Hum Ecol (2009) 37:421–440
DOI 10.1007/s10745-009-9261-2

Agriculture and Inequality in the Colonial Andes: A Simulation of Production and Consumption Using Administrative Documents

Steven A. Wernke · Thomas M. Whitmore

Published online: 14 July 2009
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Abstract During the sixteenth and seventeenth centuries, indigenous communities in the Viceroyalty of Peru suffered forced resettlement, introduced disease, and onerous colonial tribute levies. These produced an onslaught of petitions for new tribute counts, as their diminished populations were obliged to pay the head taxes set by earlier censuses. The resulting *visitas* (administrative surveys) provide a wealth of information on the demography and agricultural systems of colonial Andean communities. However, comparatively little quantitative research exists on the distribution of agricultural resources and the nutritional demands of households. We model agricultural production and nutritional demand using household demographic and landholding declarations in the visitas from the Colca Valley of southern highland Peru, combined with ethnographically-derived estimates of agricultural production and nutritional demand. The results indicate that despite surplus agricultural production in the aggregate, there were significant differences in intra- and inter-community land wealth and production sufficiency ratios, leaving about 30% of households with caloric shortfalls. In contrast to regional-scale carrying capacity-type models, this simulation characterizes agricultural inequality within colonial Andean communities, and thus accounts for the hardship evidenced by tributary recount petitions, even in a breadbasket province from which much surplus production was extracted to fill colonial coffers.

S. A. Wernke (✉)
Department of Anthropology, Vanderbilt University,
VU Station B #356050, 2301 Vanderbilt Place,
Nashville, TN 37235, USA
e-mail: s.wernke@vanderbilt.edu

T. M. Whitmore
Department of Geography, University of North Carolina,
Chapel Hill, NC, USA

Keywords Indigenous land use · Agriculture · Historical demography · Subsistence simulation · Colonialism · Andes

Introduction

How did Andean communities adjust their agricultural systems to respond to the calamities of demographic decline, dislocation, and natural disasters during the early colonial period? How were agricultural resources distributed (or redistributed) among households within these communities in the decades following colonial resettlement in the late 16th century? Some answers to these questions have already been charted: we know that in aggregate, Andean communities continued to generate agricultural surpluses through the 16th and early 17th centuries; the colonial coffers depended on such surplus extraction. Just as clearly, however, some households and communities were increasingly impoverished and unable to meet subsistence, let alone onerous tribute, requirements. At the same time, colonial resettlement in the 1570s and subsequent population declines probably contributed to a major episode of agricultural terrace and canal abandonment across the Andes (Donkin 1979; Denevan 2001:296–299). Colonial administrative archives are replete with petitions for tributary recounts by *kurakas*—indigenous lords who acted as intermediaries between the colonial state and the dozens of ethnic groups that made up the former Inka empire—in the face of declining populations and increasing hardship through the seventeenth century (Spalding 1982; Stern 1982; Cook 2007). Even where reliable aggregate surpluses were produced, some households were vulnerable to food shortage due to inequalities within and between communities. Reconstructing skewed land distribution was and the scale of the subsistence crisis suffered by Andean communities during this period requires household-and community-level analysis of the distribution of agricultural resources within regions.

Most cultural–ecological research analyzing demographic and agricultural decline in the colonial Americas has been regional in scale (e.g., Cook and Borah 1979; Sanders *et al*. 1979). This body of scholarship has provided important general views of population/resource ratios, but addressing the issue only in terms of regional agricultural productivity (total supply) and aggregate human nutritional need (total demand) says little about the circumstances at finer resolutions where distributional disparities may have skewed supply against need (Sen 1981; Bohle *et al*. 1994; Whitmore and Williams 1998). Even in cases of regional production surplus, inequalities in the distribution of agricultural resources can result in chronic food poverty and associated nutritional shortfalls for a significant portion of the population even in otherwise ordinary times (Whitmore and Williams 1998). It is the household's ability to command food resources by exchange or production (i.e., its entitlements to food) that determines its vulnerability to harm (Guillet 1981; Mayer 1984). In the late prehispanic and early colonial Andes, such entitlements were negotiated primarily through relations of kin and community. Our framework for analyzing colonial Andean agricultural economics thus incorporates both cultural- and political–ecological approaches. While we are concerned with energetic exchange between human populations and their supporting environment, we emphasize how that relationship is mediated and continually transformed by changing political and economic organization (Gelles 2000; Trawick 2003). Consideration of how household and wider political economies articulated is especially important in the colonial Andean context, when the relationships between populations, resources, and the political and economic systems linking them were in high flux.

In general, surprisingly little is known of these questions or other details of agricultural production in the Andes during colonial times, especially compared to Mesoamerica (see Whitmore and Turner 2001). Very little quantitative study of colonial agricultural systems, such as the analysis presented here, has been attempted. In general, understanding of colonial Andean agricultural economies has been hindered by what David Robinson (2003b: lvii) aptly calls a "double projection". That is, on the one hand, as in the paradigmatic ethnohistorical work of Murra (1964, 1968, 1972), Pease (1982, 1989), and Rostworowski (1973, 1975), colonial agricultural systems have been projected back in time from colonial documentary sources to model prehispanic agricultural systems. On the other hand, ethnographically-documented agricultural practices have been projected back in time to model colonial agricultural systems. Less research has been dedicated to analyzing colonial Andean agricultural systems to understand their functioning in the colonial past. Notable exceptions include the work of Larson (1998) in Bolivia, Knapp (1991) in Ecuador, and Benavides (1987, 1990b, 1995), Cook (2007), Denevan (1987, 2001), Julien (1985), Ramírez (1986), Robinson (2003b, 2006b), Treacy (Treacy 1994), and Zimmerer (1996) in Peru. By and large, however, little is known about how agricultural resources were distributed within and between colonial Andean communities, or how such disparities might translate into differences in wealth or subsistence adequacy as communities were stressed by demographic collapse, violent conflict, colonial tribute and labor regimes, and displacement.

We seek to address these problems by providing a quantitative analysis of the input–output parameters of the agricultural economy of a regionally important colonial Peruvian highland province. Specifically, we analyze landholding inequalities and simulate the ratio of agricultural production to subsistence needs at household, village, and provincial scales using data on 7,496 agricultural fields declared by 2,151 households in a series of late sixteenth and early seventeenth century Spanish colonial *visitas* (administrative surveys) of the Collagua ethnic group of the Colca valley. The simulation combines data from three incomplete but highly detailed visitas, dating to 1591, 1604, and 1615–1617, to provide a cross-sectional dataset for six villages—Achoma, Yanque, Coporaque, Chivay, Canocota, and Tuti—spanning the middle and upper stretches of the Colca valley (See Note 3 and Tables 1 and 2). This "composite-synchronic" dataset includes household-level demographic and landholding information, including the age, sex, and civil status of each member, as well as the size, location, and predominant crop grown in each agricultural landholding. Our analysis indicates significant

Table 1 Inventory of the visitas used in the simulation

Year	Moiety	Completeness/provenience	Villages
1591	Urinsaya	Large fragment, published in Pease (1977), MNH	Yanque
1604	Urinsaya	Large fragment, published in Robinson (2006a, b), APY[a]	Achoma, Canocota, Coporaque, Tuti
1615–1617	Hanansaya	Large Fragment, published in Robinson (2006a, b), APY[a]	Chivay, Coporaque, Tuti

MNH Museo Nacional de la Historia, *APY* Archivo Parroquial de Yanque, housed in the Archivo Arzobispal de Arequipa (Benavides 1990a)

[a] Data were derived from a transcription by Laura Gutiérrez Arbulu, courtesy of Maria Benavides and William Denevan. See Note 1

Table 2 Villages, moieties, and corresponding visita data in the simulation sample

	Achoma	Yanque	Coporaque	Chivay	Canocota	Tuti
Hanansaya	Missing	Fragment—not included	1615–1617	1615–1617	No Hanansaya moiety	1615–1617
Urinsaya	1604	1591	1604	No Urinsaya moiety	1604	1604

landholding inequalities both within and between villages. Additionally, we use ethnographically-derived agricultural yield and nutritional demand parameters to simulate caloric production/demand ratios of households and villages. This simulation indicates that there was an aggregate caloric surplus in most villages and at the provincial scale, but, because of inequalities in the distribution of landholdings, there were still caloric deficits among a sizable proportion of households during the period in question. We suggest such deficiencies may have led to the growth of a rural laboring class and/or differential household exposure to nutritional shortfall risks.

The Collagua Province

The Collagua Province was the largest and most economically productive under the jurisdiction of the regional center of Arequipa during colonial times. The heart of the province was the Colca river valley, a major highland Pacific drainage in the western range of the south central Andes (Fig. 1). It is the largest of several transverse valleys that form montane oases in the vast expanses of high, semiarid *puna* grasslands that dominate this region of the highlands. Human settlement in the Colca valley is concentrated in a 50 km long stretch of the valley between about 3,000 and 4,000 m above sea level (Denevan 1987).

The valley was home to two ethnic groups: the Aymara-speaking Collaguas of the central and upper reaches of the valley, and the Quechua-speaking Cabanas of the lower portion of the valley (Ulloa Mogollón 1965 [1586]). The Cabanas were known as maize agriculturalists, while the Collaguas were divided between agriculturalists in the central portion of the valley and camelid herders in the valley's upper reaches and surrounding uplands (Ulloa Mogollón 1965 [1586]). The Collaguas were internally divided between the higher-ranking Yanquecollaguas of the central and upper reaches of the valley, and the lower-ranking Laricollaguas of the central sector of the valley (Fig. 1). All three of these primary divisions within the province—Cabanaconde, Yanquecollaguas, and Laricollaguas—were subdivided between two ranked moieties, *Hanansaya* (upper moiety) and *Urinsaya* (lower moiety), which in turn were composed of several *ayllus* (ancestor-focused, resource-holding corporate kindreds) (Málaga Medina 1977:94–97; Cook and Cook 1991:29–32).

