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Sustainability and Resilience in Prehistoric North Atlantic Britain: The Importance of a Mixed Paleoeconomic System

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Abstract - The two archipelagos of Orkney and Shetland, which form the Northern Isles of Britain, are an active focus of archaeological research. The rich Neolithic heritage of Orkney has been acknowledged by the granting of World Heritage status. Although set in both a biogeographically peripheral position and within what may be considered to be marginal landscapes, these North Atlantic islands have a large number of settlement sites with long occupational sequences, often stretching from the Neolithic to the Late Iron Age or into the Norse period. The mixed paleoeconomic strategy presented by three of these settlements—Tofts Ness, Sanday, Orkney (excavated 1985–1988); the Iron Age sequences at Old Scatness, Shetland (excavated 1995–2006); and Late Neolithic and Bronze Age cultivated middens from Jarlshof, Shetland (investigated in 2004)—provide the core of the evidence discussed within this paper (the radiocarbon chronologies for the key sequences from these three sites are provided as Appendix 1). The role of the prehistoric paleoeconomy is argued to be of central importance in the longevity of these settlements. In particular, barley production is evidenced on all three sites by the plant macrofossils and by the human investment in the creation and management of manured soils, providing an infield area around the settlement.

This paper focuses on the identification of these anthropogenic soils in the archaeological record. The investment in and management of these arable soils provides clear evidence for resource creation on all three sites. It is argued that these soils were a crucial resource that was necessary to support intensive barley cultivation. The intensive management implied by the presence of these soils is seen as a catalyst for sedentary living and sustainability within a marginal landscape. The evidence also demonstrates the continuity of agricultural practice from the Neolithic to the Iron Age together with the social dynamics that such a practice generates.

This paper is in two parts: the first section examines in detail the evidence for the presence of anthropogenic soils and the mixed economic strategies for the Neolithic and Early Bronze Age presented by the evidence from Tofts Ness and Jarlshof. The evidence for the continuity of this intensive strategy of soil management is seen from the later evidence of the Bronze Age and Early Iron Age at Tofts Ness and the Middle Iron Age evidence at Old Scatness. The second part of the paper examines the importance of these soils as an inherited resource within the Neolithic and Early Bronze Age paleoeconomic system. Two models are presented. The first examines the cyclic importance of human creation and maintenance of small arable plots to high barley production yields and therefore to site viability, and the effect this has within a mixed resource system in providing settlement viability through time. The second explores the theoretical land and seascape that would provide this mixed resource base.

The Evidence for Created Arable Soils and the Mixed-economy Strategy of the Neolithic and Early Bronze Age: Tofts Ness, Sanday, Orkney

Tofts Ness is located on the northeast peninsula of the island of Sanday, Orkney (Fig. 1). The archaeological investigations at Tofts Ness provided the opportunity to examine the relationship of a prehistoric settlement mound (dating from the Neolithic to the Early Iron Age) with its contemporary landscape, later buried by windblown sand. In terms of geographical situation, the low-lying Tofts Ness peninsula presents an exposed setting and may be regarded as being marginal when compared with other settlement locations on the same island. The excavation program was evaluative, taking place ahead of scheduling and was funded by a research grant from The Society of Antiquaries of Scotland in 1984 and by Historic Scotland between 1985–1988 (Dockrill et al. 2007b).

Because of the overlying cover of windblown sand, Tofts Ness had remarkable archaeological potential, suggesting the possibility of being able to examine the interface between a prehistoric settlement mound and its surrounding landscape. The potential survival of buried soil horizons at Tofts Ness was seen as an important opportunity to provide information about the utilization, management, and agricultural potential of such soils (Fig. 2). The surviving contours of the mound (Fig. 3) suggested that it contained two settlement foci: a bulbous primary mound to the south (containing excavation areas G and H) and a smaller and clearly secondary focus to the north (area C) that revealed elements of dry stone walling indicative of a roundhouse structural form.

This excavation strategy was intended to examine both the primary mound and this secondary element and also the relationship between these two foci of settlement and the surrounding area.

