Journal of Environmental Management xxx (2017) 1–11

Contents lists available at ScienceDirect

Journal of Environmental Management

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

Research article

A change in landscape: Lessons learned from abandonment of ancient Wari agricultural terraces in Southern Peru

Ana C. Londoño [a, *], Patrick Ryan Williams [b], Megan L. Hart [c]

[a] Department of Earth Sciences, Lindenwood University, 209 S. Kingshighway, St. Charles, MO 63301, USA
[b] Department of Anthropology, Field Museum of Natural History, 1400 S. Lake Shore Drive, Chicago, IL 60605, USA
[c] Department of Civil and Mechanical Engineering, University of Missouri Kansas City, 5110 Rockhill Road, Kansas City, MO 64110, USA

ARTICLE INFO

Article history:
Received 2 July 2016
Received in revised form
2 January 2017
Accepted 6 January 2017
Available online xxx

Keywords:
Peru
Wari
Terraces
Erosion
Resilience
Sustainability

ABSTRACT

Ancient agricultural terrace practices have survived for millennia, sustaining populations through extreme climatic shifts and political regime changes. In arid regions with abrupt relief such as Southern Peru, agricultural terracing is undergoing a resurgence, as has seen revitalization of once abandoned terrace and hydraulic systems. Wari terraces at Cerro Baul provide clues to past cultural practices. They also document sustainable farming practices by using resilient land management techniques which can help combat desertification and degradation of arable lands. Three abandoned Wari terrace systems were mapped using microtopographic methods, the erosion patterns examined, the states of preservation compared, and then the design contrasted with modern terracing practices in the Moquegua Valley. In order to negate the harmful effects of desertification, rehabilitation and reconstruction of these terraces using ancient knowledge and techniques may be necessary. Rehabilitation must be conducted with consideration for preservation of cultural patrimony that may be encountered within the terrace treads or riser structures. With future climatic shifts impacting vulnerable dryland areas more than others, the ability to resiliently respond to these changes may be found in the lessons learned from ancient farming techniques such as the Wari.

1. Introduction

Abandoned agricultural terraces hold the key to understanding the cultural, environmental, and agricultural practices of ancient civilizations. In Southern Peru abandoned Wari agricultural terraces are found in the Moquegua Valley, mostly on the western slopes of Cerro Baul (2200 m a.s.l.) and on the south slopes of Cerro Mejia (2250 m a.s.l.) (Fig. 1A). In order to understand the causes of abandonment of Wari terraces, analysis and exploration of the relic features is necessary. The arid environment, limited vegetative cover, and known original configuration or morphology make these abandoned terraces ideal for determining the causes and the rates of degradation of these once productive lands. Understanding these aspects of land management provides hints at how the Wari resiliently negotiated local and global climatic shifts and environmental changes.

This study examines the ancient use of abandoned Wari agricultural terraces, the causes of abandonment, the current state of preservation, and examines how management of these terraces may impact current farming and land management techniques. Patterns of erosion are derived from detailed ground surveys and intensive three dimensional terrestrial laser scanning, basin analysis, isochronology, and soil characterization. This Wari agricultural system was abandoned around 1000 AD. Abandonment may possibly be due to changing climatic conditions including droughts, flash flooding and landslide events due to increased precipitation, and the political collapse of the Wari colony that destroyed the labor organization mechanisms needed to maintain the intervalley canal and terrace systems it supported (Williams, 2002). Since these terrace systems required extensive and labor intensive maintenance, and the slopes on which they were located were prone to be highly unstable, especially in times of intense precipitation, they were inherently vulnerable to climate shifts and human labor availability (Williams et al., 2005).

2. Study area

The agricultural systems in this study are located in the slopes of

* Corresponding author.
E-mail address: ana_cristinal@hotmail.com (A.C. Londoño).