The distinctive ethnic identities and productive foci of the Cabanas and Collaguas appear to pre-date Inka imperial incorporation. Archaeological investigations have documented a large growth in population and irrigated terraced agriculture throughout the valley during the Late Intermediate Period (AD 1000–1450) (Wernke 2003; Doutriaux 2004; Wernke 2006b), with distinctive modes of settlement and land-use between the Collagua and Cabana areas of the valley (Doutriaux 2002). Population, settlement, and agricultural infrastructure reached their apogee under Inka imperial occupation (AD 1450–1532). Demographic retrodiction estimates by Cook (1982:84–88) produced a terminal prehispanic population range of 62,000–71,000 for the province—a size on par with other large ethnic polities of the late prehispanic southern Andes.

The province was of major political and economic importance within regional Inka administration. The Inkas established a series of administrative centers in the Colca valley, and many of the largest settlements under autonomous rule became secondary administrative nodes (Wernke 2006b). Two primary administrative centers were built in the locations of the future colonial *reducción* villages of Yanque and Lari, the capital sites of Yanquecollaguas and Laricollaguas, respectively (Wernke 2003:217–225, 290–295; Doutriaux 2004:278–287; Wernke 2006b). Under Inka rule, irrigated terrace systems were renovated and expanded further into the (formerly marginal) steep lower valley slopes (Malpass 1987; Shea 1987; Treacy 1994; Wernke 2003:234–244), while pastoralism intensified in the high altitude uplands through the construction of artificial wetland pasturage above dammed *bofedales* (alpine springs) (Wernke 2003:244–245). The Inkas also partially reorganized local ayllus along decimal administrative lines, especially within the Urinsaya moieties of the Collaguas (Wernke 2006b, 2007).

Following the Spanish invasion, the province remained the largest single contributor to tribute revenue collected in Arequipa (Manrique 1985; Guillet 1992:23). The *encomiendas*[1] of the Collagua province were among the most sought after in the region and viceroyalty (Málaga Medina 1977:94–97; Cook and Cook 1991:29–32; Cook 2007). Each of the moieties of Cabanaconde and Laricollaguas

[1] *Encomiendas* were trusteeships granted to Spaniards for rights to Indian labor and tribute in exchange for duties of taxation and religious indoctrination.

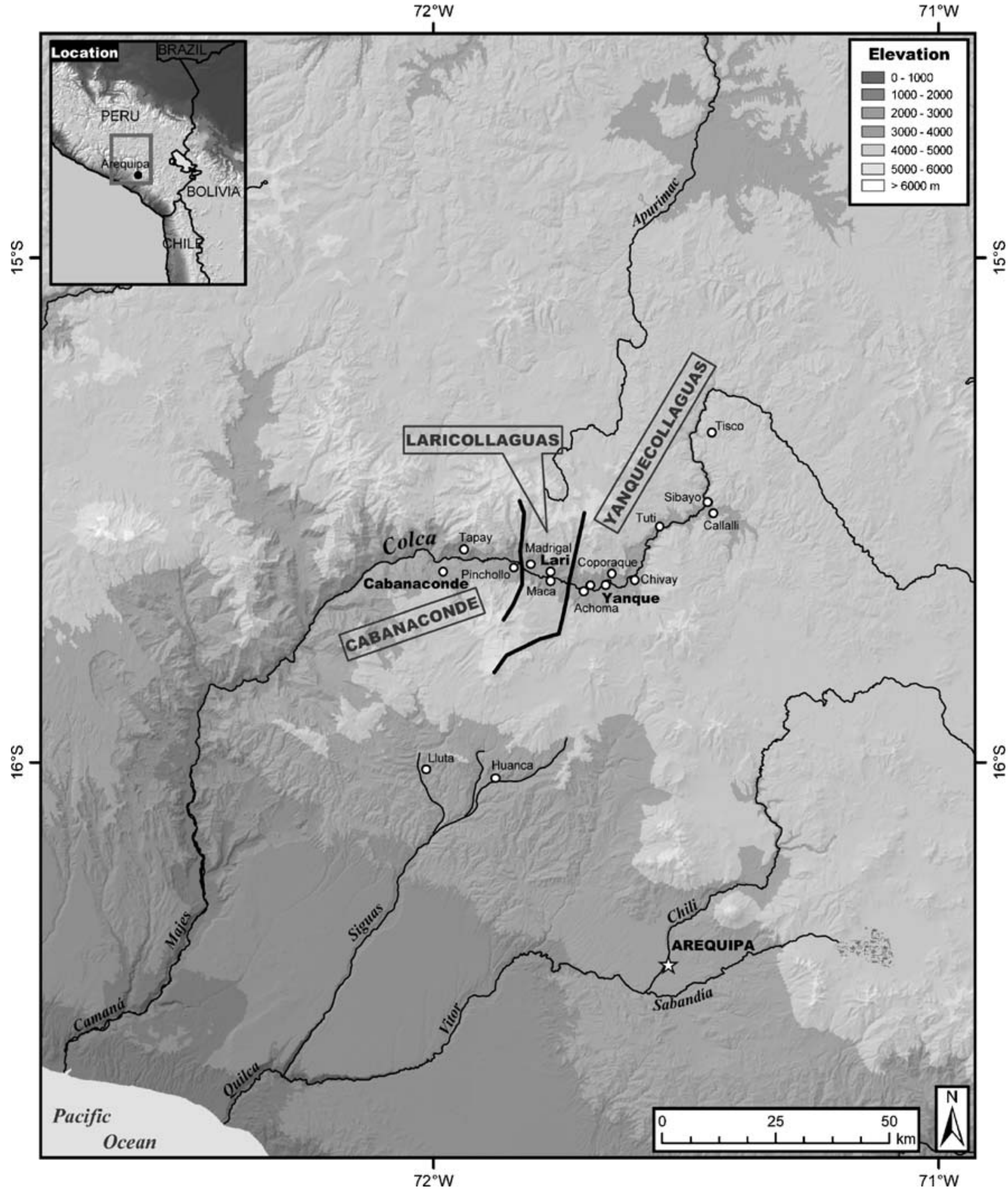

Fig. 1 The Colca Valley in relation to Arequipa, showing provincial subdivisions and villages mentioned in the text

were granted in separate encomiendas to prominent Spaniards (*vecinos*) of Arequipa, while Yanquecollaguas—the largest and highest ranking of the three provincial subdivisions—was administered as a single encomienda and was passed between the highest echelons of the colonial elite and the crown itself (Málaga Medina 1977). The Yanquecollaguas encomienda, which included the villages analyzed here, was highly lucrative. The 1549 Yanquecollaguas encomienda tribute assessment of the (acting) Viceroy Pedro de La Gasca (the first standardized assessment) called for a variety of manufactures, produce, and livestock, including 400 pieces of *cumbi* (sumptuary) cloth, 100 pieces of *abasca* (homespun) cloth, 400 *fanegas* of corn (1 fanega≈1.5 bushels), 100 fanegas of wheat, 300 fanegas of potatoes, *chuño* (freeze dried potatoes), and *oca* (an Andean tuber, *Oxalis tuberosa*), 123 sheep, 27 lambs, 120 llamas and alpacas, 30 pigs, 150 fowl, 144 pairs of partridge, 72 loads of salt, eight arrobas of candle wax, and 100 pairs of shoes (Cook 2007:67, 132–133). Further, the encomendero (who resided in Arequipa) was to enjoy the services of 25 men and women for household service, 15 herders, 8 fanegas of wheat and corn for seed for the encomendero's fields, and 12 fanegas of wheat and corn for seed to be planted in native fields of Guanca and Lluta, between the Colca valley and Arequipa (Cook 2007:132–133).

However, here as elsewhere in the viceroyalty, by the 1560s the encomienda system had become increasingly unruly, as encomenderos acted as virtual feudal lords over their native charges with little regard to the prerogatives of the Crown. After a protracted series of conflicts and rebellions, Phillip II dispatched the viceroy Francisco de Toledo to sharply curtail the extractive and political roles of the encomenderos, as well as to institute a rationalized system of tribute and colonial governance, to put down the neo-Inka rebellion, to foster conversion to Christianity, and to boost production in the ever-critical mining sector of the economy. The administrative system put in place by Toledo endured with only minor modifications well into the seventeenth century.

As a first step to reform after arriving in 1569, Toledo embarked on a *visita general* (general inspection tour) of the viceroyalty during the first half of the 1570s, when most of the population of this and other highland provinces was forcibly resettled into compact, European-style *reducción* (literally, "reduction") villages built around central plazas and churches. The reducción project, affecting some 1.5 million native Andeans, was one of the largest forced resettlements in history (Hemming 1983:393). Long advocated by the Crown and colonial magistrates, the reducciones were intended to provide closer state surveillance, facilitate tribute collection and conversion to Christianity (Málaga Medina 1974; Abercrombie 1998; Cummins 2002; Wernke 2006b). The villages registered in the visitas we analyze were established at the orders of the corregidor Lope de Suazo, acting on behalf of Toledo, between 1571 and 1574 (Cook 2007:92).

Although the original visita documents produced by Suazo have never been located in archival holdings, the summary ledger (*tasa*) derived from them has (Cook *et al.* 1975 [1582]). In contrast to the complicated in-kind tribute levies of the earlier La Gasca encomienda system, the tasa reveals a tributary regime based on just a few commodities and cash, to be paid by all able-bodied males between the ages of 18 to 50. The tribute assessment, based on a head count of tributaries, was stipulated at the level of each moiety within Yanquecollaguas, Laricollaguas, and Cabanaconde. For example, the 2,481 tributaries of Yanquecollaguas Hanansaya were assessed 4,962 pesos (i.e., 2 pesos per tributary), 2,000 pieces of abasca cloth (or cash equivalent, at 2.5 pesos per piece), and 481 head of camelids (most likely alpaca, or a cash equivalent, at 2.5 pesos per head), for a total cash value of 11,164.5 pesos, or 4.5 pesos per tributary. Evidently, then, the levy was calculated such that each tributary was to pay 2 pesos in cash, and one item in-kind or its cash equivalent. Tributary administration, however, remained indirect. The paramount kuraka of each moiety was responsible for coordinating the distribution of this quota with subordinate ayllu heads (also called kurakas), and the ayllu heads in turn actually collected tribute for remittance to the paramount kurakas, who then remitted the payments to the corregidor (colonial magistrate) in Arequipa, not to the encomendero as in the pre-Toledan system. Such an arrangement minimized state expenditures and oversight and had the potential advantage of delegating actual tribute collection to recognized local authorities, but also potentially destabilized kurakas' legitimacy as they functioned as extractive agents of the state.