Excavation of the stratigraphic sequence for the primary mound provided a chronology dating from the late fourth millennium to the mid-second millennium BC. A Neolithic building (Structure 1; Fig. 4)

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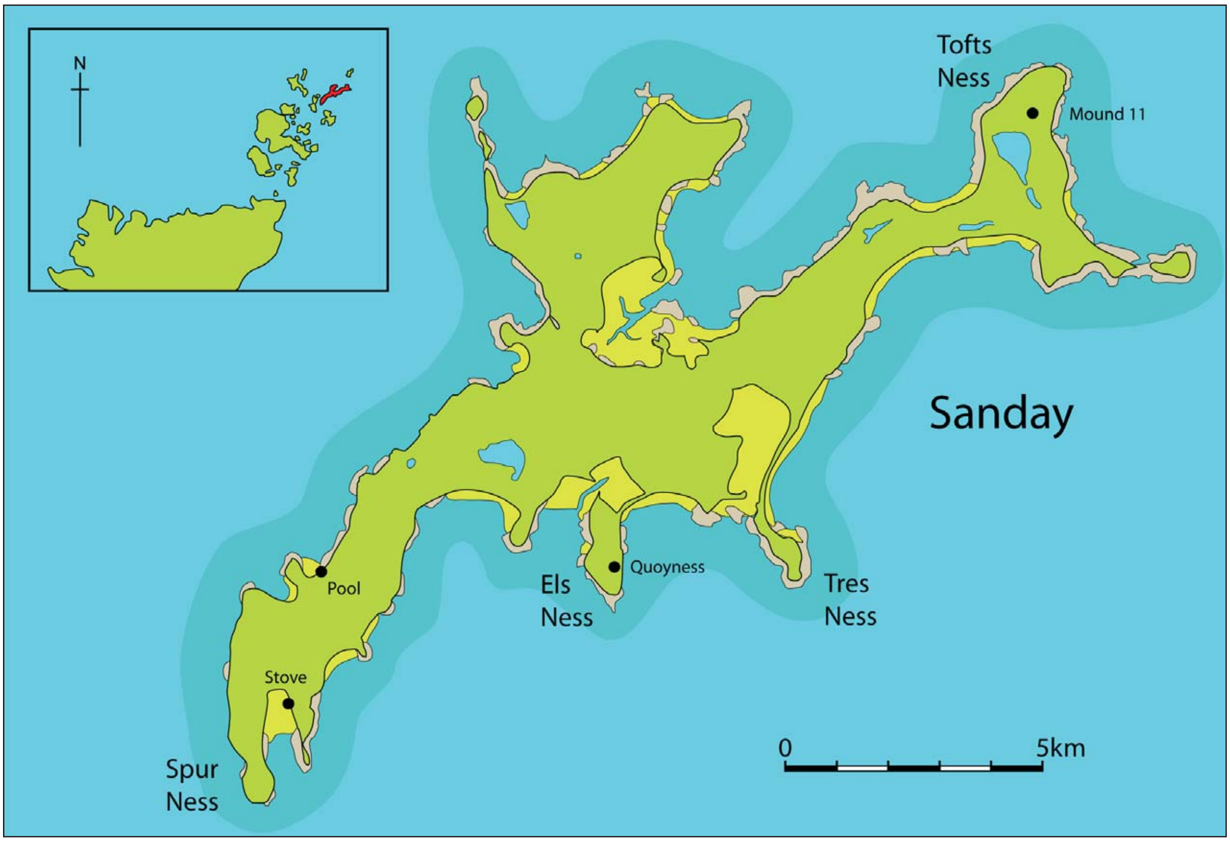

Figure 1. Location of Tofts Ness on the island of Sanday, Orkney.

Figure 2. Neolithic and Bronze Age soil, Tofts Ness, sealed by an ard-cultivated sand-based soil dating to the Early Iron Age, in turn sealed by Iron Age midden. Photograph © S.J. Dockrill.

formed part of the primary sequence in areas A, G, and H and was separated by an extensive deposition of midden from an Early Bronze Age building in area B.

