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# Fields of conflict: A political ecology approach to land and social transformation in the colonial Andes (Cuzco, Peru)

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ABSTRACT

This paper presents a political ecological framework for Geographic Information Systems (GIS) analysis to examine changes in agricultural land in ancient and early historical contexts. It raises several issues pertinent to archaeological epistemology and science, with a particular focus on the limitations of using fixed data categories to examine fluid environmental processes and ecological relationships. The paper draws on political ecological theories that define land as a social process, moving beyond economic conceptions of agricultural land that rest on productive capacity and phenomenological theories that examine the physical environment in terms of cultural perception. It combines qualitative (archival) and quantitative (archaeological) data in a GIS methodology to address how linked changes in physical land attributes and labor routines can affect regional ecologies and foment social conflict. In empirical terms, the paper traces changes from maize to wheat fields during Spanish colonization (ca. 1533-1670) in Ollantaytambo, Peru, a monumental Inca town near the capital of their empire. It reveals how ecological transformations that occurred during this century—widespread deaths throughout, abandonment of Inca fields, and introduction of European biota—in part framed conflicts between Andean people and the colonial regime, and also empowered local farmers to claim land in previously undeveloped areas.



## 1. Introduction

Archaeologists have taken markedly different approaches in their analyses of land use and social change. Political economic approaches trace the development of social complexity by documenting the varying strategies by which past people managed or adapted to resources such as rich soils, valleys, fisheries, or pastures (e.g., Algaze, 1993; Balkansky et al., 2000; Sanders et al., 1979; Spencer and Redmond, 2001). Phenomenological and hermeneutic perspectives seek to understand changes and continuities in how past people constructed the semiotic meaning or cultural significance of environmental features such as boulders, seascapes, or mountain peaks (e.g., Bender, 1993; Knappett, 2005; Tilley, 1994, 2004, 2010). Despite theoretical differences, researchers who apply these approaches often analyze land in similar ways, by classifying modern environmental types (e.g., topological variance, soil variation) and then investigating changes in the distribution of social variables (e.g., settlements) relative to those types (Dincauze, 2000: 30–34). In consequence, the physical environment is frequently cast as an independent variable or stable state, and history is rendered as change from one settlement pattern or perceptual framework to another.

Recent literature in political ecology and landscape archaeology offers an alternative approach, defining land as an active but not determining process that contributes to human social and political life (e.g., Bauer, 2015; Bauer and Kosiba 2016; Blaikie and Brookfield, 1987; Erickson, 2006; Hecht et al., 2014; Morrison, 1995, 2006, 2009). Hence, land is a generalizing term that describes a physical composite of microbes, soils, flora, terraces, and canals, which can act in particular ways and affect politics because of how they are entrained in an ecological and social context (Bauer and Kosiba, 2016). For instance, political ecologists have argued that processes of soil erosion and degradation are closely linked to social circumstances, such as inequalities in property distribution that influence farmers to continually cultivate fields without fallow seasons, and therefore exacerbate the impoverishment of both fields and people (Blaikie, 1985). By implication, soil degradation and social marginalization are inseparable aspects of the same historical process. To understand history, then, is to inquire into

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how changes in the land influence such social circumstances and the political actions they provoke (Bauer, 2015).

This paper develops an epistemological framework and methodology for understanding how land played a role in politics throughout the first century of Spanish colonization (1533–1650 CE) in Ollantaytambo, Peru, a monumental town and agricultural complex in the heartland of the Inca Empire. Several notable socio-ecological transformations occurred in Ollantaytambo and its surroundings during this time frame, including: depopulation, infrastructural failure, the introduction of European biota, a decrease in temperature, forced resettlement (*reducción*), and the establishment of individual property (Chepstow-Lusty et al., 1997; Covey and Quave, 2017; Glave and Remy, 1983; Wightman, 1990). Using the relational database capacities of Geographic Information Systems (GIS), the paper offers insights into how the shifting politics and ecology of maize (*Zea mays*) and wheat (*Triticum aestivum*) production in Ollantaytambo engendered social conflicts during these transformations. It argues that changes in fields and cultivable lands in part precipitated the social differences—between landholders, tribute payers, and workers—that both defined colonial governance and empowered Andean people.

## 2. Background: land and colonization in the Andes

The aforementioned issues with theories of the environment pervade many historical accounts of social and ecological transformation. Scholarship on the early colonial Andes, for instance, often suggests a vast gulf between Inca and Spanish visions of social and ecological order (e.g., Mayer, 2002; Murra, 1980; Ramírez, 1996; Stern, 1993), suggesting radically different cultural and economic frameworks for perceiving or valuing the environment. The Incas are cast as the imperial outgrowth of a long-established tradition of Andean land tenure rooted in a communitarian and environmental ethos whereby fields were allotted to farmers, and agricultural harvests were shared among members of a vast kin network (Murra, 1980). During Inca rule, these lands could not be exchanged and remained dedicated to a community or imperial institution, even though imperial officials annually redrew field plots (*topos*) based on changes in household sizes (Diez de San Miguel, 1964[1567]: 31–39; Kolata, 2013). This communitarian or state-mandated Andean environmental ethos, and its apparent disdain for individually-held land wealth, is often contrasted with an Iberian economic mindset driven by the notion that land is a commodity with exchange value (Mayer, 2002; Murra, 1980; Ramírez, 1996).

Though there is certainly evidence of colonial-era ecological and economic imperialism (e.g., Burns, 1999: 54–55), dichotomies between Iberian and Andean land use principles can overgeneralize colonization in terms of contrasting value systems imposed on the land (cf. Wernke, 2013). A focus on only the top-down enforcement of market principles and property rights can obscure understanding of the complicated situated processes of negotiation and conflict that, at times extended Andean or Inca ecological practices, and at other times yielded new ways of conceptualizing and working with the land (Mumford, 2012; VanValkenburgh, 2012; Wernke, 2010, 2013). These processes of negotiation and conflict would have greatly differed throughout the Andes, depending on the extent of preexisting Inca colonization and landscape modification in a particular area, and on the interests of the social actors involved, whether they were ecclesiastical authorities, former Incas, itinerant workers (*forasteros*), children of Iberian-Andean parents (*mestizos*), representatives of the Crown, etc (Wernke, 2013). Herein, we develop methods designed to throw light on the fluid socio-ecological processes that framed these colonial negotiations and conflicts. After all, the material constituents and capacities of the land also shifted during colonial times.

## 3. GIS epistemology and ecology

GIS is well-suited to analyze the interrelated materials, practices, and contexts that constitute land. GIS and similar databases are organized according to relational epistemologies that have the analytical potential to both combine and query data types at various temporal and spatial scales (Bria and DeTore, 2016). These databases can develop a framework of analysis that represents objects, loci, and fields in terms of their attributes; the assemblages of which they were parts; and the social and political processes to which they contributed. GIS studies oriented toward theory building (*sensu* Gillings, 2012) can therefore move beyond static fixed environmental data layers, and begin to inquire into the dynamic processes and entanglements that defined land and land use in the past (cf. Sturt, 2006; Wickstead, 2009).

Some archaeologists have implicitly taken steps toward such a GIS epistemology by constructing their data and objects of analysis in terms of relationships rather than attributes. This approach has long been essential to GIS predictive modeling, which distinguishes archaeological sites in terms of their land characteristics (Alexakis et al., 2010; Carrer, 2013; Ebert, 2000, 2004; Kvamme, 1992), whether soils (Fry et al., 2004), water access (Barton et al., 2010), or agricultural potential (Bolten et al., 2006). Similarly, archaeologists classify remote sensing imagery (e.g., LANDSAT) to create Normalized Difference Vegetation Indexes (NDVI), which reveal current green biomass data and can be used to extrapolate or retrodict past land conditions relative to archaeological settlement patterns (Hammer, 2014; Ullah, 2011). These approaches have been critiqued for their assumption that settlement location in the past was driven by a rational logic or adaptive strategy. But they also provide examples of how archaeologists might see beyond “the site” and its social “attributes” (e.g., size, artifact density, built features), and instead define areas of human activity in terms of interconnected socio-ecological grounds and relationships, both in and across specific spaces (see Erickson, 2006).

