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Title: How Is Visibility Important for Defence?: A GIS Analysis of Sites in the Western Fijian Islands

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Abstract:

The analysis of defensive or fortified archaeological sites in the Pacific has a long history, with Geographic Information Systems (GIS) approaches applied with increasing frequency. Much of the recent GIS-based research has emphasized views to and from defensive sites and site location relative to resources such as agricultural land. We add to this growing body of research with analyses of defensive sites in the western islands of Fiji. Our work is the first quantitative GIS analysis of visibility in the Pacific and examines views to and from sites and the content of those views with statistical comparisons to random background samples. Our results indicate that views of high fertility land were an important consideration in the placement of some defensive sites, but that views of other defensive sites were not important. Additionally, some sites are deliberately placed in areas to obscure their visibility.

Introduction

The defensive sites of Remote Oceania are abundantly distributed across island landscapes from the artificially sculpted hilltops of New Zealand (Sutton et al. 2003), to the ring-ditched villages of Fiji's deltas (Parry 1982), and the forts atop the peaks of French Polynesian islands (Kennett et al. 2006). Variation in defensive site features and locations has for some time been explained as a result of a site's relative proximity to and control of arable land (e.g., Kirch 1984). More recently archaeologists have built upon earlier research and generated quantitative analyses of agricultural potential, paleoenvironments, and other relevant variables to explain the location of defensive sites (e.g., Field 2008; Kennett et al. 2006). Visibility from and between defensive sites has also been considered important in explaining site location (e.g., Field 1998; Parry 1977). We build upon this research on site visibility and defence with the first quantitative geographic information systems (GIS) analyses to test whether visibility was an important consideration in the location of prehistoric sites in western Fiji.

We investigated 34 sites with defensive architecture or in upland and relatively inaccessible locations identified previously in the Yasawa and Mamanuca Islands of western Fiji (Cochrane 2009; Cochrane et al. 2007, 2011; Hunt et al. 1999) (Figure 1). We first examined the size of views from these sites, the content of those views, and the size of the area within which the site could be seen. We then compared these observed characteristics of defensive and upland sites to a constrained random sample of other locations on the islands. Constrained random sample locations, or background samples, are generated from (i.e., constrained by) areas geographically similar to the known defensive and upland sites. These background sample locations do not show evidence of occupation and are thus referred to as "non-sites." Some of our results are similar to the conclusions of qualitative analyses in other parts of the Pacific (e.g., Kennett et al. 2006), namely, that views to arable land were an important consideration in defensive site location. We also confirm that site elevation and size of view are positively correlated, and that fortifications were purposely placed in inconspicuous areas of the landscape. In contrast to research on fortifications in the expansive alluvial valleys and deltas of Fiji's main island (e.g., Field 1998; Parry 1977), our results do not indicate that a high degree of inter-visibility between sites, and relatively large views from sites were important considerations in the Yasawa and Mamanuca Islands. In the following sections, we outline our analyses and present our results. We conclude with a discussion highlighting the importance of GIS as a quantitative tool for testing hypotheses that explain human behavior and the archaeological record in terms of the opportunities and constraints afforded by local environments.

Defensive site research in Fiji-West Polynesia

Fiji and West Polynesia--the archipelagos of Tonga, Samoa, and other small islands in the region--were colonized between approximately 3100-2900 BP by populations carrying Lapita pottery and other typical artefacts of the Lapita Cultural Complex (Anderson and Clark 1999; Burley and Dickinson 2001; Kirch 1997; Rieth and Hunt 2008). The vast majority of colonization sites are situated along the coasts with inland settlements appearing only after about 2500 BP (Burley and Clark 2003) and perhaps not in great numbers until after 2000 BP (cf. Best 1984; Field 2004). These later inland sites are associated with agricultural subsistence systems likely focused on taro and yam (Field 2004). Geoarchaeological analyses suggest that such agricultural practices in some regions contributed to erosion and deforestation (Anderson et al.

2006; Dickinson 1998; Morrison and Cochrane 2008). For the Sigatoka Valley on Fiji's main island, Viti Levu, the development of upland and fortified sites in the interior and near the coast has been explained as a result of human competition, warfare, and the defence of arable land (Field 2004, 2005). A similar explanation likely also applies to the development of fortified sites in other areas of Fiji and the islands of West Polynesia with limited resources and where prehistoric population growth can be assumed (cf. Aswani and Graves 1998; Frost 1974).

A typical Fijian fortification consists of a habitation area surrounded by a defensive feature or located in an inaccessible place, or both. Early research emphasized the location of the constructions, categorizing forts into two groups: ring-ditch fortifications that often appear in river valleys or coastal flats and hilltop forts that also appear on ridges or mountain peaks (Best 1993; Parry 1977). Field (1998) devised a different classification by dividing forts into those that were constructed and forts that relied on natural or unmodified terrain for defence. Field (1998) suggests that part of the natural defence was a reliance on both inaccessibility and visibility, that is having a large view and one relevant to defence of the site. Supplementary defensive features such as ditches and scarps were sometimes added to less naturally defendable areas.

The constructed defensive features of sites often include ditches, palisades, and other structures such as stone walls, sometimes used in combination, around a settlement area. These types of sites are most often located on valley floors or coastal flats, and also on low lying ridges and undulating terrain (Parry 1977; Parry 1984). Access to the habitation area of the site is usually through one or more causeways that span a surrounding ditch. In Fiji, the outer walls or palisades of these sites were constructed of bamboo, reed, or other material that formed a surrounding barrier to tolerate, at least for a time, projectiles which were thrown by attackers.

The ditches of these sites may have been filled with water and embankments placed around the outside or inside of the ditch (Frost 1979). Interestingly, Parry notes that fortifications were often constructed to remain unseen from close distances and were difficult to access (Parry 1977:18).

The Yasawa and Mamanuca Islands Sites

Our analysis is based on thirty-four fortified or upland sites (out of over 240 total sites) recorded on six islands in the Yasawa and Mamanuca Islands of western Fiji (Table 1). Initial identification of sites by Simon Best and Geoffrey Irwin took place in 1978 with additional surveys, excavation and artefact collection by University of Hawaiʻi and University College London teams since the 1990s (Cochrane 2009; Cochrane et al. 2007, 2011; Hunt et al. 1999). Sites were identified by the presence of surface artefacts (primarily pottery) and included in this analysis if they exhibited constructed defensive features such as annular ditches, or if they were placed in relatively inaccessible locations, ridge-lines or hilltops without any obvious natural resource nearby. Of course, some relatively inaccessible sites without defensive architecture may not have served a defensive function and their location may be explained by processes other than competition and defence.

