Supplemental Text 1 for "Modeling Colonial Paternalism: GIS and Multi-Spectral Satellite Imagery at Kingstown, British Virgin Islands"

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1. Qualifications of the LCP Model

It should be noted that the highest resolution elevation model available for this analysis was 30 m, meaning that each cell in the raster covered a 30 m by 30 m area. Because of this resolution, the analysis produces somewhat simplified lines: straight-line elements of 30 m up to 100 m or more for areas that are either level or have a consistent slope, when in reality travelers would have encountered small changes in elevation, boulders, trees, human-made impediments such as walls, etc. While the figures are accurate in roughly quantifying the differences between the respective paths to the fields, the path lengths given in Table 1 are therefore somewhat imprecise. However, the LCP model provides for important information not available from the topographic map alone, however stylized. Most importantly, it allows for a quantification of the journey to each field and its difficulty. While this difficulty is clear from the topographic map, or indeed from standing at the bottom of the hill and looking up, quantification allows for the combination of multiple other kinds of data—historical, archaeological, and technical, which we incorporate below and in the main text—even though the precision of the DEM is somewhat coarse.

Some other potential limitations of the LCP method deserve mention as well. Herzog (2014) reviewed a large number of studies making use of least cost and time modeling, raising questions about some of the literature. Her main concerns relevant here, besides correct applications of the technological components of the models, focused on the DEM. As noted, the DEM available for this study had a resolution of 30 m, which appears to be approximately average among the studies Herzog considers, and avoids the most problematic issues she raises, such as analyzing 10 m wide canyons with a 90 m resolution DEM (Herzog 2014: 230), as we consider a landscape of 300 acres or more (the Kingstown site plus neighboring areas) with such a DEM. Another issue Herzog considers is the effect of time on the landscape between the collection of DEM data and the past behavior archaeologists are trying to model: that is, recent modification to the landscape may influence simulations of ancient movement. We suggest that the lack of modern development in the area of Kingstown and the relatively short distance in time of the reconstructed behavior—roughly 175 years before the time of analysis—compensates for this concern. Some other considerations, such as assumptions used in the Tobler model, are discussed more below.

2. Calculation of Energy Expenditure

Energy use was calculated in terms of kilocalories burned during the trip, taking into consideration the total elevation gain and total distance traveled along the LCP to and from each field. The calculation was done with an online hiking calculator[1] based on an equation published in the Journal of Applied Physiology (Minetti, et al. 2002), assuming a 175-pound person carrying a 20 pound weight. The weight of the pack is estimated based on the weight of food and water one would be expected to have carried into the field. The water was calculated as being up to 12 quarts for a 12 hour work day (weighing 12 pounds plus the weight of the container) based on published recommendations for water intake for those engaged in heavy manual labor in high temperatures (Mountain, et al. 1999). It is assumed that, on average, farmers would have carried such a weight each direction, as on the return, the lack of water and food would have been balanced by produce carried back to the village, along with tools being carried both directions. All of these assumptions are estimates, of course, but they allow for the calculations to be comparable between fields.

3. Sweet Potatoes, Time, and Energy

The difference in kcal usage in accessing the most and least accessible fields is 328.78 kcal per trip, or, assuming 4 trips per week year-round (a figure justified in the discussion below), 68,386.24 kcal per year. According to information published by the USDA, baked and eaten whole, a medium sweet potato (about 2” by 5” before cooking) weighs about 114g (4.02 oz or 0.251 pounds) and provides about 103 kilocalories (US Department of Agriculture n.d.). This means that a person farming the farthest fields needed to produce 664 more sweet potatoes—75,690g or 166.86 pounds—per year compared the person farming the nearest field, just to account for the additional energy usage in walking to their field. Another way to contextualize this data is through experimental agricultural work recreating prehistoric sweet potato productivity in New Zealand, although this uses prime land specifically selected for the purpose (Burtenshaw and Harris 2007: 241). Here, productivity using pre-modern farming methods with one cultivar ranged from about 14,000 pounds per acre down to 4,450 pounds per acre over eight experimental seasons, with an average of 8,600 pounds per acre. This work took an average of 2130 hours of work per acre each year. This figure supports the suggestion above that those farming one-acre plots at Kingstown would have needed at least four days a week to do so, as 2130 hours could be accomplished in four 10.25 hour workdays over 52 weeks. Even at that level, on some days during the winter, this is more time than there is daylight for those who have an hour’s commute to their fields.

