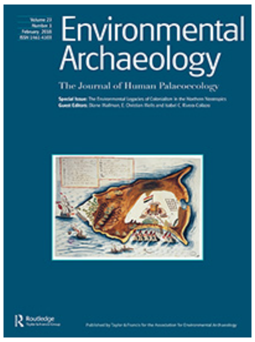

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Plantation Soilscapes: Initial and Cumulative Impacts of Colonial Agriculture in Antigua, West Indies

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ABSTRACT
This paper examines physical, chemical, and biological properties of soils and sediments from landforms in eastern Antigua, West Indies, to better understand the long-term consequences of colonial plantation agriculture for soil health. Plantation farming played a central role in the history of Caribbean societies, economies, and environments since the seventeenth century. In Antigua, the entire island was variably dedicated to agricultural pursuits (mostly sugarcane monoculture) from the mid-1600s until independence from the United Kingdom in 1981, when most commercial cultivation ceased. Today's soilscapes are highly degraded, although it is unknown what the role of the island's plantation legacy has played in this process. Our research combines geoarchaeological survey and sampling, sediment core analysis, and historical archival research to model the initial and cumulative impacts of the plantation industry on the island. We focus on the region surrounding Betty's Hope, the island's first large-scale sugarcane plantation in operation from 1674 to 1944. We find that current erosion and degradation issues experienced by today's farmers are not attributable to intensive plantation farming alone, but rather are part of a complex mosaic of human-environmental interactions that include abandonment of engineered landscapes.

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Introduction

The dual commercial industries of sugar and rum (both made from sugarcane) have played a central role in the history of Caribbean societies, economies, and environments since the seventeenth century (Mintz 1985). From 1665 to 1833, plantation sugarcane agriculture was present on nearly every island of the West Indies (Watts 1990). From 1710 to 1750, the northern Leeward Islands became the most productive and profitable sugar colonies of the Caribbean (Dyde 2000). Of these, the island of Antigua was nearly entirely dedicated to this industry from the mid-1600s until independence from the United Kingdom in 1981 (Midgett 1984).

It has long been suspected by governmental and non-governmental organisations in Antigua and elsewhere in the Caribbean that intensive monocropping of sugarcane had devastating effects on soil quality and integrity, and that this form of agricultural intensification likely created conditions conducive to the large-scale degradation of island landscapes witnessed today (Abbott 1964; Campbell et al. 1992; Garside, Bell, and Magarey 2001; Meniketti 2016; Meyer, Van Antwerpen, and Meyer 1996; Ragatz 1928; Sheridan 1960, 135; Ward 1978, 198). In 2004, the United Nations Technical Advisory Committee conducted a rapid field appraisal of land degradation in Antigua, concluding that the country is experiencing major problems with soil loss (United Nations 2005). Apart from Meniketti's (2016) important work in Nevis and a few recent studies concerning the effects of sugarcane farming on relatively short (e.g. decadal) time spans (e.g. Gonzalez-Scollard 2008), there has been no systematic study of the cumulative impacts of sugarcane agriculture on Caribbean landscapes over the colonial/post-colonial transition. In this article, we describe our recent research, which seeks to establish the long-term environmental legacies of colonial plantation agriculture in Antigua. We propose that understanding the differences between ephemeral versus enduring impacts to local soilscapes by colonial plantation farming can aid in addressing the loss of soil productivity experienced today.

Sugarcane monoculture and land degradation

Environmental degradation occurred rapidly in the West Indies following European colonisation (Dillman 2015; Gonzalez-Scollard 2008). The impacts of intensive sugarcane monoculture and the commercial plantation system were especially pronounced, and

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involved land clearing and deforestation followed by soil erosion from surface runoff, which diminished soil fertility (Meniketti 2016; Watts 1990). Many scientists have argued that intensive monoculture causes soil to lose fertility over time, thereby progressively decreasing crop yields (Abbott 1964, 1; Campbell et al. 1992; Garside, Bell, and Magarey 2001, 16; Meyer, Van Antwerpen, and Meyer 1996; Ragatz 1928, 67; Sheridan 1960, 135; Ward 1978, 198). By 1661, the first official statement about decreasing levels of soil fertility in the Caribbean was made by the President and Council in Barbados, reporting that 'the land is much poorer, and makes much less sugar than heretofore' (Great Britain Public Record Office 1661–1668, 45).

In response to reduced returns on labour and capital investments into the land, plantation owners experimented with new methods and techniques that left detectable ecological legacies. For example, in 1784, Samuel Martin of Green Castle Estate in Antigua declared that West Indian soils had been depleted of nutrients 'by long and injudicious culture' (Martin 1784, 253), leading him to suggest new methods of tillage and manuring for each Antiguan soil type (Ragatz 1928, 67; Watts 1990, 425). These included fallowing, fertilisation with manure, tilling, and drainage by 'round ridging' in which a series of ridges and trenches were constructed on flat land in order to remove excess surface water and allow cane fields to drain adequately (Martin 1784, 258–259; Sheridan 1960, 133). Martin (1784, 271–272) also discussed the widely practiced technique of digging cane holes as a means to prevent erosion by runoff, maintain soil moisture, protect roots and shoots from wind, and concentrate fertiliser near the base of the cane. This diversity of strategies employed by plantation farmers over time has resulted in spatial variation in paedogenic processes that continue to drive landscape change today (Midgett 1984; Rebovich 2011).

The Antiguan sugarcane industry peaked in the eighteenth century when over 90% of Antigua was devoted to agricultural production. To enable sugarcane production on such a large scale, native forest cover was removed and large acreages of land unsuitable for agriculture were cleared and planted (United Nations 2005, 22). Although sugarcane dominated in Antigua for three centuries, a period of dramatic change to land use occurred from 1961 to 1995 when sugarcane cultivation declined and livestock grazing increased (United Nations 2005, 48). Currently, animal grazing negatively impacts ecosystem services; indigenous plant species cannot take root because the seedlings are consumed by domestic sheep and goats. Larger livestock, such as cows and an increasing population of feral donkeys, also affect local soilscapes (Day 2007, 178). In addition, forest clearance for resort tourism has also played a role in contemporary land degradation (United Nations 2005, 22, 49).

The 2004 United Nations field appraisal of land degradation in Antigua found that significant topsoil erosion has occurred recently and, in the most acutely affected areas, 'much of the A and B horizons was eroded away' (United Nations 2005, 22). The United Nations team concluded that Antigua is experiencing 'serious problems with land degradation in the more vulnerable areas of steep and shallow soils' (United Nations 2005, 42) and that recovery from degradation of this type and at this scale is very slow, occurring at geological time scales. The already severe pressures on Antigua's landscape are expected to be exacerbated by anthropogenic climate change and other human pressures, such as increasing tourism (Day 2007, 181).

The study area

The location of our study area lies in the fertile Central Plain of eastern Antigua (Figure 1). Archaeological investigation of this area began at Betty's Hope plantation in 2007, and continued through 2015, and includes excavation of the Great House and adjoining kitchen area, a section of the Still House, and a portion of the village of enslaved Africans (Fox 2014, 2016). Regional survey and geomorphological studies in the surrounding area were conducted from 2014 to 2016. One of the most remarkable aspects of Betty's Hope is its long-term occupation and ownership by the Codrington family, who took possession of the property in 1674 (Oliver 1896, 124–125). Once Christopher Codrington II assumed ownership, the plantation grew in size by the acquisition of adjacent lands, further expanded by William Codrington I, nephew of Christopher Codington III. Before his death in 1738, William Codrington purchased the Cotton New Works and Garden Estates, which resulted in extensive landholdings for the Codrington family (see the Map of 1755: Codrington Papers 1700–1944, P-10). Our archaeological investigations at Betty's Hope are aided by the Codrington Papers (1700–1944), which are housed in the National Archives of Antigua and Barbuda. This rich trove of maps, correspondence, and various accounts and estate papers dating from 1700 to 1944 complement and assist our understanding of this plantation and other Codrington land holdings.