The reducción radically altered the distribution of people over the landscape, but it also grafted onto extant community organization, both conceptually and literally in terms of settlement patterning (Wernke 2003:344–434; 2006a). The former primary centers of Inka administration—Yanque and Lari—became reducciones and capitals of their respective colonial *repartimientos*[2] among the Collaguas. Reducción villages also remained linked by ayllu relations, and groups of ayllus formed moieties within villages, which usually resided in discrete areas within the villages (Benavides 1988). Households maintained access to diverse fields within and beyond their village of residence (Wernke 2003: 393–434; 2006a). Likewise, ayllu organization and kuraka authority were not coterminous with village boundaries, but instead extended to several villages in diverse ecological contexts throughout the region (Pease 1977; Galdos Rodríguez 1984; Guillet 1992:25; Benavides 1995; Robinson 2003b, 2006a; Wernke 2006a).

Despite these locally-negotiated accommodations, the Toledan reducción program hastened the demographic and agricultural decline of local communities here and elsewhere in Peru (Hemming 1983:392–410). Locally, the Toledan-era population of 33,900 inhabitants was only about half of its estimated terminal prehispanic size (Cook 1982). Population losses worsened in the years following resettlement, as the effects of epidemics spreading through Peru in the 1580s were exacerbated by the close living quarters of the villages (Cook 1981, 1982, 1992). The population of the province continued to decline to its nadir of only 8,000–10,000 in the mid-eighteenth century (Cook 1982:84–88).

The visitas in question, then, were recorded at a time of demographic decline and distress from epidemics. Theoret-

[2] In this context, a repartimiento refers to a provincial territorial subunit that coincided with the encomienda grants.

ically, a lower population could lead to greater per capita landholding, but in practice, population decline also decreased the labor pool for the necessary maintenance of agricultural infrastructure—especially important for canals, which require annual cleaning and patching (see Guillet 1992; Treacy 1994; Trawick 2001, 2003). Overall, about 40% of all fields in the Colca valley are now abandoned (Denevan 1987:31), and a large body of research has been dedicated to the timing and causes of that abandonment (Denevan 1986; Guillet 1987; Malpass 1987; Shea 1987; Denevan 1988; Guillet 1992; Treacy 1994; Brooks 1998; Wernke 2003:336–342; Williams and Wernke 2008). Some of the presently-abandoned terraces were ancient, unirrigated fields that were abandoned long before the Spanish invasion (Treacy 1989:93–99, 123–133; Brooks 1998), but the abandonment of irrigated fields and terraces was a largely or even entirely colonial phenomenon (Denevan 1987:31; Treacy 1989; Denevan 2001:192–201; Wernke 2003:336–342; Williams and Wernke 2008). Thus, population and agricultural infrastructure appear to have declined roughly in tandem as labor shortages led to the dereliction and eventual complete abandonment of some canals and their dependent terrace groups, (Wernke 2003:336–342; Williams and Wernke 2008). How the lands that remained in production were distributed within communities, and how many households were left with marginal or insufficient means of subsistence is poorly understood, and is thus the subject of this analysis.

Research Questions

We use household-scale data from visitas that recorded both demographic (sex, age, and civil status for all individuals by household) and agricultural (number, size, and predominant crop in all household fields) information for three counts spanning 26 years: 1591, 1604, and 1615–1617 (see Tables 1 and 2). We first use this data to examine the distribution of household landholdings among villages and households. Given differences in ecological contexts, and distinct political and economic roles of the villages in the visitas, we expect that there would be significant differences in household landholdings within and among them. Specifically, we hypothesize that households in the villages in the agricultural core of the valley would have greater land wealth than the agro-pastoralist villages of the upper reaches of the valley, reflecting overall differences in ecological context and productive foci. But we also expect that the role of particular villages in the political and economic organization of the province would be reflected in differences in landholding inequalities within and among villages: namely, that there would be greater inequality among the households of Yanque, due to its position as the seat of governance for Yanquecollaguas and the province as a whole.

Landholding differences between villages or households alone, however, are insufficient measures of inequality because household demographic structures vary. We thus calculate household per capita landholdings, and simulate the productive capacity of household lands, as well as the nutritional need (demand) of each household based on gender and age classes of household members. This simulation produces a ratio of household agricultural production to nutritional demand—what we term the Household Production Sufficiency Ratio (HPSR). Given the agricultural importance of the province in the regional economy, we expected to find surplus production in aggregate, but significant variability of resources within and between villages.

Agriculture in the Colca Valley

Like neighboring semiarid Pacific drainages of the south central Andes (e.g., the Cotahuasi Valley, Trawick 2001), agriculture in the Colca valley is characterized by high productivity and intensity in an irrigated, non-fallow regime (Treacy 1994:198–199). Colca valley agriculture is at the highly individualized end of the spectrum of Andean land tenure systems (Guillet 1981, 1987). In contrast to sectoral fallowing systems, which require communally-coordinated rotation of crops and large field sectors to maintain soil productivity (Guillet 1981), irrigation in the more intensive agricultural regimes such as that of the Colca valley was organized more independently. Individual fields were thus managed more autonomously at the household scale (Treacy 1989:312–316). Communal lands were almost entirely limited to grazing lands on the high slopes and plains above the terraced slopes of the valley (Benavides 1990b). While fields were held individually, crop selection and cultivation scheduling were constrained by the communal controls of irrigation scheduling and maintenance (Treacy 1989:316–329; Guillet 1992). Visita declarations indicate that such individualized land tenure patterns extend at least as far back as the early colonial period (Benavides 1990b), and probably well into prehispanic times (Wernke 2006a, 2007). Individuals held lifelong, heritable rights to agricultural fields, and many field declarations include testaments of inheritance (Benavides 1990b; Robinson 2003b). Fields lacking legitimate heirs—a scenario not uncommon in the context of colonial period demographic decline—appear to have reverted to the ayllu and were reapportioned to individuals by its kuraka (Robinson 2003b).

The Colca valley is one of the most intensively terraced valleys in the hemisphere; terrace complexes cover virtually all slopes under about 4,000 m (Denevan 2001:172–201). The high agricultural productivity of the valley is due in part to its rich soils, which are Mollisols of comparable fertility to those of the Midwest region of the United States (Sandor 1992; Sandor and Eash 1995). The primary limiting factor to local agricultural production is water availability (Guillet 1987). Average annual precipitation in the 400–600 mm range is concentrated between the months of December and March, making dry farming extremely risky (ONERN 1973). Agriculture thus depends on canals that carry glacial meltwater, spring water, and runoff from the surrounding peaks to terrace and field complexes along the valley sides and bottom.

The Colca Valley Visitas

The visitas consulted for this study are part of the largest collection for a single locale in the New World.[3] That there were so many visitas to the Colca valley reflects not only how important the province was in the regional economy, but also the adversities faced by the valley population, since tributary recounts were conducted only after repeated petitions by local kurakas. References to epidemics, general hardship, or natural catastrophe are evident within the texts of the visitas. For example, epidemic deaths from a particularly virulent strain of smallpox that swept through the Arequipa region in 1589–90 (Joralemon 1982; Cook 1998) were referred to in the 1591 visita of Yanquecollaguas Urinsaya (Verdugo and Colmenares 1977 [1591]:97r). The subsequent 1604 revisitas (recounts[4]) were undertaken in response to a petition to the viceroy by the *protector de naturales* (protector of Indians) as the remaining tributary population could not produce the required tribute levies, both because they were based on higher previous census counts and because of crop failure due to heavy ashfall from the massive eruption of the Huaynaputina volcano in 1600 (APY [Archivo Parroquial de Yanque] Laricollaguas Urinsaya 1604, ff. 1v–2v).

Visita Sample Used in the Simulation

Visitas in post-Toledan times, when the colonial government strained under a flood of revisita petitions, were often conducted hastily and sloppily (Guevara-Gil and Salomon 1994). But the Colca valley visitas are a significant exception to this rule. Though none of the three survives in complete form (see Tables 1 and 2),[5] they were each recorded in a meticulous manner, rivaling modern censuses in their detail and verifications of accuracy. The colonial government had a clear interest in maintaining accurate information on the population and resources of the province, given its regional economic prominence. Village *pregoneros* (town criers) were to notify the village for 2 days prior to the arrival of the visita entourage, and the ayllu heads were to assemble their constituent members in the central plaza for the accounting on the appointed day. The *visitadores* were acutely aware that the communities' interests ran counter to their own. Warnings against hiding individuals or households from the counts were given (documentation of these proclamations are in the visitas), and individuals who revealed other community members attempting to hide or escape the census, were rewarded with tribute exemptions or promotions to kuraka status.[6] Apparently missing individuals were checked against death registries maintained by resident clergy.[7] The visitadores also used a variety of checks to verify declarations.