Other archaeologists have more explicitly sought to use GIS in an effort to build relational epistemologies for environmental analyses (Gillings, 1998, 2012, 2015, in press; Llobera, 1996, 2017). In particular, some have drawn on J.J. Gibson's (1979: 127–138) theory of affordances, which considers how the constraints and attributes of specific environments afford possibilities for action and evocations of meaning, for particular kinds of people at particular times. In applying this approach, these archaeologists seek to understand how environmental features such as stone monuments might accomodate and influence kinds of practices, experiences, and perceptions (Gillings, 2009, 2012; Jonietz and Timpf, 2015; Llobera, 1996; Preston and Wilson, 2014). In this view, the physical environment is not a definable and stable state that precedes human perception (see Gillings, 2012: 606–607; also Chemero, 2003: 182–183; Ingold, 1992; cf. Webster, 1999). Rather it is an assemblage of “relational capacities” (DeLanda, 2013: 66–67) that is constituted in situated interactions between people, things, and the land. Hence, an area with rich soils, sunlight, and water can only become “good farmland” if it is defined and physically produced as such by particular people under particular social and historical circumstances.

Drawing on these advances in archaeological GIS, the objective here is to develop a GIS epistemology to examine the human and non-human interactions that framed political action and social change in the past. Such an objective is consistent with political ecology and environmental history approaches that analyze social processes by considering the materials or organisms that mediate and to some degree motivate human action (see Appadurai, 2015 on mediation). A classic example of this approach is William Cronon's (1991) *Nature's Metropolis*, which masterfully assembles an ecological history of Chicago by closely following how the movements of and concerns about grain, wood, and cattle lay at the foundations of the city and its geography of inequality. Taking a cue from Cronon, we concentrate on the social and political roles of cereal crops in the colonial Andes. These crops and their growing conditions did not any way *determine* human action, but they played a part in the colonial encounter because they were things of interest and value on which political problems and social concerns often pivoted.

## 4. Materials and methods

### 4.1. Setting

The study focuses on Ollantaytambo, an Inca monumental town and estate situated 42.5 aerial kilometers from the imperial capital city of Cuzco (Figs. 1–3). Current evidence suggests that Ollantaytambo was established at the height of Inca rule in the 1400s (Kosiba, 2015). Similar to other estates in Cuzco, such as Machu Picchu and Chinchero, Ollantaytambo's massive stone structures and terraces were meant to embody and denote an Inca imperial ideology of environmental and social order (e.g., Nair, 2015; Niles, 1999). The carefully planned agrarian environment of Ollantaytambo extended along at least an 12 km corridor of the Vilcanota Valley and encompassed two neighboring secondary valleys (Patacancha and Socma) (Kosiba, 2015: 174). Many of the town's fields were shaped into intricate designs that seemingly manifested Inca prowess to move the earth (Fig. 4). Archival documents show that the land was also partitioned to position Inca nobles and their allies near the center in the fields of Pomatallis (*Cuzco Ayllu*, *Chinchaysuyu Ayllu*), while relegating many local people (*Araccama Ayllu*) and resettled laborers (*yanacona*, *mitmaqkuna*) to fields across the river, or outside of the central area of terraces (Kosiba forthcoming).

But the massive Inca complex at Ollantaytambo was short-lived. Still under construction during the Spanish invasion, the town became a site of conflict in 1537, when some of the Incas quickly converted its facades into defensive features in an effort to drive off the Spaniards and their allies. Though successful in this endeavor, these Incas retreated. The Spaniard Hernando Pizarro then took charge of the town as his *encomienda*, but preserved much of the Inca field allocation and governing order including the distribution of land plots among social groups (ayllus) and their Andean leaders (*kurakas*) (Biblioteca Nacional del Perú [BNP]; F: Manuscritos; B-1030, f: 20, 35V, 64V, 165V (1629)). Despite continuity in the town's social and spatial organization, its composition drastically changed. In the late sixteenth century, the indigenous population of Ollantaytambo sharply declined as many died from diseases, others joined the Inca rebellion, and still others fled (Fig. 5). Indeed, in 1628, inhabitants of the town estimated a drop from 80 to 20 tribute-paying adults (BNP, F: Manuscritos; B-1030, F. 33-33V (1629)), though historians cite a more conservative number for population diminution (Glave and Remy, 1983). The deaths affected the physical environment, and many fields lay abandoned because there were not enough people to till them (see below). Also, they occurred at the same time as other socio-ecological transformations. The Little Ice Age (ca. 1550–1850 CE) decreased temperatures and altered the growth conditions of major crops, such as maize (e.g., Brooks, 1998; Hastorf, 1993). And, Andean farmers near Ollantaytambo faced tribute requirements (*tasas*) from the Toledan government—to be paid in maize, wheat, and potatoes—and often had to modify existing fields and labor schedules to introduce wheat (Covey and Quave, 2017: 283). Hence, in many places there was more land than labor, in other cases extant fields could no longer produce harvests, and in still other cases new crops and

**Fig. 1.** Ollantaytambo, viewed from a settlement once-occupied by farmers who worked its fields.

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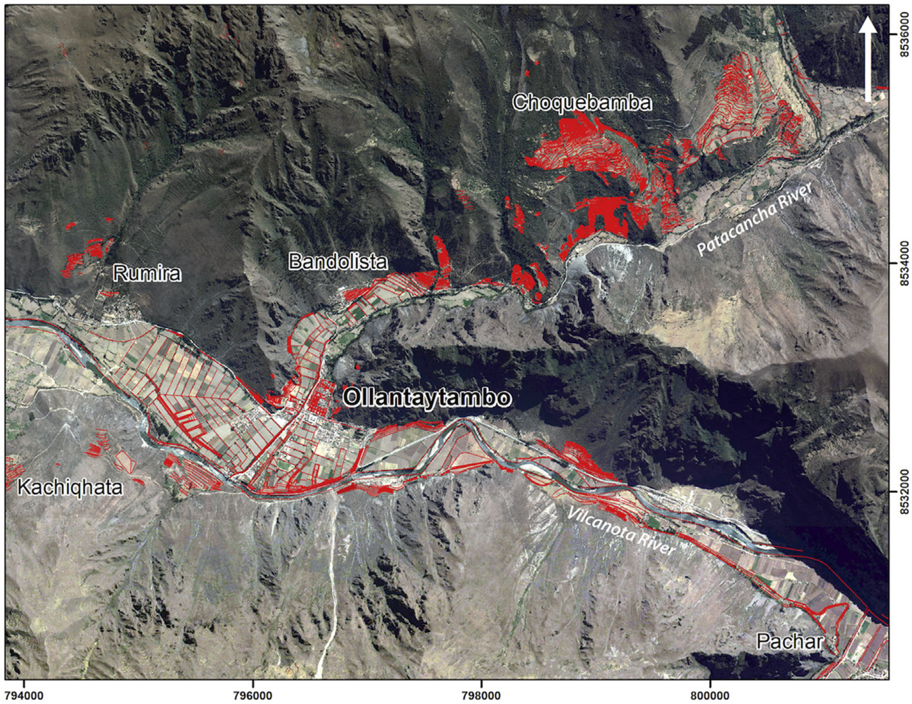


**Fig. 2.** Ollantaytambo was a vast agrarian landscape and urban complex comprising settlements, canals, and terraced fields (red lines). Photograph courtesy of Google Earth Pro (2016). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