Betty's Hope, which was about 700 acres in its heyday, was one of Antigua's largest plantations on an island that comprised almost 200 plantations at the height of 'King Sugar' (Dyde 2000, 30). The Codrington Papers (1700–1944) record that, prior to industrialisation, Betty's Hope produced as much as 4000 tons of sugar per year (see Pratt 2015, 101–113), although production fluctuated from year to year (Lowes 1994, 10). While the size and topography varied for Antigua's many plantations (see Rebovich 2011), the basic approach to cane farming was relatively similar in that as a labour-intensive crop, sugar cane required

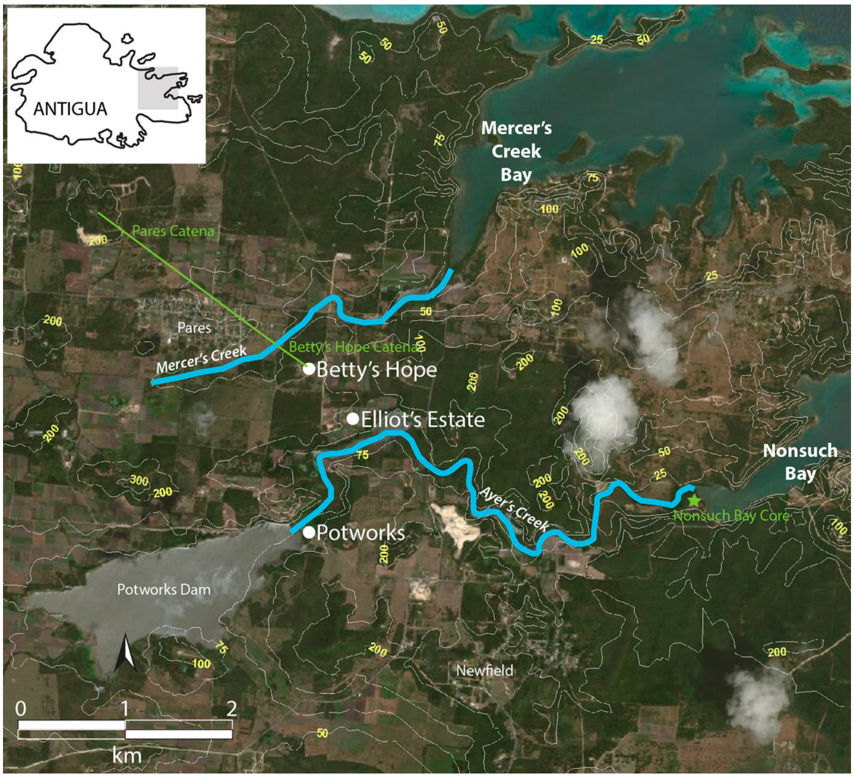

Figure 1. Eastern Antigua showing the study area and major landscape features mentioned in the text, including the locations of the Nonsuch Bay core and the Pares and Betty's Hope catenas.

the planting of the small stalks or ratoons, fertilising with animal dung, weeding, and harvesting, with considerable dependence on rainfall to assure successful crop production. The archives show a long-term consistency in farming methods on the Codrington plantations until the advent of mechanisation and steam power in the mid-to late nineteenth century (see Wells et al. 2017), with the introduction of the tractor to replace animal-driven ploughs between 1936 and 1938, and the switch from animal dung to chemical fertilisers in 1938 (Codrington Papers 1700–1944, C-66, C-67).

Between 1937 and 1938, sugar production eventually moved off the Codrington estates to the Antigua Sugar Factory. By the early 1940s, Betty's Hope and its consolidated land holdings proved to be a financial drain on the Codrington coffers, culminating in the sale of Betty's Hope in 1944 to Antigua Sugar Estates Ltd. (Codrington Papers 1700–1944, C-65). The land continued to be farmed for the next 30 years, but Betty's Hope eventually moved to tourism status, with the establishment of the Betty's Hope Trust in 1990. The former adjoining lands are now either privately owned and operate as small-scale farms or else are broken into parcels of private homes and the emergence of modern-day villages, such as the nearby village of Pares.

The areas adjacent to and surrounding Betty's Hope that we tested for this study include the former Elliott's Estate and the land comprising Potworks Dam. Elliott's lies to the southeast of Betty's Hope, and is also regarded as an important prehistoric Saladoid site on Antigua (Murphy et al. 2000). Founded in 1668 by planter Robert Elliott, who died in 1672, the plantation thrived for almost as long as Betty's Hope, well into the late 1920s (Agnes Meeker, personal communication, 22 September 2016; Oliver 1894, 240–241). Potworks Dam, located south of Betty's Hope, was once surrounded by numerous plantations, but was within walking distance to Betty's Hope and the adjacent Codrington estates. Known for its excellent clays for making coarse earthenware pots, the Potworks Dam area was once the site of pottery production, as indicated by the depiction of kilns on the 1710 map in the Codrington Papers (1700–1944). A pedestrian survey conducted in 2016 yielded only minor traces of this once semi-industrial activity.

Environmental context

Antigua is situated in the eastern Caribbean among the northwestern leeward islands of the Lesser Antilles, a chain of volcanic islands stretching 700 km long and comprising what is often referred to as the 'West Indies' (Adderley 2004, 1584). Antigua has a circumference of approximately 87 km and a land area of 281 km^2 (Sheridan 1960, 127). The island's climate is warm and humid, with annual temperatures ranging 22.4–30.5°C and average annual rainfall of 1050 mm, although droughts have historically been a frequent problem (Wilson 2005). The Codrington Papers (1700–1944) contain numerous references to drought

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on the island. Almost no pre-contact vegetation exists today in Antigua, but from early English accounts we can surmise that much of the island was covered in forest and scrubland, with the eastern portion of the island supporting deciduous vegetation and scrubs dominated by *Bursera* and other flowering shrubs and trees (Loveless 1960). This region is composed of Plio-Pleistocene coral limestone developed on an older volcanic base (Watts 1990, 12), yielding calcareous and kaolinitic clay soils with impeded drainage and near neutral pH (United Nations 2005, 10).

The present-day landscape is characterised by hills and ridges (100–300 feet asl) forming basins drained mostly by seasonal streams (Gonzalez-Scollard 2008, 7). The basin encompassing Betty's Hope, Elliot's Estate, and Potworks is bifurcated. It is drained by Mercer's Creek to the north (into Mercer's Creek Bay) and Ayer's Creek to the south (into Nonsuch Bay), both of which deposit waters into flooded or drowned river valleys (parallel rias) along the coast that have developed into open estuaries. The basin is approximately 22 km^2 and is divided roughly north/south by a low ridge that separates the northern portion of Betty's Hope into the Mercer's Creek drainage system and southern end of Betty's Hope into the Ayer's Creek drainage system along with Elliot's Estate and Potworks. The basin is composed of a series of overlapping and interfingering colluvial fans and alluvial terraces. Much of the land currently under cultivation is on broad, flat alluvial terraces (1.5–3.0 m high) with highly eroded terraces reserved for cattle grazing. The handful of extant higher and older terraces (3.0–5.5 m high) are topped with residential settlements associated with the communities of Pares in the northwest and Newfield in the southeast.

Research design and sampling

To begin to understand the kinds and magnitudes of impacts of plantation farming on soil health in the basin, we examined indices of landscape aggradation and degradation by identifying depositional sequences in the soil strata that alternated between periods of stability, erosion, and deposition. Stability is marked by deeply buried soils with strong horizonation, compared to dynamic periods characterised by rapidly accumulating sediments that lack the characteristic weathering horizons present in soils. In the Ayer's Creek drainage system, we were able to extract one sediment core from the estuary in Nonsuch Bay that provides us with an uninterrupted record of sedimentation over the past 500 years. Since the estuary in Mercer's Creek Bay has been disturbed by development in recent times, we focused our efforts in this drainage on studying two contiguous catenas adjacent to Betty's Hope. A catena is a sequence of soil types on a downhill slope; each soil type differs slightly from neighbouring soils, but all are formed in the same climate and on the same substrate. Combined, both datasets – from the mouth of one drainage system and the upper reaches of another – provide us with complementary perspectives on land degradation in eastern Antigua over the past five centuries.