[3] Their recent publication (Robinson 2003a, 2006a) as part of a series initiated in the 1970s by Franklin Pease (1977) has made these invaluable documents available to scholars. Our analysis is based on the paleographic transcriptions completed in the 1980s by Laura Gutiérrez Arbulú, as part of the Río Colca Abandoned Terrace Project, directed by William Denevan. Most funding for the Gutiérrez transcription was provided by William Denevan, with additional funding from Maria Benavides (head ethnohistorian of the Río Colca Abandoned Terrace Project) and Mauricio de Romaña (see Benavides 1990a). In 2000, Maria Benavides and William Denevan graciously provided Wernke access to these transcriptions and photocopies of the original archival documents. Wernke has spot-checked the transcriptions against the photocopied originals as needed. The recently published versions (Robinson 2003a, 2006a) are derived from these same transcriptions.

[4] All post-Toledan "visitas" could also be termed *revisitas* (re-surveys) since they are technically recounts from the earlier Toledan visita general. However, the terms "visita" and "revisita" are used interchangeably within the documents.

[5] The 1591 Visita de Yanquecollaguas Urinsaya was conducted during the tenure of two corregidores, beginning with Gaspar Berdugo (fs. 1r–96v), and completed, starting with Coporaque, by Gaspar de Colmenares. The original is housed in the Museo Nacional de Historia (MNH), Lima, and has been published (Verdugo and Colmenares 1977 [1591]). It is the smaller and more deteriorated fragment of the two Yanquecollaguas Urinsaya visitas, preserved from fs. 1r-119v. Folios 120r-155v are fragmentary and illegible. The 1604 Visita de Yanquecollaguas Urinsaya was conducted by the corregidor Licenciate Juan de Rivero. It is well-preserved from fs. 53r–413v. The document is archived in the Archivo Parroquial de Yanque (APY) within the Archivo Arzobispal de Arequipa (AAA). The 1615–1617 Visita de Yanquecollaguas Hanansaya was conducted by the Corregidor (and) Capitán Jerónimo de Pamanes. It is well-preserved from fs. 303r–643v (with 32 folios missing), and is also archived in the APY.

[6] For example, in the 1604 Urinsaya visita, Juan Rastrollo was promoted to second in charge of his ayllu and his son, Domingo Ayqui Rostrollo of the village of Sibayo was reserved from tribute and mita service for having revealed the identities of several fugitives hiding from the census-taking (APY Yanquecollaguas Urinsaya 1604 f. 70r/v).

[7] For example, in the preamble to the Coporaque section of the 1591 Urinsaya visita, it is stated that the village priest, the noted Franciscan friar Jerónimo de Oré had brought forth the death registry to assist in the proper accounting of deaths caused by recent epidemics of smallpox and measles (Verdugo and Colmenares 1977 [1591]).

Marginalia in the 1604 and 1615–1617 visitas indicate that the visitadores went through the previous census line by line in the field to keep tabs on each household, noting deaths, marriages, and changes in tributary status of each individual. Also, even as late as the 1615–1617 visita, the visitadores called forth local *khipucamayoc* (keepers of khipus—Andean knotted cord registries) to cross-check their counts (APY Yanquecollaguas Hanansaya 1615–1617, f. 338v).

The analysis includes six villages. Two of these—Tuti and Canocota—are located in the *suni* ecological zone (Pulgar Vidal 1996), characterized locally by mixed bunch grasses and scrub brush between about 3,600 and 3,800 m, where a mixed agro-pastoral economy predominates. Here, communities tend large herds of Andean camelids (primarily alpacas—*Lama pacos*), and cultivate more frost-tolerant, high altitude Andean crops such as potatoes (*Solanum tuberosum*), quinoa (*Chenopodium quinoa*), and kañiwa (*Chenopodium pallidicaule*). We include these villages even though we know that they were more reliant on herding (for which we have little data in the visitas) in part because they serve to illustrate the differences elevation and ecology make in Andean village subsistence. The other four villages—Chivay, Coporaque, Yanque, and Achoma—are located in the *kichwa* ecological zone (Pulgar Vidal 1996), between about 3,200 and 3,600 m in central portion of the valley, where intensive, irrigated agricultural production predominates (see below). Our analysis takes into account these differences in ecological context and economic focus. Because our model does not simulate herding production, however, we have excluded the declarations from the three highest altitude herding-only villages of Callalli, Sibayo, and Tisco, which are also recorded in the visitas.

The censuses were conducted by moiety (called *parcialidades* in colonial administration)—either Hanansaya or Urinsaya within each of the three provincial subdivisions. For a given village, then, only one moiety (about half of its population) was recorded in any particular visita document. Unfortunately, complete data from both moieties for any single visita year are lacking.[8] To obtain as complete a sample as possible of both moieties, the following analysis combines data from all three of the survey periods (Tables 1 and 2). All Urinsaya data are from the 1604 visita except for the case of Yanque, which, because only a small fragment of the Yanque section is present in the 1604 visita, are derived from the 1591 Urinsaya visita. All Hanansaya data are from the 1615–1617 visita, although the Hanansaya moiety of Yanque is missing from that visita as well, and only a small fragment is preserved from the 1591 Hanansaya visita.

This "composite cross-section" sample obscures any diachronic change over the 26 year span of the visitas, but it is the only way to compare the full range of villages and moieties within villages. As is evident in Tables 1 and 2, the data across villages, with the exception of Yanque, are comparable since the data for the Hanansaya moiety of each village (where available) are derived from the 1615–1617 visita, and the data for the Urinsaya moiety of each village (where present) are derived from the 1604 visita. This effectively controls for change through time as a confounding factor, with the important exception of Yanque. Only a small fragment of the Yanque section of both the 1604 and 1615–1617 visitas remains. We therefore use the 1591 Urinsaya visita for Yanque; data are lacking for the Hanansaya moiety (only a small fragment of the 1591 Hanansaya exists—see Note 8 and Table 2). Thus, although the sample is an imperfect cross-section, a standard cross-sectional study from a single visita would have other drawbacks: it would either exclude the critically-important provincial capital village of Yanque (since a sizable sample for it only exist in the 1591 visitas), or several other villages (if only the 1591 visitas were used), and in either case would provide data for only about half of the population (one of the two moieties). Also, a diachronic analysis is not possible since complete data for either moiety do not exist in more than one visita in the series. Even after combining them into one sample, the Hanansaya data from Achoma, Yanque, and Chivay remain incomplete due to the fragmentary nature of the documents (see Tables 1 and 2).

Within each census roll, households were organized by ayllu, and ayllus were generally registered in descending order of rank. Within each ayllu, tributary households—those with male heads of household between the ages of 18 and 50—were recorded first, followed by widowers, single men of tributary age (referred to simply as *indios* or *indios tributarios*), orphan boys and girls (less than 18 years old), widows, single women, elderly (i.e., more than 50 years old) and disabled men, and "rabbles" of boys and girls without guardians (*chusma de muchachos* and *chusma de muchachas*). Within each household, data registry included the age, sex, and civil status of each household member, followed by their agricultural landholdings. Each field declaration included its location by toponym, its size, and the predominant crop grown. Any personal livestock of the household were listed last, though these declarations did not include any communal herds known to have existed through other sources (Crespo 1977).

[8] For the 1591 census round, a large fragment of the Yanquecollaguas Urinsaya visita has been located and published (Verdugo and Colmenares 1977 [1591]), but only a small, unfoliated fragment of its counterpart for the Hanansaya moiety remains. For the subsequent 1604 visita, there is a large section of the Urinsaya moiety census (APY Yanquecollaguas Urinsaya 1604 published in Robinson 2006a), but it lacks most of the section registering the declarations from the provincial capital of Yanque, and there is no known record of the Hanansaya moiety. For the next census, recorded in 1615–1617 (APY Yanquecollaguas Hanansaya 1615–1617 also published in Robinson 2006a), a large fragment of the Hanansaya moiety survives, but it also lacks the section from Yanque.

Methods

The visita data provide the basic variables necessary to measure the distribution of landholdings within and between villages and to determine the agricultural production/demand ratio for households. First, we calculate the per capita landholdings of each household and compare the distribution of land wealth (by households) within and between the villages. The visita data on field size and predominant crop grown provide parameters for agricultural production for each field. Second, we model total potential annual agricultural production for a household's fields in calories, and compare this with the demand, also in calories, for each household population. Agricultural productivity data from ethnographic studies—whenever possible, from the most directly-comparable, local agronomic studies of traditional agricultural practices conducted in the Colca valley (see below)—are used to provide simulated per hectare yields. Likewise, ethnographic studies of caloric uptake and nutritional sufficiency provide a means of simulating the nutritional needs of individuals in each household, classified by sex and age.

This simulation models the local agroecosystem and does not address wider flows of food into or out of the system. Inflows could have included trade (especially as part of broader ecological complementarity exchange networks), rations or payment for labor, other services, or for craft work. Outflows in the form of tribute or trade are similarly not included here even though they probably had important impacts.

As mentioned, the simulation also does not model pastoralist production. The Collaguas were renowned for their massive herds in these and other villages in and around the upper reaches of the valley. However, simulating herding production is not possible due to the lack of communal herd declarations in the visitas. The relatively few livestock declarations recorded (overwhelmingly alpacas) were those declared as personally-held stock by (generally land-wealthy) individual households. This blind spot also limits the scope of this simulation. Nevertheless, we can shed light on the agricultural portion of local and regional domestic and political economy. Ethnographic studies indicate that 90% of the caloric value of Andean agriculturalist diets is vegetal in origin (Leonard and Thomas 1988:255; Leonard 1991:1128), so our simulation reflects the bulk of peoples' diets.

Determining Field Sizes

Field sizes were declared using a number of measures, though by far the most common unit was the *topo*. Topo (or *tupu*) is a Quechua term used both as a unit of distance and of area in the Inka empire. As a unit of area, a topo was not an absolute spatial measure but referred to a relative area that varied according to terrain, fertility, or other factors (D'Altroy 2002; Robinson 2003b). For our purposes its standardized equivalent of 3,496 m^2 (just over 1/3 ha) used by the Peruvian Ministry of Agriculture in the modern Department of Arequipa provides a reasonable estimate. Given the highly dispersed land tenure pattern here and elsewhere in the Andes (a widespread risk-minimization strategy in the region—see Brush 1977; Winterhalder and Thomas 1978; Winterhalder 1986, 1990), each household's total landholdings generally were distributed among many small, widely-dispersed fields. Therefore, most fields were declared as fractions of a topo—most as a quarter or a half topo. Many even smaller plots were noted, using terms such as "little patch" (*pata*, *pedacillo*), "little terrace" (*andençillo*). Although the areas of these tiny fields will never be known with certainty, they presumably were somewhat smaller than even a quarter topo (the smallest fraction of a topo declared), and we have equated them with 1/8 topo.