For most of these sites, the chronology of occupation is uncertain, but it is likely that many were occupied for at least some time during the last 600 years based on the few associated radiometric dates, ceramic decorative and rim analyses, and chronologies of similar site types in Fiji. Four of the sites have radiometric dates associated with them. Site Y1-12 is an extensively modified hilltop with ditches, banks and rock walls (Cochrane 2009: 62-68). Unidentified wood charcoal recovered from a single test unit at the site (along with midden and ceramics) returned a

2σ date range of 340-110 (78.5%) and 90-40 (16.9%) calBP (AA-60257, all following dates calibrated with OxCal 3.9 [Ramsey 200])). Site Y2-22 is a ring-ditch with extensive shell midden and ceramics (Cochrane 2009: 45-47). A *Trochus* sp. shell from surface midden was dated to a 2σ range of 650-580 (15.3%) and 570-460 (80.1%) calBP (Wk-6482, ΔR correction factor for Fiji from Toggweiler [1989]). Site Y2-45 occupies an upland promontory and a *Trochus* sp. recovered from surface midden there returned a 2σ date range of 630-590 (6.2%), 570-430 (87.4%), and 360-330 (1.8%) calBP (Wk-6485, same correction factor) (Cochrane 2009: 55-57). Finally, Site Y2-46 is on a steep ridge-line with at least one earthen platform and several terraces (Cochrane 2009: 57-58). A single test unit uncovered ceramics, a shell fragment and unidentified wood charcoal that returned a 2σ date range of 550-100 calBP (Beta-93971).

Additional research related to chronology has been conducted at these four sites, plus two other sites in the GIS study, Y2-62 and Y2-09. Ceramic decorative analyses at these six sites recorded relatively abundant late prehistoric decorations, including incising and appliqué, sometimes in association with paddle-impressing (Cochrane 2009: 95-103). Additionally, cladistic analysis of rim forms at these six sites (Cochrane 2008; 2009: 116-125) suggests that all, except Y2-45, contain jars associated with a set of late-appearing (approximately 500 years BP) rim forms. Finally, radiometric dates from other fortified sites in Fiji (see Clark and Anderson 2009) suggest that many defensive sites were likely occupied in the last 500-600 years. However, without extensive excavation and dating research, we are currently unable to determine exactly which sites were occupied contemporaneously.

Analyses

Three types of viewshed analysis were used to determine if visibility was a factor in the construction and placement of the Yasawa and Mamanucas Islands sites. A GIS was created for the study from topographic maps produced by the Fiji Government (1998, Edition 2, Fiji Map Series 31) and *The Soil Resources of the Fiji Islands* (Twyford and Wright 1965). The resulting digital elevation model (DEM) has a resolution of 10 meters. This DEM was used to determine three site characteristics: the land visible from each site, the content of those views, and the amount of land from which the sites themselves are visible (Figure 2). The same measurements were made for a background sample of non-sites from the Yasawas and Mamanucas to identify if there are significant differences between the archaeological sites and the geographically-similar non-sites. The areas of both archaeological sites and non-sites was set at 20 m^2. This figure was used as areal data is not available for all archaeological sites and previous research in Fiji identified 20 m^2 as a minimum defensive-site size (Parry 1977). The possibility of constructed vantage points is not examined here, but may influence the views to and from sites.

Our analyses are based on similar work undertaken in a number of studies to estimate the effects of visibility on site placement (e.g., Krist and Brown 1994; Lake and Woodman 2003; Lake et al. 1998). Identifying a significant difference in viewshed patterns of known sites and a background sample of non-sites does not demonstrate a causal relationship between visibility and placement. However, if a significant difference is identified between known sites and non-sites randomly placed in geographically similar background sample areas, the likelihood of a causal relationship between visibility and site placement is increased (Fisher et al. 1997; Woodman 2000). Following this logic we constrained our background sample to areas geographically similar to the 34 archaeological sites. Based on elevation and slope data for the majority of archaeological sites (Figure 3), non-sites were randomly placed in background sample areas with an elevation between 2 m and 274 m, and slopes less than 40 degrees.

Once the three viewshed analyses were applied to the known sites and background sample non-sites, Kolmogorov-Smirnov (K-S) tests were performed to determine if viewsheds differ across the two groups. To simplify, K-S tests determine the equality of two continuous frequency distributions. Here, this is done by comparing the cumulative relative frequencies of cells identified in each of the three analyses: cells that are visible from each archaeological site or background sample non-site, cells of particular content types visible from each archaeological site or non-site, and cells from which the archaeological site or non-site are themselves viewable. For our K-S tests, the difference between two frequency distributions is considered statistically significant, that is the distributions are not equal, when the probability (p) of a Type II error, to incorrectly identify equality, is 5% or less. The formula for determining the critical value of the K-S test with a p-value of 0.05 is

$$1.36\sqrt{[(n1+n2) / (n1n2)]}$$

where n1 is the number of observed sites and n2 is the number of background sample non-sites. For example, comparing the cumulative relative frequency distributions of cells visible from 34 archaeological sites and 382 non-sites requires a difference in cumulative relative frequencies to exceed a critical value of 0.243 to be considered significant. Our analyses are described in greater detail below as four separate procedures.

Procedure 1: grouping defensive sites by elevation and slope

A combination of the techniques developed in archaeological GIS research is employed here (Fisher, Farrelly et al. 1997; Wheatley and Gillings 2000; Woodman 2000). First, the general spatial characteristics of the archaeological sites were recorded including elevation, slope, distance to the coast, and distance to the nearest waterway (see Table 1). Elevation and slope data (see Figure 3) suggest a division of sites into two general groups: those on slopes of greater than 20 degrees and at elevations of 100 m and higher, and those sites on slopes of less than 20 degrees and at elevations of approximately 65 m and lower. We use this division to structure our analyses.

Procedure 2: identifying and comparing views from defensive sites

We compared the size of views from each of the archaeological sites to views from the background sample non-sites. To match the archaeological sites, the background sample area consisted of 5% of each island with either elevation above 100 m and slope greater than 20 degrees or elevation less than 65 m and slope less than 20 degrees. This resulted in a sample size of 382 non-sites. Viewer height is 1.5 m and the maximum viewing distance is 1 km. This rather short viewing distance was set as oral histories describing defensive sites indicate that views in the immediate vicinity of the site are most important (Carneiro 1990). These views would allow an approaching enemy to be seen and close agricultural lands to be viewed. A line of sight algorithm was employed utilizing the ‘r.cva’ function within Geographic Resources Analysis Support System (GRASS, open-source software) for each of the archaeological sites and background sample non-sites. K-S tests were employed to determine if there was a statistically significant (5% alpha-level) difference between the viewshed size distribution from the 34 sites and 382 non-sites.

Procedure 3: determining arable land and inter-visibility within viewsheds

After comparing viewshed size, we examined the composition of those views. Wheatley and Gillings (2000) have convincingly argued that although far-reaching views may be important in site location, the less often investigated issue of viewshed content is likely to be of equal importance. We investigated viewshed content in terms of arable land and inter-visibility between sites. To explore whether views of arable land were important to site location, we examined the amount of arable land within site viewsheds. Arable land was classified according to agricultural potential by digitizing Twyford and Wright's (1965) soil maps and translating their five soil fertility categories of low, moderate to low, moderate, moderate to high, and high into a binary distinction for GIS analysis: low (including low and moderate to low) and high (including the remaining three categories). The cumulative frequency distributions of low and high fertility cells within the viewsheds of archaeological sites and background sample sites were compared in a K-S test. Separate comparison of the distributions of low and high fertility cells in the high-elevation (above 100 m) and low-elevation (below 65 m) site viewsheds were also made. K-S tests were also used to analyze site inter-visibility by comparing the number of intervisible archaeological sites to the number intervisible background sample non-sites.

