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# Dots on the Map: Issues in the Archaeological Analysis of Site Locations

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**Abstract**
The analysis of site locations is an important component of archaeological research. Recent advances in this topic include the use of ecological models such as the ideal free distribution and its variants, which predict site locations under various conditions in relation to criteria that promote the greatest adaptive success**.** Such models can face problems in determining such criteria and especially their relative importance. Another approach, which can be used in conjunction with these models, uses the concept of decision trees to infer the relative ranking and the hierarchy of the role of different criteria in the actual locational decisions underlying site placement. Examples from ethnography and European archaeology demonstrate this approach and additionally allow the consideration of another issue, the contexts in which site function and location are likely to be strongly correlated.

**Keywords** Site location · Site function · Ideal free distribution · Decision trees · Mesolithic · Neolithic

## Introduction

The study of site locations has a long and important history in archaeological research. The placement of sites can be informative about subsistence activities, economic organization and interaction, social relationships, and political structure, as well as about specific topics such as colonization and economic and political change. As a result, understanding site location has taken a variety of approaches. A number of such approaches have been developed in, and borrowed from, ecology, including recent developments of predictive models, which use theoretical considerations to determine the best site locations based on economic and other needs.

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## Models of Settlement Location

The ideal free distribution model (Fretwell & Lucas, 1969) and its variants have recently been usefully adopted into anthropology. At its most basic, the model predicts that upon entering a new area, people are free to settle first in the locations most suitable for their economy. These locations are determined using various characteristics and actual site locations are compared to them. This approach has several requirements for use in archaeology. First, sufficient knowledge of the economy is necessary in order to specify the suitable environmental characteristics. Second, a decision must be made about how to measure and combine these characteristics to calculate a location's suitability.

In recent applications of this model, various environmental and socio-political characteristics have been used, based on historical or archaeological knowledge of the economic activities and political structure involved, and have applied different methods of combining them to arrive at suitability scores. In a study of the northern Channel Islands of California, Kennett *et al.* (2009) examined drainage size, shoreline type and length, and nearby kelp forest area of coastal regions and utilized a weighted method of combining them into a measure of overall suitability. A later study in the same area (Jazwa *et al.*, 2016) refined this approach by including water flow and drainage resilience and by adjusting their weights in the combined measure. Yaworsky and Codding (2018) used the IFD to examine the distribution of historical agricultural settlements in Utah. Two environmental characteristics were utilized, moisture index and probability of cultivation, but they were examined as separate measures of suitability. In a study of pastoralist settlements in Cameroon, Moritz *et al.* (2014) used a single index that combined properties of soil, vegetation, and water. Jazwa and Collins-Elliott (2021) utilized three indices of agricultural potential within 10-km ranges, as well as distance to harbors to investigate historic settlements in Morocco. In a study of Maya settlements, Prufer *et al.* (2017) employed measures of good soils and permanent water, together with proximity to trade routes and constructed features such as monumental architecture.

These examples and others demonstrate the versatility and potential of this model. Two important variants of the model enlarge the applicability and potential of the IFD by addressing changes through time. The Allee effect recognizes that human activities can improve the suitability of occupied locations, thus increasing their ability to support growing populations by increasing their locational value (Weitzel & Codding, 2020). The ideal despotic distribution includes the impact of political differences on choices of locations when political elites can exclude others from the most suitable areas, as exemplified by studies of the Maya by Prufer (2017) and of European LBK agriculturalists by Shennan (2007).

Although the focus of this discussion is the IFD model and its variants, another recent approach to investigating settlement locations employs the maximum entropy model (Howey *et al.*, 2016). This model assumes that sites at relatively low density are distributed according to the IFD expectations and analyzes their locations in terms of a suite of environmental factors. The result is the determination of a “signature” of the locations, allowing the determination of the environmental characteristics of greatest importance. In a study of both foragers and farmers in the Southwest, Vernon *et al.* (2020) examined the location of sites according to ten different criteria, measuring aspects of landscape, climate, productivity, and resources to reveal differences between the two groups in suitable locations as well as the relative importance of each factor in determining these locations. Howey *et al.* (2016) examined separately the locations of mounds and enclosures created by mixed forager-farmers in Michigan to characterize these locations according to temperature, precipitation, elevation, and distance to lakes and rivers. They found that the most important factors were precipitation and proximity to lakes for the mounds and temperature and proximity to rivers for the enclosures. They were able to offer inciteful explanations for the difference between the two kinds of structure. A benefit of this approach is that the relative importance of each factor can be calculated, thereby producing the rank order of these factors. It does, however, assume a priori that the IFD distribution is present.

Each approach—IFD and maximum entropy—has significant strengths in elucidating the patterns of site location, but each has some weaknesses as well. The IFD models must first predict the most suitable locations based on characteristics considered to be relevant. Clearly, the type and number of relevant environmental (and demographic and socio-political) locational criteria can vary, can be at different scales, and can be almost infinite. One drawback of such models is “the probability that the choice of a location depended merely on some of many important criteria, as the consideration of all criteria probably would take too much time and effort. To determine which ones are important in a given case is virtually impossible” (de Vries, 2008, p.2). Perhaps more importantly, the method of their use and combination can have dramatic effects on the resulting scale of suitability. As stated by Weitzel and Codding (2020 p. 4), “defining suitability remains one of the greatest challenges” in archaeological applications of the IFD. Identical weighting of criteria is simple but unlikely to reflect relative importance of different characteristics. Differential weighting is common but it may be difficult to justify the specific ranking and weights. Consideration of each characteristic separately still poses a question of their relative importance.

