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# Eyes of the empire: A viewshed-based exploration of Wari site-placement decisions in the Sondondo Valley, Peru

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ABSTRACT

The Wari empire (AD 600–1000) deployed a variety of strategies to consolidate its provinces in Middle Horizon Peru. One strategy may have been building imperial sites in places with large visual magnitudes, which are attractive to empires because they are more defensible, they are suitably located for direct and implied surveillance, and they project a visually-dominant presence on the landscape. In the Sondondo Valley, Peru, the Wari empire made a significant investment of labor and resources in the construction of terraces, roads, and five imperial sites. The viewsheds of these sites are compared to those of 20 non-imperial sites, 495 randomly-placed individual sites, and 99 randomly-placed groups of five sites each. Parametric and non-parametric comparisons reject the null hypothesis that there is no difference between viewsheds. Imperial sites had significantly larger and better-coordinated viewsheds, as estimated from overlap and coverage indices. These results support the argument that imperial agents' site-placement decisions considered the benefits of locations with large viewsheds. From these sites, the empire's representatives effectively advanced imperial goals for two and half centuries. Similar factors may have been salient in other imperial settings, so this approach may help explore site-placement decisions in other regions.



## 1. Introduction

In Middle Horizon Peru, the Wari empire (AD 600–1000) expanded from its eponymous capital in the Andean highlands and incorporated a number of provinces (Fig. 1). Like other successful empires, Wari adapted conquest and consolidation strategies to each region (Schreiber, 1987, 1992). Imperial representatives would have made administrative decisions on behalf of the empire based on their knowledge of imperial goals and the local situation. This approach privileges the decisions of the individuals participating in empire building and eschews top-down perspectives that tend to treat empires as monolithic, faceless entities.

This paper's goal is to clarify site-placement decisions in one of Wari's major provinces, the Sondondo Valley[1] (Fig. 2). The empire made significant investments in the construction of agricultural terraces, a major road, and five imperial sites. The decision of where to build these sites can be explored through viewshed analysis (Whitley, 2004). Viewshed analysis offers a quantitative means of comparing archaeological and randomly-placed sites (e.g., Bongers et al., 2012; Fisher et al., 1997). Places with large viewsheds are more defensible, offer better opportunities for direct and implied surveillance, and can be used to create a visually-dominating presence on the landscape or even co-opt sacred landmarks (Williams and Nash, 2006). These factors may have been some of the reasons behind Wari's enduring control, established from sites placed in effective locations. These factors may have also been important in other empires, making this a relevant case study for exploring site-placement decisions in other contexts.

### 1.1. The Wari empire and its provinces

The first great empire of the ancient Andes was centered in the Ayacucho Valley of highland Peru (Bergh, 2012). At its peak it controlled extensive areas along the Pacific coast and Andean highlands (Fig. 1). Expansion probably began sometime in the seventh century AD and by the following century, Wari had begun building imperial-style infrastructure throughout its realm. A few of the better-known provincial centers are Viracochapampa (Topic, 1991), Honcopampa (Isbell, 1989), Pikillaqta (McEwan, 2005), Jincamocco (Schreiber, 1992), and Cerro Baúl (Williams, 2001; Nash and Williams, 2004). These centers share a number of material features such as a distinctive, uniform, rectilinear architectural style (Schreiber, 1978, 2012; Spickard, 1983; McEwan and Williams, 2012) and elaborately-decorated ceramic vessels (Knobloch, 1991; Menzel, 1964). A network of imperial roads connected these sites to the capital and each other (Lumbreras, 1974;

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[1] In previous publications, the Sondondo Valley was referred to as the Carhuarazo Valley, before the Peruvian government officially designated it the Sondondo Valley.

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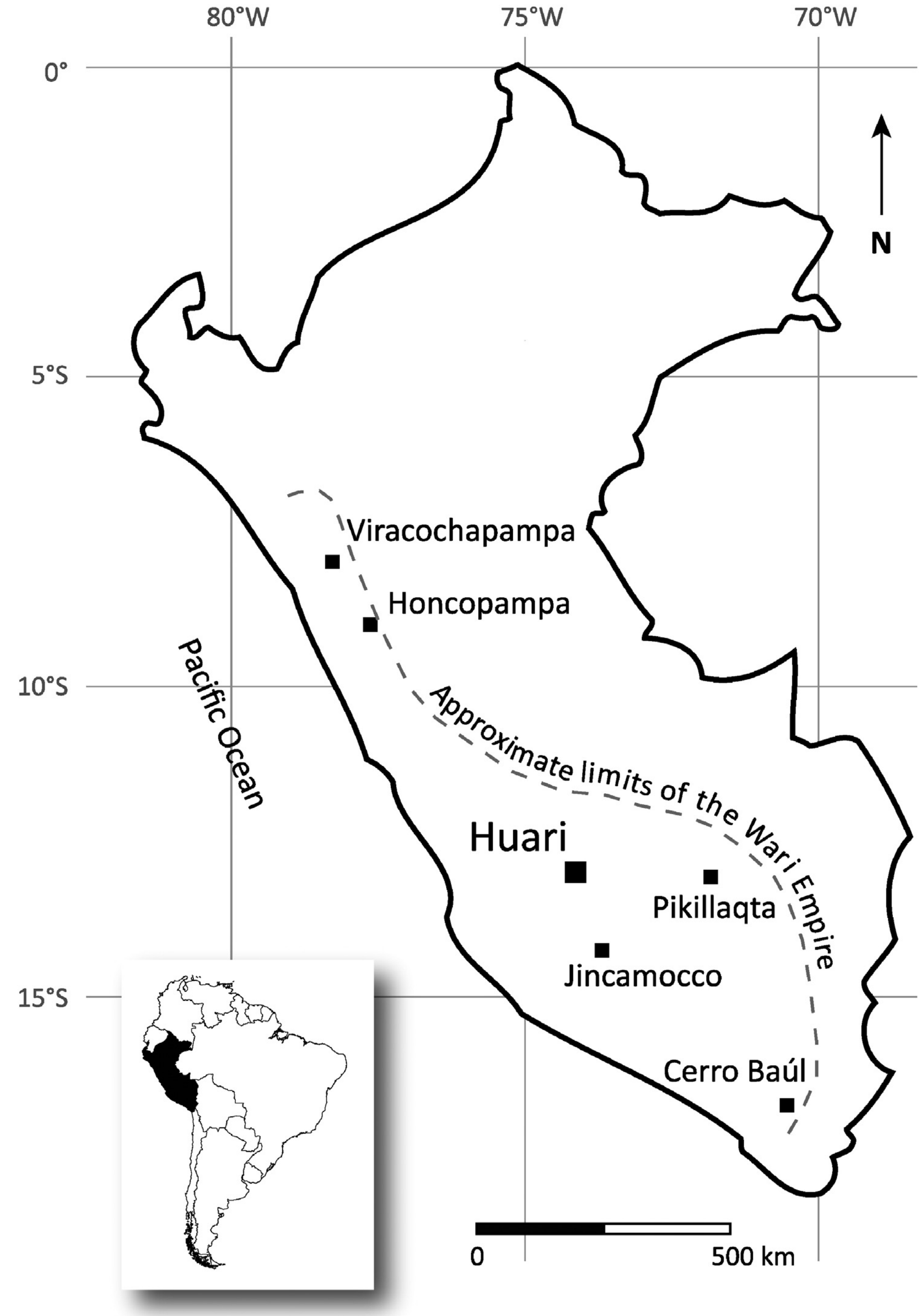