Sediment core

One sediment core was extracted by Siegel, Dunning, Jason Fenton, and John Jones from the estuary in Nonsuch Bay (Ayer's Creek drainage) using locking piston and MWI piston coring equipment, which are modified versions of the more commonly used Livingstone-type drive rod piston corer (Wright 1967). The piston corer collected successive one-meter segments of sediments, 5 cm in diameter. Sediments were later extruded with an extruder piston in a field lab and sampled for sediment analyses, radiocarbon dating, and pollen and phytolith analysis [see Siegel et al. (2015) for a review of methods]. Physical description included colour (Munsell) and other visible attributes as well as finger tests for texture. Sampling for physical/chemical analysis was based on natural strata. Laboratory testing of subsamples was carried out under the direction of Dunning at the University of Cincinnati, the University of Minnesota-Duluth, and Spectrum Analytic agronomic laboratory (Washington Court House, Ohio). Organic matter (OM) and organic carbon (OC) were determined using loss-on-ignition (LOI) in which samples were first air dried at 105°C for 24 hours to determine dry weight and then heated to 550°C for one hour for OM and 1000°C for one hour for OC (Dean 1974). Samples were then ground and the Bouyoucos (1936) hydrometer method was used to determine particle size of remaining inorganic material. Elemental concentrations of P, Ca, Mg, Na, and S were extracted with Mehlich-3 and characterised with ICP-MS (Mehlich 1984). Results of the pollen (John Jones) and phytolith (Deborah Pearsall, Neil Duncan) analyses are being reported elsewhere (Jones et al., forthcoming). In this paper, we focus on ^{14}C-based temporal variability in P concentrations, soil OM and OC, soil texture, and sedimentation rates.

Soil catenas

A total of 96 bulk soil samples was collected by Wells and Fox at 20 different locations (referred to as 'probes') along two catenas to the immediate northwest of Betty's Hope, including within or near a modern farm and village, fallow agricultural fields, and historical occupation areas. The sampling strategy across a single transect allowed for the collection of soils along a toposequence from the top to the bottom of the hillslopes in order to assess disruption to erosional and depositional patterns. All samples were collected using a three-inch carbon steel bucket auger. The vertical length of each probe reflects the depth at which

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the auger could no longer penetrate the substrate, which was typically when we reached unconsolidated bedrock. Bulk samples of approximately 500 mg were removed with a clean trowel from each stratum, placed directly into sterilised Whirlpak bags for storage, and later transported to the University of South Florida for analysis by Pratt (2015). All soils were characterised for colour (Munsell) and described using standard USDA (2014) protocols. The gravitation method was used to measure soil texture and evaluate field descriptions. Samples were also examined for pH (electrode), Mehlich-3 extractable phosphates (molybdate colourimetry), OM and OC (LOI, as described previously), and trace element quantification of Ca, Mn, Fe, Zn, Sr, Cu, and Pb using pXRF (Bruker Tracer III-SD, 40 kV/11 µA for 120 sec., no vacuum), a technique for rapid chemical characterisation that does not require sample preparation such as digestion. These methods were selected because we are interested in long-term changes to plant-available nutrients (e.g. P) as well as the sedimentary makeup of local soils. We also chose these methods to be consistent with extant soil studies from this part of Antigua, which will allow us to compare our data with other research in the area. However, it is important to note that phosphate concentrations in our study may be underestimated, since it has been shown that Mehlich-extractable P decreases with increasing soil temperature and moisture (Song et al. 2012).

Results

Ayer's creek drainage

The Ayer's Creek drainage system is roughly 12.1 km^2 and encompasses the southern portion of Betty's Hope and all of Elliott's Estate and Potworks. The drainage system was historically uninterrupted until the 1960s when two dams were erected creating the Potworks and Collins reservoirs. Soils represent a mix of young Entisols and Inceptisols along with more established and fertile Rendolls. In addition, highly weathered and leached Ultisols have developed in the central part of the basin as well as shrink-swell Vertisols. One 4.56 m-long sediment core was extracted from standing pools of brackish water in an embayed estuary near Nonsuch Bay (approximately 1 km inland from the coast), which is surrounded by red and black mangrove along with other wetland taxa, including buttonwood and Acacia among others. Radiocarbon dating indicates that the entire core sequence dates to the past half millennium and thus records land use history (sedimentation rates) associated with plantation activity in the basin (Figure 2). The core can be divided into three basic levels: 'pre-colonial' (lower), 'colonial' (middle), and 'post-colonial' (upper) (Table 1).

'Pre-colonial' level

The lowest part of the sequence stretches from 456 to 371 cm and dates to cal. 295–600 BP or approximately AD 1350–1655. This period pre-dates most of the plantation activity on the island and so we might expect to find low levels of land degradation recorded in the core. Sediments in this level are composed mainly of sapric clays (muck) with bands of hemic peats (decayed OM). The OM is generally low (6.1–8.0%) but concentrates at 48.1% in the 409–387 cm level – the highest in the entire core sequence. Likewise, the highest Na concentrations are also documented for this level as well as a unique deposit of coarse sand and micro

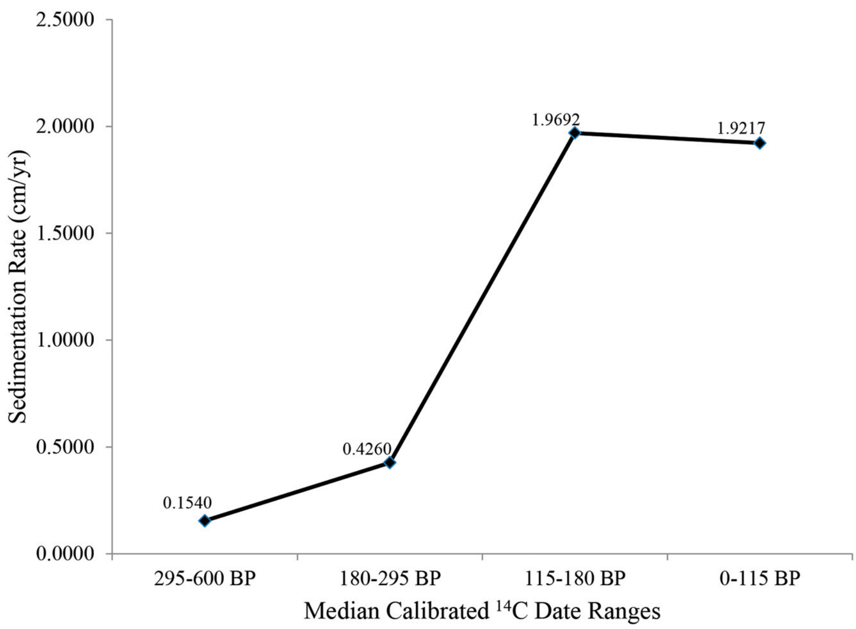

Figure 2. Sedimentation rates over time recorded in the sediment core from Nonsuch Bay.

Table 1. Nonsuch Bay core summary data.