The maximum entropy models first assume that sites are indeed distributed in the most suitable locations, which is considered “reasonable given broad empirical support” (Vernon *et al.*, 2020, p. 11). This assumption, however, ignores situations in which this assumption may not be true. Alternatively, the assumption may be true, but only when factors other than those not included in the study are important. If trade routes, in the case of the Maya study (Prufer 2017), or harbors, in the case of the historic Moroccan study (Jazwa & Collins-Elliott, 2021), are critical to the choice of locations but not included in the analysis of site locations, the real-life determinants of the site distribution cannot be fully recognized.

## Suitability and Its Criteria

All of the approaches discussed above entail a series of decisions about identifying and measuring the various criteria used to assess suitability of locations. These decisions are as follows.

### Choosing the Criteria

There is little theoretical basis for selecting the criteria used to characterize locations. Rather, as demonstrated in all of the studies discussed above, this selection process derives from knowledge about the societies, or types of societies, under consideration. This knowledge can include information (or assumptions) about subsistence needs, access to routes of interaction for trade or other reasons, and landscape features that are socially or religiously meaningful. In general, hunter-gatherers need resource patches and perhaps trails and viewpoints; farmers need certain conditions of soil and water and, possibly, trade routes, defensibility, and proximity to sacred locations. A researcher must decide which features are of importance or research interest.

Theories of risk avoidance, however, do offer some guidelines. A very general guide to the choice of criteria is their degree of variation. Certain criteria such as soil type, access to major watercourses, and view are likely to be quite stable over the short run. Such features can be relied upon to predictably provide the desired benefits and thus to be given high priority. Others, including rainfall, temperature, seasonal watercourses, and hunting areas, are more variable and unpredictable in any given year. Depending upon the degree of variation, these may not offer reliable benefits and might be accorded less or even no importance in settlement choices.

### Characterizing the Criteria

In order to operationalize a model, decisions must be made about how to measure each criterion. Proximity to water, good soil or oak grove, or to a harbor or a trade route, needs to be defined: how close should a location be in order to qualify as suitable? Considerations of the energetic costs of travel and transport, as well as the frequency of use, may provide general guidelines, but ultimately a researcher must make a decision considered reasonable, or perhaps could try different measures and assess the results.

### Ranking and Weighting the Criteria

It is likely that not all criteria are equally important. In some models, such as those for the Channel Islands of California, criteria are ranked and differentially weighted, thereby conferring different importance upon them. The rationale for the ranking, and especially for the different weights assigned, is unclear. There are no theoretical guidelines to determine quantitatively the differences in importance among criteria. Modeling each criterion separately, as has been done, avoids this issue, but nevertheless makes it difficult to determine the overall suitability of particular locations. Again, considerations of both costs and risks may provide some guidelines.

## Another Approach

If "the IFD adopts an individual-based, decision-making view of population-level phenomena such as colonization, habitat filling and subsistence intensification" (Winterhalder *et al.*, 2010, p. 479), then perhaps another useful approach might be to mimic how real-life decisions are often reached. Expanding on an approach discussed previously (Jochim, 2009), another model of site location examines the selection of settlement spots based on the existing record of sites, which reflect the decisions of the occupants. It does not, however, require the assumption that sites are distributed in accord with the IFD model. Thus, it might be combined with the IFD model to compare these decisions with the posited most suitable locations. One problem with this approach (also seen in maximum entropy models) is that the archaeological record may be strongly biased in terms of habitat sample and that areas without known sites are considered uninhabited (de Vries, 2008, p.3).

A common approach to decision-making involving multiple variables is the use of decision trees. This approach is founded upon the work of Tverski (1972), who formulated the decision strategy of elimination by aspects. As concisely described in the APA Dictionary of Psychology (2015), "a choice is reached through a series of eliminations. At each stage the decision maker selects an attribute or aspect perceived to be important and eliminates alternatives lacking that attribute. The next most important attribute is then selected, and the process continues until only one alternative is left." Tverski (1972, p. 488–489) characterizes this approach as "easy to apply, it involves no numerical computations, and it is easy to explain and justify in terms of a priority ordering defined on the aspects," particularly "since man's intuitive computational facilities are quite limited." By examining variables individually and sequentially rather than attempting to deal with them simultaneously, this reduces computational complexity and therefore is often the basis for nature field guides used to identify individual trees or birds, for example. It still requires a ranking of the variables, but does not necessitate assigning each a numerical weight. Each is examined in a hierarchical manner, progressively eliminating cases until a final choice is made.