The secondary mound to the northwest had a stratigraphic sequence which spanned a period from the Late Bronze Age to Early Iron Age. The partially exposed roundhouse (contained within area C; Fig. 5) was seen on excavation to be late in this sequence and was found to date to the mid-part of the first millennium BC. Beyond both the primary mound and secondary mound, a number of buried soil sequences were identified and excavated in areas A, B, D, E, and J. A number of these soils in areas A, B, and J were clearly amended and had been subject to ard cultivation.

A research-led approach to the examination of these buried soils enabled the integration of a number of techniques—including magnetic susceptibility measurement, total phosphate chemistry, carbon isotope measurement, soil micromorphological analysis, particle size analysis, molluscan analysis, the study of carbonized botanical remains, and the analysis of soil sterols, —to produce an integrated study of the "infield" as an economic resource (Dockrill 1993; Dockrill and Simpson 1994; Dockrill et al. 1994; Guttmann et al. 2005; Simpson et al. 1998a, 2007:239–253).

More recent research by Guttmann et al. (2005) on these early soils has also allowed a reinvestigation of the Neolithic middens to the east of the Neolithic house (Structure 2) at Tofts Ness. The fine particle size and enhanced phosphate values of both this Neolithic midden spread and the underlying cultivated soil suggested that the midden was cultivated (Guttmann et al. 2005:61). The midden extends to an area of probably less than 20 m^2 to the east, but its spread to the south and west has not been quantified. It is possible to say, however, that the evidence is suggestive of an intensive cultivated area more in keeping with garden cultivation, a model supported by the macro-botanical assemblage. The midden in this zone seemed homogenised due to cultivation and contrasted with the red, ash-rich middens that were identified around Structure 1 and which formed the foundations of the core of the settlement mound. The red, ash-rich midden appeared structured, with visible tip lines seen in the boundaries of the ash-rich deposits, and it contained layers of limpet shell that represented discrete depositional events. The ash-based material was interpreted as being derived from residues left by fuel burnt within domestic hearths. Ash had also been used as floor material within Structure 1 (Dockrill 2007c:19–20).

The plant remains from the Neolithic phases at Tofts Ness, as elsewhere in the Northern Isles, contain only six-row barley (*Hordeum vulgare, H. vulgare* var. *nudum*) as a main cereal crop; a few grains of wheat (*Triticum* sp.) have been found at Tofts Ness and other Neolithic sites, but they seem to be contaminants, perhaps from imported seed corn (Bond 1995, 2007a, 2007b). The weed seeds from Tofts Ness suggest not the open-field environment we associate with farming today, but something much more akin to a garden habitat, with intensive manuring and cultivation. For example, *Stellaria media* (common chickweed) is known today as a low-growing plant of rich garden soils, whilst *Plantago lanceolata* (ribwort plantain) is also found as a garden weed. More common agricultural weeds such as *Polygonum aviculare* (prostrate knotweed) and *Cerastium arvense* (field mouse-ear) are also present, suggesting a fairly light,