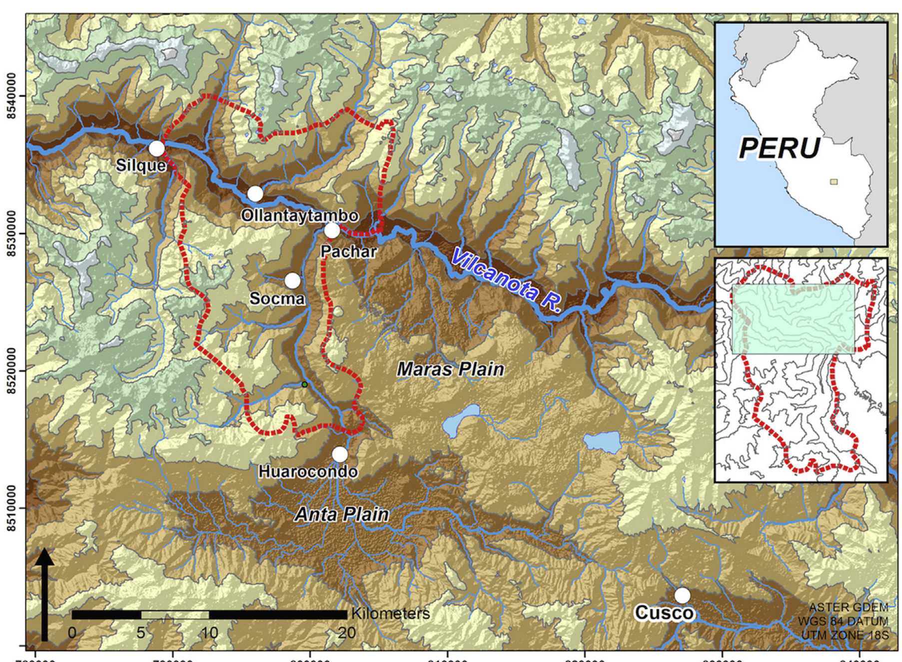


**Fig. 3.** Location of Ollantaytambo and the survey area (red-dashed line). Top inset shows the location of the Cusco study area. Bottom inset shows the approximate extent of the Inca estate at Ollantaytambo (green box). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

perhaps land boundaries had to be developed. Our analysis adds new information to these historical accounts, and provides comparative insights for studies of Inca and colonial ecologies in the highland Andes (e.g., Wernke, 2010, 2013; Zimmerer, 1993), by tracing growth environments for maize and wheat, mapping field boundaries, and comparing these to archaeological and historical data.

### 4.2. Data

Archaeological data are derived from Kosiba's (2005–2008) full-coverage survey of the Ollantaytambo region (200 km$^2$), which recorded multiple socio-ecological variables for each find or site (e.g., artifacts, buildings, erosion, water sources) (Kosiba, 2010: 35–39) (Fig. 3). The survey employed a modified distributional


**Fig. 4.** Geometric and monumental terraces in Ollantaytambo.

approach (Ebert, 1992), with team members spaced 20–40 m (depending on terrain) to record all “finds” in which they encountered three or more artifacts at a distance of more than 50 $m^2$ from similar finds. “Sites” were finds with more than five artifacts of different types. In 2011–2013, Kosiba augmented these data, using a differential GPS to document Ollantaytambo's agrarian infrastructure, including: terraces, canals, reservoirs, and colonial threshing platforms and mills (Fig. 2).

Historical data are derived from archival studies in Cuzco and Lima, in particular a 1628 land repartition document for Ollantaytambo (BNP; Fondo Manuscritos; B-1030 [1629]). This document contains the only known copy of the original 1595 land partition for Ollantaytambo, and thus offers a rare, detailed and diachronic, perspective on land use, demography, and fields during early colonization. Kosiba and Jesús Galiano Blanco, a Cuzco historian, transcribed and translated the document. Kosiba and Hunter performed the GIS analyses.

### 4.3. Analyses

The regional GIS study sought to identify areas where maize and wheat could have been cultivated near Ollantaytambo. These were the highest valued cultigens in Colonial Cuzco, though maize brought a higher price—for example, a price listed in a litigation document for Pachar was 25 pesos for maize and 10 pesos for wheat, given a comparable measure of land/seed (*fanegada/fanega*) (Archivo Regional de Cuzco (ARC), F: Colegio de Ciencias L. 47, f: 105V). Future analyses will consider other biota. The study employed ArcMap 10.5 to examine survey data; aerial photographs from the Peruvian Instituto Geográfico Militar; and remote sensing images (LANDSAT and Advanced Spaceborne Thermal Emission and Reflection Radiometer Global Digital Elevation Model Version 2 [ASTER GDEM v2]). These data were entered into GIS raster math functions (times) to reclassify ASTER DEMs and create representations of potential maize (MPT) and wheat production terrain (WPT)

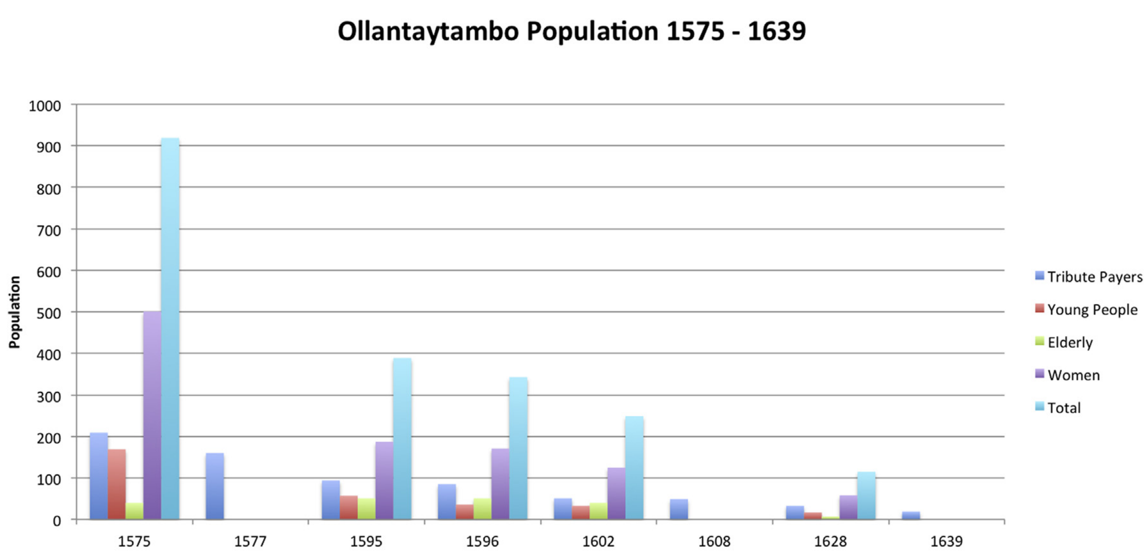


**Fig. 5.** Graph showing population loss in Ollantaytambo during early colonization. Data are derived from Glave and Remy's (1983) study and archival documents (BNP), Fondo: Manuscritos, Document: B-1030, 1629.

**Table 1**
Variables used to represent potential maize and wheat production areas in the Andes during two phases of the Little Ice Age.

| Crop and Phase | Elevation | Slope | Sunlight | Water |
|---|---|---|---|---|
| MPT1 LIA1 (1300–1550) | <3430 m | <6.84° | >6 h | 100 m |
| MPT2 LIA1 (1300–1550) | <3430 m | 6.84–11.31° | >6 h | 100 m |
| MPT1 LIA2 (1550–1850) | <3350 m | <6.84° | >6 h | 100 m |
| MPT2 LIA2 (1550–1850) | <3350 m | 6.84–11.31° | >6 h | 100 m |
| WPT1 LIA2 (1550–1850) | <3150 m | <45° | >6 h | 100 m |
| WPT2 LIA2 (1550–1850) | 3150-3750 m | <45° | >6 h | 100 m |

(process described below). Growth requirements of maize and wheat were derived from informal interviews with Andean farmers in Ollantaytambo and Kirkas, Peru, as well as established studies.