A clear example of this approach in anthropology is described in a study of settlement locations among Maasai pastoralists (Western & Dunne, 1979). The Maasai progressively subdivide the region into smaller suitable areas. In choosing the best locations for late rainy and early dry season camps, they give initial priority to the location of the best grazing areas, eliminating all other areas (Fig. 1). In subsequent steps, they consider water proximity, land form, soil condition, slope, canopy cover, and view. The resulting camp locations do not maximize all preferences because some variables are subordinated to others and compromises are reached because of the hierarchical, sequential approach to the locational criteria. In this case, the lower-ranked variables are "good enough," reflecting the approach of "satisficing" (an established term in psychological literature) rather than maximizing (Dillon &

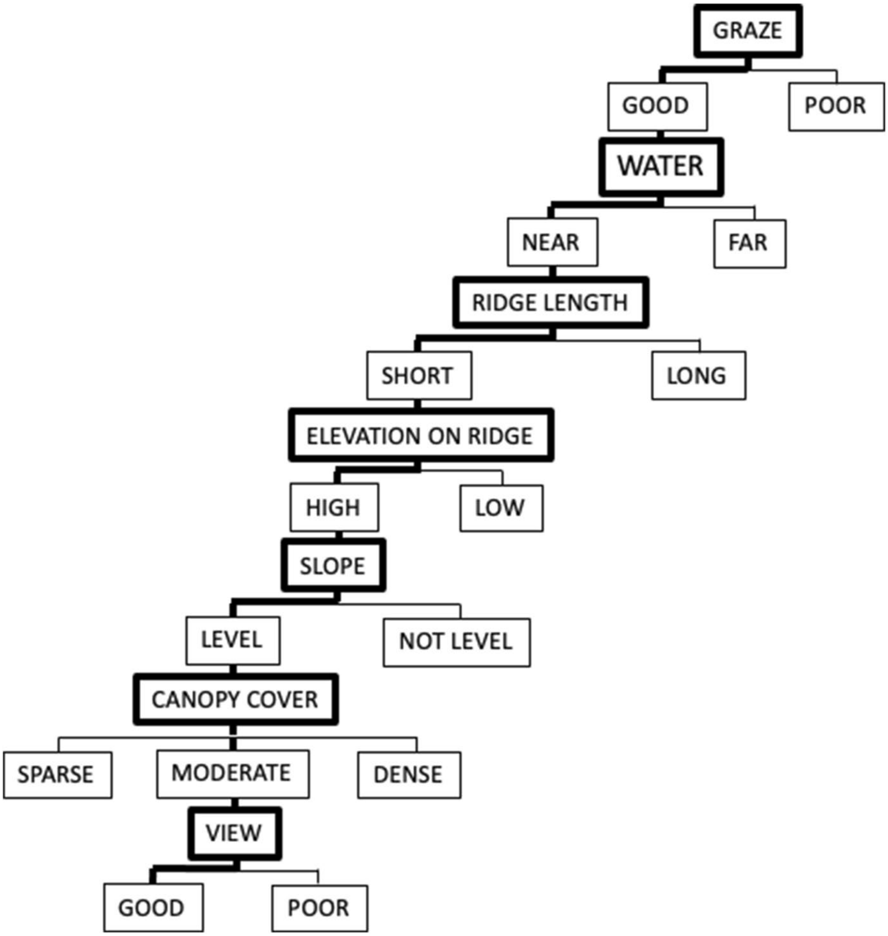



**Fig. 1** Maasai decision tree (after Western & Dunne, 1979)

Heady, 1960; Simon 1956). An archaeological problem with this approach, however, is determining the appropriate hierarchical order of criteria, but this may be revealed by patterns in the site data. This approach essentially reflects the use of decision trees in making choices, an approach developed in anthropology by Gladwin (1989), who discusses a wide variety of studies in which the success rate of predicting decisions is remarkably high.

## A Case Study: LBK Neolithic Settlement Patterns

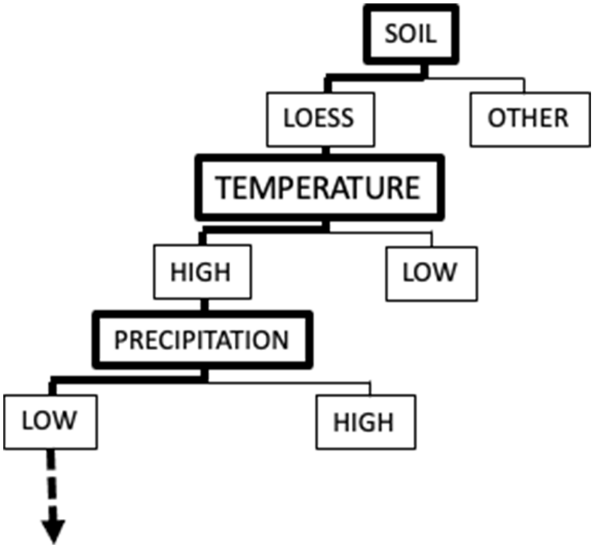
One example of the use of this approach and the IFD is the study of the distribution of sites of the Early Neolithic LBK in central Europe (Jochim, 2009). It has long been recognized that certain environmental factors were important in the location of these early agricultural settlements. As stated by Rösch *et al*., (2017, p. 2) in discussing the LBK, "the most suited environments for agriculture in temperate Europe at that time were regions with low annual precipitation (less than 500 mm per year), high summer temperatures, and fertile soils." Loess soils in particular were fertile, well drained, and easily worked. Steps in applying an IFD model to the distribution of LBK villages could first choose these criteria. Second, their presence at the specific sites rather than only within a particular radius would be appropriate, given the apparently small-scale, localized nature of LBK agriculture (Rösch *et al*., 2017). The third step—ranking and weighting the criteria—might be difficult if all three, soil, temperature, and precipitation, were important. For example, Hamond's (1981) study of LBK settlements (which did not use the IFD) simply assigned equal weights to the locational variables for such sites to analyze their placement. Using this approach with Sielmann's (1971) data for early (phase I) LBK sites in the lower Main Valley of Germany, however, suggests that only one of the ten known sites is situated in the "optimal" locations of loess soils, low temperature, and low precipitation, indicating a significant departure from the predictions of the IFD. This approach allows the possibility that a location on a non-loess soil could be considered suitable if all other factors are very good, depending on the distribution of the environmental characteristics. However, given the known strong LBK preference for loess soils, this approach may not be appropriate. Because soil type is the least variable among the three, considerations of risks would support according loess soils the highest priority.