**Fig. 1.** Major Wari sites, including the capital Huari, and the approximate limits of the Wari empire, shown within the outline of modern Peru. The limit does not imply continuous spatial control, which seems unlikely. Inset map indicates the location of modern Peru, shaded, within South America.
Adapted from Schreiber (2004, figure 8.1).

Schreiber, 1984, 1991). Overall, the evidence suggests that Wari was a unified polity that modified its relationship with each conquered province according to local conditions, such as population density, degree of political organization, available resources, and strategic location (Schreiber, 1992, 2012; Jennings and Craig, 2001).

### *1.2. The Wari empire and militarism*

Militarism was a substantive feature of the Wari empire. Subsidiary centers near the capital were fortified (Pérez Calderón and Cabrera, 1999). The 2-km$^2$ walled complex at Pikillaqta may have maintained a military garrison (McEwan, 1991: 117) and was surrounded by smaller sites and walls positioned to withstand a military threat and control access (Arkush, 2006: 292). Wari iconography features soldiers carrying shields, axes, bows, arrows, and trophy heads, suggesting the potential of violent conflict in Wari society (Ochatoma Paravicino and Cabrera, 2002). Actual violence is documented from decapitated heads and skeletal trauma at multiple sites (Verano, 1995; Tung, 2007, 2008).

Wari seems to have relied on force or the threat of force to conquer and consolidate geographically large territories (Arkush, 2006: 294; Isbell and McEwan, 1991: 301; Lumbreras, 1974: 165, 177), perhaps not unlike dynasties in China (Waley-Cohen, 2006), the Roman Empire

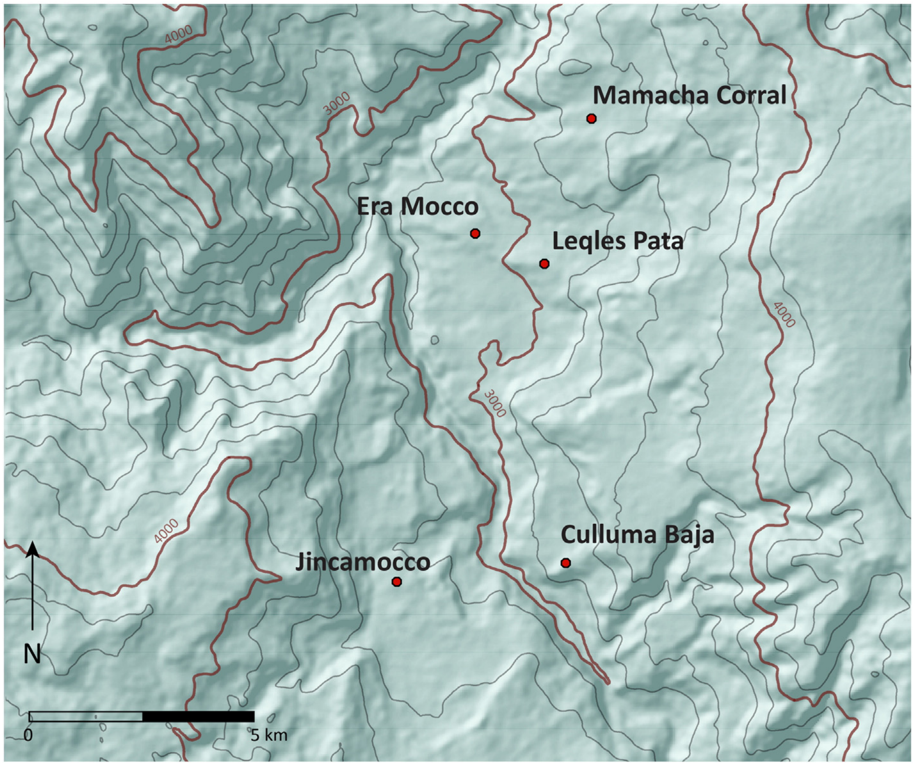


**Fig. 2.** Contour map of the Sondondo Valley, showing the five Wari imperial sites. Contour interval 200 m.

(Harris, 1979), and the Inca Empire (D'Altroy, 2002). It is likely that Wari's agents made use of cost-effective strategies such as implied force, coercive diplomacy, and co-opting local political hierarchies (Sinopoli, 1994). Military and political hierarchies may have been closely linked (Smith, 2003). Members of these hierarchies may have had peacetime responsibilities such as managing labor conscripts, food production, and directing construction projects.

### *1.3. Imperial investments in the Sondondo Valley*

The Sondondo Valley would have been attractive to imperial representatives for its maize-growing potential, lack of organized resistance, and strategic location midway between the capital at Huari and Nasca on the Pacific coast. Wari's presence lasted for around 250 years and was focused at the valley's capital, Jincamocco (Schreiber, 1978). Built in the Wari's iconic architectural style, Jincamocco's original enclosure measured about 130 × 260 m. Unlike other regional centers, the site was later expanded to cover 15 ha, implying that its importance increased over time (Schreiber, 1987: 273, 279).

The large and enduring imperial investment in the Sondondo Valley stands in stark contrast to the lack thereof in the valley's three main tributaries and the two neighboring valleys (Meddens, 1984; Valdez and Vivanco, 1994; Schreiber, 2004: 146). Assuming imperial representatives knew the region, it seems they chose the Sondondo Valley over other options. In the succeeding centuries, Wari invested more labor and resources here than in many other provinces, despite its distance from the capital (Schreiber, 1992: 262).[2]

#### *1.3.1. Terraces*

Nearly all of the lower valley flanks between 3000 and 3300 m asl were terraced, and the settlement pattern shifted toward this maize-growing altitude range (Schreiber, 1992: 151, 161). Imperial agents may have relocated local groups to sites near these terraces to increase maize production destined to quench the capital's growing thirst for ritually-drunk maize beer or satisfy the hunger of expanding urban populations (see Finucane et al., 2006). Maize would have moved to the capital along imperial roads.