Maize requires a mellow slope (<11.31°), relatively low elevation, full sunlight (6+hours), controlled irrigation, soil drainage (to prevent root waterlogging), and frost protection (FAO, 2015; Denevan, 2001). Temperature is lower and frosts are more common at higher altitudes, hence highland Andean maize fields are usually situated below 3500masl (Brooks, 1998; Seltzer and Hastorf, 1990). Some Andean farmers grow maize at higher elevations in narrow valleys or near lakes, which can mitigate frosts , and a future study of ours will examine the effects of these contexts. Here, we used the 3500 m value as the high mark for potential maize production, adjusting it to reflect the Little Ice Age (LIA). The first phase of the LIA (ca. 1250–1550 CE, LIA1) resulted in a temperature drop of about 0.6 °C and an estimated 70 m decrease in the elevation of maize fields; the second phase (ca. 1550–1850 CE, LIA2) reduced temperature by an additional 1–2 °C, resulting in an estimated 80 m elevation decrease in potential maize fields (Brooks, 1998; Hastorf, 1993; Rabatel et al., 2008; Thompson and Moseley-Thompson, 1989; Wernke, 2010). Our interviews and the aforementioned sources emphasize that slope is of major concern with maize agriculture, hence the study defined two kinds of maize land to reflect *ideal* (MPT1, Slope <6.84°) and *sufficient* (MPT2, Slope <11.31°) conditions (Table 1) (Vaught, 1983). Finally, maize requires a regular water source. The study defined MPT if it was within 100 m of a stable source (spring, stream, lake), because this is about the maximum distance which modern farmers said they will dig irrigation ditches for their fields.

The study repeated these steps to define WPT, changing slope and elevation variables relative to growth requirements. In comparison with maize, wheat is a hardier crop that can withstand colder temperatures, grow at higher altitudes, flourish on steeper slopes, and prosper in fields without much or any drainage infrastructure (Gade, 1975; Smith Sommers, 1949). Studies and farmers indicate that full sunlight is most important toward the *end* of the wheat production season, in Cuzco from March-May, when plants have begun mature development stages 4–6 (booting to anthesis) (Zadoks et al., 1974). Though wheat is generally hardier than maize, it is important to note that some researchers suggest that only newer wheat strains allowed farmers to plant at higher elevations in the Andes, while earlier wheat cultivars grew better at low altitudes of about 3300masl (Gade, 1975: 138). While many documents indicate farmers planted wheat at altitudes higher than 3300 during the colonial era (see below, regarding Markurary), we recognize that elevation was likely more of a mitigating factor than slope during the period of the study. Taking into account the effects of the LIA phase 2, we therefore coded cells as *ideal* areas for wheat production (WPT1) if between 2500 and 3150masl and *sufficient* areas (WPT2) were between 3150 and 3750masl (Table 1) (Smith Sommers, 1949).

Sun conditions for this time period were estimated using sun azimuth and altitude data from the National Oceanic and Atmospheric Administration Earth System Research Laboratory (NOAA ESRL), for September 1, 1550 and April 1, 1551. The dates were chosen because Andean farmers stated that full sunlight is most important for maize during the primary and final stages of plant growth, and September is about one month after planting while April is a month prior to harvest (Ambrocio Ariza Quispe, Abelardo Quispe Hermoza, Adrian Huarco Quispe, and Mario Quispe Hermoza, personal communication, May 2, 2017). The April date corresponds to wheat's growth cycle, which requires full sunlight during maturation, in the Andes from mid-March until harvest in mid-July. Sunlight data for September and April are almost identical, because the sun follows a similar course during those months. Though the sun shifts course from late November until mid-February, this shift does not alter the sunlight data for this study because these months correspond to the highland wet season, when the sun rarely breaks through the cloud cover. Using historical azimuth and altitude data, hillshade rasters were created for every daylight hour from 7am to 4pm (Fig. 6). For each raster (and hour), cell values were reclassified into three categories using Jenks, with the high value category representing full sunlight. The values

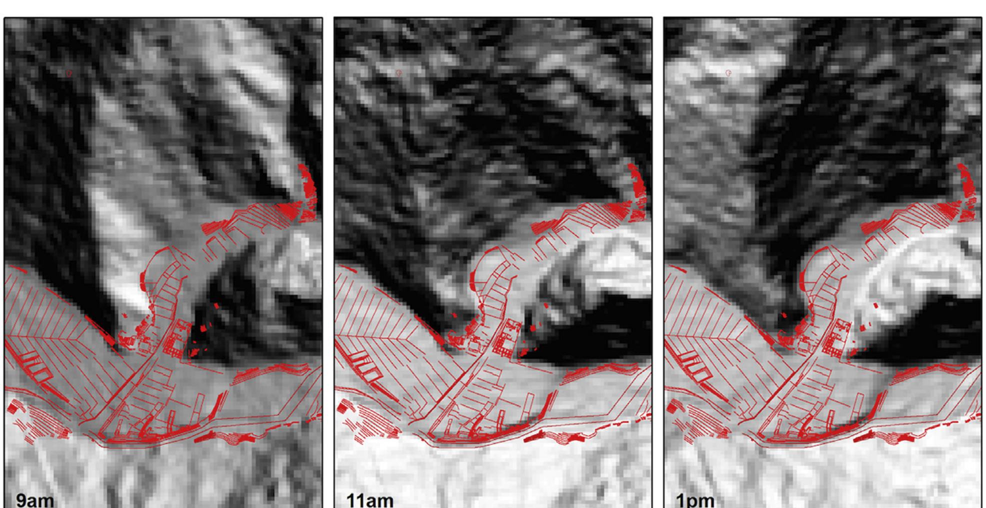


**Fig. 6.** Maps demonstrating the method for quantifying sunlight at different times and days, here showing the center of Ollantaytambo on April 1, 1551 at 9a.m., 11a.m., and 1p.m..

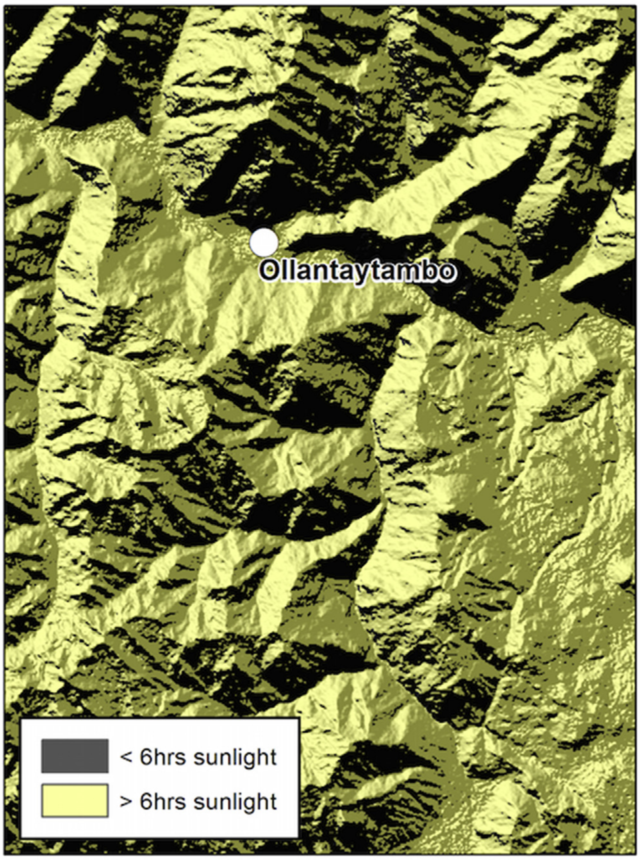


**Fig. 7.** Sunlight maps from the morning and afternoon were merged to record all areas that receive "full" (>6h) sunlight that would have been necessary for producing grain crops, such as maize and wheat.

for the high category varied according to time, so an average was derived for the lowest numbers of the high category for all rasters, and then used to represent full sunlight (6hrs+) on that day—178.5 for September and 181.2 for April (Fig. 7). All rasters were reclassified into two categories, full sun and less than full sun. Raster math was employed to combine morning (7–10am), midday (11am-1pm), and afternoon (2–4pm) data, revealing lands in full (>6hrs) and partial (<6hrs) sunlight. The resulting rasters were combined with slope, elevation, and water source data to generate the MPT and WPT representations.