An evaluation based on these same data but with a decision tree approach shows that all ten sites (100%) are situated on loess soils, only five (50%) are in areas of highest temperatures, and only four (40%) are in areas of lowest rainfall (these values are revised and corrected from those presented in Jochim (2009)). Thus, it seems as if soil quality was given the highest priority, particularly since loess soils cover only about 20% of the lower Main area. The perceived suitability of locations includes a differential weighting of criteria, and an hierarchical, sequential approach to settlement choices closely produces this pattern (Fig. 2). If some of these locations are occupied over time, it is possible that their suitability would be enhanced by such activities as progressive forest clearance, an example of the Allee effect. This might be detected indirectly by including occupation chronology as one of the locational criteria, perhaps also revealed by pollen studies.

One of the predictions of the IFD model is that as populations grow, locations of lower suitability will be utilized. Using the decision tree approach to defining suitability, the changes of LBK settlement through time demonstrate this pattern (Sielmann, 1971). During phase II of LBK settlement in the lower Main Valley, 92% of 24 known sites are situated on loess soils, 38% in areas of highest temperatures, and 25% in areas of lowest rainfall. The rank order of preference for the environmental characteristics remains unchanged, but the desired requirements have been relaxed and settlements expanded to locations of lower desirability. Later phases of settlement generally continue this trend.

This approach establishes a relative ranking of locational variables that may be hypothesized to reflect their role in IFD predictions. If so, then this can be used to predict the best site locations in other culturally and environmentally similar areas.

**Fig. 2** LBK decision tree




Such an area is the Middle Neckar Valley of southern Germany, some 150 km from the Upper Main region. Again using Sielmann's (1971) data, 100% of the 7 phase I LBK sites in the Middle Neckar region are situated on loess soils, 71% in areas of highest temperatures, and 43% in areas of lowest rainfall. Although the specific percentages differ between the two areas, the predicted rank order remains the same. The 61 phase II sites in this latter area show a similar relaxation of criteria, with 93% on loess soils, 67% in areas of highest temperature, and 13% in areas of lowest rainfall. These results suggest that the initial, inductive determination of variable ranking may be useful as an adjunct to approaches such as the IFD.

In the lower Main region, only one phase I site occurs in a location that maximizes all three criteria (loess soil, highest temperature, lowest rainfall). The nine other sites are suboptimal by these criteria, likely to have witnessed somewhat more frequent heavy rains or colder conditions. This suggests that even in early stages of settlement, some differences in agricultural productivity might have existed among the ten sites, differences that, in turn, could have created economic distinctions among villages over the long run. If these distinctions led to friction and disputes among them, this may have contributed in the later LBK to competition, violence, and the appearance of massacres and mass kills visible in the archaeological record (Meyer *et al*., 2014).

This situation raises the possibility of competitive exclusion of a portion of the population through conflict and violence. This mirrors the predictions of another model, the ideal despotic distribution (*e.g.*, in the case of the LBK, Shennan, 2007). In this model, some individuals have a superior competitive ability and can gain control over the better locations and exclude others, even to the extent of not fully utilizing all such locations. The available better locations for the LBK may be further restricted by consideration of additional criteria such as proximity to streams and grazing and presence of level ground. In this case, the excluded groups must use suboptimal sites even before the better locations are saturated. The result is again the relaxation of settlement criteria by some people, but a more rapid expansion into the suboptimal areas.

In the example of the phase I LBK settlements, the area that includes all 10 sites in the Upper Main region has the characteristics of loess soils, but only somewhat high temperatures and somewhat low precipitation. During the later phase II, this prime area includes only 14 (58%) of the 24 settlements; the remaining 10 (42%) are in areas less optimal, 2 because of absence of loess soils and 8 because of even higher precipitation. In both the Main and Neckar regions, incidentally, the relaxation of criteria involves mainly the lower-ranked temperature and especially precipitation requirements. This underscores the greater importance of the high-ranked soil needs, testifying to its primary role in settlement decisions.

## Site Location and Site Function

The issue of the relaxation of criteria for site placement is relevant to another aspect of settlement analysis: the relationship between site location and site function. The IFD models discussed above do not deal with different site functions. Each study focuses on the distribution of sites of similar function, such as residential camps or agricultural villages. Other models grounded in human behavioral ecology, such as those using a maximum entropy approach, can incorporate site functional differences. For example, Howey *et al.* (2016) contrasted the distribution of mounds and enclosures in Michigan, which presumably served different functions, but did so by constructing a separate model for each. Vernon *et al.* (2020) compared the locations of residential sites of foragers and farmers, again by building a different model for each. Based on an assumption that each group of sites was distributed according to the predictions of the IFD model, the purpose of these studies was largely to understand patterns of adaptation and their changes due to demographic, environmental economic, and socio-political factors.