Procedure 4: identifying and comparing views to defensive sites

The last step in our analysis was to identify the areas from which the archaeological sites are visible. It seems probable that a good defensive strategy would be to make defensive sites significantly harder to see from the surrounding landscape, thus obscuring possible defensive preparations by site inhabitants. The visibility of sites from the surrounding landscape was modeled by reducing the viewer height to zero and adding 1.5m of elevation to the landscape surrounding the site before performing the analysis (see Woodman 2000: 95). Again, all archaeological sites were compared to a 5% island background sample, high and low elevation sites were compared to each other and to high and low elevation background samples, respectively.

Results

Our analytical results are presented in Tables 2-5. These tables present the relevant data for comparing the differences in cumulative frequencies of cells visible from or to different site types (e.g., high elevation sites vs. low elevation sites). The maximum difference in cumulative frequencies is given along with the critical value computed for the K-S test. The significance of the comparison is also noted, that is, does the maximum difference in cumulative relative frequencies exceed the critical value? Our comparisons followed the order of procedures listed in the previous section. We did not make all possible comparisons, leaving aside those we think uninformative. To give one example, we did not compare the viewshed size of high-elevation non-sites and low-elevation sites.

Analysis of viewshed size from the 34 archaeological sites showed no significant difference compared to views from non-sites randomly placed within the background areas (Table 2). Also, no significant difference was identified between the amount of land viewable from high elevation archaeological sites and the amount of land viewable from low elevation archaeological sites (Table 2).

The number of high fertility cells visible from the 34 archaeological sites was not significantly different from the number of high fertility cells visible from sites in the 5% background sample (Table 3). However, a significantly greater amount of high fertility cells were visible from high elevation archaeological sites compared to low elevation archaeological sites (Figure 4, Table 3). Figure 4 demonstrates this by presenting two cumulative relative frequency distributions, one for high elevation and one for low elevation sites, which are compared in the K-S test. Although perhaps not intuitive, the figure shows that, for example, a total of 1500 visible high fertility cells is reached at a cumulative relative frequency of 0.6 (i.e., 60%) of the high elevation sites, while the same number of visible high fertility cells is not reached for low elevation sites until a cumulative relative frequency of about 0.9. Table 3 also shows the maximum difference in cumulative relative frequencies for these distributions and that this difference exceeds the critical value for the K-S test. We can conclude that the distributions are not equal. The remaining figures in this section display similar kinds of data.

When comparing low elevation archaeological sites, and non-sites in a low elevation background sample, a significantly greater amount of high fertility cells were visible from the low elevation non-sites (Figure 5, Table 3). In contrast, no significant difference was identified between the views of high fertility cells from the high elevation archaeological sites and the high elevation background sample (Table 3).

Analysis of site inter-visibility revealed that 68% of the archaeological sites are unable to see other archaeological sites. The inter-visibility of sites in the background sample showed no significant difference to the 34 sites (Table 4).

The amount of land from which the 34 archaeological sites are visible is less than the amount of land from which the background sample non-sites are visible (Figure 6, Table 5). Figure 6 shows, for example, that when 90% cumulative relative frequency is attained, archaeological sites are visible from only a little more than 2500 cells, while non-sites are visible from almost 5500 cells. Less surprisingly, areas from which high elevation sites were visible were much larger than the areas from which low elevation sites were visible (Figure 7, Table 5). Further analysis showed no difference between the views to the high elevation sites and the views to randomly placed non-sites in the high elevation background sample (Table 5). Low elevation archaeological sites are visible from a smaller amount of land compared to randomly placed non-sites in the low elevation background sample (Figure 8, Table 5). From all of these results, the most pertinent for our discussion are summarized in Table 6.

Discussion and Conclusion

When establishing defensive sites in the Yasawa and Mamanuca Islands people made a basic choice between low-elevation and high-elevation locations, with more than half the sites analyzed situated below 50 m in elevation and the others dispersed between 50 and 274 meters (see Table 1). The likely reason for establishing high-elevation defensive sites was to obtain large views of high-fertility land, although the exact placement of defensive sites at high-elevations did not matter in this regard, as long as they were high-elevation locations (see Table 3). There may, of course, be variables outside the scope of the GIS that explain particular high-elevation site choices, such as small-scale topography that served defensive purposes. In contrast, low-elevation sites had smaller views of high-fertility land compared to background sample low-elevation non-sites.

While they had small views of high-fertility land, low-elevation defensive sites were less visible from the surrounding landscape compared to background sample low-elevation non-sites (see Table 5). This suggests that obscurity was a valued feature of low-elevation defensive sites. Although placing sites in less visible locations would not make it impossible to view them, it would potentially make it more difficult for attackers to see the activities and possible preparations of inhabitants within a settlement. This quality of low-elevation defensive sites in the Yasawa and Mamanuca islands is presumably less valued in some low-elevation sites and ring-ditches on the alluvial and deltaic plains of Viti Levu, Fiji's main island, where these sites' location are linked to control over high fertility lands (e.g., Field 2004; Parry 1982).

While obscurity and views of high-fertility land were likely important considerations for the placement of low- and high-elevation defensive sites, respectively, good views of other likely defensive sites seem not to have been a great concern (see Table 4). Less than one-third of the archaeological sites have viewsheds that contain other archaeological sites. This conclusion that visibility between sites was not a consideration in site location contradicts the findings of other researchers. In particular Field (1998) points out that some hill forts in the Sigatoka Valley on Viti Levu included good views of other forts to compensate for a lack of constructed defences such as walls and ditches. The difference between our results and Field's are likely explained by the different landscapes of the Sigatoka Valley, a wide valley with far-reaching views of land, and the small, dissected Yasawa and Mamanuca Islands. Inter-visibility would likely be a good strategy in the valley environment, but not necessarily useful in a group of islands where views of land are relatively small. Our argument here requires contemporaneous inter-visible site occupation. Something we are unable to definitely establish, but for which our dating and ceramic analyses suggest is a good possibility.

The characteristics of defensive sites in the western Fijian islands are different from other well-studied areas of Fiji, particularly on the large island of Viti Levu (10,389 km^2). The lack of site inter-visibility, low-elevation sites built for obscurity, and high-elevation sites for viewing the most-productive land, might be related to the small island-arc geography of the Yasawas and Mamanucas and the scale of competition in the islands. Some of these characteristics make more sense if warfare was conducted at an inter-island or greater scale, compared to an intra-island scale. First, at an inter-island scale, the ability to see the ocean in all directions, and thus potential attackers, would likely be more important than maintaining inter-visibility with other sites on the same island. Except for Monu with a single known defensive site, all the islands examined have high-elevation defensive sites that combined would give an island-wide population a 360 degree view of the sea. Second, the obscurity of low-elevation defensive sites might also be useful during inter-island conflicts as attackers arriving from the sea would be less likely to know of defensive preparations within the sites near the coast, the sites potentially encountered first by attackers. Finally, it is unclear, however, how high-elevation views to fertile land might offer any advantage in specifically inter-island warfare, except possibly to signal ownership of the resource.