One notable feature of the declarations is that 20% (n= 910) of the population claimed no agricultural fields. Of these landless people, the vast majority (93%) was widows, widowers, elderly, and orphaned children. Most of these landless individuals probably lived as kin in tributary households. To approximate the economic impact of these landless individuals, we distribute this population evenly among their ayllu kin in per capita and production/demand calculations. This solution at least accounts for this sizeable population subgroup in a plausible fashion, given that poor and infirm individuals were generally cared for by ayllu kin during Inka and early colonial times (Murra 1975:40; Varón Gabai 1980:20). Leaving them out entirely would underestimate the demand side of the production/demand ratio.

Crop Mosaic and Crop Yield Estimates

The declarations of crop cultivated in each agricultural field likely reflect the predominant crop, not the only one, cultivated in a given field, and should be taken as a rough reflection of the overall crop mosaic. Reflecting its culturally-valued status, maize (*Zea mays*) was the most common cultivar, constituting 49% (423 ha) of the landholdings. Most of the rest were in quinoa (*Chenopodium quinoa*) (40%). The remaining 11% was divided about equally in potatoes (*Solanum tuberosum*) and kañiwa (or cañihua; *Chenopodium pallidicaule*).[9]

While production hectares in these six villages were composed predominately of maize and quinoa, maize was preferentially cultivated and predominated in the lower

[9] Fields of unknown crop type are rare (5% of the sample), but significant in the case of an important subset of data for 1591 in Yanque, the provincial capital. In this case, the original document is in a poor state of preservation, and the crop type of many fields is illegible. For these fields, we assign crop type proportionally with the known fields for the village.

elevation villages, while quinoa increases in the higher altitude villages (Fig. 2). With the exception of a few isolated terrace groups in the inner-river gorge, the fields of the villages from Canocota up-valley are above the limit of maize agriculture. Chivay is near the upper limit (around 3,600 m) of maize agriculture and it is minimal there today. Thus, the great majority of the maize fields claimed in the high altitude villages (Chivay, Canocota, and Tuti) were located either lower down or outside the valley. Quinoa was important in all villages. Potatoes were only important in the two highest villages (Tuti and Canocota).

There are a number of modern agronomic studies of yields for the crops mentioned in the visitas, but many (e.g., rotational fallow or rainfed systems) are not good analogs to the non-fallow, highly intensified irrigated agricultural regime in the Colca valley. Moreover, many contemporary systems use chemical fertilizers at least part of the time making extrapolation to the colonial period difficult. Here we are conservative, using local yield data from Colca valley studies where available that appear to best fit the situation in the Colca in the sixteenth century.

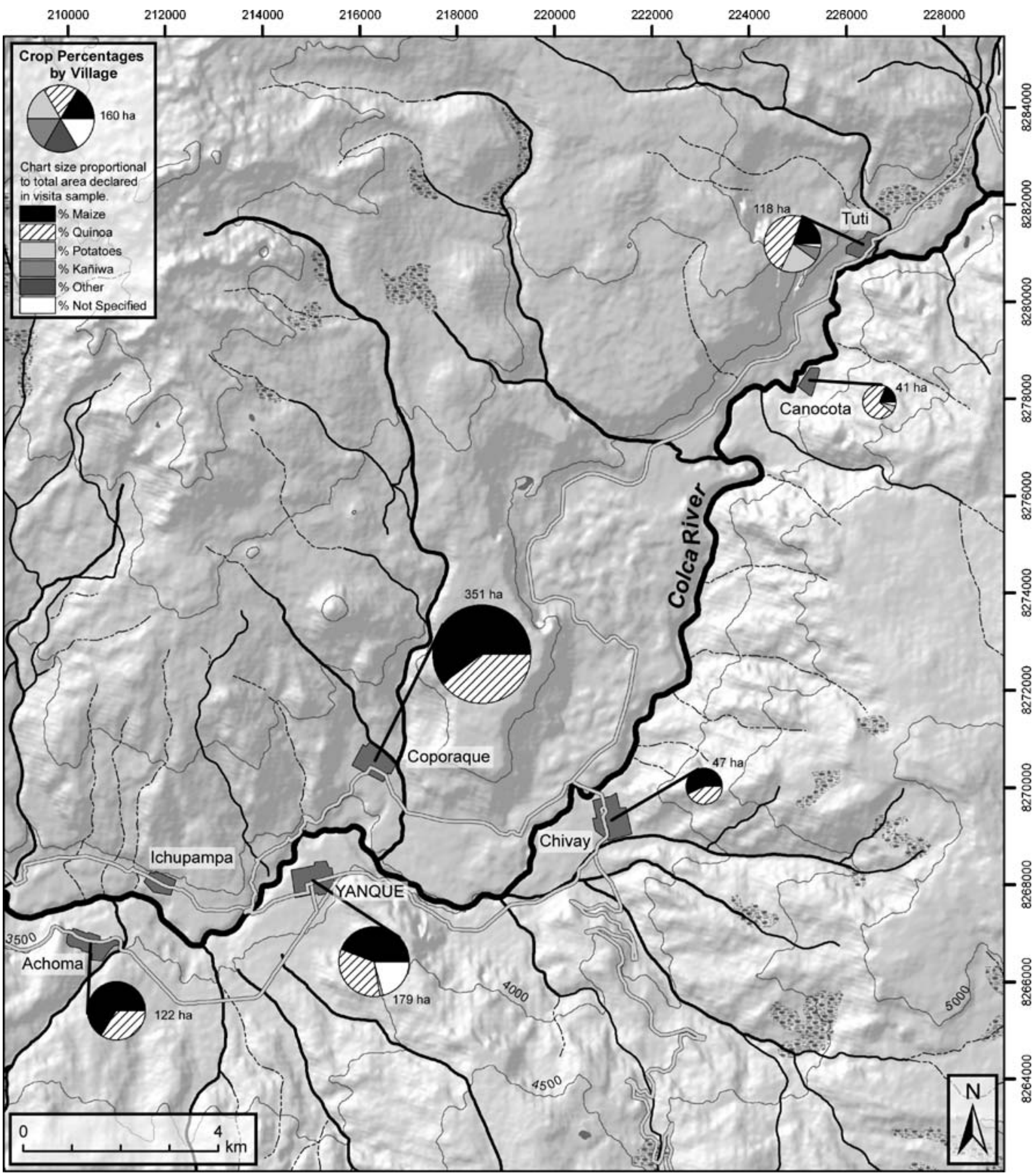

Fig. 2 Crop percentages by village as declared in the visita sample

Maize

Maize yields vary dramatically depending on water availability, fertilizer inputs, and other factors. Agronomic studies from the Colca itself probably provide the best estimates, since they are derived from the some of the same fields as those declared in the visitas. In Coporaque, Izaguirre (n.d.:50) reports maize yields in the range of 1470–3200 (dried) kg/ha, depending on the mix of varieties grown in a given field, soil type, and risk factors, which is in line with those reported in other valleys of comparable climate and soil fertility, such as the Vilcanota. There, Gade (1975) reports even better yields of 3990–4956 kg/ha in fields cultivated with manure and regular irrigation. Given the similarities in soil and evidence for indigenous soil management and fertilization in the Colca (Sandor 1987, 1992; Eash and Sandor 1995), the 1,470–3,200 kg/ha yields reported in Coporaque is reasonable. Here, we estimate yields on the lower side of this range, 2,000 kg/ha.

Dried maize calorie nutrition varies but is commonly reported in the range of 3,400–3,700 kcal/kg (Hernández *et al*. 1974: 6; Food and Agriculture Organization of the United Nations 1992: Table 16; Hastorf 1993: Appendix D). We use an average figure of 3,600 kcal/kg. Using this we can calculate a maize yield of approximately of 7.22 million kcal/ha.

Quinoa

Overall, 40% of landholding area in our sample was declared as quinoa fields. Today, quinoa is usually intercropped with broad beans, peas, or maize in the Colca, but in other circum-altiplano locales, monocropping is common. The visitas indicate that it was monocropped in colonial times. As with maize, fertilization has a significant yield impact. In Coporaque, a range of 1,222–2,083 kg/ha is reported for quinoa intercropped with broad beans and other crops (Treacy 1994:201; Izaguirre Urbano n.d.:150). This is at the low end of the monocropping yields reported in the altiplano, which are in the 2,000–5,000 kg/ha range (Ad Hoc Panel of the Advisory Committee on Technology Innovation of the National Research Council 1989: 160). So, conservatively, we use a 2,000 kg/ha yield estimate.

In caloric value, maize and quinoa are virtually interchangeable (although they are distinct in quantity and quality of protein.). Quinoa provides about 3,510 kcal/kg (Wu Leung and Flores 1961:17), so we calculate an estimated quinoa yield of about 7.02 million kcal/ha.

Kañiwa

Kañiwa, another Andean chenopod, makes up 1% of visitas declarations. Kañiwa yields range widely depending on cultivation regime. Low-input, non-irrigated cultivation, yields in the range of 400–800 kg/ha (Hernández Bermejo and León 1994: 134). But with hoeing and commercial fertilizer, adequate plant spacing, etc., yields can soar to 1,500–5,000 kg/ha (Ad Hoc Panel of the Advisory Committee on Technology Innovation of the National Research Council 1989: 134; Hernández Bermejo and León 1994: 134). Given the intensive irrigated agricultural regime of the Colca, we suggest the low end of this more intensive pattern, 1,500 kg/ha, is a reasonable estimate. Kañiwa caloric nutrition is slightly less than quinoa or maize at 3,270 kcal/kg (Wu Leung and Flores 1961:13), for a total of about 4.91 million kcal/ha.