These agricultural representations required grounding through GIS analysis of historical data. In 2014 and 2017, toponyms were recorded in Quechua and matched to the 1595 and 1628 documents. Toponyms allowed for analysis of the geography of field abandonment, property claims, and crop cultivation in Ollantaytambo and its immediate surroundings. Informants were asked to identify common and other names for fields but were not asked if they recognized names from documents, which can generate biased responses. The study recorded two kinds of toponyms: broader field areas (e.g., Rimacpampa) and plots (*topos*) within those field areas (e.g., a *topo* in Rimacpampa). Using these toponyms in tandem with enduring features such as named arroyos, walls, roads, or terraces, the study identified 52.7% (19/36) of the field areas, and the approximate location of 71.9% (404.5/562.5) plots (*topos*). The area of a *topo* in these documents is listed as 96 × 48 *varas reales* (a Spanish measure equivalent to about 0.83 m, meaning each *topo* was about 0.32 ha), hence the analysis considered changes in agriculture for 129.4 ha of land in a total area of 180 ha.

## 5. Results

The analysis found significant differences in MPT and WPT, in particular a much larger and more variegated growing area for

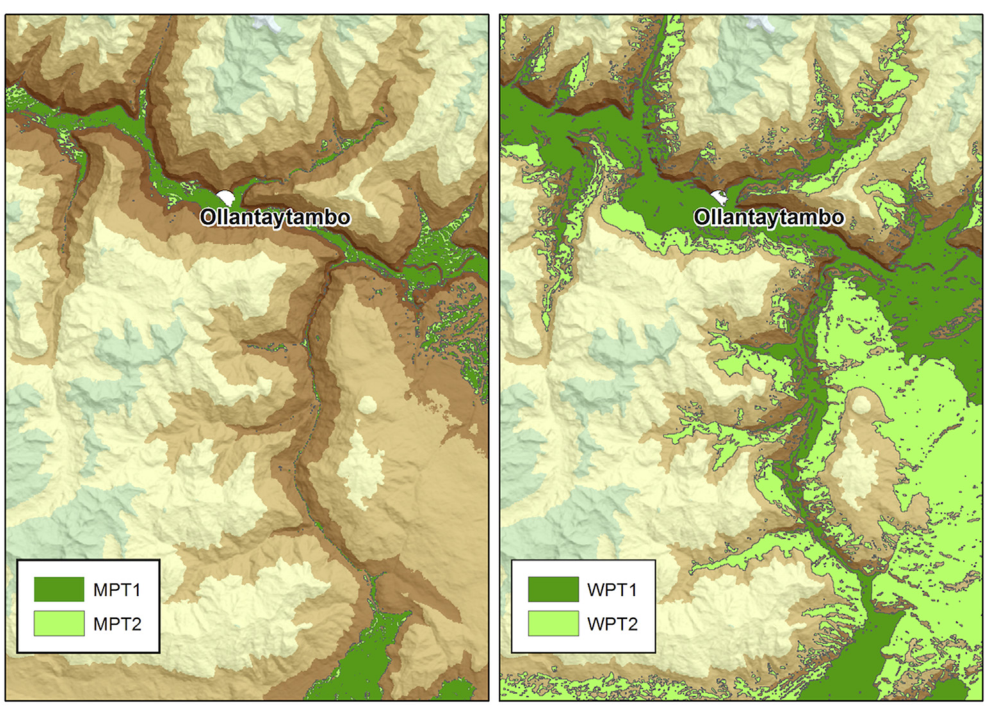


**Fig. 8.** Sunlight rasters were combined with other data layers pertaining to water availability, slope, and elevation in an effort to map the minimum growth requirements of maize and wheat production in this area. These data are not a model or reconstruction of agriculture; rather they provide a foundation for understanding the socio-ecological requirements of grain production in terms of infrastructure and labor.

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**Table 2**
Potential maize and wheat terrain (hectares) within a 5 km buffer of Ollantaytambo and the data frame for Fig. 8.

| Crop and Phase | Ollantaytambo (5 km) area | Data Frame area |
|---|---|---|
| MPT1 LIA1 (1300–1550) | 489.5 | 3010.4 |
| MPT2 LIA1 (1300–1550) | 168.7 | 1431.4 |
| MPT1 LIA2 (1550–1850) | 488.1 | 2720.6 |
| MPT2 LIA2 (1550–1850) | 165.9 | 1132.1 |
| WPT1 LIA2 (1550–1850) | 1911.4 | 8334.6 |
| WPT2 LIA2 (1550–1850) | 935.5 | 12,957.5 |

wheat (Fig. 8; Table 2). The analysis compared the MPT and WPT results to our NDVI map from LANDSAT data, and revealed that the vast majority of MPT and WPT correspond to current green biomass, though there are many areas of MPT and WPT that are not presently under cultivation. This test demonstrated some limitations of NDVI, which often reflects market prices and current water distribution more than crop requirements. Though our approach is also limited in some ways, the MPT and WPT data illustrate that wheat could have been planted in areas that could never have supported maize, or in areas that could no longer support maize because of decreased labor or temperature. The MPT data also show the effects of the LIA, demonstrating dramatic reductions in the quantity of potential maize land in particular areas. Future iterations will consider changes in labor power and intensification techniques, such as fertilization.

### 5.1. *Inca agriculture*

The results provide insights into land conditions in Ollantaytambo during Inca ascendancy (ca. 1350–1533 C.E.). The valley floor in which the Incas built Ollantaytambo offered prime conditions for maize production. It was a low, relatively flat valley that received full sun throughout the entire growing season. But these conditions required engineering. Before Ollantaytambo, the valley floor was also an alluvial floodplain that was regularly inundated, resulting in waterlogged or poorly drained soils (Kosiba n.d.). The Incas channelized approximately 17.26 km of the Vilcanota and Patacancha Rivers, and built drainage and irrigation infrastructure for 252ha of fields (Fig. 9). GPS mapping revealed this system comprised approximately 376 km of terraces and canals. The majority (82.1%, or 635.3 of 773.45ha) of the Ollantaytambo area's terrace complexes were situated in or next to MPT areas, suggesting that the fields extended areas with suitable sunlight and slope, rather than creating new lands outside of the maize requirements (Kosiba's forthcoming publications provide more detail on the Inca system). The system required coordinated construction and maintenance labor—at least 3233.6 days of labor for a one hundred-person team (based on Guillet's 1987:412 data).

The MPT and survey data reveal different socio-ecological contexts in the valley and on the secondary valley hillsides, and these differences had consequences for labor scheduling and colonial era transformations. Inca infrastructure in the valley created dependencies among adjoining fields and farming communities. Canals distributed water along the valley floor, requiring farmers to sequentially schedule irrigation and planting from one field to the next. A rupture in one of these canals, for instance the 11 km canal of Kulluspukio, could affect fields across the entire valley. These valley canals and fields constituted a contiguous tract of land that worked precisely because of carefully synchronized social dependencies between people, water, and plants. The 1595 document suggests that these inter-field dependencies carried over into the colonial era, when fields were named according to their own caretaker, *as well as* caretakers of neighboring fields.