Although not directly addressed by the IFD, the differential distribution of sites of different functions can be informative about economic and socio-political organization by focusing on differences within regions among sites in terms of size, content, and locations, as well as their spatial interrelationships. In this case, the relationship between site function and location assumes importance because a site's location is often used in interpretations of settlement patterns, together with evidence from site assemblages and features, particularly when an archaeological record consists largely of surface material or excavations with little organic preservation.

For example, in a small region on the edge of the Black Forest of southwestern Germany, there are nine known Early Mesolithic (10,300–7800 bp) sites, notable for their stark contrast in location (Pasda, 1994; Stoll, 1932, 1933). Eight of these sites, discovered by surface collecting in the 1930s, are located on the edges of high ridges overlooking the Nagold River, a small tributary of the Neckar. Their elevation ranges from 500 to 610 m above sea level and provides wide views over the landscape. On the narrow valley floor below, at an elevation of 430 m, is the partially excavated site of Altensteig. Such a clear locational difference between the two groups of sites intuitively suggests a difference in site activities and function, a distinction that is supported by the stone tool assemblages. The ridgetop sites are dominated by microlithic armatures among the retouched tools, with percentages between 70 and 88%. The valley site by contrast has a much more diverse assemblage, with microliths comprising only 26% of the retouched tools. An interpretation of the valley site as a residential camp and the ridgetop sites as hunting camps seems appropriate. In this example, there is a strong correlation between site location and site function.

This locational pattern is not rare. Another example is provided by Early Mesolithic sites near the Colbricon Lakes in the Italian Alps. Three of these sites are located near the lakeshores and have assemblages in which armatures are a relatively small part of the collections, which include a variety of other tool types. Five other sites have assemblages dominated by armatures and are located on ridges and hills away from the lakes and possess good views of the countryside. Researchers have suggested that these represent a distinction between residential lakeshore camps and hunting camps in the hills (Bagolini & Dalmeri, 1992). Other examples of such specialized hunting camps in the Italian Alps are three sites located on hills above the Buse lake, in which microlithic armatures make up between 65 and 82% of the tool assemblages (Dalmeri & Lanzinger, 1992).

Such a clear pattern, however, is not universal and there are many examples in which site activities and function differ significantly among sites with very similar locational characteristics. One example comes from work in the former lake of the Federsee in southwestern Germany. Three sites of the Late Mesolithic (ca. 7800–6500 bp), all located in similar locations on the former lakeshore within 300 m of each other, appear to represent very different site activities and functions. Henauhof NW is a large residential site with diverse activities and substantial evidence of site cleaning to form an extensive discard area in the former lake shallows (Jochim, 1998). Henauhof NW2, by contrast, is a small residential camp focused on big game hunting and manufacturing of antler tools (Ibid.). The third site, Henauhof Nord, is a small logistical camp possibly focused especially on fishing (Kind, 1997). In this case, site location is a poor indicator of site function and raises the issue of how the two are related.

In the case of the Nagold Valley sites mentioned earlier, the correlation is high, presumably because environmental requirements for the two types of sites are relatively restrictive. If, in situations of growing population through time, locational restrictions are relaxed, as suggested by the predictions of the IFD, such a correlation may be weakened and interpretations of site function more problematic.

An example of differential relaxation criteria in locational choices may be found in another region of southwestern Germany. There is a large concentration of Early Mesolithic sites in the hills east of Stuttgart, Germany, where private collectors have been active for almost a century. Over the course of this time, more than 200 surface sites have been documented. The number and types of artifacts at these sites vary considerably, from isolated microliths or a few flakes to hundreds or thousands of finds. These larger assemblages usually contain a high diversity of tool types, suggesting that a wide range of activities occurred in these locations. Part of the variation in assemblage size no doubt reflects the intensity of collection activities as well as the surface visibility, but part probably indicates considerable differences in occupation intensity and site function. Certain places on the landscape were presumably repeatedly occupied, while others witnessed much more limited use.

An examination of site placement was carried out with 170 sites in these hills, focusing on determining the environmental features that characterize the site locations (Kvamme & Jochim, 1990). In comparison to the entire area, the site locations show a clear preference for level ground on high elevations in areas of high local relief—essentially on ridge crests and the edges of broader plateaus providing wide views. A consequence of this locational preference is that the sites are farther from water than would be expected by chance alone, suggesting that proximity to water was a relatively low-ranked criterion.

More recently, it has been possible to divide this sample of 170 sites into subcategories. As mentioned, it is clear from the reports that some of these sites represent sizable settlements with diverse assemblages, while others are much smaller, less dense, and less diverse in their assemblages. A total of 39 of the sites seem to have been particularly large and diverse, apparently representing more intensive or functionally different occupations than other sites in the area. If so, such sites should also differ from the others in location, reflecting selection for repeated and/or functionally more diverse occupations. The same computer database was therefore used to compare these 39 big sites to the remaining 131 in order to determine whether these two groups differed in locational characteristics. Not surprisingly, the big sites were located on considerably more level ground than the other sites. They were also in locations that provided somewhat more shelter and a more southerly exposure, but perhaps as a result, even farther from the nearest water both horizontally and vertically. It appears, then, that ease of camping on level ground, the greater warmth of south-facing slopes, and the degree of protection from winds were particularly important criteria in choosing locations for longer-term or repeated occupation, and that stricter criteria were used in their selection. Similar factors were used for the location of the other sites, but the requirements were relaxed somewhat.