#### *1.3.2. Roads*

Roads are the backbone of empire. Administrations rely on roads as conduits for soldiers, support staff, commerce, tribute, and information. Like major rivers in lowland settings, roads articulate core and peripheral social networks, integrate political apparatuses, and allow for effective long-distance movement of goods. Wari built a major trunk of the imperial highway through the Sondondo Valley, connecting the highland capital and the Pacific coast (Schreiber, 1984, 1991: 251). The main road connected three imperial sites in the Sondondo Valley, including Jincamocco (Schreiber, 1991: 244).

#### *1.3.3. Creating a local political hierarchy*

Wari created a new local political hierarchy in the Sondondo Valley because no such system existed previously (Schreiber, 1978; Schreiber, 1992: 263). This meant investing in the construction of five new sites. The largest was Jincamocco, located on the western flank of the valley (Fig. 2). To the north, Mamacha Corral[3] was near an obsidian source and adjacent to the Wari road. Lower in the valley was Era Mocco, which may have served as a secondary administrative center. Leqles Pata[4] was built on a high ridge near a religious shrine. Culluma Baja lies directly opposite Jincamocco in an area of rich agricultural land. The choice of where to build these new sites can be illuminated through viewshed analysis.

## 2. Exploring site placement with viewshed

Viewshed can be used as a proxy to explore site placement (Wheatley and Gillings, 2000; Stančič and Veljanovski, 2001; Lake and

[2] The occupation of Moquegua is a notable exception to this tendency (Williams, 2001).

[3] This site was called Willkaya in Schreiber (1992: 155).

[4] This site was called Anta in Schreiber (1992: 154).

Woodman, 2003; Wheatley, 2004; Whitley, 2004). This approach investigates motivations for site placement from an individual's perspective of the landscape (Wheatley, 1995; Ruggles and Medyckyj-Scott, 1996; Loots et al., 1999; Gillings and Wheatley, 2000: 26; Ogburn, 2006; Williams and Nash, 2006). Wari imperial agents would have had the opportunity and motivation to deliberately consider and choose locations for new sites. Local and imperial data provide reasonable suggestions for possible factors in these decisions. Furthermore, it is reasonable to assume that site-placement decisions were roughly contemporaneous, based on radiocarbon and ceramic chronologies.

Locations with large viewsheds may reflect a preference for scenic views, but they are more useful as a means for identifying places where (1) soldiers can more effectively defend from attackers, (2) guards can directly or implicitly monitor military maneuvers, imperial infrastructure, economic activities, and peoples' movements, and (3) iconic architecture and other imperial symbols visually dominate the landscape. The combined effect produces a political landscape that legitimizes control and power (Smith, 2003) and creates an imperially-centered "sight community" based on a shared visual landmarks (Bernardini and Peeples, 2015).

### 2.1. Defensibility

Viewshed analysis can identify defensibility via lines of sight (Haas and Creamer, 1993: 25–35). Along lines of sight, allies can communicate, see potential threats, and effectively use projectile weapons (Loots, 1997; Conolly and Lake, 2006: 229; Keeley et al., 2007: 70–72). Hence viewshed reflects a site's potential defensibility (see Lock and Harris, 1996; Loots et al., 1999; Maschner, 1996).

### 2.2. Direct visual surveillance

Direct visual surveillance would been one of the most effective methods of gathering information in prehistoric empires. It would have been indispensable for tracking friendly and unfriendly military operations, policing imperial infrastructure, construction projects, labor parties, tracking road traffic, and monitoring dissent.

### 2.3. Implied surveillance

Implied surveillance is epitomized by Bentham's (1995 [1787]) Panopticon (e.g., Marcoux, 2003). Subjects are aware of the possibility of being monitored and regulate their own behavior, which is a cost-effective means of surveillance (Foucault, 1995 [1977]: 201–203). Contrary to Foucault's suggestion, this has considerable antiquity: the Romans used it to consolidate rebellious territory (Cohen, 1999; Yekutieli, 2006).

### 2.4. Implied power

Dominant social groups often reinforce asymmetrical power relationships by occupying higher and more visible locations (Smith, 2003: 232–238), which was likely part of Wari's strategy at the visually dominant sacred peak Cerro Baúl (Williams and Nash, 2006). The effect can be amplified through dominating architecture (Tinniswood, 1998), exemplified by the rectilinear Nazi style that consciously embedded messages of power (Lane, 1986; Del Rosario Betti, 2006; Macdonald, 2006). Wari architects may have designed buildings to appear "invincible and bureaucratically efficient" (Spickard, 1983: 141), an effect that would have been amplified against the natural landscape. Such implied power and surveillance can be very effective when combined with coercive force (Tzu, 2001).

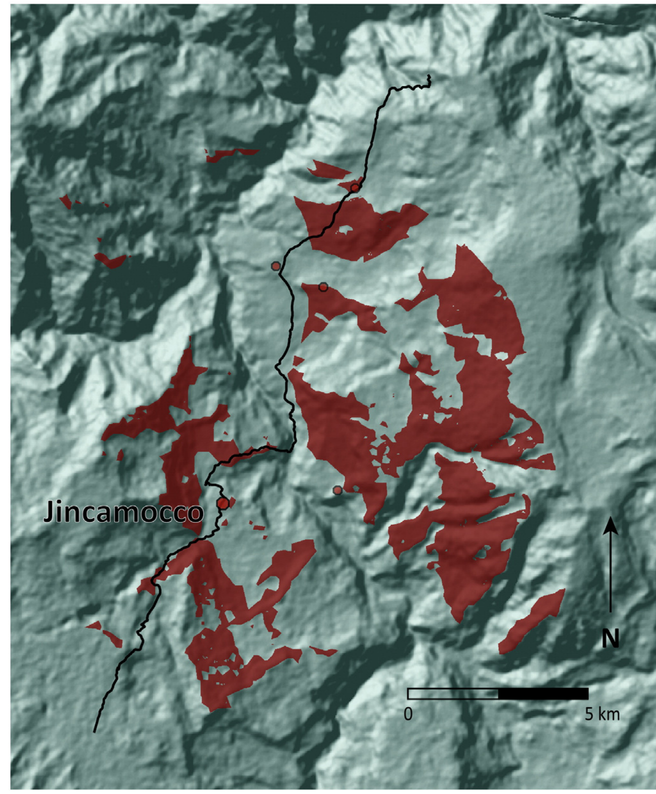


**Fig. 3.** Viewshed of Jincamocco, shaded in red. The black lines marks the likely route of the Wari road through the valley. The route is based on inspection of aerial photographs, which is visible in about three-fourths of the total length. Jincamocco is a red dot; the other Wari sites are gray dots. The viewshed is based on a 1.5 m tall viewing point in the center of Jincamocco. Sentries patrolling this 15 ha site would have had a much larger view that completely covered the road approaching the site from both directions. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