This study demonstrates that both visibility of fertile land and site obscurity were important considerations when constructing defensive sites in the western Fijian islands. These characteristics were probably important on many Pacific Islands and in other world regions. If so, such widespread patterns imply a general mechanism as a likely explanation. Because defensive sites seem so intimately linked to community agricultural resources, we suggest mechanisms within an ecological framework are a good place to start building explanations. For example, Kennett et al. (2006) argue that the Ideal Free Distribution (IFD) may explain the rise of fortified sites on the island of Rapa in French Polynesia. Briefly, the IFD predicts that people (and other animals) that compete for resources will distribute themselves across resource patches in proportion to resources available in each patch. On Rapa, the chronology of defensive settlements tracks the changing distribution of the best agricultural resources, such that “fortified communities developed within the context of intense competition for limited territory” (Kennett et al. 2006: 351). Models such as the Ideal Free Distribution and others, combined with good demographic data, will move us a long way toward explaining variability in past defensive strategies.

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Figure 1. Western Fiji showing sites of the Yasawa and Mamanucas Islands in the analysis indicated by grey boxes. Individual island names are italicized. Individual site locations on Naviti not shown at this scale for clarity.

Figure 2. A graphic example of the DEM used in the analysis. Naviti Island defensive sites indicated by red dots and their view sheds in orange. Darker oranges indicate areas visible from more than one site.

Figure 3. Yasawa and Mamanuca Islands sites in the analysis plotted by elevation and slope.

Figure 4. Cumulative relative frequency of high fertility cells that are visible from high elevation and low elevation sites. The null hypothesis of no difference in the size of views from high elevation sites to high fertility cells and the size of views from low elevation sites to high fertility cells is rejected as the critical value of 0.50 is exceeded by the maximum difference of 0.57. Note the last bin on the x-axis is scaled differently compared to the others.

Figure 5. Cumulative relative frequency of high fertility cells that are visible from low elevation sites and a background sample of low elevations. The null hypothesis of no difference in the amount of high fertility cells viewable from low elevation sites and the amount of high fertility cells viewable from a background low elevation sample is rejected as the maximum difference of 0.38 exceeds the critical value of 0.30.

Figure 6. Cumulative relative frequency of cells from which the target, either sites or randomly placed non-sites in the background sample, is visible. The null hypothesis of no difference in the size of area from which the sites are visible and the size of area from which a background sample is visible is rejected because the critical value of 0.24 is surpassed with a maximum difference of 0.34.

Figure 7. Cumulative relative frequency of cells from which the targets, either low elevation or high elevation sites, are visible. The null hypothesis of no difference in the size of area from which the low elevation sites are visible and the size of area from which the high elevation sites are visible is rejected as the critical value of 0.50 is exceeded by the maximum difference of 0.60.

Figure 8. Cumulative relative frequency of cells from which the targets, either low elevation fortifications or low elevation sample, are visible. The null hypothesis of no difference in the size of area from which the low elevation sites are visible and the size of area from which the low elevation background sample is visible is rejected as the critical value of 0.30 is exceeded by maximum difference of 0.70.

Table 1. Characteristics of defensive and upland sites in the Yasawa and Mamanuca Islands, Fiji. Elevation and distances in meters.

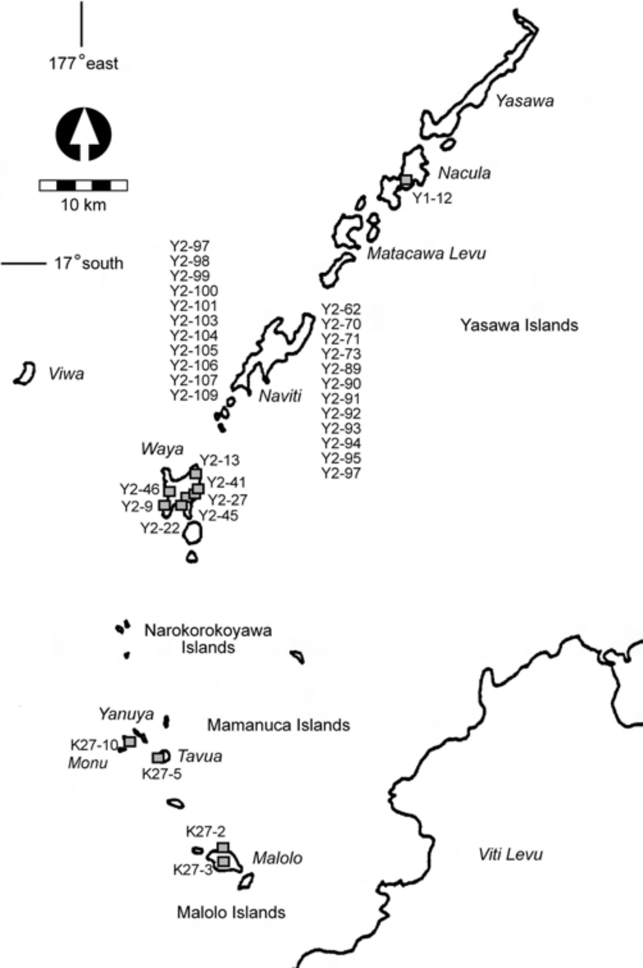
Table 2. Results of K-S tests comparing differences between cumulative relative frequencies of overall viewshed sizes.