## A Hypothetical Case Study

It is not necessary to use complex, quantitative approaches to examine the effects of the relaxation of criteria. As a framework in which to pursue this issue, I establish a simple, fictional study area of 12 × 12 km, an area of hills and valleys carrying streams. The area is divided into 576 cells, each measuring 500 m on a side. Each cell is coded (from its center) for two environmental variables: horizontal distance to water and angular view within a radius of 1.5 km. These two variables are presumably important for hunter-gatherers and play a role in many settlement analyses. Proximity to water facilitates drinking and bathing as well as access to fish and other resources. Wide views may allow both game monitoring and scouting for strangers. Within this study area, viewsheds range from 30 to 360°, with an average of 189°, and distance to water varies between 0 and 4.1 km, averaging 1.35 km. As might be imagined, the two variables are somewhat negatively correlated (Pearson's $r = -0.51$): locations with good views tend to be high and far from water. This relationship means that settlement decisions emphasizing both variables will have to achieve some compromise.

The approach to decision-making used here is consistent with observations of informal decisions and reflects the computational limitations of the human brain. Decisions are hierarchical and sequential. A hypothetical group of hunter-gatherers is now placed on the fictional landscape and asked to select locations for two functionally different types of settlement: fishing camps and hunting camps. In locating fishing camps, proximity to water should be of greater importance, while hunting camps should emphasize the advantages of wide view angles. This highly selective group chooses the locations for its fishing camps as follows:

1. Eliminate all areas farther than 500 m from water.
2. Within the remaining area, select those spots with the greatest views, up to a certain number of locations (in this case, 24).

The hunting camps were chosen in a similar manner:

1. Eliminate all areas with view angles less than 300°.
2. Within the remaining area, select those spots closest to water (again, 24 spots).

Inspection of maps of the two types of camp locations resulting from these procedures shows distinct differences, as might be expected (Fig. 3). The fishing camps are aligned along the streams like beads on a thread and are somewhat clustered at locations where the valleys widen or bend to afford greater views. The hunting camps, by contrast, are all upslope on points jutting out into the valleys and on plateau tops. There is no overlap in the distribution of these two settlement types (Fig. 4A).

In simple quantitative terms, these two site types also contrast significantly. The fishing camps are located at an average distance of 0.38 km from water, while the

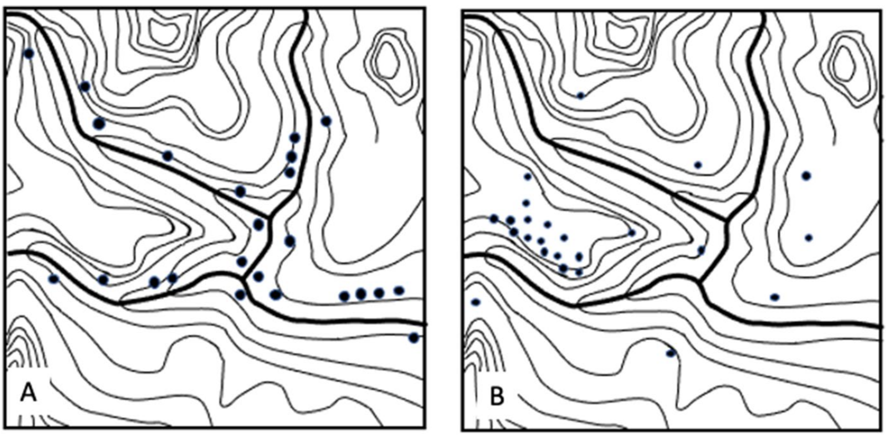



**Fig. 3** **A** Strictly defined fishing camps. **B** Strictly defined hunting camps

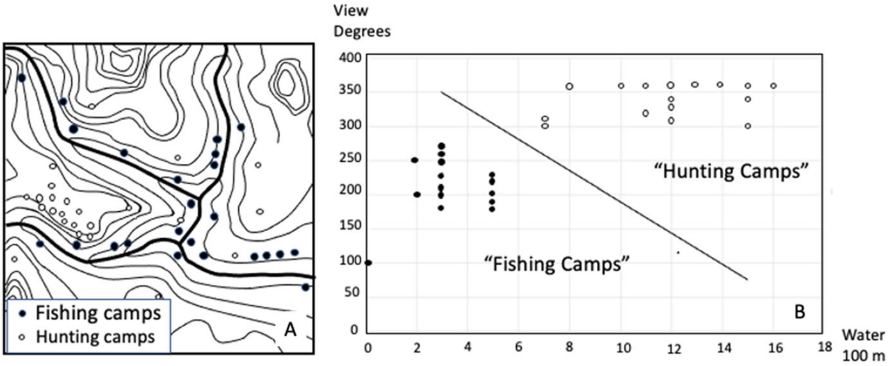



**Fig. 4** **A** All strictly defined camps. **B** All strictly define camps (some camps have same characteristics)

hunting camps average 1.22 km. By contrast, fishing camps have an average view angle of only 215°, whereas the hunting camps average 346°. It should be noted that both camp types differ significantly in these averages from the study area as a whole, indicating that both types show some selectivity for both variables. A scatterplot of the 48 locations according to the two variables reinforces the distinctiveness of the two settlement types (Fig. 4B). Two clusters of points are clearly visible corresponding completely to the two settlement types.