## 3. Viewshed analysis: data and methods

### 3.1. Data

Archaeological sites were located during full-coverage pedestrian survey of the Sondondo Valley. Their period of occupation was based on diagnostic ceramics, architectural patterns, and radiocarbon dates (see Schreiber 1978; Schreiber, 1984; Schreiber, 1992). Two sets of imagery made it possible to improve the accuracy archaeological sites' locations as well as the road's route (Fig. 3). The first set of images used was of 1955 aerial photographs from the Peruvian Air Force, which were georectified and corrected for lens distortion. These images were taken before recent construction projects and significant landscape modifications, which are visible in the second set of images, high-resolution satellite imagery in Google Earth (Fig. 2).

Viewshed analysis was run with the Spatial Analyst tools in ESRI's ArcGIS 9.2,[5] which estimated the total visible area, or cumulative viewshed (Wheatley, 1995), from 25 archaeological, 495 randomly-placed sites, and 99 groups of five sites each (Figs. 3, 4). All analyses were automated with python scripts.[6] The landscape was represented by a smoothed Digital Elevation Model (DEM) from the ASTER image library (the AST14DEM dataset) with cells that measure 30 × 30 m

[5] Different software packages use different algorithms and do not produce identical viewsheds, even with identical data (Fisher, 1993). In comparison to other common software packages, ESRI's algorithm most accurately predicts viewsheds checked against field data (Riggs and Dean, 2007: 185). In more recent versions of ESRI's software, the viewshed algorithm remains unchanged.

[6] Available from the author by request.

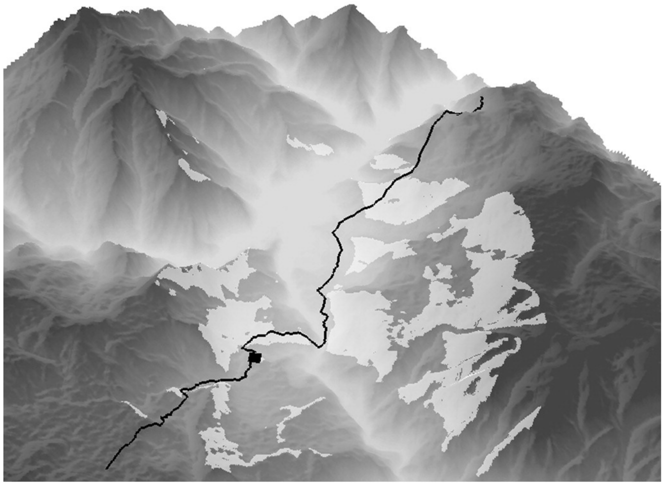

**Fig. 4.** Viewshed of Jincamocco rendered in 3D using ArcScene, as seen from the south. The area visible from Jincamocco is shaded. Jincamocco is marked as a black square; the line is the Wari road. Elevation is exaggerated for effect.

(900 m$^2$). We avoided edge effects by using a DEM that extends 10 km beyond the study area (Van Leusen, 2002).

### 3.2. Viewshed parameters

A variety of parameters can be incorporated into viewsheds (see Conolly and Lake, 2006: 228–233; Gillings and Wheatley 2001: 33–36; Wheatley and Gillings, 2000, 2002: 209–216). Our goal was to make comparisons between data sets, not to approximate the ancient visual experience.[7]

First, topography and vegetation changes can affect visibility, but they have likely not changed much since the Middle Horizon, when most of the valley was terraced and deforested (Schreiber, 1984: 248; Schreiber, 1987). Second, the curvature of the earth makes objects appear lower than they are while refracting light produces the opposite effect (Moffitt and Bouchard, 1987). The net result is that an object appears lower than it is by about 0.68 m per horizontal kilometer, which was estimated with ESRI's standard correction (based on Yoeli, 1985). We did not account for the thin air of the Andes, which has a negligible effect at this scale. Third, the heights of the observer and the target were set to 1.5 m to approximate two people looking at each other (Lock and Harris, 1996; Wheatley, 1995). Fourth, maximum viewshed was set to 10 km, based on three independent types of data: (1) military studies report a similar maximum distance for pilot vision and ground observers targeting aircraft (Baldwin, 1973; Foyle and Kaiser, 1991; Hoffman, 1981), (2) many weather stations use 10 km as a maximum visibility distance, including at those at the airports in the Andean highlands, and (3) someone with excellent vision can resolve a 1.5 m object at a distance of 10.3 km (Ogburn, 2006: 406, 410). Fifth, this analysis uses binary viewsheds and cells are treated as visible or not, to make comparisons more straightforward.

Viewsheds were calculated from a single cell at the center of each site, even though some sites are larger than a single cell. The principal reason to do this is to maintain similar criteria for archaeological and randomly-placed sites, which makes the datasets directly comparable. This approach makes the null hypothesis more difficult to reject because it underestimates the viewshed of larger sites such as the Wari installations. This approach is not meant to precisely recreate the ancient visual experience but rather to make comparisons that shed light on site-placement decisions. The *relative* differences between viewsheds should not be significantly affected by additional parameters (Lake and Woodman, 2003: 698).

### 3.3. Total viewshed

A total viewshed is a useful first step in exploring a landscape (Llobera, 2003: 33). It is generated by summing the number of cells visible from all other cells on a landscape, also known as "times seen" (Fisher et al., 1997), and can be reliably estimated from a sample of points (Lake et al., 1998: 36; Wheatley, 1995). We summed viewsheds from 1000 randomly-placed points to estimate the total viewshed of the Sondondo Valley (Fig. 5).