Potato

Potatoes account for fewer than 5% of all lands declared, and these are concentrated in the two higher villages of Canocota and Tuti. Potato yields in the Colca valley in the 1980s using traditional methods ranged from 10,000–15,000 kg/ha. We use an average of 12,500 kg/ha. Treacy (1989:236) and Izaguirre (n.d.:150) both report potato yields in Coporaque in this range. Nutritionally potatoes have fewer kcal/kg—only 750 (Wu Leung and Flores 1961:37). But given the big yields, we model potato production as yielding 9.38 million kcal/ha.

Storage Losses

Not all of a household's production is consumed, some is needed for the next year's planting and a larger fraction is lost in storage to rot and vermin. Post-harvest losses are not precisely known even for contemporary agricultural systems, but commonly surpass 10% for grains and 25% or more for tubers, fruits and vegetables (Board on Science and Technology for International Development *et al*. 1978: 76; Smil 2000: 183). Thus, we argue that storage losses and seed set aside probably totaled 15% of the harvested total in the colonial Colca. Thus, to achieve healthy levels of nutrition a household would need to have produced 115% of their caloric needs. We decrease a household's yields (in kcal) in our production model by 15% before we compare the net production to the household's demand.

Modeling Demand

Since the visitas list individual ages and genders we are able to assign an energy need figure (kcal/day) to each individual in the data set, in turn enabling calculation of total household daily and annual energy needs. To calculate the daily energy need for each individual it is necessary to note that caloric needs vary according to one's Basal

Metabolic Rate (BMR) and Physical Activity Level (PAL) (Food and Agriculture Organization *et al*. 1985). Moreover, the BMR is itself a function of age, sex, and body weight. Even similar humans (e.g., same-aged adult males) vary in their needs and we use mean or median values to accommodate that variability (Food and Agriculture Organization *et al*. 1985; James and Schofield 1990: 94–95). Total caloric needs, then, equal the BMR plus the nutritional needs generated by Physical Activity Level (PAL). Totals are typically noted as multiples of the BMR calorie needs.

Throughout, we use age- and sex-specific BMR data calculated from the United Nations' *Energy and Protein Requirements: Report of a Joint FAO/WHO/UNU Expert Consultation* (Food and Agriculture Organization *et al*. 1985).[10] To calculate BMRs for adults we assume women weigh 55 kg and men 65 kg. These averages are similar to ethnographically documented weight ranges (Thomas 1973:154–159). Total caloric needs for healthy working adults typically range from 1.5–2.1 BMR (James and Schofield 1990: 74). We assume average PAL values in the middle of this range, resulting in a total caloric need for adults of 1.8 times the BMR in each age class.[11] These PALs represent an average of days with little activity and ones with heavier workloads. For children under age 18 we use the FAO/WHO's median age and sex specific weights and PALs (1.6–1.75 BMR) (Food and Agriculture Organization *et al*. 1985).

In general, one would expect that high altitude populations would require more kcal/day than sea-level populations, since a thinner atmosphere and colder weather leads to higher respiratory rates and heat loss, both of which contribute to increased BMR. However, ethnographic work in the Andes shows that populations consume consistently less than standard FAO recommendations (Thomas 1973; Picón Riátegui 1978; Leonard and Thomas 1989; Leonard 1991). In a contemporary Andean population Leonard (1991) found that food scarcity is highly seasonal, and that adults, especially men, really tighten their belts around planting time, getting by on a spartan diet in the 1,475 kcal/day range. He shows that the household strategy was focused on insulating children from this food scarcity—their pre- and post-harvest diets vary significantly less in caloric terms. Based on earlier research in the same village, Thomas (1973: 76) also notes that all sex–age groups consume on average only between 54%–71% of the FAO recommendations. Leonard and Thomas (1989:69–70) suggest that Leslie *et al.*'s model (1984), which produces generally lower kcal/day numbers (for an Andean population, 1,435 kcal/day for females—75% of FAO—and 1,512 kcal/day for males—61% of FAO), is more appropriate. It is important to note, however, that here we are interested in modeling desirable, healthy nutritional intake as a benchmark to then infer whether such levels were possible in a given set of households. We thus use the FAO/WHO-derived estimates.[12]

Modeling Production/Demand Ratios

To judge a household's ability to meet its own subsistence needs, we calculate its HPSR by dividing the production possible (in kcal/year) given the crops and lands associated with each household in the visita, by the sum of the caloric needs of the individuals comprising the household (also in kcal/year) (Whitmore and Williams 1998: 89). An HPSR of 1.0 therefore signifies a household that produces just enough for customary nutritional needs (accounting for post-harvest losses and seed set aside).

However, this ratio alone is not sufficient to understand the consequences of production insufficiency. Households with apparent production shortfalls may well have exchanged their agricultural labor for food, specialized in camelid herding (thereby trading animals for agricultural products with households with surpluses), or performed other services for goods or wages. Moreover, even in households not augmenting food supplies in these ways, individuals can accommodate insufficient nutrition by altering activity patterns (as discussed above; Food and Agriculture Organization *et al*. 1985; James and Schofield 1990: 94–95). Beyond that, chronic under-nutrition does not directly and quickly lead to death but can make a population or individual less robust and more vulnerable to infectious disease (Taylor

[10] The FAO argues that "[t]he energy requirement of an individual is the level of energy intake from food that will balance energy expenditure when the individual has a body size and composition, and level of physical activity, *consistent with long-term good health; and that will allow for the maintenance of economically necessary and socially desirable physical activity* [emphasis added]" (Food and Agriculture Organization et al. 1985). Moreover, the FAO estimates of requirements "…are derived from measurements on individuals. Actual measurements on people of the same sex and of similar age, body size, and physical activity are in practice grouped together to give the average energy or protein requirement of that set of people…". We recognize that there is variability in all these measurements as there was for the Colca population, but argue that for modeling purposes these averages are appropriate since we do not know the distribution of body sizes, activity levels, etc. for the population.

[11] This value lies between the FAO's calculated energy requirement of a "subsistence farmer (moderate activity work)" and that of their "male engaged in heavy work." (Food and Agriculture Organization et al. 1985, section 2.1) We use the same value for all adults because BMR decreases by only about 1% per decade through age 60 (Food and Agriculture Organization et al. 1985, section 3.5.1).

[12] The consumption values we used in our models for daily kcal demands are: Adults (14+): male 2,475, female 1,920; Children (5–13): male 1,609, female 1,360; Small children (1–4): male 860, female 850.

and DeSweemer 1973: 205–206; Scrimshaw 1975: 353; Beisel 1982: 746–747; Rotberg and Rabb 1983: 307).

HPSRs below 1.0 are possibly deficient, but James and Schofield (1990: 94–95) argue that intra-individual variability in adequate nutrition may be as much as ±20% of the mean. Nevertheless, at least some households with HPSRs in the lower half of this range (0.8–1.0) potentially suffered nutritional shortfalls. Since we assumed households need about 1.8 times their summed BMRs, a household HPSR of 0.80–1.0 suggests that caloric intake for individuals in those households would approximate 1.4–1.8 times BMR. This intake range is adequate for "maintenance," although at the lower end this nutritional level presupposes little work other than minimal movement and "no occupational or socially desirable activity" (James and Schofield 1990: 95). Unless they had other means to augment food supply (e.g., wage labor or camelid herding), households or some individuals within them in this category may have endured some long-term negative consequences of under-nutrition. Uncompensated HPSRs at the lower end of the range from 0.65 to 0.79 (potential caloric intakes of 1.2–1.4× BMR) can "only be seen as an emergency measure…and the body will deteriorate progressively at this intake" (James and Schofield 1990: 95).

Lastly, intakes of less than 1.2 × BMR clearly entail considerable risk of famine-related illness and even death and individuals in households with HPSRs of less than 0.65 are very likely to have had alternative subsistence strategies and/or were seriously deficient in caloric nutrition.

We recognize that there were important non-agricultural household-level means of obtaining food (e.g., day laboring, trade, etc.) and supra-household mechanisms for food sharing (e.g., ayllu-based relations of reciprocity or redistribution and community chests), but the means by which these contributed to particular household economies are not documented in the visitas. Thus, we do not argue that deficient households were necessarily starving, but rather that they were at risk absent access to food via means other than direct agricultural production. Further, we do not argue that everyone in these households got an equitable share of food (ethnographic evidence suggests otherwise—see Graham 2004), but for simplicity our model assumes they did. Special needs individuals such as pregnant women, the elderly, small children, or the sick are more likely to suffer the deleterious consequences of these food shortages (Gordon *et al*. 1967; Taylor and DeSweemer 1973; Frisancho 1978: 180–181; Hugo 1984; Watkins and Menken 1985: 655), though ethnographic research suggests that children receive disproportionate shares of household food in times of shortage (Leonard 1991).

The model also does not consider the possible impacts of colonial tribute; rather it is designed to give a view of the basic production/demand parameters of the agricultural sphere of a more complex agro-pastoral economy. But importantly, what the model does provide is a quantitative characterization of household and village-level agricultural economies; it can thus serve as a basis for generating further hypotheses to be tested when considering the broader political economy and the impacts of tribute. As discussed below, the large and detailed database at hand for the Colca valley make it an ideal case study for estimating the productivity and adequacy of a provincial Andean agricultural system during the colonial era.