Layer	Depth (cm)	Colour	P (ppm)	SOM%	Sand%	Silt%	Clay%	Notes
'Post-colonial' (ca. AD 1835–present), AMS date: cal. 1-σ 111 ± 32 BP at 221 cm	0–3	Black						Fibric OM (Mangrove)
	3–19	Gley 10Y 2.5/1	422	6.9	3	27	70	Some fibric OM
	19–27	Gley 10Y 5/1	397	4.2	2	19	79	Clay
	27–52	Gley 10Y 4/1	433	10.4	4	36	60	Hemic clay
	52–66	Gley 10Y 3/1	336	8.8	2	32	66	Hemic clay
	66–77	Gley 10Y 3/1	291	13.2	1	24	75	Hemic clay
	77–100	Gley 10Y 5/1	280	16.4	2	34	64	Hemic clay; one small snail; some fibric bands
	100–113							Hole slop
	113–117	Gley 10Y 5/1	246					Hemic clay
	117–122	Gley 10Y 6/1	279	11.8	7	33	60	Hemic clay; small snails
	122–124	Gley 10Y R3/1		35.3				Thinly bands of peat
	124–133	Gley 10Y 4/1	254	12.5	4	27	69	Hemic clay
	133–171	Gley 10Y 5/1	187	17	3	34	63	Hemic clay with thin fibric bands
	171–181							Hole slop
	182–186	Gley 10Y 4/1	243	4.5	4	16	80	Numerous small snail shells
	186–193	Gley 10Y 4/1	220	11.7	8	21	71	Hemic clay
	193–222	Gley 10Y 5/1	235	5.8	3	27	70	Sapric clay; wood at 220 cm
'Late colonial' (ca. AD 1770–1835), AMS date: cal. 1-σ 191 ± 38 BP at 349 cm	222–226	Gley 10Y 5/1	272	5.1	9	30	61	Sapric clay
	226–231	Gley 10Y 6/1	283	4.6	3	28	69	Sapric clay
	231–249	Gley 10Y 5/1	254	6.9	0	33	67	Sapric clay with darker bands
	249–261	Gley 10Y 5/1						Sapric clay with dark bands
	261–262	Gley N 3/N						Sapric clay
	262–274	Gley 5Y 4/2	173	6.6	1	15	84	Clay
	274–281							Hole slop
	281–295	Gley 10Y 4/1	201		2	26	72	Sapric clay
	295–299	Gley 10GY 4/1	186	5.2	1	18	81	Clay
	299–308	Gley 10Y 5/1	144	6.3	4	27	69	Sapric clay
	308–312	Gley 10GY 4/1		4.6	10	13	77	Banded clay; ash /sand lens at 311 cm
	312–326	Gley 10Y 5/1	138	6.7	3	24	73	Sapric clay; a few lighter bands
	326–330	Gley 10Y 6/1		5.4	4	25	71	Sapric clay
	330–331	Gley 5GY 5/1	113					Sapric clay
	331–333	Gley 10Y 5/1-4/1						Tightly banded sapric clay; thin ash lens at top
	333–335	Gley 5GY 5/1	77	4.9	2	18	80	Clay
	335–340	Gley 10Y 5/1	118	6.6	1	27	72	Sapric clay
	340–348	Gley 10Y 4/1	125	7	2	29	69	Sapric clay
	348–351	Gley 5GY 6/1			38	9	52	Irregular band of volcanic ash
'Early colonial' (ca. AD 1655–1770), AMS date: cal. 1-σ 254 ± 36 BP at 398 cm	351–358	Gley 5GY 5/1	89	4.4	3	30	77	Clay
	358–360	Gley 10Y 5/1	101		2	33	75	Clay
	360–362	Gley 10GY 5/1			33	8	59	Irregular band of fine volcanic ash
	362–367	Gley 10Y 5/1	128	5	7	25	68	Sapric clay
	367–371				44	30	26	Fibric band atop coarse sand with micro snail shells
	371–374							Hole slop
	374–382	Gley 10Y 5/1	140	8.8	6	27	77	Sapric clay; Irregular bands
	382–387	Gley 10Y 6/1	135	6.1	46	11	43	Coarse sand and micro shells
	387–409	Gley 10Y 2.5/1	142	48.1				Banded hemic peats
'Pre-colonial' (ca. AD 1350–1655), AMS date: cal. 1-σ 577 ± 37 BP at 445 cm	409–456	Gley 10Y 3/1	164	7	3	26	71	Sapric clay with thin peat bands

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shells (387–382 cm) consistent with the presence of a shoreline. Together, these markers suggest that the marine shoreline was possibly farther inland than its current location and that storm surge, such as from a hurricane, likely resulted in this unique sand and shell-enriched sedimentation event. Overall, the sedimentation rate for this zone is a meagre 0.1540 cm yr^{-1}.

'Colonial' level

The middle part of the sequence, from 370 to 231 cm, records evidence for major landscape changes in the basin from ca. 1655 to 1835 (Figure 3). Sediments from this level are dominated by alternating layers of organic peats and clays (with fine banding) indicating periods of landscape stability and layers of inorganic sands and sediments (with little to no stratification) marking periods of landscape instability. The sedimentation rate documented for this level ranges from 0.4260 cm yr^{-1} at the beginning of the period to 1.9692 cm yr^{-1} at the end, a 460% increase over time. Notably, this level also contains deposits of fine volcanic ash interlayered with microscopic volcanic glass that likely relate to the eruption of La Grande Soufrière on the island of Guadeloupe. The large lenses at 351–348 cm and 362–360 cm may correspond to the eruption in 1797–1798, while the smaller lenses at 308–312 cm and 333–331 cm may record the eruptions in 1836–1837, or eruptions at an unknown source.

'Post-colonial' level

The uppermost zone (230–0 cm) dates to the period after Emancipation, ca. 1835 to present. Few interruptions in the stratigraphic record are observable, suggesting a continuous deposition of sediments until

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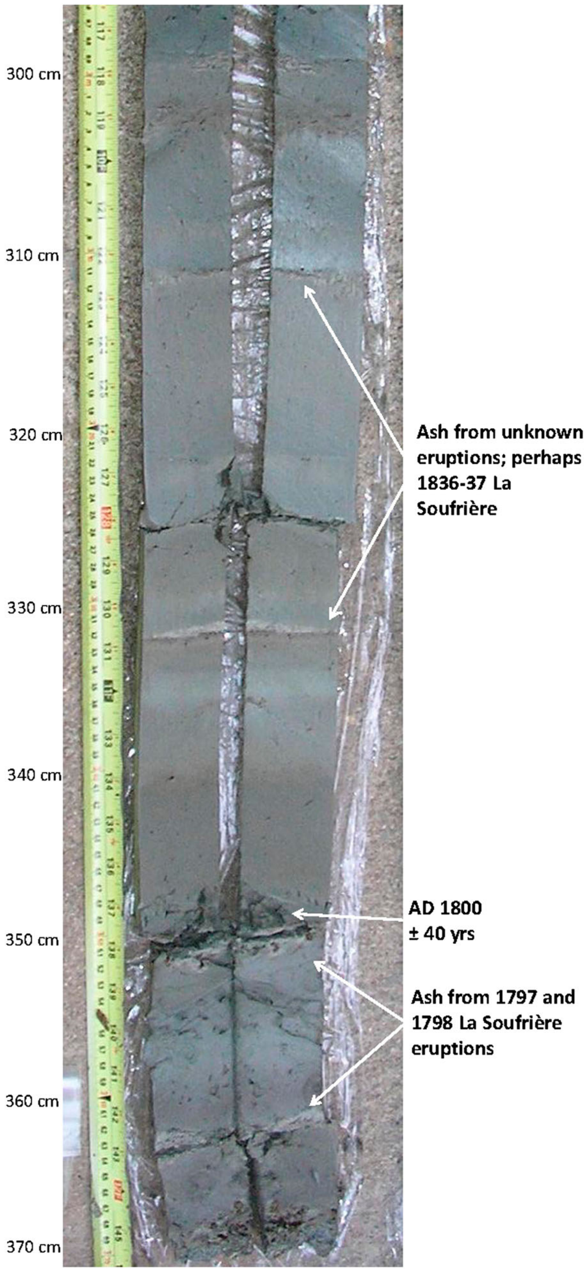

Figure 3. Nonsuch Bay core segment from 330 to 370 cm showing a zone of accelerating sedimentation during the end of the eighteenth and first half of the nineteenth century.

recent times. Phosphate concentrations begin to increase significantly, from an average of 254 ppm (230–66 cm) to 397 ppm (66–19 cm), probably marking the introduction of commercial fertilisers in the early part of the twentieth century. The sedimentation rate in this level continued at an advanced pace of 1.9217 cm yr^{-1}.