### 3.4. Null hypothesis

The null hypothesis is that there are no differences between the viewsheds of archaeological and randomly-placed of sites. This would mean that the benefits of locations with large viewsheds were not significant factors in site-placement decisions. The hypothesis was evaluated in SPSS 20.0 (IBM Corporation, 2011) with (1) two non-parametric tests, Monte Carlo (Fisher et al. 1997: 587) and Kruskal–Wallis, and comparisons of medians, percentiles, and ranks and (2) parametric t-tests and comparisons of means and standard variations. Visible areas were compared for individual and groups of Wari sites, contemporary non-imperial Middle Horizon sites, sites from the previous Early Intermediate Period (EIP), and randomly-placed sites, following other similar approaches (Bongers et al., 2012; Fisher et al., 1997; Lake et al., 1998: 35; Lake and Woodman, 2003: 693; Wheatley, 1995).

Randomly-placed sites were limited by (1) altitude, 2900–3800 m asl and (2) the extent of the Sondondo Valley for a total area of 260 km$^2$ (Fig. 6). Limiting placement by altitude and using a smoothed DEM excluded many improbable locations such as mountain tops and gullies. The potential effects of such sites on the dataset were further reduced by using a large sample and comparing group averages and indices.

The altitude restriction of 2900–3800 m asl ensures that sites are located within the productive altitude range for farming and herding, based on the assumption that proximity to productive lands was a primary factor in site-placement decisions. This seems reasonable as most human occupation of the valley is within this range and often near the ecotone between maize and tuber growing zones of around 3300 m asl. We chose not to include other factors in the analysis such as proximity to terraces or the imperial road because it is possible they were built after the new sites and hence not involved in site-placement decisions. In sum, rejecting the null hypothesis implies that site-placement decisions considered proximity to productive lands and the benefits of places with large viewsheds proximity.[8]

### 3.5. Group comparisons: overlap and coverage indices

For randomly-placed groups of sites, we made the null hypothesis more difficult to reject by creating groups with similarities to the Wari group. Each group included five sites located within 10 km of each other at economically-productive altitudes. To create these groups, we placed a central point surrounded by a circular buffer with a 10-km

[7] Future research could incorporate methodologies that better approximate the ancient visual experience or even "perception-sheds," (Wichter, 1999; Tschan et al., 2000; Gillings and Wheatley, 2001: 35–36; Conolly and Lake, 2006: 232). Fuzzy viewsheds can be developed with factors such as changing seasons, weather, and sunlight as well as a target's distance, color, luminance, movement, and background contrast (Blackwell, 1946; Greyson and Payne, 1971; Travnikova, 1985; Anitole et al., 1991; Waldman et al., 1991; Fisher, 1994; Peli, 1995; Toet et al., 2000; Watson, 2000; O'Kane et al., 2005; Hautiere et al., 2006; Neider and Zelinsky, 2006; Ogburn, 2006). United States Coast Guard search operations use algorithms that model recognition but these have not yet been incorporated into viewshed analysis (Cooke et al., 1995; Hover, 1988).

[8] Our focus here is on larger, permanently occupied settlements. This would exclude smaller, single-activity sites at other altitudes, for example sites used temporarily for fishing, hunting, or herding near the river, mining camps, defensive outposts, caravan stops, or religious shrines. Hence, small sites (<0.4 ha) were excluded.

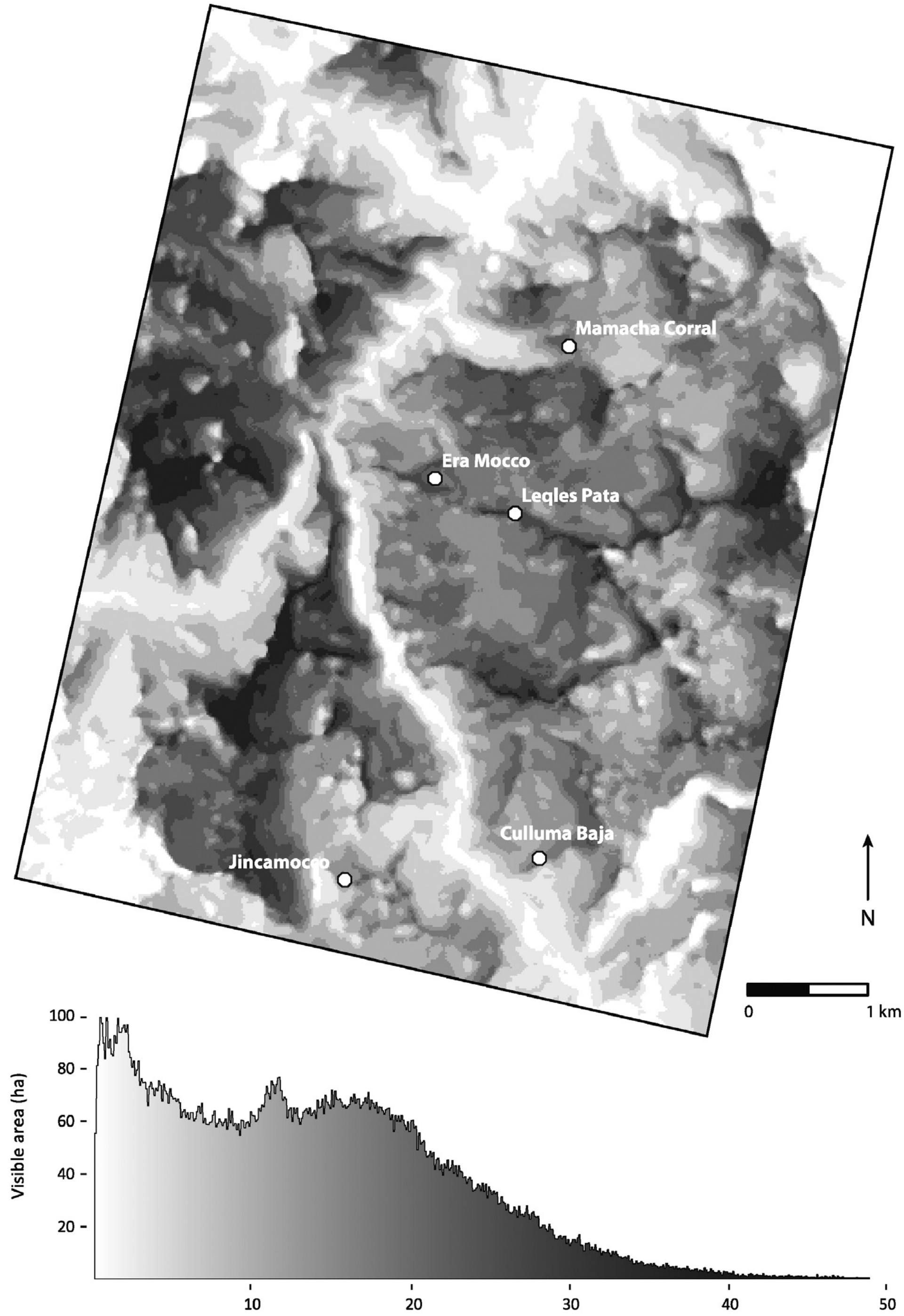


**Fig. 5.** Total viewshed of the Sondondo Valley, estimated as the cumulative viewshed of 1000 randomly-placed points. The histogram compares visible hectares and times seen, showing a curve typical of landscapes with ridges (compare Llobera, 2003, figure 6). The long tail suggests that very few locations have large viewsheds.

diameter, and placed five random sites within the buffer. Both placements were limited to 2900–3800 m asl (Fig. 6). We calculated the viewshed of each site, the group's cumulative viewshed, and overlapping areas, which were exported to a table. These steps were automated for 99 groups.