Hillside fields had different ecological conditions and labor requirements. Hillsides were suitable growth environments for small-scale maize farming because, without much added labor, they drained excess water and created updrafts that prevented cold air and frosts from settling on the slope (Hastorf, 1993: 103). In the survey zone, hillside fields were small (mean: 10.48ha; range: 1.4–24.6ha) and dispersed, with short terraces (~1 m), suggesting localized management and dependencies. The hillside fields may have been more self-sufficient than the valley because each terrace system relied on vertical water flow from a particular highland lake

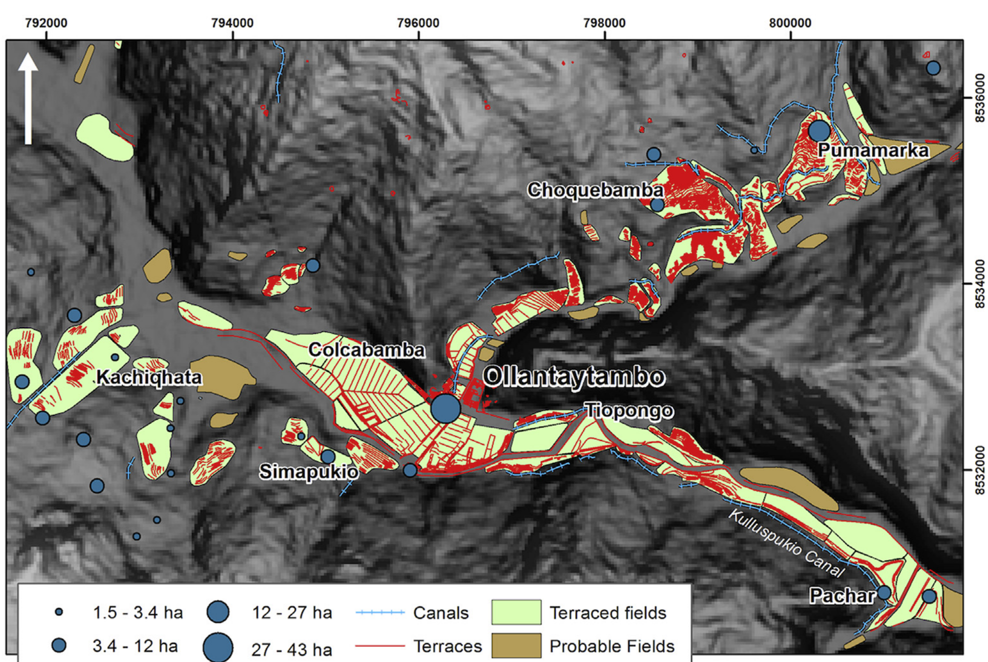


**Fig. 9.** The results of survey and GIS land analysis, illustrating the vast infrastructure of agricultural production during Inca rule.

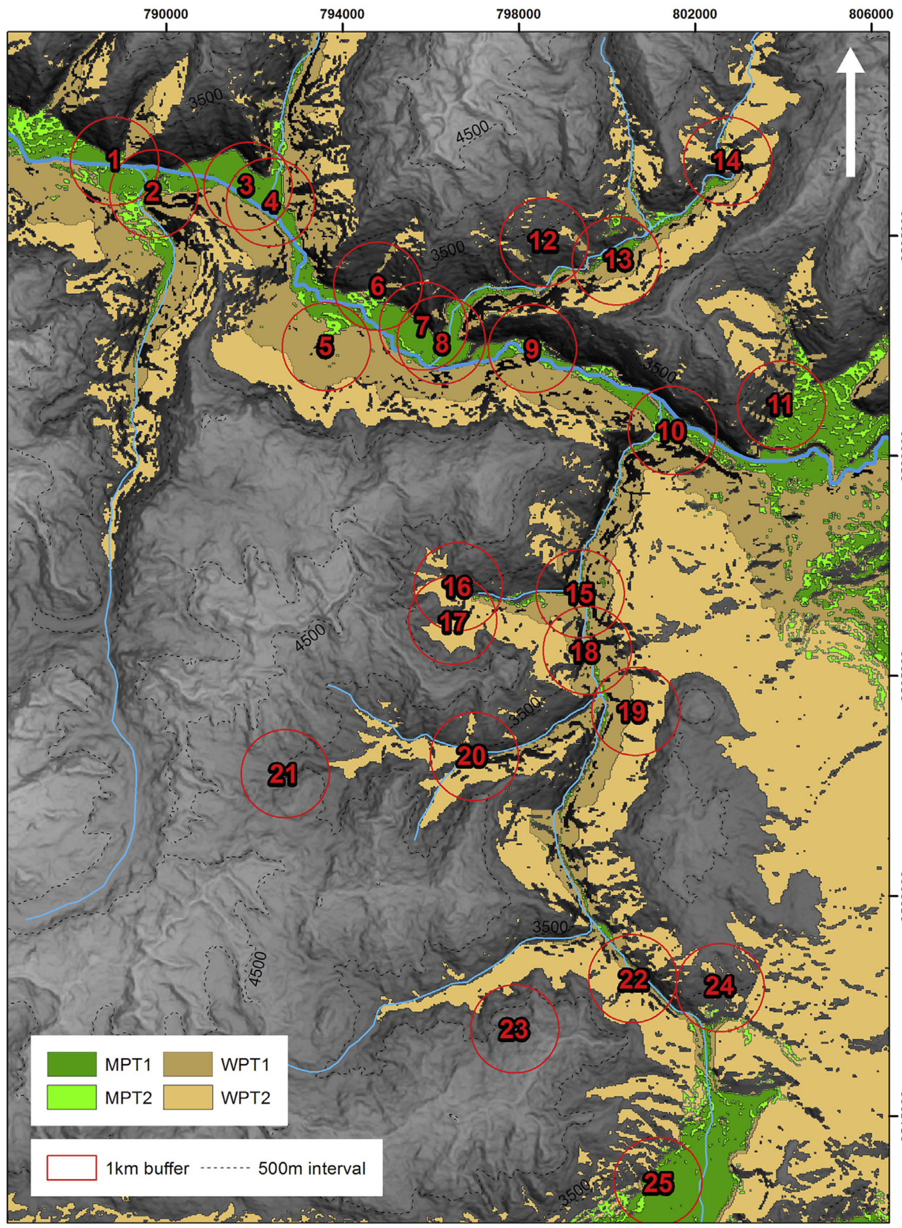


**Fig. 10.** Map showing the areas of early colonial settlement relative to potential maize and wheat production terrain. 1 km buffers around each settlement provide a measure of cultivable land. See Table 3 for details. The map and table reveal that haciendas and towns were often situated in areas with adequate lands for a mixed maize and wheat agricultural economy.

or spring, rather than canals that delivered water to multiple contiguous fields. Overall, these distinct hillside and valley floor ecological contexts would set the stage for changes in the land during early colonization.

### 5.2. Colonial era changes in the land

The MPT and WPT data shed light on socio-ecological processes during the colonial era. The analyses indicate a decrease in MPT during LIA2, at the same time that diseases caused widespread deaths among the indigenous population (Glave and Remy, 1983: 21), and field abandonments increased. The Inca system remained, but as witnesses in early colonial litigations stated, particular terraces and structures lay in ruins (ARC, F: Benficencia Publica, L: 46, f. 435v [1568–1722]). Many fields could no longer operate as a coordinated maize system, so in some cases they were repurposed for a mixed grain economy of wheat and maize cultivation. Some farmers at this time rotated wheat and other crops into maize fields, or planted wheat at the margins of already established fields (BNP; F: Manuscritos, B-1030, f. 32V, 36V, 42–43, 244, 258 (1629)), instituting a schedule that is often employed in the contemporary Andes (Hastorf, 1993; Mayer, 2002). Settlement pattern data demonstrate that larger colonial towns and plantations (*haciendas*) were situated in areas with high quantities of both MPT and WPT (Fig. 10, Table 3), perhaps to develop mixed grain production. This is not to imply intentional settlement location; indeed, colonial settlement was influenced by many factors, including the location of Inca terraces and alliances with Inca families. But these data suggest that changes in labor and cultivable land played social roles in defining the socio-ecological contexts of new institutions and new