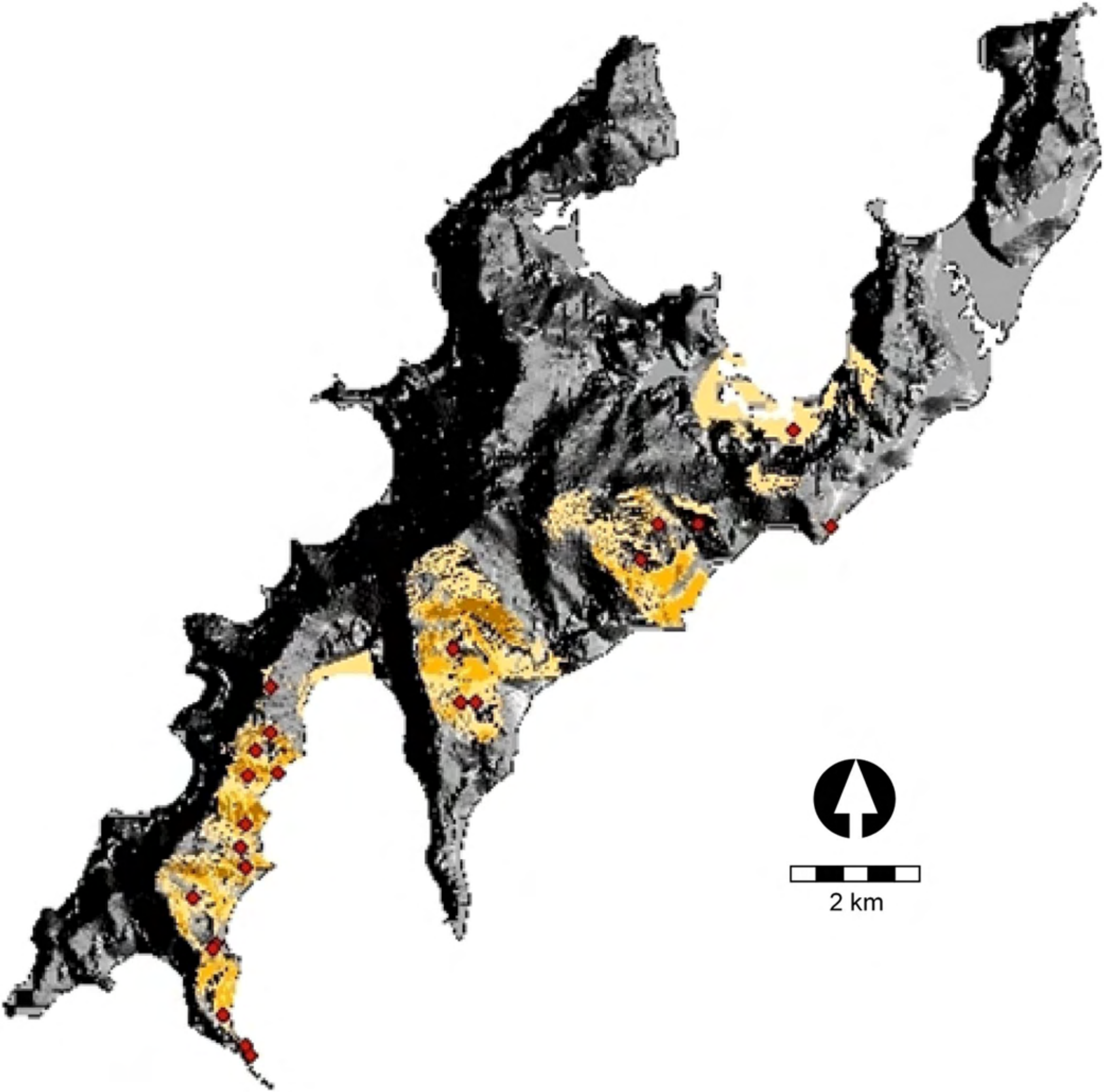
Table 3. . Results of K-S tests comparing differences between cumulative relative frequencies of views to arable land.

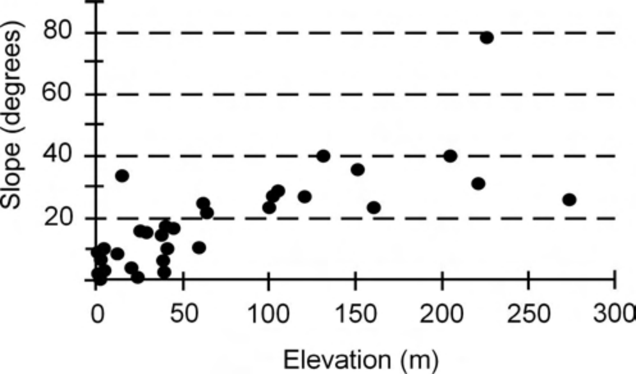
Table 4. Result of K-S tests comparing differences between cumulative relative frequencies of site intervisibility.

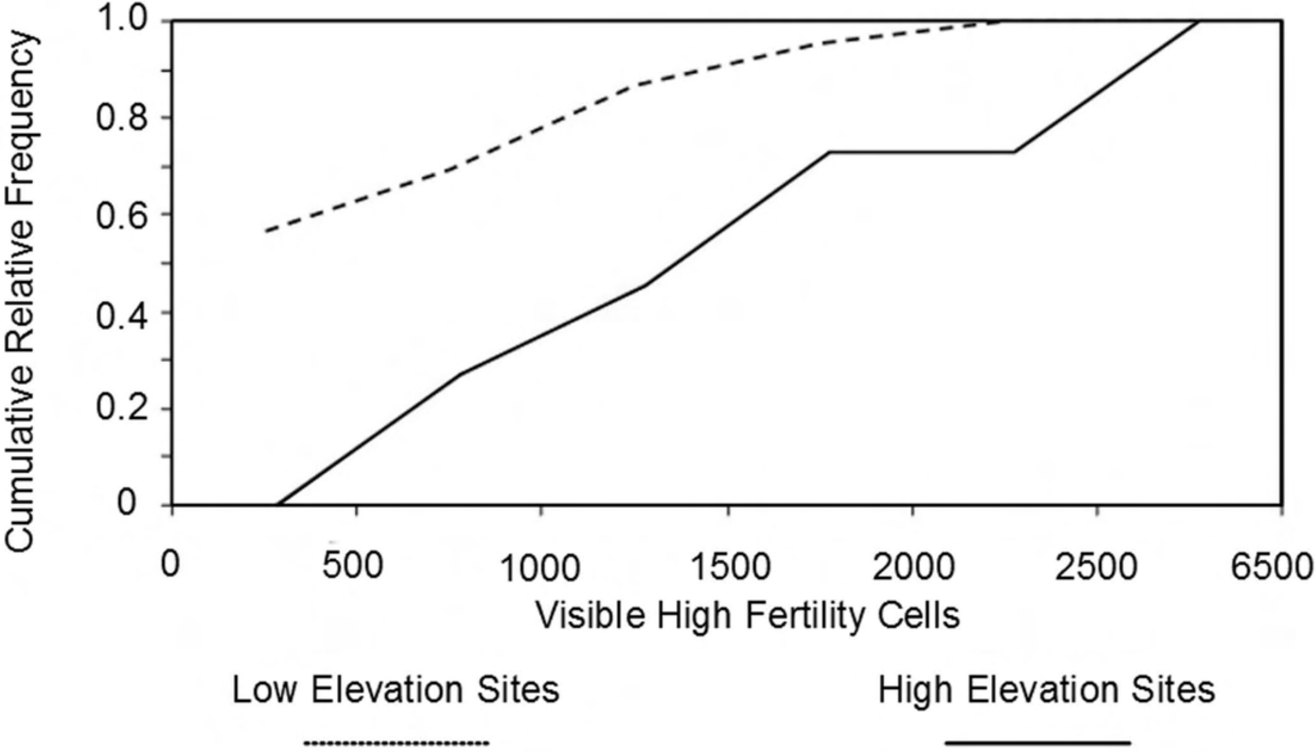
Table 5. Results of K-S tests comparing differences between cumulative relative frequencies of land from which sites are visible.