We used overlap and coverage indices to describe how well a group of sites' viewsheds were coordinated. The overlap index is a relative measure of the degree of overlap between viewsheds of sites within the same group. It ranges from 0 to 5, that is, from zero to complete overlap. It is calculated by multiplying times seen by total area, dividing by weighted area, and summing the weighted areas (Table 4). This improves comparisons by normalizing groups with different total visible areas. Finally, the coverage index is the product of the overlap index and total visible area. A group with a high coverage index has both many areas visible from multiple sites and a large overall visible area. Such a group would best take advantage of the benefits of places with large viewsheds.

## 4. Results and discussion: viewsheds in the Sondondo Valley

The total viewshed illustrates overall patterns of visibility in the area surrounding the valley (Fig. 5). This severe and majestic topography can

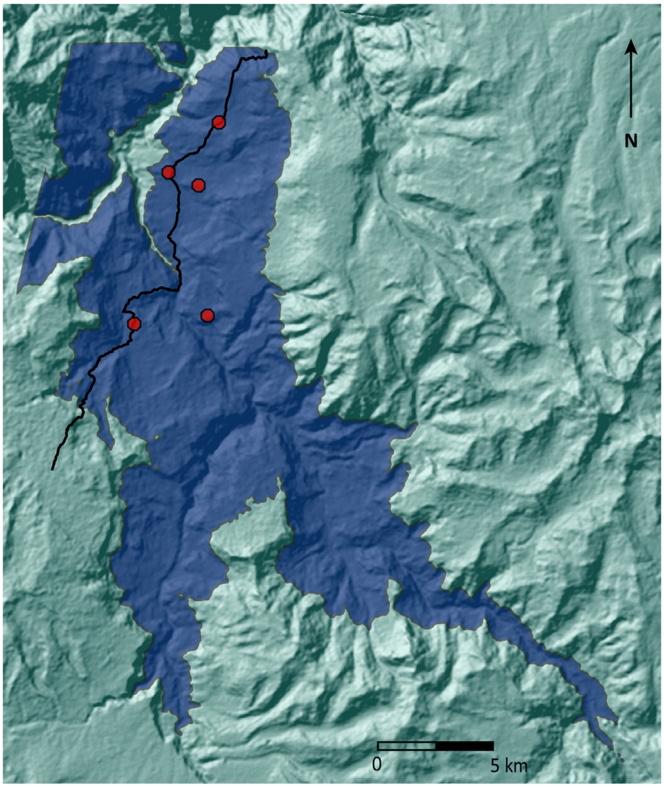


**Fig. 6.** The Sondondo Valley, with shaded terrain between 2900 and 3800 m asl. Wari sites are marked for reference.

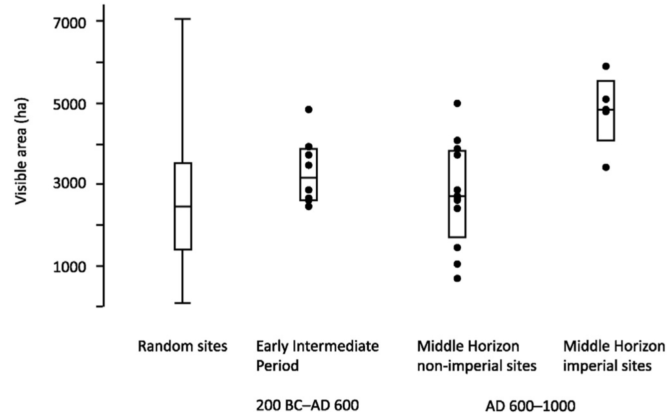


**Fig. 7.** Scatter plots of viewsheds for EIP and Middle Horizon archaeological sites. Vertical boxes indicate the 75th, 50th (median), and 25th percentiles, from top to bottom. Dots indicate viewsheds of individual sites. For randomly-placed sites, the quartiles are indicated in the vertical box and the top and bottom bars indicate the minimum and maximum values. Based on data in Table 1.

be expressed quantitatively as a histogram, which suggests there are many places (times seen) with low visibility and very few places with high visibility. In the total viewshed, the western flank of the valley is highly visible. However, the steep slope of this area makes it impractical to build roads or large sites.

### *4.1. Comparing viewsheds of archaeological and randomly-placed sites*

Comparing the random sites and three sets of archaeological sites, at least one of these sets of data is statistically different, according to a Kruskal–Wallis test ($p < .003$). This test is more appropriate than the similar Kolmogorov–Smirnov test because it can compare more than two groups (Table 1, Fig. 7). The randomly-placed sites show a wide range and a median of 2448 visible ha. In the EIP, eight villages had a median viewshed of 3180 ha. Similarly, non-imperial Middle Horizon hamlets, villages, and towns had a median viewshed of 2703 ha. Viewsheds for these two sets of archaeological sites and the randomly-placed sites are not statistically different, according to Kruskal–Wallis tests ($p > .05$ for all combinations). Hence, for EIP and non-imperial Middle Horizon sites, factors other than viewshed and the related benefits were probably more important in site-placement decisions. In the Middle Horizon, the main factor may have been proximity to lower altitudes for maize production, a possibility supported by the contemporaneous construction of nearby terraces. This may also explain the slightly reduced viewsheds as compared to the previous period; there are three sites with exceptionally low viewsheds of less than 1500 ha (Fig. 7).