Results

Household Landholding Differences among Villages

Although the study population is incomplete for some villages, the sample is large. The population of the six villages in our multiyear sample totals 4,598 individuals in 2,151 households. There are 7,496 individual agricultural fields in our sample; totaling about 858 ha. This yields a global landholding area ratio of 0.19 ha per capita.[13] However, if households are used as the unit of analysis in calculating per capita landholdings (household landholdings [in hectares]/household population), considerable variation and inequality in the distribution of land is evident in the box plots in Fig. 3 (also see Tables 3 and 4).[14] The median household landholding area is 0.13 ha per capita (0.22 ha among landholding households) while the inter-quartile range is 0.00–0.26 ha per capita (0.13–0.35 ha among landholding households). The overall spread is extreme, with values ranging from 0.00–3.76 ha/capita.

To examine landholding inequality within and between villages, the data must be disaggregated. In the foregoing comparison of landholding inequality, household per capita landholding (total household landholdings [in hectares]/total household population) values are calculated for each village. When comparing villages, they are also grouped by their ecological context and production regime. The villages in the central part of the valley—Achoma, Yanque, Coporaque, and Chivay—are grouped as "agriculturalist" villages, and the villages in the upper part of the valley—

[13] Smil (2002: 126) notes that pre-modern Chinese agriculture likely could support only about 5.5 persons per ha (0.18 ha/capita) in overwhelmingly vegetarian diets due to limits in available nitrogen recycling. Clearly, the Colca was close to this limit if consumption of camelids is not counted. This is especially true for the two higher villages.

[14] The boxplots in Figs. 3 and 4 display values for both the overall population of each village (all households) and for the landholding households only (landless households excluded) in order to view the effects of including/excluding the large population of landless households.

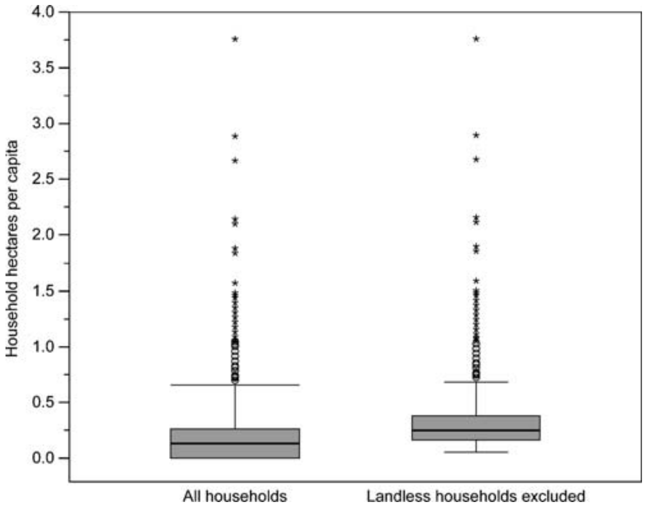

Fig. 3 Household per capita landholdings, all villages combined

Canocota and Tuti—are grouped as "agro-pastoralist" villages (Tables 3 and 4, Fig. 4)

The boxplots in Fig. 4 show that the distribution of household per capita landholdings varies considerably within and among villages. Looking at the median values of household per capita landholding between villages demonstrates these differences. Yanque has by far the highest median value (0.29 ha/capita; 0.36 ha/capita with landless households excluded). The other agriculturalist villages have markedly lower median values (ranging from 0.15 to 0.23 ha/capita). The median values for the agro-pastoralist villages are similar and smaller yet (0.11 and 0.09 ha/capita respectively).

These differences are further highlighted by examining the range of household per capita landholding in each village (Fig. 4). The inter-quartile range of household land per capita holdings is by far the greatest in the provincial capital, Yanque; from 0.23 to 0.57 ha/capita. Moreover, the boxplot shows how the top quartile households in Yanque were extremely land-wealthy compared to the other villages. The other agriculturalist villages show similar inter-quartile distributions (0.11–0.32 ha/capita). The higher villages of Tuti and Canocota show the lowest variation among households in the middle quartiles; from 0.097 to 0.22 ha/capita. Aside from Yanque (and, to a lesser extent, Chivay), the villages stand out for their self-similarity and relatively small range of household land-holdings per capita.

Analysis of variance (ANOVA) demonstrates that the households in Yanque have significantly greater average landholdings per capita than any of the other villages, F (5, 1471), $p<0.001$. There are no significant differences between the other three agriculturalist villages. When grouping the agriculturalist and agro-pastoralist villages into two groups, households in agriculturalist villages are shown to have significantly greater average per capita landholdings than the agro-pastoralist villages, t (1,588.03)=8.613, $p<0.001$.

Household Production Sufficiency Ratios (HPSR) among Collagua Villages

To address the question of whether such landholding disparities correspond with differences in production sufficiency, we simulate agricultural production and caloric demand at several scales. To determine the overall caloric sufficiency of all households in the data set we sum the total calorie demand of the entire sample population and compare it with the total calorie production from all listed fields. Overall, the valley's populace could have produced 130% of its need in a typical year (Table 3). Thus, in aggregate, there was evidently enough production to cover subsistence demands and still leave a significant surplus (an expected result, given the reputed agro-pastoral wealth of the province). This appears to be true at the village level as well; each village *in aggregate* produced enough calories from its agricultural lands to support its population, with the exception of the highest-altitude agro-pastoralist village

Table 3 Summary statistics by village

Village	Village class	N (households)	Population	Total fields	Total area (ha)	Ha/ capita	kcal production (in millions)*	kcal demand (in millions)	Production/ demand ratio
Achoma	Agriculturalist	329	692	859	122.23	0.18	743.0	603.2	1.23
Yanque	Agriculturalist	233	468	1,291	178.69	0.38	1,079.8	400.2	2.70
Coporaque	Agriculturalist	947	2,003	3,098	351.44	0.18	2,124.9	1,728.7	1.23
Chivay	Agriculturalist	101	217	334	47.41	0.22	285.1	185.0	1.54
Canocota	Agro-Pastoralist	136	268	346	40.73	0.15	241.6	233.5	1.03
Tuti	Agro-Pastoralist	405	950	1,568	117.68	0.12	666.9	816.6	0.82
Total		2,151	4,598	7,496	858.18	0.19	5,141.4	3,967.2	1.30

Table 4 Summary statistics: household per capita landholdings by village

Village	N	Mean household ha/capita	Std. deviation	Min.	Max.
Achoma	239	0.254	0.182	0.022	1.005
Yanque	162	0.610	0.526	0.044	3.759
Coporaque	646	0.278	0.219	0.022	1.835
Chivay	74	0.311	0.215	0.055	1.049
Canocota	79	0.265	0.212	0.044	1.267
Tuti	277	0.188	0.161	0.022	1.136
Total	1,477	0.295	0.282	0.022	3.758

in our data set, Tuti, which could only meet 82% of calorie demand from agricultural production. Undoubtedly, Tuti households relied more heavily on pastoralist production—consumption of meat and sale or exchange of meat for agricultural produce—to meet their subsistence needs (Table 3).

But it is at the household level that food resources were produced and consumed, so we must examine production/need ratios by households (Fig. 5). If we consider all villages aggregated together, the median HPSR (1.14) was clearly adequate. Nearly 60% (57%) of households enjoyed HPSRs at or above 1.0 and another 13% had values from 0.8–1.0. Notwithstanding, 10% of households had HPSRs in the 0.65–0.8 range and another 20% were below 0.65. So 30% of households in the sample could not have met their own caloric needs from agricultural production on their own plots, and another 13% only met bare subsistence levels, even before colonial tribute is taken into consideration.

Some of the differences in HPSR values for villages as a whole correspond to differences in their respective economic foci and political roles within the provincial administrative structure. The mean HPSR value among the villages in the agricultural core of the valley was 1.60, compared to 0.92 among the agro-pastoral villages—a significant difference, $t\ (1{,}310.90)=12.828$, $p<0.001$. These results indicate that the mixed agro-pastoral economies of Canocota and (especially) Tuti required pastoralist production for self-sufficiency. Clearly, some of the household HPSR variability between villages can be attributed to ecological context and the relative importance of pastoralist versus agricultural production. Low HPSR values based on agricultural production in the agro-pastoralist villages is to be expected, given that much of their economies were dependent on herding (livestock declarations were very patchy in the visitas, precluding modeling).

But if analysis is focused to only the agriculturalist villages, marked variation in HPSRs is better attributed to differences in political and economic status (Fig. 6). Among the agriculturalist villages, Achoma, Coporaque, and Chivay appear quite similar overall, with median HPSR values of 1.20, 1.10, and 1.40, respectively. Nearly 60% of households in both Achoma and Chivay were at or above the HPSR self-sufficiency mark of 1.0, while 74.3% of Chivay households were at or surpassed HPSRs of 1.00. But this seeming difference in household production sufficiency is not statistically significant. These three give the impression of modest populations of subsistence