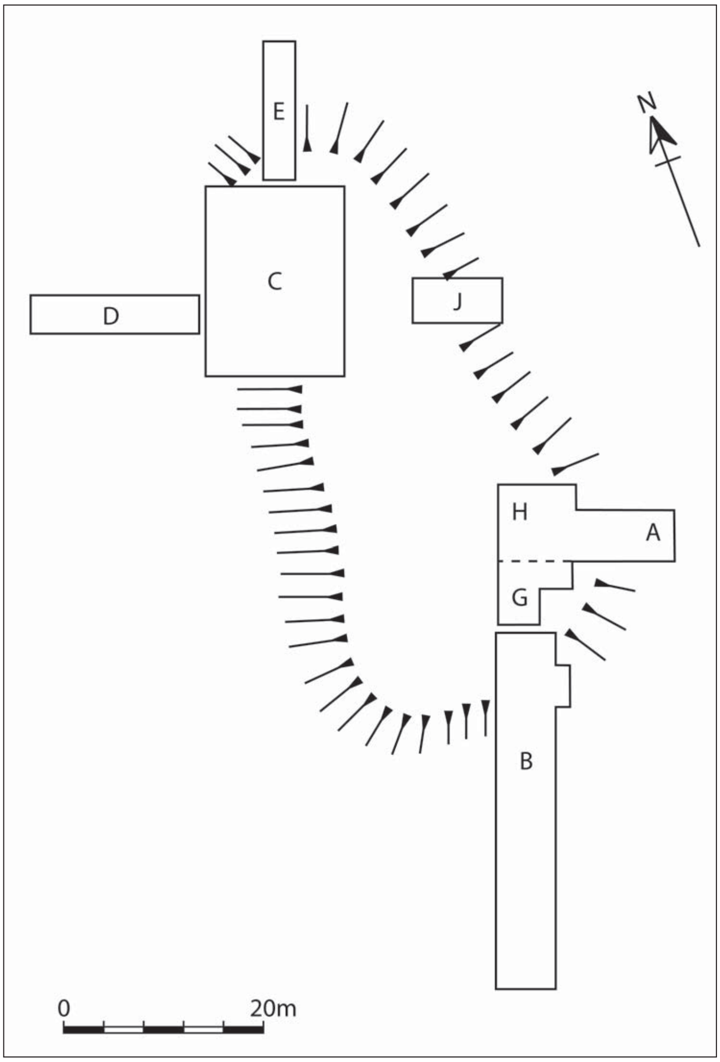

Figure 3. Mound 11, showing the location of the excavation areas and height contours superimposed on the earth resistance survey data.

Figure 4. Structure 1, Tofts Ness, dating to the Neolithic, sealed by Neolithic midden in the far section. The sand at the top of the far section dates to the Early Iron Age. Photograph © S.J. Dockrill.

Figure 5. The Early Iron Age roundhouse at Tofts Ness, Sanday, Orkney. (Photograph © S.J. Dockrill.)

rich soil. The presence of *Galium aparine* (bedstraw), a weed which is particularly troublesome on light, loamy soils, supports this. No soil on the Tofts Ness peninsula today could be described in these terms, though interestingly, the plant remains from the Neolithic settlement at Pool, 12 miles away on the same island, closely parallel these findings (Bond 2007b). No buried soils have been located at Pool, but the soils and landscape there are very different to Tofts Ness today, suggesting that the similarities arise from similar crop cultivation practices in the Neolithic (Bond 2007a, b). The Bronze Age assemblages at Tofts Ness have a similar composition, though an increase in the size of the barley grains and increasing numbers of both *Stellaria media* seeds and fungal spores, perhaps from byre material, all point to greater manuring of the soils at this period. Plant remains from the Iron Age phases at Tofts Ness suggest a continuation of this regime.

The mammal bone from Tofts Ness showed a high proportion of marrow splitting and fracture of bones in all phases, suggesting that every possible source of nutrients was being utilized (Nicholson and Davis 2007). Evidence from butchery marks suggests muscle was stripped from the bone, perhaps to enable drying and storage of some meat. Cattle and sheep were present in roughly equal numbers according to the minimum numbers of individuals, although there are many more sheep fragments (Table 1 shows the NISP for larger and medium-sized mammals). No goats were identified, and there were only a few pigs. There is some evidence for non-intensive dairying in cattle from the Neolithic through to the Iron Age phases (Serjeantson and Bond 2007). Surprisingly, there is little evidence for the utilization of wild mammals at Tofts Ness except for a few seals; this inability or reluctance to use wild animal sources is echoed at other Neolithic sites in Britain. Later phases at both Tofts Ness and Pool have evidence for the utilization of red deer, otter, and seal, though never in very large numbers.

Table 1. The animal bone from Neolithic and Early Bronze Age Tofts Ness, as percentages of the number of identified specimens (NISP).