In contrast, the Middle Horizon imperial sites had very large viewsheds, with a median of 4855 ha. The EIP and non-imperial Middle Horizon sites only had one site each with a viewshed similar to the imperial average. Compared to the randomly-placed sites, four of the five imperial sites fall at or above the 95th percentile (Table 2). This suggests that they had significantly larger viewsheds ($p > 0.05$), based on a Monte Carlo test. A Kruskal–Wallis test shows that the viewsheds of the Wari sites were not from the same population as the randomly-placed sites ($p < 0.001$), the non-imperial Middle Horizon sites ($p < .011$), nor the EIP sites ($p < .040$). If we were to assume normal data distributions, t-tests show similar results ($p < .004$, .003, and .016, respectively, not assuming equal variances). The average site viewshed within the Wari group was 4773 ha, 2.5 standard deviations above average for randomly-placed groups of 2532 ± 904 ha (Table 3). Various approaches to the data sustain that the Wari sites had much larger viewsheds than other sites. This analysis in fact underestimates the vast extant of Wari intervisibility and viewsheds because they were estimated from a single-point in the center of each site. Larger sites like Jincamocco would have had multiple sentries and much larger viewsheds.

### *4.2. Placing the five Wari sites*

The quantitative results can be contextualized by looking at each site's setting (Fig. 2.). The northernmost site is Mamacha Corral, which was located at the valley's northern entrance and exit and well positioned to monitor or restrict movements on the Wari road. It was also near a source of obsidian with large workshops that provided nearly half of the obsidian at Jincamocco (Burger et al., 1998, Table 3; Schreiber, 1992: 246). Mamacha Corral also had a clear line of sight to Jincamocco, despite "very broken topography" (Schreiber, 1992: 156), which results in increasingly small and scattered pockets of cross-

**Table 1**
Summary and viewshed data of archaeological and randomly-placed sites.

| | Sites | | | Viewshed (ha) | | |
|---|---|---|---|---|---|---|
| | n | Mean size (ha) | Size range (ha) | Median | 25th–75th percentiles | Minumum–Maximum |
| Random sites | 495 | – | – | 2448 | 1378–3537 | 88–7074 |
| Early Intermediate Period villages | 8 | 2.0 | 0.5–5.3 | 3180 | 2612–3861 | 2487–4860 |
| Middle Horizon hamlets, villages, and towns | 12 | 2.0 | 0.4–4.8 | 2703 | 1709–3833 | 694–4998 |
| Middle Horizon imperial sites | 5 | 5.0 | 0.8–15.0 | 4855 | 4095–5409 | 3415–5758 |

**Table 2**
Wari sites' viewsheds and ranks, as compared to 495 randomly placed sites.

| Site | Altitude (m asl) | Viewshed (ha) | Rank (of 500) | Percentile |
|---|---|---|---|---|
| Culluma Baja | 3283 | 3415 | 143 | 72 |
| Era Mocco | 2964 | 5060 | 18 | 97 |
| Jincamocco | 3315 | 4855 | 26 | 95 |
| Leqles Pata | 3124 | 5758 | 13 | 98 |
| Mamacha Corral | 3314 | 4776 | 27 | 95 |

valley intervisibility (Fig. 3). The two sites were separated by around 10 km, the farthest distance between any two Wari sites, and perhaps not coincidentally, the practical limit for human vision. Sentries at this site would have had a clear view of movements along the imperial road and could have communicated with Jincamocco via visual signals.

Era Mocco had a very large viewshed of 5060 ha, unexpected for its lower altitude, 2964 m asl (Table 2). It is located along the Wari road and near terraced agricultural areas, which could have been monitored from the site. On top of the adjacent ridge, Leqles Pata enjoyed an impressively large viewshed of some 5758 ha. Its placement was probably related to the manipulation of worship at scared locations, two of which are located beyond the site. "The need to pass through [Leqles Pata] might have been intended to send the message to the people that their activities, even religious activities, were subject to the control of the empire" (Schreiber, 2004: 144). The site includes ritual architecture and is only Wari site outside the capital with stone-slab tombs. The site was built at one of the most visible points in the valley, at a spiritually-charged location with visually-dominant iconic architecture, and near temples that projected Wari hegemony.

Culluma Baja is also located on a ridge. Its viewshed of 3415 ha is smaller than other Wari sites', but is still relatively high compared to archaeological and randomly-placed sites (Table 2, Fig. 7). It is located immediately above a village near a series of terraces with some of the best agricultural land in the valley (Schreiber, 1992: 153). This site's placement may have prioritized agricultural production and storage.

Finally, the large provincial capital of Jincamocco is located along the road before it climbs out of the valley. This site had a commanding view of the valley covering some 4855 ha. The name of the adjacent modern town, Cabana, is derived from the Quechua *qhwana*, which means "lookout" or "place with a good view" (Schreiber, 1992: 153). Jincamocco had a variety of functions and myriad factors may have influenced the decision of where to build it. It is located on the road and at the ecotone between maize- and tuber-growing altitudes. From here, imperial agents carried a variety of activities and enjoyed the concomitant advantages of a large viewshed.

All Wari sites individually enjoyed the benefits associated with highly-visible locations but also seem to have been placed in a coordinated fashion. There are lines of sight between Jincamocco and Mamacha Corra, Leqles Pata, and Culluma Baja (and probably Era Mocco). There is intervisibility between the Jincamocco and the secondary sites but not between the secondary sites. This would have facilitated a centralized organization of information that required visual messages to pass through Jincamocco.

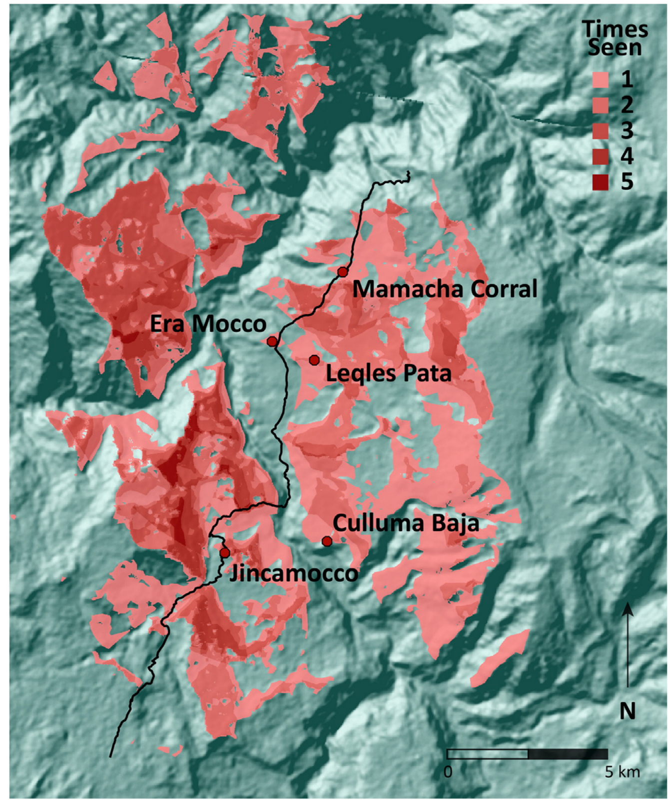


**Fig. 8.** Cumulative viewshed of the five Wari sites. The pink and red shading indicates an area's "times seen." Even though the sites are well-spaced, the area north of Jincamocco is visible from four or perhaps five Wari sites. This could have been intentional, as this was an area where agricultural fields and non-imperial sites were located. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

### *4.3. Comparisons to randomly-placed groups*

Randomly-placed groups of sites were compared to the Wari group, which could see an impressive 12,873 ha (Fig. 8). This is 4.5 standard deviations above the mean of the randomly-placed groups, 5412 ± 1672 ha. This ranks the Wari group 100 of 100 groups in cumulative viewshed. If viewshed were not a factor in site placement decisions, such large individual and cumulative viewsheds would be highly unlikely.