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[1]“Hiking Science,” http://hikingscience.blogspot.com/p/calculate-calories-burned_22.html, accessed November 17, 2015.

This figure of 8,600 pounds of sweet potatoes per acre (which would yield 3,524,491 kcal per year) seems substantial, but calorie usage of the Kingstown people would have been substantial as well, as most of their work was manual labor as noted in the main article. Fogel and Engerman's (1974) now-classic discussion of the economics of slavery has been much discussed and improved-upon in the decades since its publication, but it still provides a useful rough estimate of 4,185 kilocalories per day for an enslaved person's diet and 3,741 for free. These are based on adult rations in the US South, but even a very conservative estimate of 3,500 kilocalories per Kingstown person per day yields a figure of 1,277,500 kcal/person/year. With these numbers, an acre of prime land would fall more than 300,000 kcal short of providing for a family of three. Further, as discussed in the NDVI section of this paper, few parts of the Kingstown property could be considered "prime."

4. Social and Practical Factors

Other limits on the model actually provide further insight into the lives of anyone who might have attempted to enact the plan as pictured in the 1831 map. The least cost paths are just that: best case scenarios, and there are at least two reasons the actual journeys to these higher elevation fields might have been longer. For one, the LCPs often lead diagonally across other fields, when in reality farmers would have had regular paths which they followed to avoid trampling crops, some parts of which would have diverted them from the most efficient possible path.

Least cost paths are also modern, etic understandings of the field: a "God's-eye view" which assumes that every individual on the ground would have seen and had available the best possible scenario and would have chosen to follow it. In reality, traveling with and visiting friends, taking preferred paths in the shade, or avoiding others in the settlement may have caused residents to choose more costly paths. Another important conclusion of the GIS model is that, as shown in Figure 3, because the valley divides at higher elevations and the site partially overlaps a neighboring valley, the best path to the upper fields lies not through the lower ones, but through the neighboring property. It is an open question if such travel would have been permitted, considering Dookhan's (1975:102) report of a confrontational relationship between the Kingstown people and others on Tortola.

Another complicating factor is that the data are all computed from a single central point in the center of the north side of the village near the church, the area nearest the fields. However, the village included a substantial pond (no longer present today), and some houses were on the seaward side of this pond. While the map marks this as "now nearly filled up" the body is still more than 5 acres in extent and nearly 70 meters across, so except in the driest of seasons it would still have required a detour for those living to seaward, which would have added up to an additional half kilometer and at least 6 minutes to the walk. Again, the calculations given above represent best-case scenarios for many Kingstown people, and any departure from these ideals would exacerbate the results suggested here, tending towards greater inequality and lower likelihood of a successful implementation of the British plan.

5. NDVI Methodology

High resolution, multi-spectral, Worldiew-2 satellite imagery was obtained of the study area via an imagery grant from the Digital Globe Foundation. These images were converted from radiance to reflectance and were corrected for atmospheric effects (Chander, et al. 2009; Salvatore 2015; Updike and Comp 2010) using the ENVI software package. This made it possible to calculate Normalized Difference Vegetation Indexes (NDVI) for each pixel and to assign these to the separate fields allocated to the Kingstown people.

NDVI is useful for determining vegetation health and thus underlying soil conditions based on reflectance spectra. Because healthy vegetation reflects very little in the red wavelengths (0.630-0.690 μm) and much in the near-infrared (0.770-0.895 μm), the function of (NIR-Red)/(NIR+Red) yields values that indicate a spectrum of unhealthy to healthy vegetation (Tucker 1979), allowing modern vegetation to serve as a proxy for the natural productive potential of the land in each field. Though NDVI necessarily is calculated on present (or relatively recent) satellite imagery, it is gaining increasing use in understanding archaeological contexts. For deeper introductions to remote sensing from archaeological perspectives, see Lasaponara (2012) and Parcak (2009), and for a deeper discussion of plant biology, vegetation indices like NDVI, and archaeological crop marks from an archaeological viewpoint, see (Verhoeven 2012).

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