In a case of less selective hunter-gatherers who relax their requirements, somewhat a different picture emerges. Again, decisions about two different camp types are modeled, but the tolerable ranges of the primary variable are changed as follows.

For fishing camps:

1. Eliminate all locations farther than 1 km from water.
2. Within the remaining area, select 24 spots with the greatest view angles.

And for hunting camps:

1. Eliminate all locations with view angles of less than 270°.
2. Within the remaining area, select 24 spots that are closest to water.

An inspection of maps of the two settlement types reveals some differences from the first set of maps (Fig. 5). The fishing camps have now moved somewhat upslope and the hunting camps somewhat downslope. Moreover, there is now considerable overlap in the distribution of the two settlement types: 12 specific locations appear in both sets of selected spots (Fig. 6A).

In quantitative terms, the two camp types still differ from another, but not as much. Fishing camps are now an average of 0.67 km from water, while hunting camps average 0.97 km. The average view angle from fishing camps is 275°, whereas that from hunting camps is 292°. Again, both differ from the averages for the study area as a whole, however, indicating that the two variables are still important in the selection of locations.

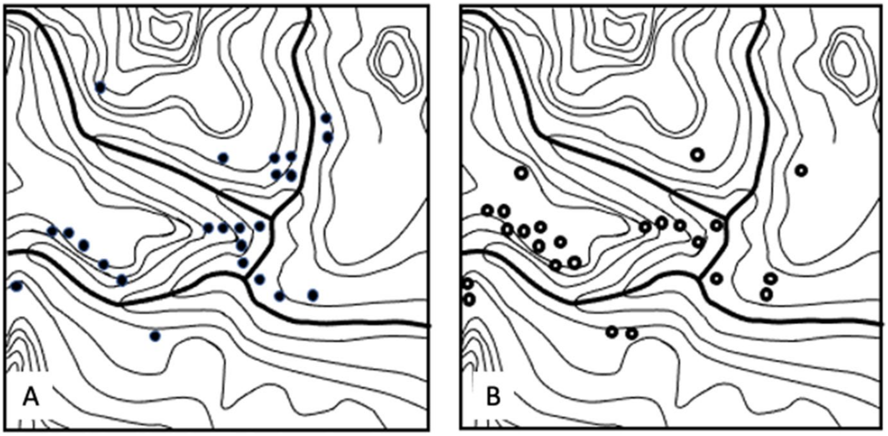



**Fig. 5** **A** Relaxed fishing camps. **B** Relaxed hunting camps

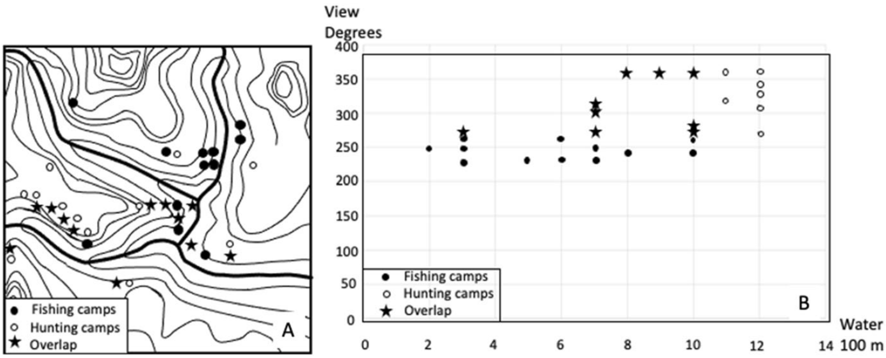



**Fig. 6** A Relaxed camps. B Relaxed camps

A scatterplot of these two sets of locations is much different from that in the first example (Fig. 6B). No longer are there two clear clusters of points. More importantly, however, is the fact that any spatial clustering is not indicative of the functional type of settlement. The overlap between the two sets is so great that the locational patterns do not clearly reflect site functional differences. If one were to classify these sites according to these locational variables, one would learn little about the site functions. In general, for any functional type of site, the more the locational criteria are relaxed, the greater is the variability within the group of suitable locations. If different functional types of sites share many of the same criteria, the higher is the possibility that they will share suitable locations.

For the sake of comparison, it is worthwhile to consider another approach to site selection using these two variables. Instead of using a hierarchical, sequential approach, the two variables may be considered simultaneously and given equal weight. This approach would produce only one site type but could be seen as an example of trying to optimize both variables in site selection. If the two variables are scaled to each other, weighted equally, and then the 24 best locations are selected, a different picture emerges yet again.