Mercer's creek drainage

The Mercer's Creek drainage system is roughly 10.3 km^2 in area and extends to the southwest of Betty's Hope, passes along the base of the hill on which the former Great House was located, and extends to Mercer's Creek Bay to the northeast. We selected two adjacent catenas running perpendicular to the stream channel (Figure 4). The first, Pares catena, extends from the uplands above the community of Pares, downslope at a gradient of 16° through a series of fallow and active agricultural fields, across a small drainage and into the town located on a T3 terrace remnant, down the adjacent T2 terrace at a gradient of 11° to the active stream [alluvial terrace nomenclature is based on Waters (1992, 150)]. The second catena, Betty's Hope catena, begins on the T3 terrace underlying the Great House complex at Betty's Hope and cascades downslope at a gradient of 6° across a narrow T2 terrace tread to the thalwag of the stream channel. We selected these two adjacent catenas because they crosscut different landscape patch types and many contemporary and historical features including agricultural fields associated with the plantation in historical times. The creek drainage system begins about 1 km southwest of the Great House complex at the base of a slight ridge separating Betty's Hope from Elliot's Estate. Soils within the watershed represent a mix of calcareous soils, from Entisols and Inceptisols on the more sloped areas to Rendolls on the flatter T2 terraces.

Pares catena

The Pares catena consists of 14 probes located along the sampling transect (Table 2). The profile exposed by probes 8–12 from summit (12) down the shoulder (8–11) represents a typical sequence of hillslope sedimentation and colluvium cover, where subsurface horizonation increases down the slope and where lower portions of the slope have received sediments from higher elevations. The OM and phosphates tend to concentrate in upper horizons while carbonates and heavy metals, especially Fe, increase slightly down the soil profile (indicating leaching). Probes 9 and 10 were sampled from fallow fields that have historically been under cultivation. Accordingly, the upper horizons of these probes have slightly lower pH and there is a gradual transition from A (2.5Y 2.5/1) to B (2.5Y 3/2). Probe 9, in particular, exhibits deep A (20 cm) and Bt (60 cm) horizons that transition to a Btk layer, indicating an argillic subsurface horizon that one might expect from a cultivated field. Finally, probe 8 was recovered from an active agricultural field where a variety of crops were under cultivation, including corn, papaya, and peppers. While the soil is relatively thin compared to adjacent plots, the Ap-Bt1-Bt2-Cr1-Cr2-Cr3-Cr4-Cr5-C sequence exhibited by this probe is complex, with alternating layers of high and low pH, P, Fe, OM, and carbonates. Generally, all indications point to a relatively stable soil body with little evidence for erosion other than what might be expected due to slope.

The backslope of the Pares catena represented by probes 13–15 show evidence for degradation and

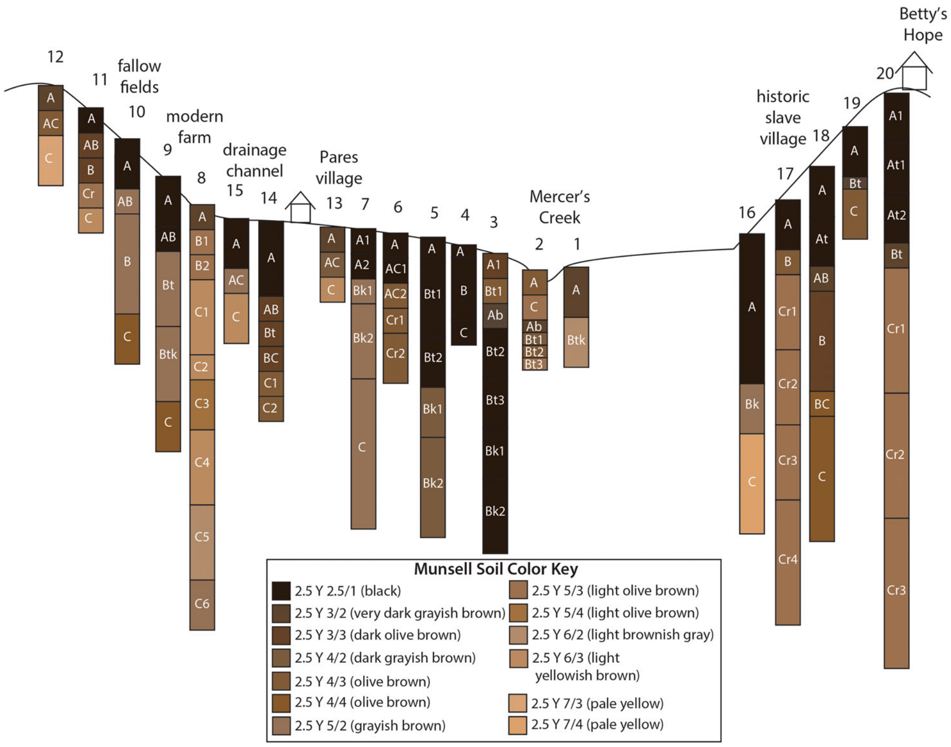

Figure 4. Toposequence and corresponding soil profiles of the Pares and Betty's Hope catenas.

episodic erosion. Probe 15 was sampled from near a shallow drainage channel and, as a result, has a thin profile with higher concentrations of heavy metals (Fe and Mn) from particles suspended in the water channel that likely derive from the shoulder slopes. Notably, the B horizon is absent and there is a gradual transition from A (sandy clay loam, 2.5Y 2.5/1) to C (sandy loam, 2.5Y 7/3), again pointing to the dynamic nature of this part of the hill. In contrast, probe 14 shows an over-thickened Mollisol with high OM (5.1%) and phosphate (137.5 mg kg^{-1}) along with a deep A-AB-Bt-BC-C1-C2 sequence indicating a more stable landform. Finally, probe 13 represents the crest of a section of the T3 terrace near the residential community of Pares. The landform in this area is highly eroded with very thin, sandy (60%) soils and unconsolidated sediments. The OM ranges from 1.6 to 2.1% and carbonates are high at 24.7–38.9%.

Probes 5–7 were sampled from the footslope, the concave surface at the base of the hill that represents a transition from upslopes of erosion and downslopes of deposition. This area appears to contain a high degree of slope alluvium. Probe 7 reaches a depth of 120 cm and has gradual transitions between horizons. Similar to probe 8, the profile is complex, with alternating increases and decreases in pH, phosphate, and heavy metals. Clays and OM tend to concentrate in the upper horizons. Probe 6 exhibits a dynamic record of erosion where the A horizon can be characterised as an Entisol (sand is 73.3%) with a sharp transition to the underlying unconsolidated bedrock. Probe 5, located on the T2 terrace approximately 50 m to the east, has deeply buried soils; the probe did not reach the end of the B horizon at 120 cm below ground surface. This terrace is composed of relatively thick horizons undifferentiated by texture in the upper layers, suggesting the possibility of a major depositional event associated with the nearby Mercer's Creek. Horizon B2 in this sequence could represent a buried Ab horizon given its consistency and darker hues.

The toeslope of this catena sequence was examined with probes 3 and 4. Probe 4 is highly eroded with somewhat thin upper horizons. There is almost no OM (0.2%), although phosphates are generally higher on the surface (122 mg kg^{-1}). Probe 3 shows the clearest evidence of a dynamic landscape on this terrace. We discovered a buried Ab horizon at roughly 25 cm below ground surface (Figure 5). The horizon is thin (5 cm thick), but is distinguished from adjacent horizons by its dark black colour (2.5Y 2.5/1) and sharp changes in OM and phosphate. The rest of the sequence in this profile, which extends down 130 cm, suggests a stable landform as indicated by gradual transitions between layers, slowly decreasing OM and phosphate. Finally, probe 2 sampled the creek bed/fluvial terrace and exhibits a sequence of fine layers of clay (Bt1-Bt2-Bt3) underlying a buried Ab horizon, which is capped by eroded sediments (A-C) from a higher elevation.