	% NISP
Cattle	43.0
Sheep	52.0
Pig	1.9
Dog	0.2
Red deer	0.9
Seal	1.4
Otter	0.02
Cetacean	0.3
Total identified	57.0
Unidentified	43.0

In contrast to the lack of wild mammals, there is evidence for the utilization of a wide range of fish and a diverse range of seabirds including gulls as well as ducks and geese (Nicholson 2007, Serjeantson 2007).

Little sieving was possible on the earliest levels at Tofts Ness as the deposits were clay-rich and damp. Nevertheless, a range of fish bones was collected partly by hand and also from small (5-litre) wet-sieved samples and from the flot residues. These samples added a range of smaller fish to the hand-recovered material. Most of the bones recovered were from large gadids (the most common was cod, though ling, saithe, and pollock were also present). Measurements suggested that the majority were large fish, over 0.75 m in length, with two cod close to 1 m in length. Other fish present included large conger eel, ballan wrasse, and large and medium-sized flatfish (Table 2). Measurements of some of the flatfish (turbot) bones indicated fish of up to or over 0.75 m in length. Nicholson (2007) suggested the majority of these fish would have weighed over 10 kg each.

Nicholson argued that the range of fish indicate a variety of fishing methods: fishing in rock pools and from shore, but also using lines and hooks from boats. Large ling such as those from the Neolithic assemblages are now only found in deep waters of 100 m or more. Because of the nature of the coastal shelf around the Orkney Islands, the nearest water of such depth would be roughly 15 km northeast of Tofts Ness. Megrim (*Lepidorhumbus whiffiagonis*) are also found in waters of 50 m or more. Even allowing for possible changes in fish distribution and for a bias towards larger bones introduced to the assemblage by a lack of total sieving, it seems impossible

Table 2. Identified fish bone from Neolithic and Early Bronze Age Tofts Ness. Data from Nicholson (2007). nfi = not further identified.

	Phase 1	Phase 2	Phase 3
Tope, *Galeorhinus galeus*	-	-	1
Elasmobranch, nfi	-	1	-
Conger Eel, *Anguilla anguilla*	1	7	3
Cod, *Gadus morhua*	22	18	3
Pollack, *Pollachius pollachius*	-	5	-
Saithe, *Pollachius virens*	2	1	-
Saithe/pollack	1	1	-
Ling, *Molva molva*	4	10	-
Gadid nfi	9	18	8
Ballan Wrasse, *Labrus bergylta*	1	-	1
Turbot, *Scopthalmus maximus*	-	3	-
Turbot/brill	-	3	-
Right-sided flatfish	-	1	1
Flatfish, nfi	-	1	-
Unidentified	6	52	8

to deny that Neolithic fishermen were exploiting a range of techniques and habitats, including offshore fishing in deep waters from boats capable of dealing with such conditions. Deep-sea fishing would have been a high-risk activity, and we can only assume that it was driven by economic or social necessity.

Bird bones from the Neolithic and Early Bronze Age phases at Tofts Ness were studied by Serjeantson (2007). Surprisingly, the majority were from *Larus marinus* (Great Black-backed Gull), with *Larus argentatus* (Herring Gull) or *Larus fuscus* (Lesser Black-backed Gull) being the next most common followed by the now-extinct *Alca impennis* (Great Auk), with a wide range of other birds present (Table 3). Gulls are now not generally considered as an important food source, though they and their eggs have been gathered in the past (Fenton 1978:519–21). The gulls, which were for the most part adult birds, are likely to have been captured at their breeding sites in the spring, with the Great Auks available a little later. There are no cliffs suitable for gannets or Greater Black-Backed gulls close to the site at Tofts Ness, again suggesting mobility and the willingness to travel for certain resources. The wide range of other birds including *Phalacrocorax carbo* (Cormorant), *P. aristotelis* (Shag), *Cygnus* spp. (swans), *Anser* spp. (geese), and *Haematopus ostralegus* (Oystercatcher) suggests the utilization of a wide range of habitats and different methods of trapping or hunting.

