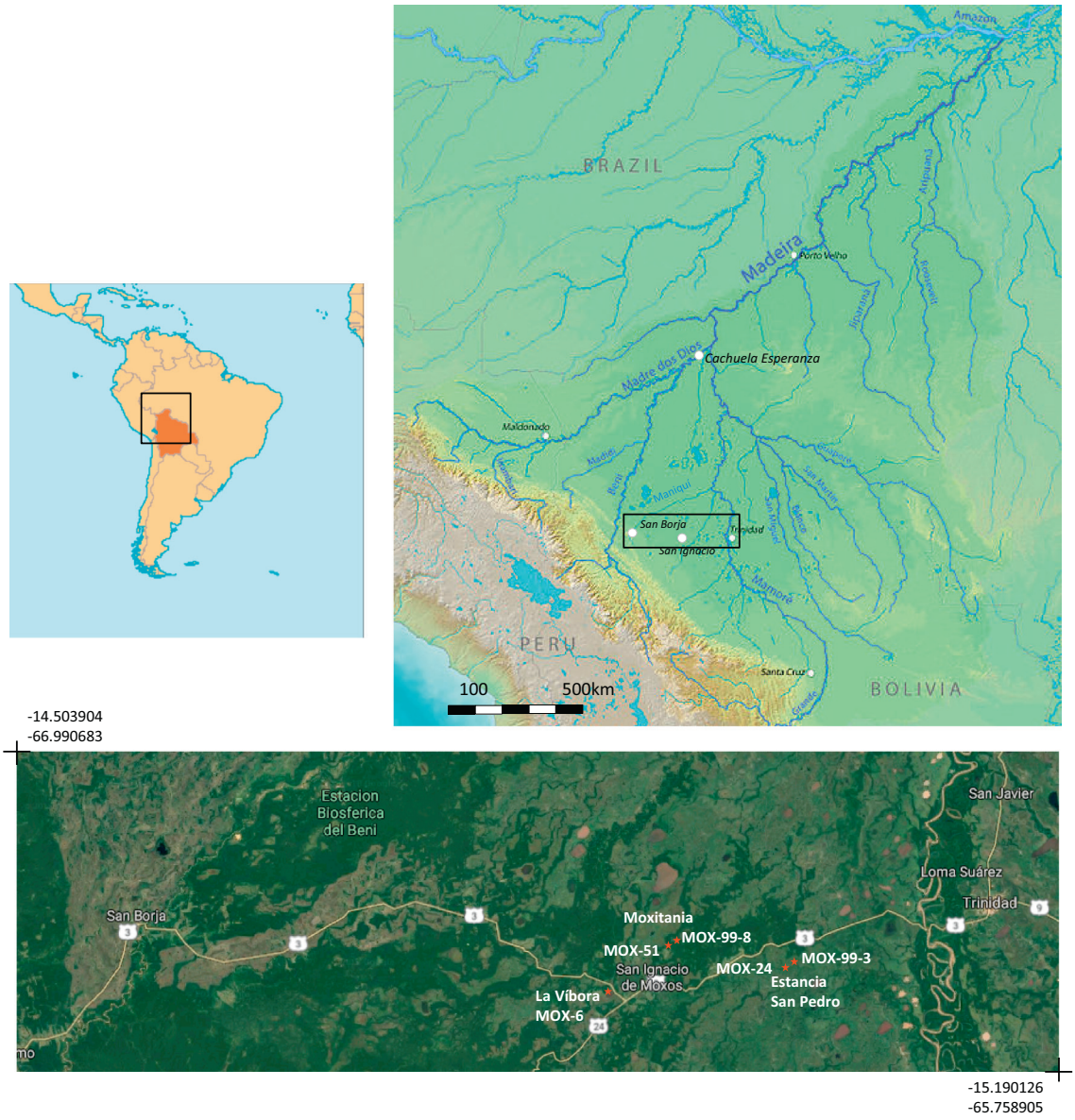

Fig. 1. The San Ignacio de Moxos study area (Google maps, 2018).

Table 1
Location, geomorphology, vegetation and geometric characteristics of the studied raised fields.

Location	Site	Coordinates	Geomorphological position	Vegetation/land use	Ridge		Actual height difference ridge/ channel cm	Reworked soil material	
					Length m	Width m		Ridge cm	Channel cm
La Vibora	MOX-6	15°00′01.5″ S 65°43′25.3″ W	Basin	*Pampa*; herbaceous pastures	> 200	2.1	40	33	25/43
Estancia San Pedro	MOX-24	14°56′36.0″ S 65°20′12.6″ W	Basin; near a small lake (*curiche)*	*Pampa*; herbaceous pastures	–	4.0	50	–	–
	MOX-99-3	14°56′20.1″ S 65°19′34.8″ W	Levee	Moist inundated evergreenforest (1) (*monte lavadero*)	200	3.0	150	40–80	200
Moxitania	MOX-51	14°54′47.8″ S 65°35′16.6″ W	Former levee	Moist evergreen forest (1) (*monte alto no chaqueado*)	85	5.0	36	53	34
	MOX-99-8	14°54′20.7″ S 65°34′47.2″ W	Basin	*Pampa*, *sartejenal* (2); herbaceous pastures	90	5.0	30	46	20

(1) In the sense of Mayle et al. (2007)
(2) Defined in Beck (1984)