Betty's Hope catena

The Betty's Hope catena consists of six probes along the sampling transect (Table 3). Probe 20 was taken from the hill summit in the environs of the Great

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Figure 5. Excavated Pares catena sediment profile from Probe 2 showing evidence for a buried Ab horizon at 25–30 cm below ground surface.

House complex. As indicated by the probe, this is a deeply weathered T3 terrace with a thick, stable A/At horizon that extends approximately 65 cm below ground surface and is rich in clay (26.7–33.3%) and anthropogenic phosphate (137.5 mg kg^{-1}). There is some horizonation in this layer, however, suggesting that the soils are anthrosols and have been highly disturbed by plantation and other, more recent, activities. The underlying Bt horizon (2.5Y 3/3) is very thin (5 cm) and marked by a sharp contrast with the unconsolidated limestone, which extends down to 230 cm below ground surface to the regolith.

Probe 19 represents the shoulder of the hill and shows evidence for a high degree of erosion. The A horizon extends 20 cm to a shallow 5 cm Bt horizon, which transitions sharply to C, extending 45 cm below ground surface to the regolith. Given the slope (approximately 25% in this area), a relatively high degree of erosion might be expected.

Probes 17–18 fall within the backslope of the hill and were sampled from the environs of the historical village of enslaved Africans on the plantation. Probe 18, in particular, shows a long and complex sequence of alternating stable and dynamic episodes with deep A/At and B horizons separated alternatively by sharp and gradual transitions. Phosphate concentrations are high at 137.5 mg kg^{-1}, as in the area of the Great House complex on the summit. Soils in the upper layers are largely sandy loams with high carbonate content (10.4%). Probe 17 shows a similar pattern but with a shorter A–B sequence and a long sequence of Cr (2.5Y 6/2) strata. Here, human occupation is indicated by high OM and pH increasing down the sequence from areas of the profile where we encountered cultural materials. There is also a notable change in soil texture, moving from very sandy to very clayey soils down the profile. The upper layers (25 cm thick) appear to contain eroded sediments from upslope that may have been deposited in more recent times, as the sediments cover the presumed historical occupation surface.

Probe 16 represents the footslope and has perhaps the highest levels of deposited sediment from upper elevations. The A horizon, representing somewhat recent deposition, measures roughly 60 cm in thickness. This layer covers a Bk horizon in which we recovered historical materials from Betty's Hope that had been washed downslope in previous erosional processes. The probe was taken from an active agricultural field, in which the enriched A horizon (2.5Y 3/3) is being used to cultivate corn and soy. The gradual transitions between the horizons suggest that this part of the T2 terrace has been stable for a long period. Finally, probe 1 was sampled from the toeslope at the edge of the T2 terrace near the creek bed. As with probe 16, this part of the terrace exhibits a very stable profile, with a deep A horizon and gradual transition to Btk. These alluvial sediments are overall lower in heavy metals and OM (0.7%), and are largely composed of clays (53.3%). The clays are so dense in this part of the terrace that the C horizon could not be located past 40 cm below ground surface. Here, similar to probe 2 of the Pares catena across the modern stream channel, aggradation is most likely the direct result of human activities.

Discussion

The sediment core from Nonsuch Bay yielded a detailed record of landscape change in eastern Antigua over the past half millennium, with sediments at the bottom of the core dating to the period immediately prior to the development of large-scale plantations. As such, the core allows us to reconstruct environmental shifts from before, during, and after colonial plantation life. The sedimentation rate of the largely pre-colonial period level of the core, from 445 to 398 cm, was relatively low, suggesting that the upper reaches of the Ayer's Creek drainage had sufficient vegetative cover to prevent significant or sustained erosion of soils. Between ca. AD 1655 and 1835, the period documented in the core that corresponds to the establishment and height of plantation farming in this part of Antigua, the sedimentation rate increased dramatically. Since then, topsoil loss is documented at approximately 2.0 cm yr^{-1}. At the current rate, today's farmers will experience continuing declines in soil productivity and, in some areas where soils are especially thin (e.g. Entisols and Inceptisols on T2 and T3 terraces), farmers might expect to see complete loss of arable land by 2050.

The sedimentary record from the Pares and Betty's Hope catenas provides a complementary record to the Nonsuch Bay sediment core. The Pares catena

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Table 2. Pares catena summary data.