Prehistoric Middens and Cultivation at Jarlshof, Shetland

In 2004, clearer evidence of midden cultivation was recorded at the multi-period site of Jarlshof. Situated at the southern tip of Shetland (Fig. 6), Jarlshof is of central and continuing importance in the archaeological understanding of late Neolithic to late Norse settlement in the North Atlantic. It was, however, excavated in the earlier half of the 20th century (Hamilton 1956:6–7) and had neither scientific dating of its chronological sequence nor any usable paleoeconomic or environmental data.

The extreme northeast corner of the site was excavated by Childe in 1937 and revealed the earliest occupational evidence for the settlement and a sequence of midden and sand deposits spanning the period from this early activity to the middle ages (Childe 1938, Hamilton 1956:8–17).

The new Jarlshof research program was designed to inform on both the economy of the settlement and the absolute chronology of the sequences observed by Childe (based on the integrated use of AMS radiocarbon dating and optically stimulated luminescence dating). These sequences were examined in three areas. Trench 1 was located on a flat, terraced lawn above the earliest elements of the site (possibly dating to the late Neolithic). Trench 2 was located on the adjacent higher terrace to the west, next to walls associated with the Norse structural sequence (north of Hamilton's House 2). A third small area, Trench 3, was opened to the northwest in the hope of retrieving the Norse period environmental and dating evidence which proved to be missing from Trench 2.

Table 3. Bird bone from the Neolithic and Early Bronze Age (phases 1, 2 and 3), Tofts Ness. Data from Serjeantson (2007). ? = unsure of species identification. nfi = not further identified.

	Phase 1	Phase 2	Phase 3
Manx Shearwater, *Puffinus puffinus*	-	1	-
Gannet, *Sula Bassana*	2	10	11
Cormorant, *Phalacrocorax carbo*	3	10	7
Shag, *Phalacrocorax aristotelis*	1	6	5
Cormorant/Shag	1	1	1
Swan, *Cygnus ?olor*	1	1	-
Bewicks Swan, *Cygnus columbianus*	-	-	1
Whooper Swan, *Cygnus cygnus*	-	3	-
Swan Mute/Whooper, *Cygnus* sp.	-	5	1
Large Grey Goose, *Anser anser/fabalis*	1	3	4
Goose, *Anser albifrons/brachyrhynchos*	2	2	-
Grey Goose, *Anser* sp.	-	3	2
Teal, *Anas crecca*	-	-	1
Mallard, *Anas platyrhynchos*	-	1	-
Pochard, *Aythya ferina*	1	3	-
Scaup, *Aythya marila*	-	1	-
Eider, *Somateria mollissima*	1	1	2
Red-breasted Merganser, *Mergus serrator*	1	2	1
Anatidae	2	3	1
Buzzard, *Buteo buteo/lagopus*	1	1	2
Peregrine, *Falco peregrinus*	-	-	1
Crane, *Grus grus*	-	-	1
Water Rail, *Rallus aquaticus*	-	-	1
Crake, *Porzana ?porzana*	-	-	1
Wader (Charadriiformes), nfi	-	-	1
Oystercatcher, *Haematopus ostralegus*	-	5	2
Lapwing, *Vanellus vanellus*	-	-	1
Curlew, *Numenius arquata*	-	2	-
Common Gull, *Larus canus*	1	4	-
Herring Gull/ Lesser Black-backed Gull, *Larus argentatus/fuscus*	13	26	20
Great Black-backed Gull, *Larus marinus*	14	38	36
Gull, nfi, *Larus* spp.	-	6	7
Kittiwake, *Rissa tridactyla*	2	-	-
Great Auk, *Alca impennis*	8	15	8
Razorbill, *Alca torda*	-	1	-
Guillemot, *Uria aalge*	2	2	1
Puffin, *Fratercula arctica*	-	1	-
Short-eared Owl, *Asio flammeus*	-	-	1
Passerine	-	-	1
Raven, *Corvus corax*	-	1	1
Bird, nfi	18	73	47