**Table 3**
MPT and WPT within 1 km of Colonial era settlements listed in documents.

| Site | Type | Map # | MPT1 LIA1 | MPT2 LIA2 | WPT1 | WPT2 | Terraces |
|---|---|---|---|---|---|---|---|
| Anapawa | Hamlet | 20 | 0 | 0.09 | 4.55 | 127.04 | 1.24 |
| Andenpata | Hamlet | 11 | 93.77 | 43.5 | 153.59 | 7.756 | 1.53 |
| Chiara | Hamlet | 21 | 0 | 0 | 0 | 0.11 | 0 |
| Chilca | Hacienda | 1 | 102.77 | 40.39 | 204.5 | 0 | 51.54 |
| Choquebamba | Farm | 12 | 3.33 | 1.25 | 27.88 | 30.87 | 98.66 |
| Compone | Hacienda | 7 | 156.51 | 20.3 | 214.3 | 0.31 | 186.94 |
| Corimarka | Inca elite | 16 | 0.763 | 2.4 | 10.9 | 108.36 | 19.79 |
| Huamanmarka | Spanish elite | 25 | 4.19 | 3.34 | 44.82 | 177.15 | 8.24 |
| Huarocondo | Town | 22 | 179.96 | 13.69 | 200.36 | 45.54 | 11.87 |
| Kachiqhata | Village | 5 | 35.32 | 23.73 | 292.8 | 16.5 | 43.18 |
| Kanaqchimpa | Village | 24 | 3.38 | 3.63 | 15.81 | 87.42 | 0 |
| Markaqocha | Village | 14 | 9.05 | 3.72 | 29.4 | 170.57 | 1.72 |
| Markuray | Hamlet | 17 | 0.47 | 2.035 | 8.3 | 142.14 | 4.51 |
| Mascabamba | Church land | 9 | 46.89 | 16.4 | 154.7 | 13.2 | 108.67 |
| Murispampa | Village | 13 | 19.55 | 15.22 | 118.56 | 85.39 | 72.79 |
| Ollantaytambo | Town | 8 | 139.35 | 21.41 | 228 | 0 | 244.84 |
| Pachar | Hacienda | 10 | 65.09 | 26.43 | 170.54 | 4.19 | 56.62 |
| Phiri | Hacienda | 4 | 103.18 | 23.51 | 270.4 | 0 | 19.19 |
| Pomatallis | Village | 18 | 4.52 | 5.03 | 161.23 | 72.55 | 0 |
| Qolqapata | Hamlet | 19 | 3.26 | 4.31 | 107 | 125.65 | 0 |
| Racca | Village | 15 | 5.78 | 11.57 | 180.4 | 40.35 | 27.07 |
| Rumira | Village | 6 | 67.04 | 26.19 | 118.17 | 1.23 | 57.12 |
| Sambor | Hamlet | 23 | 0 | 0 | 0 | 8.37 | 0 |
| Silque | Hacienda | 2 | 93.94 | 56.29 | 229.73 | 0.54 | 9.87 |
| Tanccac | Hacienda | 3 | 135.87 | 25.09 | 265.04 | 0 | 12.14 |

kinds of conflict.

In particular, changes in labor and land affected the valley floor of Ollantaytambo. While these lands did not lose MPT, a more pressing issue was the loss of Inca period labor to maintain infrastructure. The 1628 document reveals that a minimum of 249 and a maximum of 323.5 *topos* of land in Ollantaytambo lay vacant (maximum number includes people missing from town at the time of re-partition). The toponym survey demonstrated that field abandonments were widespread in all parts of Ollantaytambo's valley field system, which would have potentially led to fractures in infrastructure at any given place or time, or severe disruption in particular areas, leading to changes in maize agriculture (Fig. 11, Table 4). But WPT data reveal large patches of cultivable wheat land in areas that adjoin and overlook the Inca terrace system. The 1628 document verifies that these lands played a part in the reorganization of fields and economic practices: A 1628 witness states that the only new land boundaries corresponded to rain-fed wheat fields (*tierras de trigo de temporal*) on the slopes above the town (BNP; F: Manuscritos; B-1030; f. 23V-24; see also similar evidence in Covey and Quave 2017). This statement suggests that farmers innovated new agricultural practices and schedules during a time of social and climate change that affected Ollantaytambo's intricate system of terraces.

The data also demonstrate how changes in the land affected

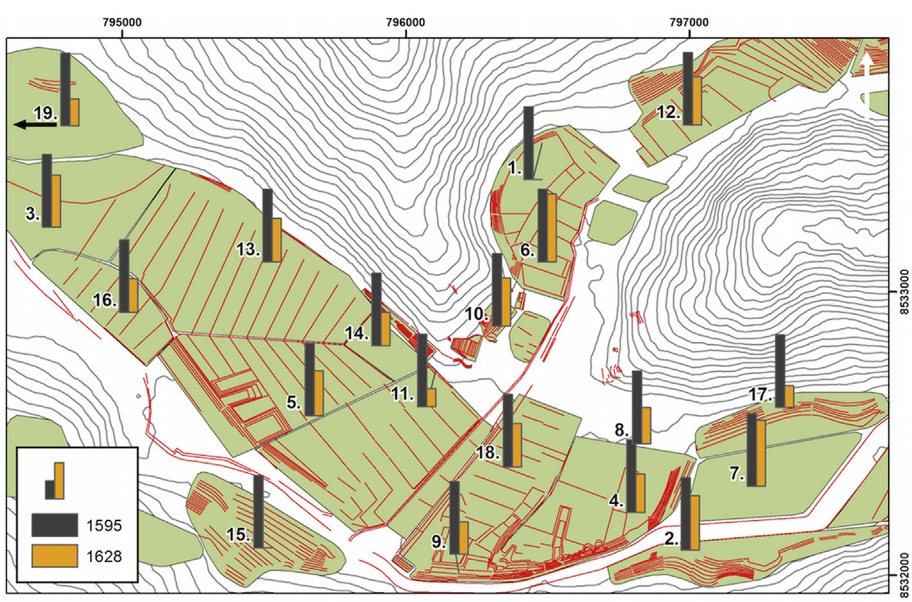


**Fig. 11.** A preliminary study of land use change at Ollantaytambo. Bar graphs illustrate differences in the quantity of identified plots (*topos*) that were under cultivation in 1595 and 1628. Each number corresponds to a field area, and data in Table 4.

**Table 4**
The maximum amount of fields that were under cultivation in 1595 and 1628, and percent change (corresponds to Fig. 11).

| Name | Map# | Topos 1595 | Topos 1628 | Percent Change |
|---|---|---|---|---|
| Alsabamba | 1 | 9 | 0 | −100 |
| Choquepata | 2 | 16 | 12 | −25 |
| Colcabamba | 3 | 35 | 25 | −28.6 |
| Guaranguay | 4 | 17 | 9 | −47.1 |
| Guatabamba | 5 | 21 | 13 | −38.1 |
| Llanguarqui | 6 | 16 | 15 | −6.3 |
| Mascabamba | 7 | 21 | 20 | −4.8 |
| Palpancaro | 8 | 3 | 2 | −33.3 |
| Pomacchupan | 9 | 6.5 | 1.5 | −76.9 |
| Pomatallis | 10 | 42 | 28 | −33.3 |
| Quinchapata | 11 | 12 | 3 | −75 |
| Quincoguachinca | 12 | 39 | 26 | −33.3 |
| Quishauarpata | 13 | 14.5 | 9 | −37.9 |
| Rimacpampa | 14 | 26 | 12 | −53.8 |
| Simapuqio | 15 | 9 | 0 | −100 |
| Tambobamba | 16 | 26 | 12 | −53.8 |
| Tiopongo | 17 | 20 | 6 | −70 |
| Paucarchaca | 18 | 9.5 | 6 | −36.8 |
| Surayco (to west) | 19 | 62 | 23 | −62.9 |

**Table 5**
Relative changes in MPT in secondary valleys and the Vilcanota valley floor.

| Crop and Phase | Secondary Valleys (ha) | Vilcanota Valley Floor (ha) |
|---|---|---|
| MPT 1300-1550 | 1712.74 | 2167.44 |
| MPT 1550-1850 | 1324.87 | 2163.25 |
| Percent Change | −22.7% | −0.19% |

secondary valleys. During the second phase of the LIA, MPT land all but disappeared in smaller valleys such as Socma (Fig. 12). That is, in comparison, there was a 22.7% decrease of MPT in the secondary valleys of the study area, but only a 0.19% decrease in the Vilcanota valley floor (Table 5), which suggests that socio-ecological changes differentially influenced land use and politics in these environments. Despite the loss of MPT, extensive patches of land could support wheat in the secondary valleys, and these were often located in places where maize previously could not have been produced. Comparable studies have presented colonial documentary sources stating hillsides became attractive areas for wheat production because a smaller labor force could cultivate them, in comparison with maize (Covey and Quave, 2017: 302). In our survey