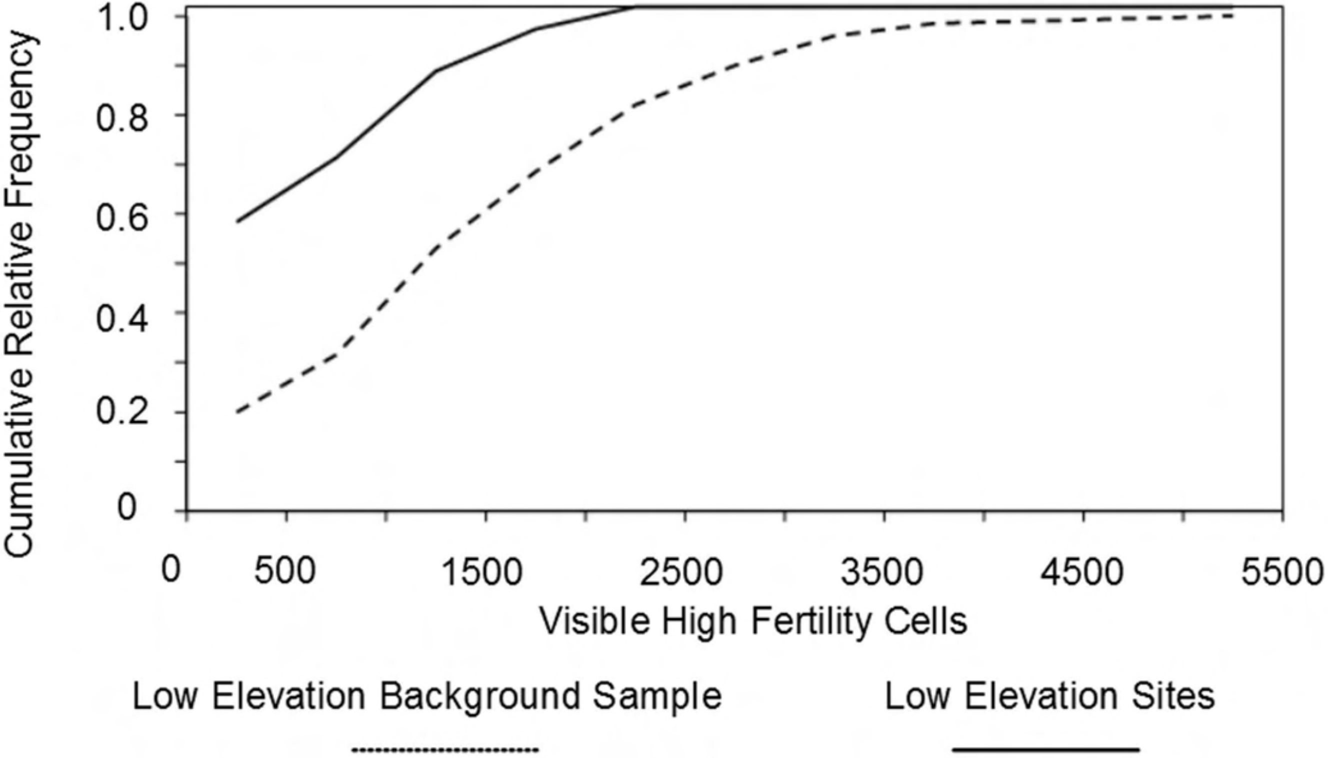
Table 6. Results summary of the GIS analysis of fortified and upland sites in the Yasawa and Mamanuca Islands, Fiji.

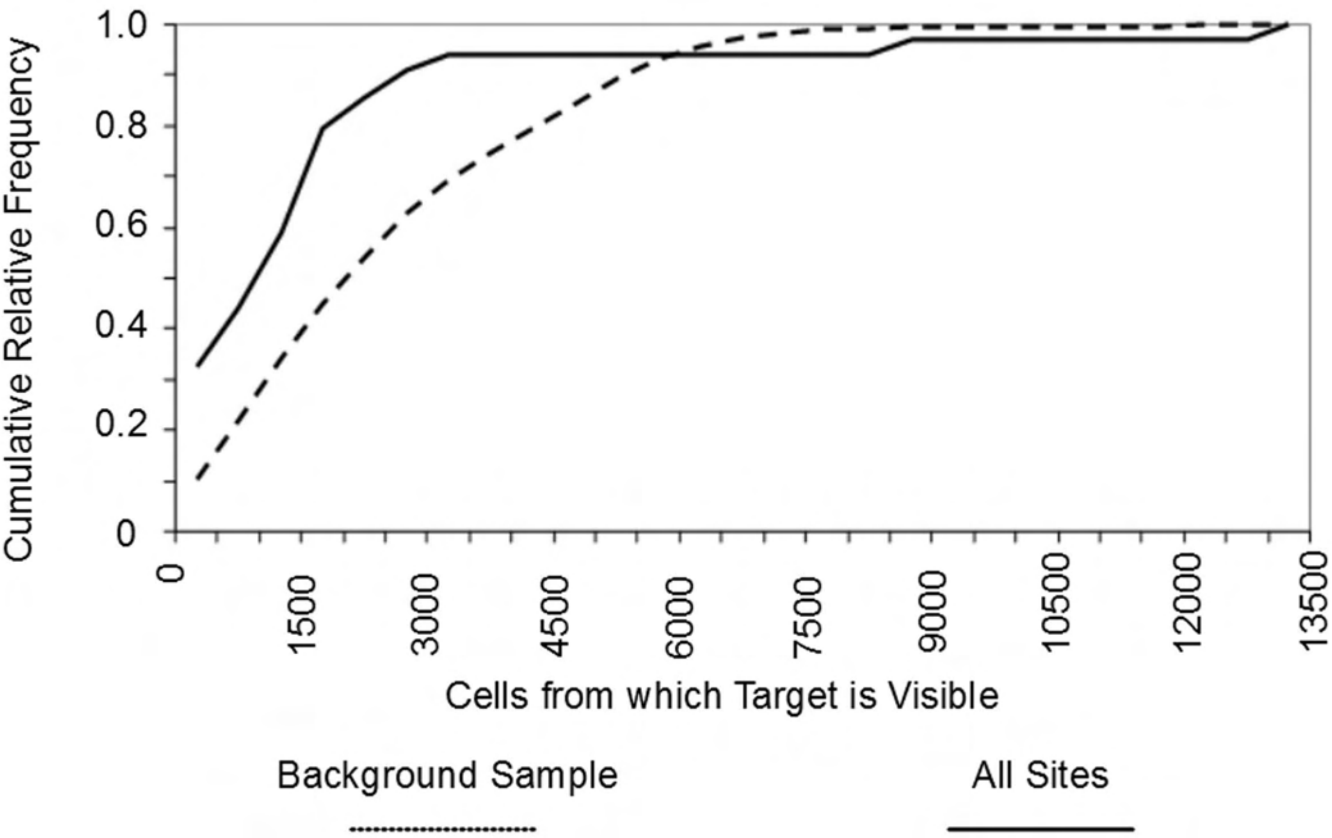

177° east
10 km
17° south
Yasawa
Nacula
Y1-12
Matacawa Levu
Yasawa Islands
Y2-97
Y2-98
Y2-99
Y2-100
Y2-101
Y2-103
Y2-104
Y2-105
Y2-106
Y2-107
Y2-109
Viwa
Naviti
Y2-62
Y2-70
Y2-71
Y2-73
Y2-89
Y2-90
Y2-91
Y2-92
Y2-93
Y2-94
Y2-95
Y2-97
Waya
Y2-13
Y2-46
Y2-41
Y2-27
Y2-9
Y2-45
Y2-22
Narokorokoyawa Islands
Yanuya
Mamanuca Islands
K27-10
Monu
Tavua
K27-5
K27-2
K27-3
Malolo
Malolo Islands
Viti Levu