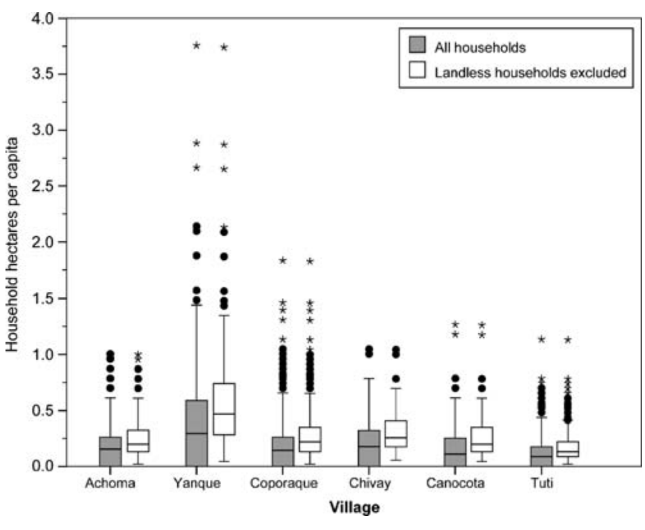

Fig. 4 Household per capita landholdings, by village

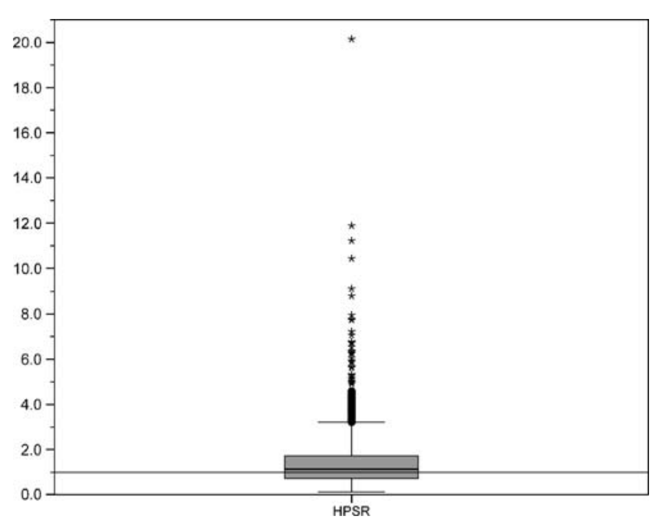

Fig. 5 HPSR values, all villages combined

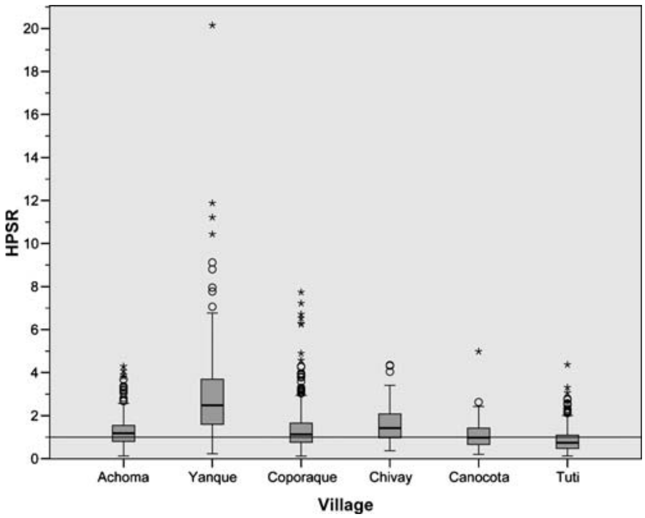

Fig. 6 HPSR values, by village

agriculturalists. In Achoma and Coporaque, households with HPSRs below 0.80 made up about a quarter (25% and 28% respectively) of the households, while at least the top quartile of houses in both were producing twice as much or more than needed for subsistence.

By contrast, Yanque, the provincial capital, stands out as clearly the most prosperous of the villages in our sample, both in land resources (see above), and surplus agricultural production. Its households enjoyed a median HPSR of 2.50 (Fig. 6). Indeed, 90.1% of households in Yanque have HPSRs greater than 1.0. The variability of HPSRs is quite extreme in Yanque, ranging from households producing over eight times subsistence level (>8.0 HPSR) to ones with HPSRs less than 0.50. Most of the remaining households (8.0%) have HPSRs between 0.8 and 1.0. A tiny minority (1.9%) have HPSRs below 0.65.

Thus, in answer to our second question, analysis of the visita data suggests a significant variability in HPSR within and among villages. The core agriculturalist villages demonstrate adequate HPSR *in the aggregate*, while the agropastoral villages did not. Moreover, there appears to be significant variation of HPSRs within the agricultural villages, especially for the provincial capital, Yanque.

Discussion and Conclusion

These results go some way to explaining how a "breadbasket" province was also a place of considerable hardship during early colonial times. On the one hand, the agricultural economy of Yanquecollaguas was clearly capable of producing a sizeable surplus. If the equally (if not more) significant herding sector were amenable to comparable quantitative measure, aggregate agro-pastoral surpluses were probably considerably larger, reflecting the reputed wealth of the province as a whole. But just as clearly, inequities in the distribution of agricultural lands within and among villages show the inadequacy of regional carrying capacity models. Many households were not agriculturally self-sufficient because of large inequalities in the distribution of landholdings within and between villages.

That we discovered great variation in landholding and HPSR perhaps should not be surprising. Archaeological evidence—particularly the size range of local prehispanic domestic structures—point toward major disparities in wealth and status during the Late Intermediate Period and Late Horizon (Wernke 2006a, b). Colonial period demographic and agricultural decline may have exacerbated these inequalities in several ways. Communal lands, while probably not great in extent in the Colca valley (see below) may have been partially appropriated by local elites as their own fields in the visita declarations. Kurakas also may have appropriated some lands left by deceased individuals with no direct heirs. So agricultural inequalities almost certainly widened in the colonial period.

But the results are not just a reflection of our inability to measure pastoralist production. If the agro-pastoralist villages—those likely to be more reliant on herding—are excluded the HPSRs reveal an intriguing pattern. In Achoma, 24% of the households (i.e., 57 of 239) had HPSRs less than 0.8, values we suggest are below normal variations and show households unable to feed themselves from their own production. The corresponding figures for Coporaque are 28% (181 of 646) and for Chivay 16% (12 of 74). Thus, nearly a quarter (23%) of these households in these three agriculturalist villages must have suffered significant nutritional deficiency or had alternative means to support themselves. Turning to Canocota and Tuti, their HPSR data indeed do show a large fraction of the households have ratios less than 0.8 (37% for Canocota and 56% for Tuti), which undoubtedly—at least in part—reflect the greater salience of herding in their economies. So they were not as impoverished as it would seem based on the agricultural data alone. Also, as has been documented elsewhere (Wernke 2003:359–365; 2006a), the ayllus of these villages were linked politically to their counterpart ayllus in the agriculturalist villages, which undoubtedly channeled the exchange of agricultural and camelid products. So the low HPSR and household land per capita data in Canocota and Tuti partly reflects ecological complementarity practices and not just nutritional deficiency. This complementary exchange most likely offset the apparent deficiencies among some agriculturalist households on the cusp of self-sufficiency, but its effects should not be overestimated. In contemporary times, even among pastoralist communities, meat consumption is not as high as might be expected (Picón Riátegui 1978:223–224). It therefore seems unlikely that exchange for meat (or direct production of meat) made up for households with over 20% (<0.8 HSPR) subsistence shortfalls.

Moreover, the above discussion does not take into consideration the impact of colonial tribute and labor levies. For the period of interest here, the annual colonial tax rate for the Yanquecollaguas (set by Toledo in 1572) was 4.5 pesos per tributary. The total tribute levy (the *tasa*) was divided between 44% cash and 56% in-kind goods (Cook *et al*. 1975 [1582]:217–218), but in the cash-poor regional colonial economy, most households probably paid in kind, according to the set cash equivalencies discussed previously. However, due to demographic decline (primarily from epidemics), the effective tax rate in most years was even higher, since the living were required to continue paying the tributes of the dead until revisitas were completed. A full discussion of tax burdens is beyond the scope of this paper, but a preliminary analysis suggests that households were paying a de facto rate of 6.0 pesos per tributary on the eve of the 1591 revisita, some 18 years after the visita general (Whitmore and Wernke 2005). Generating the cash (or equivalent produce) for these high tributes would have been extremely difficult or impossible for the 30% of households producing 80% or less of their subsistence needs, and almost certainly pushed otherwise marginally self-sufficient households into a precarious economic and subsistence situation. Additionally, approximately 1/7 of the tributary population was obliged to serve a rotating labor tax (the colonial *mita*), which by the 1590s was usually served through portage of wine and other goods through the region, or as labor on the Spanish haciendas of neighboring valleys and in the city of Arequipa (the *mita de plaza*) (Cook 2007:158–159). Mita service, though theoretically timed to minimize disruption to the agricultural calendar, in practice did impact agricultural productivity of conscripted households. So the clamor for recounts on the part of the kurakas, especially in the wake of epidemics or natural disaster (such as the earthquake of 1582 and the eruption of 1600), was clearly motivated by intense pressures from their increasingly impoverished ayllu kin.

In sum, these findings document that while the economy of Yanqueollaguas as a whole produced sizeable agricultural surpluses, inequalities in the distribution of landholdings produced net subsistence deficits among a sizeable proportion of the population. At the macro-scale, some of the lower HPSR values of the agro-pastoralist villages are attributable to their greater dependency on herding, a segment of the economy that is nearly invisible in the visitas. But the marked inequalities among the agriculturalist villages—particularly Yanque and the other villages—most likely reflects real differences in the ability to meet subsistence demands. We suggest that most of these households were probably land poor families who traded labor for food or who received food through redistribution from within their ayllus. But it remains unclear to what degree these land-poor households represent an incipient laboring class alienated from the means of agricultural production. Countervailing forces of the ideals of ayllu self-sufficiency on the one hand, and the extractive demands of the state (including colonial labor drafts and tribute levies), created a fluid political and economic situation that produced a small but growing rural laboring class (Spalding 1982: 324–332; Stern 1982:148–153). As discussed, some expropriation also came from endogenous factors; primarily land-grabbing by kurakas (well-documented in many other areas).

Although this analysis raises at least as many questions as it answers, it identifies the scale of the landless and resource-poor population, where they come from, and suggests that such disparities were likely to grow as a result of demographic and agricultural declines, coupled with the potential for exploiting marginally self-sufficient and poor households by colonial kurakas. By simulating and analyzing household- and community-scale economics we begin to shed light on how communities, and which households within them, became increasingly impoverished in a colonial economy of surplus extraction.

Acknowledgements This research was made possible by the Postdoctoral Fellowship Program at the Carolina Population Center (University of North Carolina at Chapel Hill). The Wenner-Gren Foundation for Anthropological Research supported the establishment of the visita database (Grant No. 6431). The authors wish to thank Clark Gray and Tiffiny Tung for the critical input on drafts. Anonymous reviewers provided thoughtful suggestions and criticisms. Maps were created in the Vanderbilt University Spatial Analysis Research Lab. Copies and transcriptions of the Colca Valley visitas were made available to Wernke by Maria Benavides, with the support of William Denevan. Any errors are the sole responsibility of the authors.

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