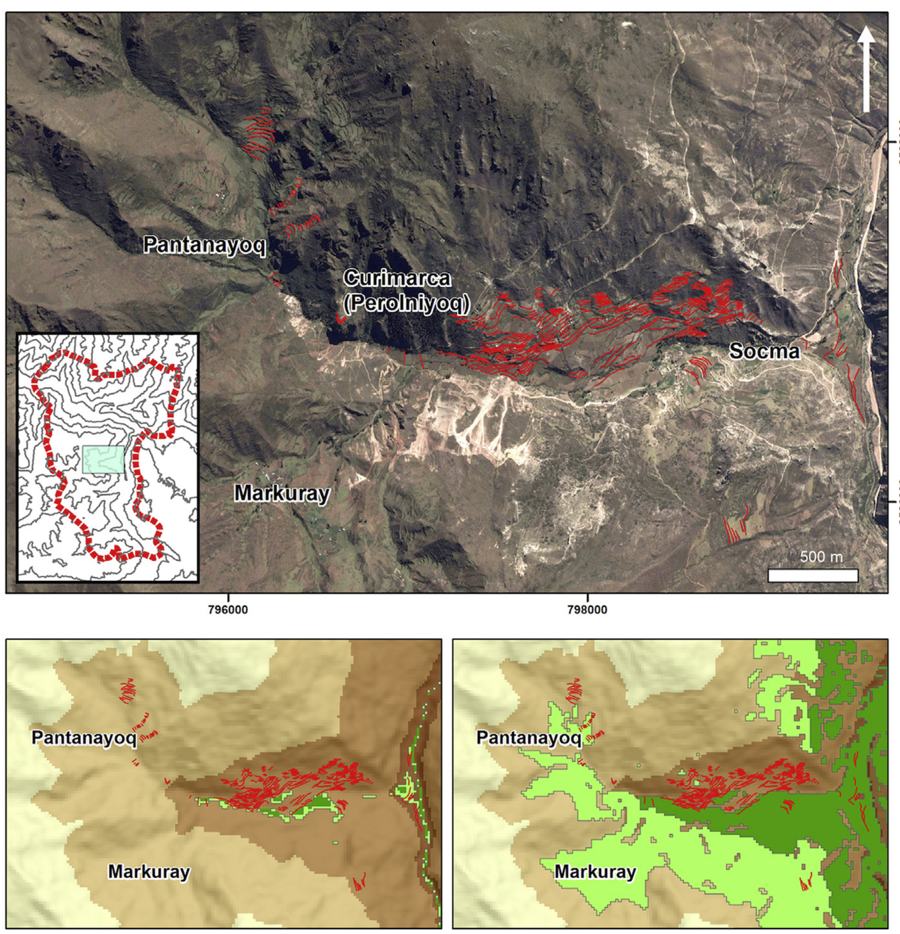


**Fig. 12.** (Top) The Socma Valley, at the southern margin of Ollantaytambo. The inset map shows the location, and the photograph reveals a limited amount of Inca terracing and infrastructure, largely centered on the monumental site of Curimarca. Photograph courtesy of Google Earth Pro (2016). (Bottom) Socma witnessed drastic changes in agricultural potential, as small upland ravines such as Markuray and Pantanyoq became areas suitable for grain cultivation. These changes in the land created possibilities for indigenous Andean farmers to develop small independent plots, outside of the colonial regime's purview.

region, documents and archaeological data also reveal that secondary valleys were places where former Incas and Andean farmers came into conflict over land use (see discussion; ARC, F: Colegio de Ciencias L. 47, f. 2–19V).

## 6. Discussion

These analyses bring to light several points that would have remained opaque if the study had narrowly focused on land as if it were a stable state.

Changes in crop growth and agricultural labor in the valley floor in part influenced the development and nucleation of landholdings in and around Ollantaytambo. Wheat had a different schedule and growing environment, so even a diminished labor force could care for adjacent or nearby maize and wheat fields (*chacaras de maíz y trigo*), as do many contemporary Andean farmers. In the beginning of the seventeenth century, population decline affected the horizontal dependencies of the Inca system in the valley floor, leading to infrastructural failures. Many farmers and land managers near the town began to rotate wheat into maize fields and adjoining areas. Some farmers expanded their holdings by cultivating rain-fed wheat fields (*trigo de temporal*) on steeper slopes with patches of WPT, in areas such as Bandolista or Rumira (BNP; F: Manuscritos; B-1030; f. 23V-24). Other, more wealthy, landholders explicitly developed a mixed grain economy. Indeed, following the 1628 re-partition, enterprising Spaniards such as Pedro de Soria immediately sought to acquire contiguous vacant lands and develop them as *chacaras de maíz y trigo*. These lands were listed as maize fields in 1595, but after Soria's purchase they were converted to maize/wheat and became the grounds of a rich hacienda (see Glave and Remy, 1983).

Furthermore, the data from the secondary valleys reveal how indigenous Andeans sought to bolster their social position via land claims during early colonization. Litigation documents from 1567-1654 offer insights into farmers' actions and land use practices during colonization. During these decades, small-scale farmers could provide for their tribute payment and subsistence by cultivating WPT in secondary valleys such as Socma, areas that did not at first interest the valley's landholders. In Socma, terraces at Curimarca had been Inca land, and were still claimed by former Incas well into the seventeenth century (Fig. 12) (ARC; Benficencia Publica L. 46; f. 9–19V; Glave and Remy, 1983: 11–12). But documents and Inca/colonial architecture show that the *Huicho*, former worker-servants (*yanacona*) of the Incas, gained property by planting rain-fed wheat fields (*trigo de temporal*) in ravines and hillsides of Socma such as Markuray that had not previously been cultivated (Fig. 11) (ARC; F: Benficencia Publica L. 46; f. 9–10; 16–17; 57–68). The WPT data suggests that they were able to claim and cultivate these lands, in particular, because of the patchy and undulating topography, which means that they would have been outside of the prevailing definitions of "good" land.

Finally, these different land use practices—hillside wheat cultivation by Andean farmers and valley floor maize-wheat production for extensive landowners—came into conflict in the early colonial era. For example, in 1648 the Huicho *yanacona* in Socma complained of harassment and threats from nearby hacienda workers at Silque, who had stolen the grain and tools of the smallholding Andean farmers (Glave and Remy, 1983: 98–99). The hacienda owner was none other than Pedro de Soria, who after developing his extensive maize and wheat fields in the valley, now sought to force the Huicho smallholders into abandoning the hillsides and working in the valley floor where labor was needed. Hence, the MPT and WPT analysis shows how the land itself, and changes in crop requirements, played a large part in conditioning this colonial social drama in which landholders of Spanish descent sought to divest indigenous people of their land. But this example also illustrates how the intentions of these actors were in part rooted in shifting socio-ecological conditions, rather than solely preexisting cultural or economic values.

## 7. Conclusions

The study adds to political ecological scholarship that sees the land as an active process that can contribute to social change (e.g., Bauer and Kosiba, 2016; Blaikie, 1985; Braun, 2004; Carney, 2001; Castree, 2005; Nietschmann, 1973). It presents a GIS methodology focused on the crops and ecological conditions that mediated relationships between people and land. Here, GIS analysis provides an account of the socio-ecological conditions that framed specific actions and conflicts during a time of socio-ecological transformation. Though this study combines historical and environmental records, such an approach only requires a close correspondence between multiple forms of data, whether historical, paleobotanical, geoarchaeological, etc (see Bauer, 2015). In empirical terms, the analysis revealed that changes in cultivable land and crop schedules took on political roles and shaped social conflicts during early colonization in the Cuzco region of Peru. A suite of entrained actions—agricultural transformation, climate change, depopulation, infrastructural dilapidation—set into motion different kinds of land claims during the colonial era, from small-scale farms to extensive haciendas. Changes in the land played a part in these social conflicts and claims.

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