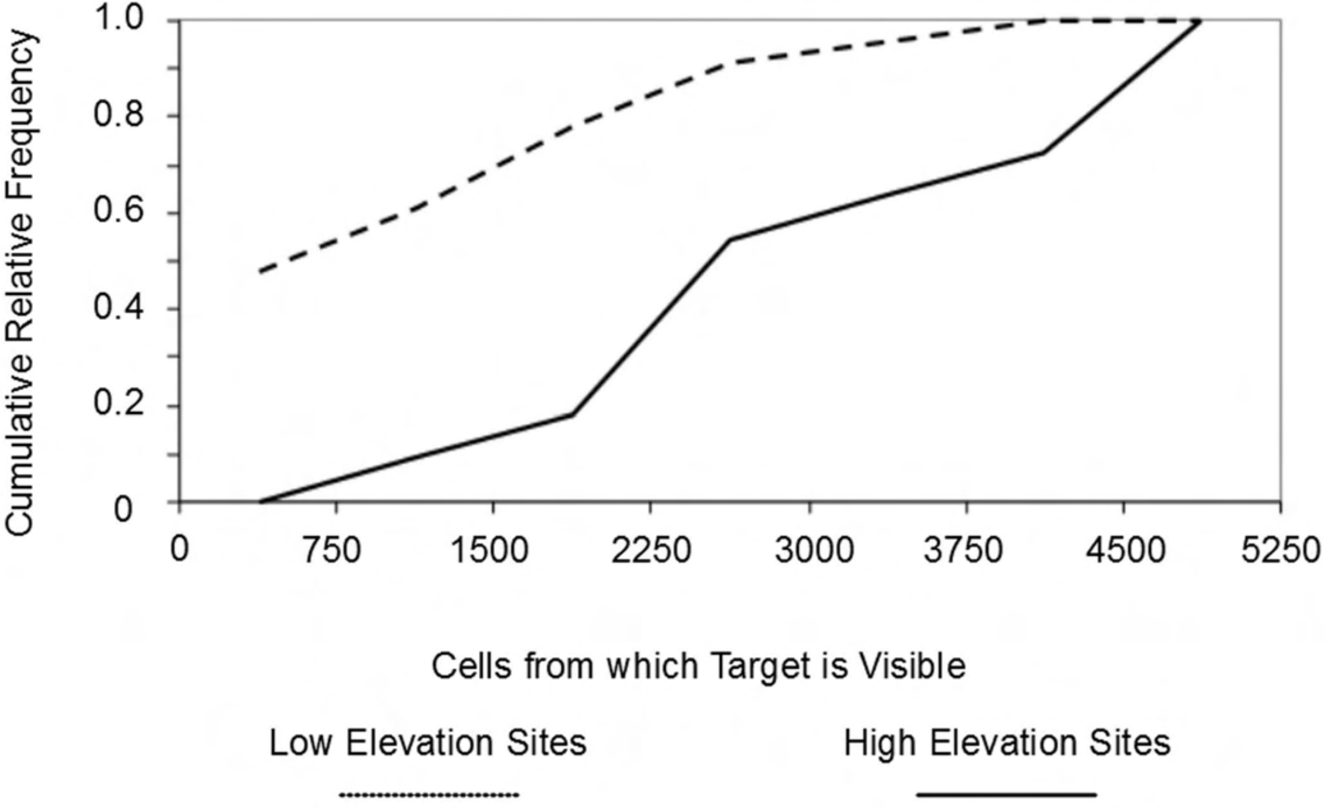

2 km


Slope (degrees)
80
60
40
20
0
50
100
150
200
250
300
Elevation (m)


Cumulative Relative Frequency
1.0
0.8
0.6
0.4
0.2
0
0
500
1000
1500
2000
2500
6500
Visible High Fertility Cells
Low Elevation Sites
High Elevation Sites


Cumulative Relative Frequency
1.0
0.8
0.6
0.4
0.2
0
0
500
1500
2500
3500
4500
5500
Visible High Fertility Cells
Low Elevation Background Sample
Low Elevation Sites


Cumulative Relative Frequency
1.0
0.8
0.6
0.4
0.2
0
0
1500
3000
4500
6000
7500
9000
10500
12000
13500
Cells from which Target is Visible
Background Sample
All Sites


Cumulative Relative Frequency
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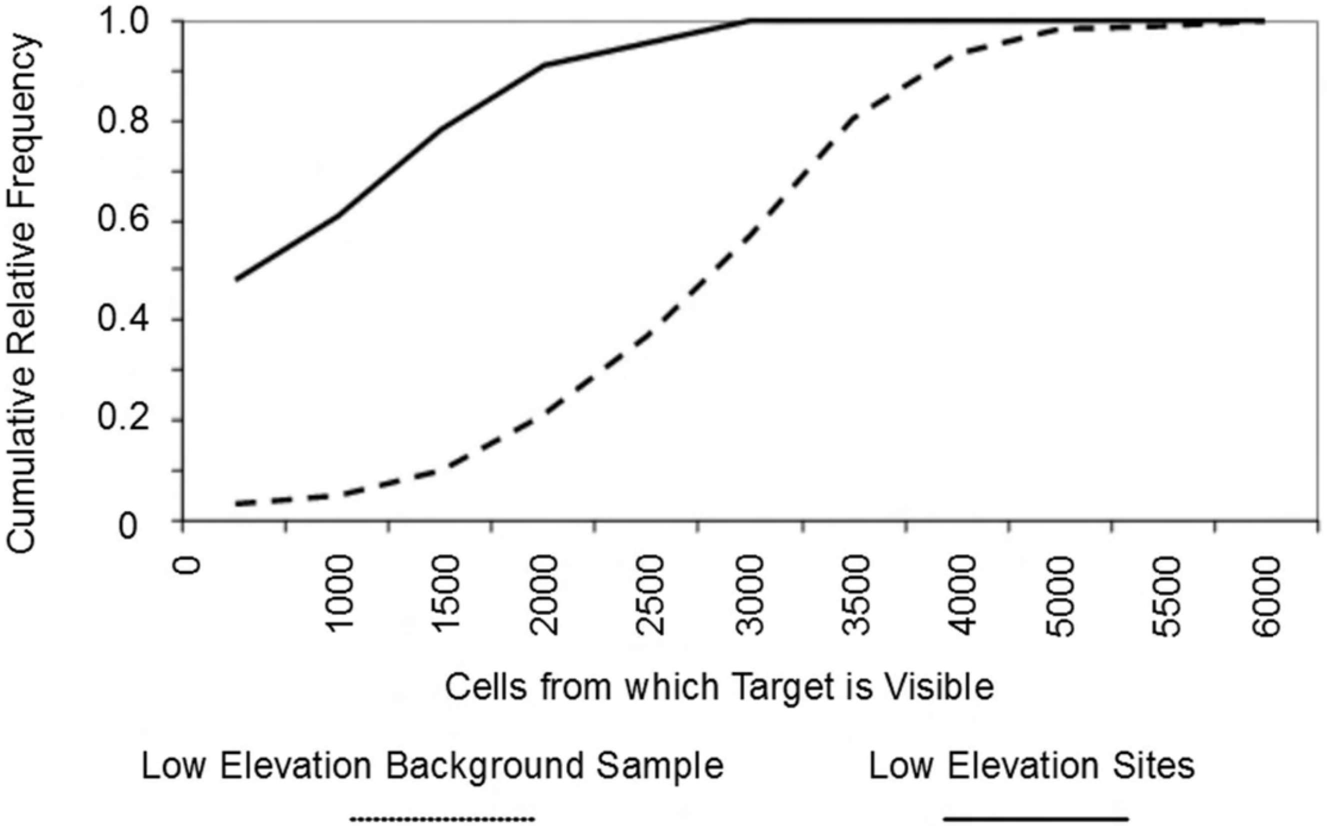
0.8
0.6
0.4
0.2
0
0
750
1500
2250
3000
3750
4500
5250
Cells from which Target is Visible
Low Elevation Sites
High Elevation Sites