The map of these sites indicates some overlap with each of the other distributions (Fig. 7). The average values for the environmental variables differ considerably from both those of the entire study area and those of any other particular example. The average distance to water is only 0.39 km, about as low as the most selective fishing camps, and the average view angle is 241°, lower than that of all but the most selective fishing camps. As might be expected given the equal weighting of the variables, this set of sites on average differs more from the entire study area than does any other single set of sites selected. It is not likely that this approach accurately reflects actual decision-making, however, particularly in real complex situations where more than two variables are given consideration. It is presented here only to emphasize that the approach produces results different from those of the previous models.

## Some Implications

The results of these simple simulations have a number of implications for archaeological analyses.

1. Small differences in decision procedures can have dramatic effects on site distribution. In these examples, a slight relaxation of the limits placed on variables resulted in a very different array of locations selected.
2. Typologies of sites based upon locational variables may not correlate well with functional differences among settlements. In this case, even though hunting and

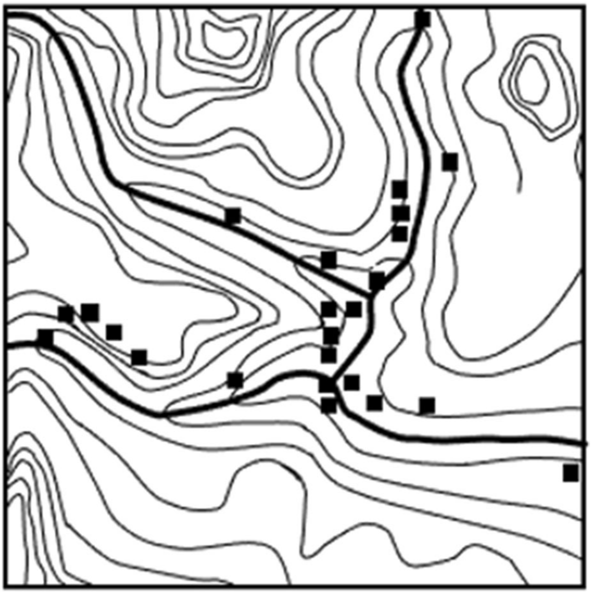


**Fig. 7** Both water and view considered simultaneously

fishing camps were selected giving different priorities to variables, they overlapped greatly when tolerable variable ranges were sufficiently relaxed.

3. Reoccupation of sites for functionally different purposes may be more likely in those situations where decision criteria are not highly selective. In these examples, the less selective hunting and fishing camps showed significant overlap in their distributions.
4. If critical variables in site selection are positively correlated (such as may be true of proximity to water and degree of shelter), then functionally, different sites may be harder to distinguish locationally. In the examples above, the major distinctions between site types arose because the variables were negatively correlated. Gains in terms of one variable were obtained at the expense of the other.

## Contexts of Selectivity

As these examples suggest, differences in the degree of selectivity in site placement can create significant differences in the resulting archaeological record of settlement patterns. While there may be many determinants of the degree of selectivity, certain contextual factors certainly play a role.

1. Resource distribution

   If resources are uniformly distributed across the landscape, then all locations are equal in desirability. As resources become more clustered, however, fewer locations begin to stand out in attractiveness. Consequently, selectivity in camp placement should increase together with resource clumping and one might expect highly restricted site locations in very patchy environments.
2. Resource abundance

   Quite apart from the distribution of resources, their abundance may also play a role in selection criteria. If resources are relatively scarce, then no one location can easily satisfy needs for an extended stay. Movement and the establishment of new camps should therefore increase with resource scarcity. As the number of occupied camps increases, so too does the number of locations that need to be utilized. In such situations, selection criteria may need to be relatively broad.
3. Population density

   Selection criteria may also vary with the density of population. In contexts of denser settlement, there is greater competition for choice locations. In the absence of changes in activities (such as intensification, greater sedentism, increased group size), an increase in population density should lead to the occupation of more locations and hence a relaxation of selection criteria.
4. Differential competition and despotic control

The expectations here are similar to those associated with an increase in population density, but often include, in the despotic center, evidence of intensification, greater sedentism, and increased settlement size, as well as evidence of territoriality such as cemeteries and of conflict in the form of defensive structures.

## Conclusions

Decision tree approaches may allow insight into the actual decisions made by people on the landscape. The results may be useful in comparisons with, or even formulation of, models like the IFD, which posit the most adaptive choices of location. In addition, decision tree approaches may be useful in combination with IFD models, but at a different spatial scale. For the Maasai, for example, Moritz *et al.* (2014) developed IFD models of the pastoralists' land use locales with a radius of 1.5 km, resulting in predictions of optimal locations, which were successfully compared to their actual distribution. As suggested by the study of Western and Dunne (1979), the decision tree approach could then be useful in evaluating settlement locations at a finer scale within these areas, providing greater insight into patterns of settlement.

Considerable complexity underlies settlement decisions. Patterns of sites on the landscape are sensitive to, and reflect, many factors, including the methods of decision-making, the demographic and socio-political context of decisions, and the structure of the environment in terms of resource distribution and abundance as well as the interrelationship of variables. While some of these factors will not be obvious in prehistoric situations, multiple approaches may be useful, should be sensitive to the influence of these factors, and should strive to take them into account before assigning meaning to the dots on the map.

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## Declarations

**Ethics Approval** This article does not contain any studies with human participants or animals performed by the author.

**Informed Consent** No informed consent was necessary.

**Conflict of Interest** The author declares no competing interests.



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