#### *4.3.1. Overlap and coverage indices*

Compared to the random groups, the overlap index of the Wari group was strong, 1.37, but only 0.8 standard deviations above the mean, ranking 79 out of 100 (Table 3). This is a result of the shape of the valley, which has two long and narrow sections to the south (Fig. 6). Groups in these sections have sites that are very close to each other, resulting in disproportionately large overlap indices and small cumulative viewsheds. To take both of these factors into account, we use a coverage index (Tables 3 and 4).

**Table 3**
Summary statistics of randomly placed groups compared to the Wari group.

| | Individual site viewshed (ha) | Cumulative viewshed (ha) | Overlap index | Coverage index |
|---|---|---|---|---|
| Random and Wari groups (mean ± standard deviation) | 2532 ± 904 | 5412 ± 1672 | 1.06 ± 0.42 | 5913 ± 3286 |
| Wari group | 4773 | 12,873 | 1.37 | 17,622 |
| Wari group's standard deviations above the mean | 2.5 | 4.5 | 0.80 | 3.6 |
| Wari group's rank (out of 100) | 100 | 100 | 79 | 100 |

**Table 4**
Calculation of the Wari group's overlap and coverage indices.

| Times seen | Area (ha) | Weighted area | Overlap index | Coverage index |
|---|---|---|---|---|
| | | (times seen × area) | (weighted area / total area) | (total area × total overlap index) |
| 2 | 3329 | 6657 | 0.52 | |
| 3 | 2381 | 7142 | 0.55 | |
| 4 | 784 | 3136 | 0.24 | |
| 5 | 137 | 686 | 0.05 | |
| Totals | 12,873 | | 1.37 | 17,622 |

The average coverage index for randomly-placed groups was 5913 ± 3286 ha, much lower than the Wari group's 17,622 ha, which was 3.6 standard deviations above the mean and ranked 100 out of 100 (Table 3). This can also be expressed as a bivariate plot (Fig. 9). In this figure, the randomly-placed groups form a coherent cloud of points. The edges of the cloud reflect the expected inverse relationship between cumulative viewsheds and overlap indices. Defying the pattern, the Wari group is located well outside of the cloud—it has a strong overlap index yet simultaneously maintains a vast cumulative viewshed.

### 4.4. Discussion

These results indicate that it is highly unlikely that a randomly-placed group could have had such large and coordinated viewsheds as the Wari group. We reject the null hypothesis and suggest the benefits of locations with large viewsheds were primary factors in site-placement decisions. The same pattern is apparent in comparisons to archaeological sites from the previous EIP and contemporaneous non-imperial sites from the Middle Horizon.

From their newly built sites, Wari administrators occupied defensible locations that would have permitted effective actual and implied surveillance while conveying a highly-visible message of power. The sites were built at agriculturally-productive altitudes of the valley, an additional factor in site-placement decisions that facilitated imperial interests in maize production. Placing sites in these locations were decisions that enabled Wari administrators to effectively consolidate the Sondondo Valley.

## 5. Conclusion

Using viewshed to explore site placement from a phenomenological perspective, viewshed analysis can advance our understanding of ancient cultures (Whitley, 2004). These results reinforce the utility of applying viewshed analysis to complex societies, and more specifically, militaristic empires. In other empires, there may have been similar factors involved in site-placement decisions. The results of this paper suggest that viewshed analysis may be an effective first step in evaluating imperial site-placement decisions. By not including additional factors, the benefits of locations with large viewsheds are even more apparent. Future analyses may refine our understanding of these decisions by including other factors such as proximity to agriculturally-suitable land or roads. These results may be useful in generating hypotheses about the function of unexcavated sites; in the Sondondo Valley, only one of the Wari sites has been excavated.

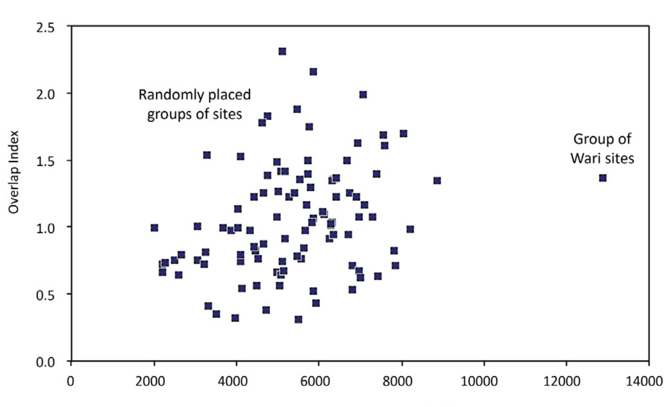


**Fig. 9.** Scatter plot of overlap index (y-axis) and cumulative viewshed (x-axis), showing a group's coverage. The random groups show a well-defined cluster. The Wari group is a clear outlier, with a high overlap index and an extraordinarily large cumulative viewshed.

Wari's consolidation of the Sondondo Valley included the construction of five new sites. From these places, imperial agents effectively advanced imperial goals for centuries. Local infrastructure and administration would have allowed officials to integrate the valley into the empire's bureaucracy. Visual surveillance may have been motivated by a need to monitor and protect productive activities, road traffic, and extensive construction projects. Implied surveillance would have been a subtle and cost-effective expression of power, which would been especially effective from buildings designed in Wari's imposing, emblematic architectural style that projected a visually-dominant presence on the landscape. The extensive remodeling of the valley's landscape in the form of roads, terraces, and new sites enabled the empire to materialize its political order on the landscape and significantly reorder local residents' social and physical space. The arrival of Wari's agents brought many enduring changes to the daily lives of local residents, who spent centuries under the sweeping gaze of the eyes of the empire.

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