Probe	Horizon	Depth (cm)	Colour	Fe (ppm)	Sr (ppm)	Mn (ppm)	P (ppm)	pH	OC%	SOM%	Sand%	Silt%	Clay%	Texture
BHAP2	A	0–15	2.5Y 4/3	26258.7	316.0	247.0	101.0	7.3	14.8	2.5	66.7	13.3	20.0	Sandy clay loam
	C	15–25	2.5Y 5/3	24692.0	296.0	246.5	87.0	8.0	15.2	0.9	66.7	13.3	20.0	Sandy clay loam
	Ab	25–30	2.5Y 3/2	30482.8	255.0	381.6	100.0	8.0	8.5	1.1	66.7	13.3	20.0	Sandy clay loam
	Bt1	30–35	2.5Y 4/2	30482.8	264.5	97.9	101.5	8.0	8.4	0.2	53.3	26.7	20.0	Sandy loam
	Bt2	35–40	2.5Y 4/3	31209.4	469.0	50.2	112.0	7.9	8.6	0.7	53.3	13.3	33.3	Sandy clay loam
	Bt3	40–45	2.5Y 5/3	29020.1	452.5	50.2	122.0	8.0	8.6	0.7	66.7	13.3	20.0	Sandy clay loam
BHAP3	A	0–15	2.5Y 3/3	23998.8	249.9	314.5	100.5	7.8	12.8	3.0	66.7	20.0	13.3	Sandy loam
	Bt1	15–25	2.5Y 4/3	26789.0	300.2	128.0	114.0	7.8	14.0	1.1	66.7	20.0	13.3	Sandy loam
	Ab	25–35	2.5Y 3/1	26256.1	253.4	631.5	94.5	7.9	8.0	1.8	46.7	13.3	40.0	Sandy clay
	Bt2	35–55	2.5Y 2.5/1	25262.4	251.6	635.5	103.0	7.8	8.4	0.9	40.0	6.7	53.3	Clay
	Bt3	55–75	2.5Y 2.5/1	26335.8	305.2	841.5	116.0	7.9	8.5	0.2	33.3	6.7	60.0	Clay
	Bk1	75–95	10YR 2/1	26958.5	243.9	1858.5	89.0	7.8	9.5	1.0	40.0	6.7	53.3	Clay
	Bk2	95–120	10YR 2/1	24862.5	260.1	1036.0	91.5	7.8	8.5	0.5	53.3	13.3	33.3	Sandy clay loam
BHAP4	A	0–10	2.5Y 2.5/1	29080.5	218.1	701.0	122.0	8.0	7.7	0.2	26.7	20.0	53.3	Sandy clay loam
	B	10–35	2.5Y 2.5/1	27211.9	212.8	410.5	89.0	8.0	7.7	0.2	26.7	20.0	53.3	Sandy clay loam
	C	35–40	2.5Y 2.5/1	28196.2	281.4	137.0	95.0	8.0	8.3	0.5	46.7	26.7	26.7	Loam
BHAP5	A	0–15	2.5Y 2.5/1	30575.0	141.6	1113.5	109.0	7.9	7.8	3.8	53.3	40.0	6.7	Sandy loam
	Bt1	15–45	10YR 2/1	29229.8	155.4	1129.5	105.0	7.8	7.7	2.8	66.7	6.7	26.7	Sandy clay loam
	Bt2	45–65	10YR 2/1	31069.5	119.1	271.0	95.5	7.9	8.1	1.2	6.7	6.7	86.7	Clay
	Bk1	65–85	2.5Y 4/2	31600.6	152.1	1132.0	118.0	7.9	6.4	1.4	13.3	33.3	53.3	Clay
	Bk2	85–120	2.5Y 4/2	28892.5	134.6	939.5	108.0	7.8	9.2	1.9	20.0	20.0	60.0	Clay
BHAP6	A	0–15	10YR 2/1	32230.1	91.7	1360.5	130.5	7.5	9.5	5.6	73.3	20.0	6.7	Sandy loam
	AC1	15–25	2.5Y 2.5/1	32140.8	109.7	1181.5	93.0	7.6	12.6	3.3	60.0	26.7	13.3	Sandy loam
	AC2	25–35	2.5Y 4/3	17535.1	130.2	589.5	101.5	7.6	30.5	1.5	60.0	20.0	20.0	Sandy clay loam
	Cr1	35–45	2.5Y 4/3	15051.7	172.3	791.0	100.0	7.7	31.0	0.9	73.3	13.3	13.3	Sandy loam
	Cr2	45–60	2.5Y 4/3	18578.1	160.4	925.5	111.0	7.9	31.4	1.3	73.3	13.3	13.3	Sandy loam
BHAP7	A1	0–15	2.5Y 2.5/1	30654.7	177.7	822.0	88.5	7.8	13.0	4.2	13.3	13.3	73.3	Clay
	A2	15–25	2.5Y 2.5/1	31266.7	155.3	1626.0	89.0	8.0	12.3	2.5	20.0	6.7	73.3	Clay
	Bk1	25–35	2.5Y 5/2	30945.1	141.1	1918.0	100.5	7.8	13.3	2.3	33.3	6.7	60.0	Clay
	Bk2	35–65	2.5Y 5/2	27212.0	117.6	1403.0	83.5	8.0	13.6	0.0	40.0	6.7	53.3	Clay
	C	65–120	2.5Y 5/2	28857.3	99.2	138.0	107.5	8.1	12.6	0.0	46.7	20.0	33.3	Sandy clay
BHAP8	Ap	0–15	2.5Y 3/2	25535.4	161.8	665.0	111.5	8.1	11.0	1.1	66.7	6.7	26.7	Sandy clay loam
	Bt1	15–25	2.5Y 5/3	18570.2	233.8	390.0	109.0	8.0	16.7	0.9	60.0	13.3	26.7	Sandy clay loam
	Bt2	25–35	2.5Y 5/3	17134.3	189.3	327.0	118.5	7.9	18.3	0.7	40.0	13.3	46.7	Clay
	Cr1	35–65	2.5Y 6/3	9373.7	140.8	185.5	87.5	7.9	29.1	1.0	33.3	13.3	53.3	Clay
	Cr2	65–75	2.5Y 6/3	13981.1	241.8	597.5	92.5	7.8	20.7	0.2	53.3	20.0	26.7	Sandy clay loam
	Cr3	75–95	2.5Y 5/4	18884.2	241.8	597.5	110.5	7.8	13.2	0.0	53.3	6.7	40.0	Sandy clay
	Cr4	95–125	2.5Y 6/3	13837.3	256.4	630.0	105.5	7.9	21.2	0.7	40.0	13.3	46.7	Clay
	Cr5	125–155	2.5Y 6/2	15314.8	142.4	484.0	96.0	7.8	22.2	1.2	40.0	13.3	46.7	Clay
	C	155–170	2.5Y 5/2	17037.6	144.2	591.5	100.0	7.9	14.5	0.7	40.0	13.3	46.7	Clay
BHAP9	A	0–25	2.5Y 2.5/1	29424.9	97.1	637.0	118.0	7.8	12.4	3.5	20.0	7.0	73.0	Clay
	AB	25–35	2.5Y 2.5/1	27939.9	79.1	1035.5	123.5	7.6	11.7	0.9	20.0	6.7	73.0	Clay
	Bt	35–60	2.5Y 5/2	27885.5	73.6	490.5	90.0	7.9	11.4	0.7	20.0	6.7	73.3	Clay
	Btk	60–95	2.5Y 5/2	30691.0	62.5	568.5	90.0	7.9	11.4	0.7	20.0	6.7	73.3	Clay
	C	95–110	2.5Y 4/4	26201.3	197.9	2684.0	95.5	7.7	12.1	0.9	33.3	13.3	53.3	Clay
BHAP10	A	0–25	2.5Y 2.5/1	28812.0	105.5	624.0	125.5	7.7	11.9	2.4	13.3	6.7	80.0	Clay
	AB	25–35	2.5Y 5/2	25921.0	110.0	187.5	99.0	7.9	12.9	0.7	13.3	13.3	73.3	Clay
	B	35–70	2.5Y 5/2	27961.0	110.0	143.5	98.5	7.9	14.2	0.2	73.3	13.3	13.3	Sandy loam
	C	70–90	2.5Y 4/4	33895.0	232.0	114.5	107.5	7.9	11.6	0.0	40.0	13.3	46.7	Clay
BHAP11	A	0–15	2.5Y 2.5/1	31684.4	61.1	513.5	106.0	7.9	13.5	1.2	66.7	6.7	26.7	Sandy loam
	AB	15–25	2.5Y 3/3	28648.1	59.0	133.5	75.5	7.9	9.8	1.5	66.7	20.0	13.3	Sandy loam
	B	25–35	2.5Y 3/3	33296.5	121.6	1045.3	81.5	7.8	13.5	1.2	73.3	6.7	20.0	Sandy loam
	Cr	35–45	2.5Y 5/3	17352.6	175.1	1045.3	91.5	7.8	19.6	11.1	66.7	6.7	26.7	Sandy clay loam
	C	45–50	2.5Y 6/3	11611.1	193.1	389.0	91.0	7.9	9.7	22.0	60.0	20.0	20.0	Sandy clay loam
BHAP12	A	0–15	2.5Y 3/2	17895.9	110.4	310.0	108.5	7.8	17.0	15.1	53.3	13.3	33.3	Sandy clay loam
	AC	15–25	2.5Y 4/3	16512.4	170.2	208.5	77.5	7.8	32.9	1.2	66.7	13.3	20.0	Sandy clay loam
	C	25–40	2.5Y 7/3	11369.8	129.0	108.5	80.0	7.8	38.8	0.7	40.0	26.7	33.3	Clay loam
BHAP13	A	0–15	2.5Y 3/2	19352.9	104.6	601.0	90.0	7.4	24.7	2.1	60.0	13.3	26.7	Sandy clay loam
	AC	15–25	2.5Y 4/2	12308.1	93.3	297.0	100.0	7.6	30.7	1.9	66.7	6.7	26.7	Sandy clay loam
	C	25–30	2.5Y 6/3	7187.9	94.4	129.5	102.0	7.6	38.9	1.6	66.7	13.3	20.0	Sandy clay loam
BHAP14	A	0–35	2.5Y 2.5/1	29425.1	81.1	724.5	137.5	7.7	16.7	5.0	73.3	13.3	13.3	Sandy loam
	AB	35–45	2.5Y 3/3	32391.4	50.0	546.0	96.0	8.0	13.3	0.3	66.7	13.3	20.0	Sandy clay loam
	Bt	45–55	2.5Y 3/3	33991.6	58.3	789.5	83.5	7.9	8.2	1.9	60.0	13.3	26.7	Sandy clay loam
	BC	55–65	2.5Y 3/3	33534.0	126.0	361.0	85.5	7.9	16.9	1.4	80.0	13.3	6.7	Loamy sand
	C1	65–75	2.5Y 4/3	29790.5	147.1	412.5	74.5	7.9	23.0	1.5	53.3	20.0	26.7	Sandy clay loam
	C2	75–80	2.5Y 4/3	25989.9	140.4	287.5	70.0	8.0	24.3	1.3	60.0	13.3	26.7	Sandy clay loam
BHAP15	A	0–25	2.5Y 2.5/1	29484.3	79.6	800.0	66.5	7.8	16.5	2.4	60.0	6.7	33.3	Sandy clay loam
	AC	25–35	2.5Y 5/2	13733.9	65.3	295.5	105.5	7.8	26.7	2.4	53.3	13.3	33.3	Sandy clay
	C	35–50	2.5Y 6/3	8190.4	88.0	262.0	110.5	7.8	34.4	1.1	66.7	20.0	13.3	Sandy loam

shows evidence of land degradation in the form of downslope erosion, while the Betty's Hope catena exhibits mostly features of landscape stability surrounding the plantation settlement. The differences between these two catenas is likely a function of land use – the Pares catena crosscuts T1, T2, and T3 alluvial terraces and hillslopes where sugarcane was actively farmed, while the Betty's Hope catena intersects more

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Table 3. Betty's Hope catena summary data.