Cumulative Relative Frequency
1.0
0.8
0.6
0.4
0.2
0
0
1000
1500
2000
2500
3000
3500
4000
5000
5500
6000
Cells from which Target is Visible
Low Elevation Background Sample
Low Elevation Sites

Site	Site Name	Island	Type	Features	Elevation	Slope (°)	Distance to coast	Distance to waterway
K27-10		Monu	Defensive site	Very limited access, house mounds, located on cliff	100	23.41	100	54
K27-2	Navasua	Malolo	Ring-ditch	Annular ditch & bank, causeways, pottery	2	0.60	50	157
K27-3	Uliusolo	Malolo	Modified hilltop	Highest point on island, in situ pottery	220	30.63	1162	103
K27-5		Tavua	Modified ridge	Terraces, possible ditches, pottery	132	40.26	543	131
Y1-12	Druidrui	Nacula	Modified hilltop	Ditches, banks, rock walls, pottery, domestic refuse	225	78.73	266	37
Y2-62		Naviti	Ring-ditch	Annular ditch & bank, pottery, shell midden	2	0.00	68	34
Y2-70	Vuce	Naviti	Unmodified ridge	Ridgeline, pottery	28	15.39	140	116
Y2-71	Sa Bay	Naviti	Unmodified ridge	Ridgeline, pottery	27	15.22	123	135
Y2-73		Naviti	Unmodified ridge	Ridgeline, pottery	13	8.00	74	198
Y2-89	Korolesivo	Naviti	Defensive site	Possible ditch & bank, pottery	2	6.84	35	78
Y2-90		Naviti	Unmodified ridge	Ridgeline, pottery	60	10.33	327	93
Y2-91	Batukorokoro	Naviti	Defensive site	Hilltop, possible ditches, pottery	151	35.21	373	206
Y2-92		Naviti	Unmodified ridge	Ridgeline, pottery	64	22.55	320	61
Y2-93		Naviti	Unmodified ridge	Upland slopes, pottery	25	0.86	897	25
Y2-94	Namarasa	Naviti	Unmodified ridge	Ridgeline, pottery	38	6.56	600	10
Y2-95	Nawai	Naviti	Unmodified ridge	Ridgeline, pottery	25	0.82	516	98
Y2-97		Naviti	Unmodified ridge	Ridgeline, pottery	38	14.14	198	62
Y2-98		Naviti	Unmodified ridge	Ridgeline, pottery	40	2.39	188	20
Y2-99	Ululala	Naviti	Defensive site	Ridgeline, possible ditches & terraces, pottery	20	3.75	234	52
Y2-100	Dromunavatu	Naviti	Defensive site	Hilltop, pottery	62	24.45	413	110
Y2-101	Navutu	Naviti	Unmodified ridge	Ridgeline, pottery	45	16.62	152	221
Y2-103	Namo	Naviti	Unmodified lowland	Limited access, pottery	6	3.24	5	608
Y2-104		Naviti	Unmodified lowland	Limited access, pottery	4	10.02	5	526
Y2-105		Naviti	Unmodified uplands	Upland slopes, pottery	41	16.63	407	121
Y2-106	Uluivaturua	Naviti	Defensive site	Upland slopes adjacent high rock peaks, pottery	105	28.72	651	35
Y2-107		Naviti	Unmodified uplands	Upland slopes, pottery	41	10.38	678	60
Y2-109		Naviti	Ring-ditch	Possible annular ditch & bank, pottery	2	8.63	20	5
Y2-09	Lakala	Waya	Defensive site	Hilltop, limited access, terraces, rock walls, pottery	204	39.94	426	385
Y2-13	Weralevu	Waya	Unmodified cave	Cave and upland slopes, terraces, pottery	121	27.47	681	86
Y2-22	Korowaiwai	Waya	Ring-ditch	Annular ditch & bank, causeways, pottery	2	2.03	166	152
Y2-27		Waya	Modified upland	House mounds, pottery	15	33.49	20	254
Y2-41		Waya	Defensive site	Hilltop, terraces, ditch, pottery	104	27.09	604	57
Y2-45	Nasau	Waya	Defensive site	Uplands, house mounds, midden, pottery	160	23.41	189	37
Y2-46	Natavosa	Waya	Modified ridge	Terraces, pottery, midden	274	25.57	721	77

Number of DEM cells seen from:	Maximum Difference	Critical Value	Significance
All Sites vs. 5% Background Sample	0.212350	0.243	not significant
High Elevation Sites vs. Low Elevation Sites	0.391304	0.499	not significant

Number of arable DEM cells visible from:	Maximum Difference	Critical Value	Significance
All Sites vs. 5% Background Sample	0.220049	0.243	not significant
High Elevation Sites vs. Low Elevation Sites	0.565217	0.499	0.05
Low Elevation Sites vs. 5% Low Elevation Background Sample	0.37963	0.297	0.05
High Elevation Sites vs. 5% High Elevation Background Sample	0.393939	0.423	not significant

Number of sites visible from:	Maximum Difference	Critical Value	Significance
All sites vs. 5% Background Sample	0.163844	0.243	not significant

Number of DEM cells from which the following are visible:	Maximum Difference	Critical Value	Significance
All Sites vs. 5% Background Sample	0.343856	0.344	0.05
High Elevation Sites vs. Low Elevation Sites	0.600791	0.499	0.05
High Elevation Sites vs. 5% High Elevation Background Sample	0.408550	0.423	not significant
Low Elevation Sites vs. 5% Low Elevation Background Sample	0.700922	0.297	0.05

1. There is no significant difference in viewshed size when comparing defensive sites and background sample of non-sites.
2. There is no significant difference in viewshed size when comparing high-elevation and low-elevation defensive sites.
3. There is no significant difference in the amount of high-fertility land viewable when comparing high-elevation sites and a background sample of high-elevation non-sites.
4. High-elevation defensive sites have views of more high-fertility land than low-elevation defensive sites.
5. Low-elevation sites have views of less high-fertility land than a background sample of low-elevation non-sites.
6. There is no significant difference in the area from which high-elevation defensive sites are visible and the area from which background sample high-elevation sites are visible.
7. Low-elevation sites are visible from a smaller area than a background sample of low-elevation non-sites.
8. High-elevation defensive sites are more visible than low-elevation sites.
9. Approximately two-thirds of defensive sites had no other defensive site within their viewshed.