Trench 1 was located on the first terrace, northwest of the displayed remains (Fig. 7) representing the features within Childe's early sequences (Childe 1938:351–356). The terrace appears to have been formed by the removal of material (termed by Hamilton "Viking layers" and "Midden I") during either Childe's or Miss Laidler's excavations of these features (Fig.3; Hamilton 1956:8–10). The stratigraphic sequence revealed in Trench 1 can be summarised as: topsoil, a grey sand, midden (equating to Childe's "Midden II"), and a white windblown calcareous sand, which separated this upper midden from a more extensive lower midden (equating to Childe's "Midden III") (Fig. 8). Both midden deposits contained artifacts and bone and showed clear signs of ard cultivation. Below this, a series of mineral sand deposits and buried turf lines sealed a black humic silt that covered bedrock.

Trench 2 (Fig. 7) was located on the second terrace in order to provide a link between the prehistoric

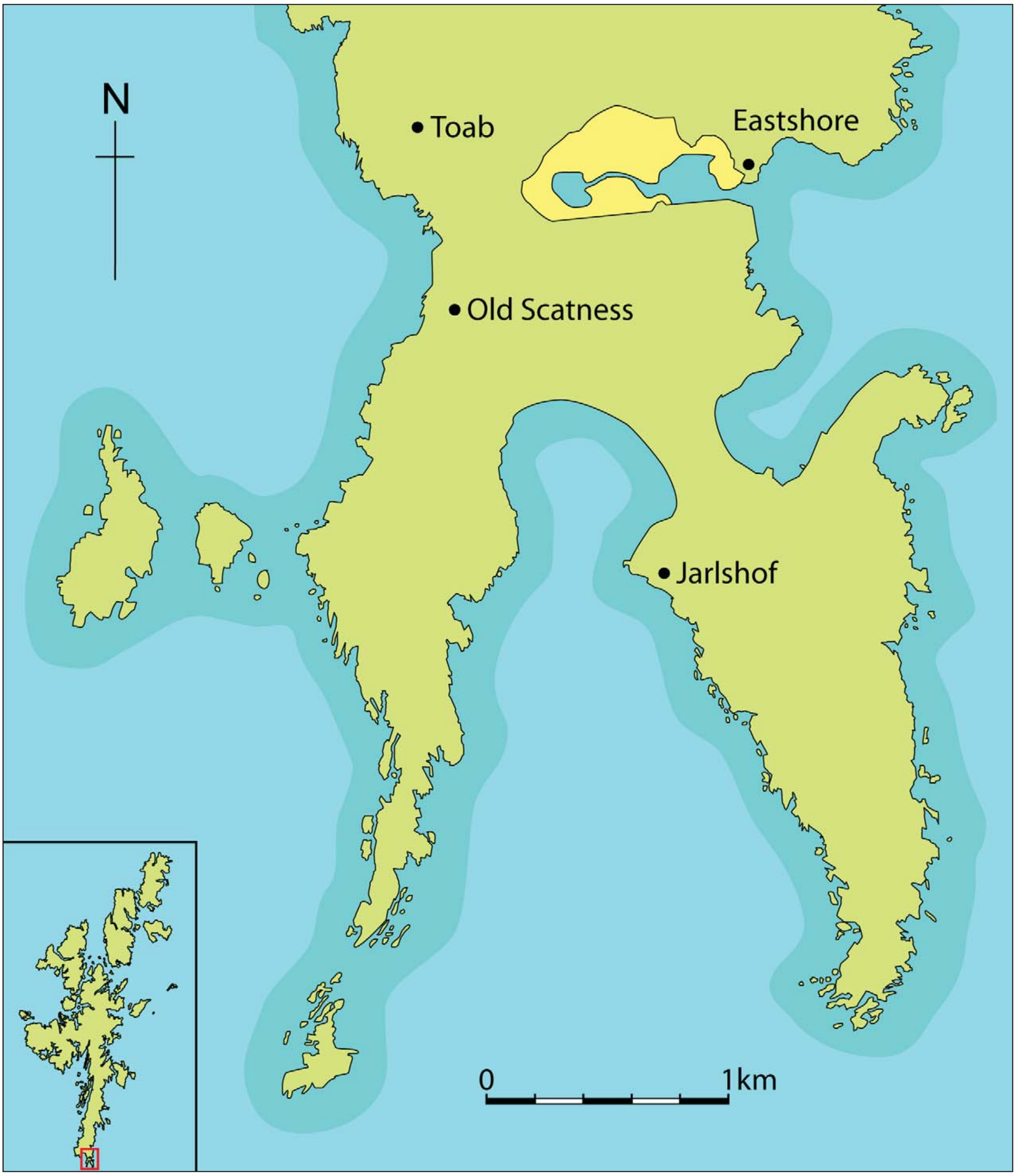

Figure 6. Location map of Jarlshof, Shetland.

middens in Trench 1 and the Medieval and Viking middens and possible Iron Age soils identified by Childe as overlying the deposits in the northeast corner of the site (Childe 1938:349). Trench 2 was also excavated to natural, revealing in the lower part substantially the same stratigraphic sequence as that observed in Trench 1.