http://dx.doi.org/10.1016/j.jenvman.2017.01.012
0301-4797/

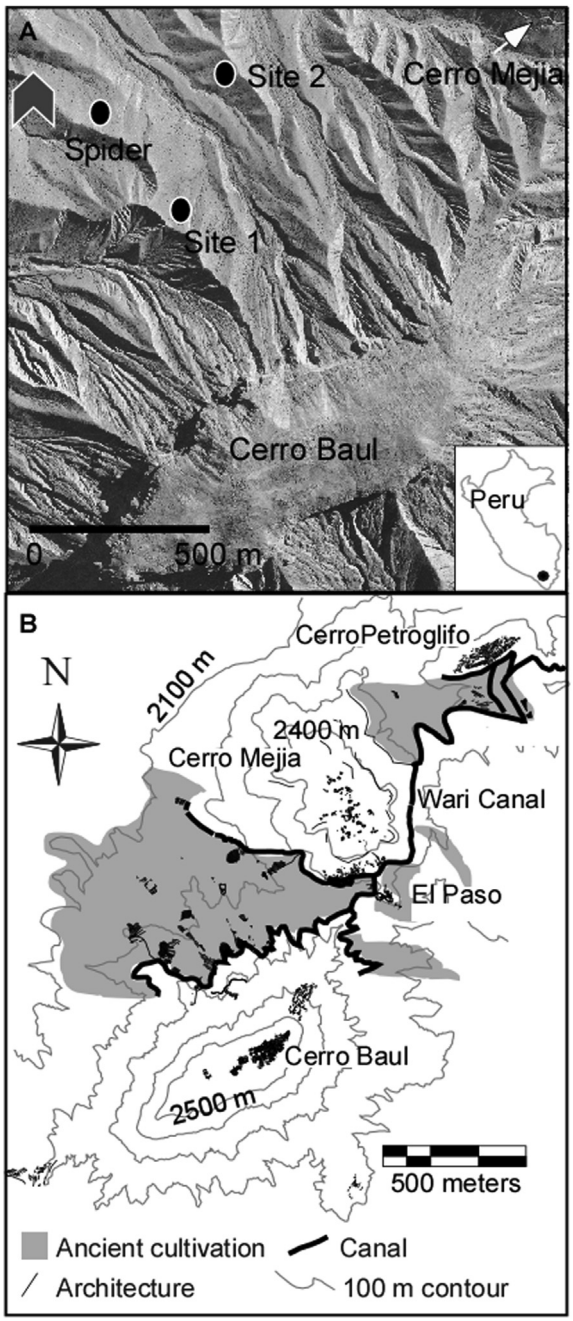

Fig. 1. A) General location of sites investigated with Cerro Baul and Cerro Mejia as reference points. B) Known extents of Wari agricultural production and hydraulic works, 600 A.D.-1000 A.D. Adapted from Williams, 2006.

Cerro Baul. This terraced mountain consists of Paleogene-Neogene rocks of the Moquegua Formation, a sedimentary formation composed of conglomerates, coarse sandstones and lithic tuffs which form the cap rock of Cerro Baul (Bellido, 1979; Martinez and Zuloaga, 2000). Pleistocene alluvial deposits, and early Holocene sands and gravels form the lower slopes (Martinez and Zuloaga, 2000). In February 19, 1600 AD., a massive eruption of the Huaynaputina Volcano deposited a layer of ash over the study area (Thouret et al., 1999) forming isochronous marker horizons used to date natural and anthropogenic processes.

Cerro Baul is located in an arid environment characterized by thin soil draped over rocky terrain. Precipitation in the study area is limited, but occurs as short, intense events during the Austral summer between December and March, yielding a total average of <25 mm annually. Ice core records of the Quelccaya ice cap (5670 m a.s.l.), located 350 km northeast of the study area, show fluctuations between drier and wetter conditions during the last thousand years (Thompson et al., 1985, 1986). The ice and lake Titicaca water level records shows wetter periods from 760 to 1040, and 1870–1984 A.D., and drier periods from 1040 to 1500 A.D. with particularly severe dry conditions during 1250–1310 A.D. (Thompson et al., 1985; Binford et al., 1997; Abbott and Anderson, 2009); wetter periods predominated from 1500 to 1720 A.D., followed by drier periods from 1720 to 1860 A.D. (Thompson et al., 1986; Binford et al., 1997; Abbott and Anderson, 2009). These patterns were confirmed in part by archaeological record that indicate a dry period and decreasing discharge in the Moquegua (Osmore) River around 1000 AD (Mächtle and Eitel, 2012), and by historic records from the Moquegua Valley which indicate a wet period between 1857 and 1870 (Ortlieb, 1995). Drought effects prevail at altitudes of 2000 m when *El Niño* events are present (Satterlee et al., 2000).

2.1. Climate and its influence on Wari agricultural and irrigation practices

The Wari culture was an empire occupying the lowland areas of Southern Peru between 600 A.D.-1000 A.D. (Moseley et al., 2005). Irrigation systems were developed to divert water from nearby streams emanating in the highlands to agricultural fields on terraces constructed into the sides of the mountain and alluvial fans at the base Cerro Baul (Londoño et al., 2013: 508; Fig. 1B). Cerro Baul is a towering 2000 foot high mesa, which formerly served as a regional political seat and ceremonial center (Nash and Williams, 2009), and based on radiocarbon dates on irrigation infrastructure as well as associations with dated archaeological settlements, we can date these terraces exclusively to the Wari period (Williams, 2003: 167). The principal irrigation canal that fed these terraces was the largest agricultural work constructed in the valley in pre-modern times and provided Wari a means of control over the surrounding landscape (Williams, 2006). Competition over the control of water was potentially critical during climate change events and likely proved to be a source of conflict between groups occupying the region (Williams, 2002). Wari people settled around Cerro Baul (Fig. 1A and B) around 600 A.D. (Moseley et al., 2005) and introduced terraced agriculture in the high sierra (2000–2500 m a.s.l.). Decreased precipitation between 660 and 680 A.D. and 700–720 A.D. caused the colonies to contract, while increased precipitation from 750 to 1000 A.D. led to expansion of agricultural activities (Williams, 2003; Moseley et al., 2005).

3. General Wari agricultural terrace construction

Constructed farming terraces in this region consist of stone wall risers with a flat surface or terrace tread on which agricultural production occurs (Fig. 2A). Preserved stone risers show construction which used locally sourced stones assembled into a wall and spackled together with a mud based mortar. Vertical risers are continuous in lineal contour; they vary in height between 80 cm and 1 m with variations depending upon the slope of the natural terrain and (McEwan and Williams, 2012). Agricultural terraces in this area were installed along natural contour breaks such that gravity driven hydraulic distribution was possible. Cultivation of the slopes in a terraced manner allowed for a maximization of surface area for agricultural production while maintaining an equilibrium with water inflow for irrigation. Southern Peru's arid environment coupled with intensive rainfalls can cause extensive wash and erosion without careful management. The Wari people were focused on farming and environmental management by

Please cite this article in press as: Londoño, A.C., et al., A change in landscape: Lessons learned from abandonment of ancient Wari agricultural terraces in Southern Peru, Journal of Environmental Management (2017), http://dx.doi.org/10.1016/j.jenvman.2017.01.012