Probe	Horizon	Depth (cm)	Colour	Fe (ppm)	Sr (ppm)	Mn (ppm)	P (ppm)	pH	OC%	SOM%	Sand%	Silt%	Clay%	Texture
BHAP1	A	0–25	2.5Y 3/2	24057.0	323.0	718.5	120.0	7.2	8.5	0.7	26.7	20.0	53.3	Clay
	Btk	25–40	2.5Y 6/2	25897.0	385.5	1494.3	84.0	7.6	15.8	3.4	40.0	26.7	33.3	Clay
BHAP16	A	0–65	2.5Y 2.5/1	21124.3	215.3	657.0	108.5	8.1	13.9	0.9	13.3	26.7	60.0	Clay
	Bk	65–85	2.5Y 5/2	18870.5	147.3	380.5	86.0	8.3	17.0	0.5	66.7	13.3	20.0	Sandy clay loam
	C	85–120	2.5Y 7/4	16806.5	115.8	461.5	71.0	8.2	23.6	0.7	53.3	20.0	26.7	Sandy clay loam
BHAP17	A	0–25	2.5Y 2.5/1	22627.9	296.6	456.0	104.0	8.0	6.9	0.9	66.7	26.7	6.7	Sandy loam
	B	25–35	2.5Y 4/3	25586.5	218.2	285.0	122.0	8.3	5.7	0.9	46.7	20.0	33.3	Sandy clay loam
	Cr1	35–60	2.5Y 5/3	24917.7	216.2	580.5	106.5	8.0	6.1	24.4	66.7	13.3	20.0	Sandy clay loam
	Cr2	60–95	2.5Y 5/3	24185.3	224.5	580.0	107.5	8.0	6.0	0.7	13.3	26.7	60.0	Clay
	Cr3	95–125	2.5Y 5/3	24492.4	213.0	225.5	98.5	8.0	6.5	0.5	13.3	20.0	66.7	Clay
	Cr4	125–170	2.5Y 5/3	23629.1	215.0	959.0	96.5	8.1	4.9	1.2	13.3	6.7	80.0	Clay
BHAP18	A	0–25	2.5Y 2.5/1	22015.6	260.6	628.5	137.5	7.7	10.4	3.7	73.3	13.3	13.3	Sandy loam
	At	25–45	2.5Y 2.5/1	21273.0	279.1	672.0	137.5	7.8	8.8	2.0	66.7	13.3	20.0	Sandy clay loam
	AB	45–55	2.5Y 3/2	21926.9	285.3	550.0	114.0	7.9	7.3	0.0	53.3	20.0	26.7	Sandy clay loam
	B	55–95	2.5Y 3/3	22417.2	269.0	208.5	94.5	8.2	6.0	0.0	60.0	20.0	20.0	Sandy clay loam
	BC	95–105	2.5Y 4/4	23452.2	291.5	642.0	94.5	8.0	5.1	1.4	66.7	20.0	13.3	Sandy loam
	C	105–150	2.5Y 4/4	20815.5	337.0	397.0	88.0	8.0	4.6	1.6	40.0	20.0	40.0	Clay
BHAP19	A	0–25	2.5Y 2.5/1	21766.5	275.8	592.5	137.5	7.8	12.7	3.4	60.0	13.3	26.7	Sandy clay loam
	Bt	25–30	2.5Y 3/1	23936.5	226.1	490.0	137.5	7.8	10.6	1.2	66.7	6.7	26.7	Sandy clay loam
	C	30–45	2.5Y 4/3	26732.3	396.3	317.5	108.5	7.9	9.4	1.2	33.3	60.0	6.7	Silt loam
BHAP20	A	0–30	2.5Y 2.5/1	20048.3	280.9	474.0	137.5	7.8	16.0	5.1	66.7	20.0	13.3	Sandy loam
	At1	30–50	2.5Y 2.5/1	20408.4	271.7	575.0	137.5	7.8	11.3	1.4	53.3	20.0	26.7	Loam
	At2	50–70	2.5Y 2.5/1	19860.6	323.8	683.5	137.5	8.0	7.5	0.5	53.3	13.3	33.3	Clay loam
	Bt	70–80	2.5Y 3/2	20264.3	223.5	364.5	103.5	8.1	4.7	3.8	60.0	13.3	26.7	Sandy clay loam
	Cr1	80–130	2.5Y 5/3	21063.9	245.4	47.0	103.5	8.2	4.7	3.8	53.3	20.0	26.7	Clay loam
	Cr2	130–180	2.5Y 5/3	24251.3	202.9	16.0	135.0	8.1	6.8	1.7	60.0	6.7	33.3	Clay
	Cr3	180–230	2.5Y 5/3	22795.0	243.5	240.5	104.0	8.0	6.7	1.7	60.0	6.7	33.3	Sandy clay loam

gently sloping terrain where activities took place associated with the operations of the Great House and auxiliary buildings including the windmills and rum distillery. As a result, we see a complex picture of impacts. The profiles at the summit of the Pares catena have thin A horizons, but the A horizons thicken on lower slopes, suggesting that sediment has consistently eroded from the upper to lower elevations. The material accumulated at the foot of the hillslope indicates locations of buried land surfaces and stratigraphic records of human activity where erosion has been active. Soil profiles at the foot of the catena (especially probes 7, 6, 5, and 4) have thicker A horizons which overlie Cr sediments on top of older A horizons, representing episodes of presumably recent (post-1970s) sediment accumulation on the lower portions of the catena. These erosional events are most likely associated with the cessation of farming and the subsequent conversion of land use to livestock grazing and residential settlement. Similarly, the profiles from probes 4, 5, 6, 7, 10, and 11 exhibit declines of phosphate in the B horizons and concentrations in the C horizons, which suggest a steady depletion of phosphate in the past. These findings are consistent with the idea that the declining sugar production observed on Antigua after 1753 was caused by a decline of soil fertility due to long-term monoculture.

Conclusions

Our findings indicate that landscape degradation by soil erosion is highly correlated with the introduction of plantation agriculture in this part of Antigua. We also conclude that the abandonment of the built environment of sugarcane farming is associated with more recent episodes of soil erosion. As such, current land degradation experienced by today's farmers cannot be attributed to intensive plantation agriculture alone, but rather must be seen as the result of a complex mosaic of human-environmental interactions that included long-term monocropping followed by abandonment of engineered landscapes. This finding supports those of similar studies of the intersection of plantation farming and environmental change elsewhere in the Caribbean (e.g. Dillman 2015). On Nevis, for instance, Meniketti (2016) found convincing evidence for major environmental transformations associated with the development of the British agro-industrial complex. In contrast, on the neighbouring island of Barbuda, which did not support large-scale plantations such as those found on Antigua and other Caribbean islands, Boger et al. (2014, 2016) found evidence for sustainable land use and tenure strategies including small-scale agriculture and livestock herding that did not degrade local soils. More broadly, our research contributes to emerging historical-ecological perspectives that seek to understand the social/economic, engineered, and environmental factors that create 'landscape legacies' (Crumley and Marquardt 1990; Fisher and Thurston 1999; Håkansson and Widgren 2014; Lewis et al. 2006; Morrison 2014; Wells 2006; Wells, Davis-Salazar, and Kuehn 2013). By identifying the initial and cumulative impacts of sugarcane monoculture on soilscape degradation in Antigua, this research helps inform future land use policies and decision making here and potentially in other former sugar islands in the Caribbean that experienced similar processes.

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