The early midden sequences identified by Childe in his 1937 excavations (M.IIA and B, M.III) were adjacent to structural features such as hearths, stone settings, and wall elements and were separated by sand-blow events. From the descriptions of Childe and the re-interpretation by Hamilton, the nature of the midden adjacent to the settlement appeared to be one of simple deposition and accumulation (Hamilton 1956:8–17). No traces of ard cultivation were recorded by either archaeologist, and the pottery appears to have been less abraded than that recovered in 2004.

The midden sequences in both Trench 1 and Trench 2 are separated by a sand-blow event and seem likely to represent Childe's Midden II and Midden III. A sequential development of the anthropogenic soils can be seen within Trench 1. AMS radiocarbon dating of barley grains indicates that these soils were developed within the Neolithic/Early Bronze Age period (see Appendix 1).

Plant remains from the middens in Trench 1, Jarlshof

As might have been expected, samples from the midden/ploughsoil (contexts [017], [018], and [019]) were richest in charred remains.

The cereal component of each of the samples assessed from Trench 1 consisted of grains of *Hordeum*

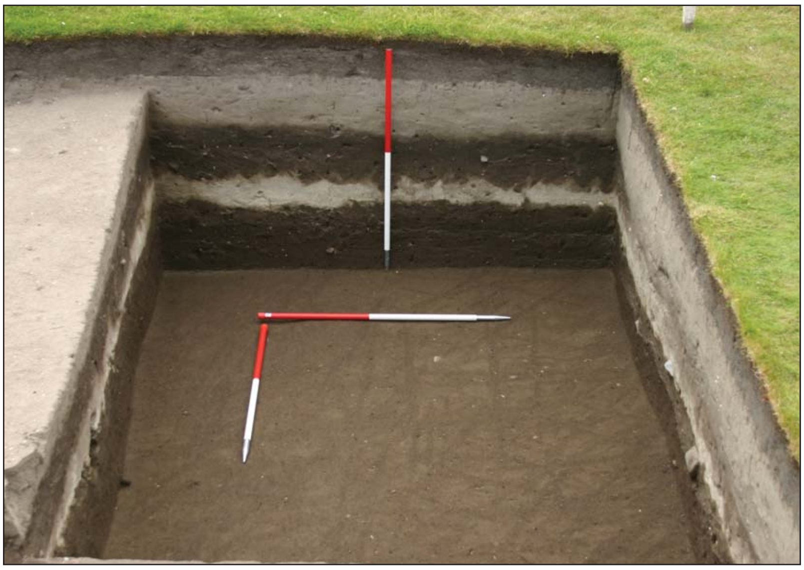

Figure 8. Jarlshof: ard marks within the primary midden sequence of Trench 1. (Photograph © S.J. Dockrill.)

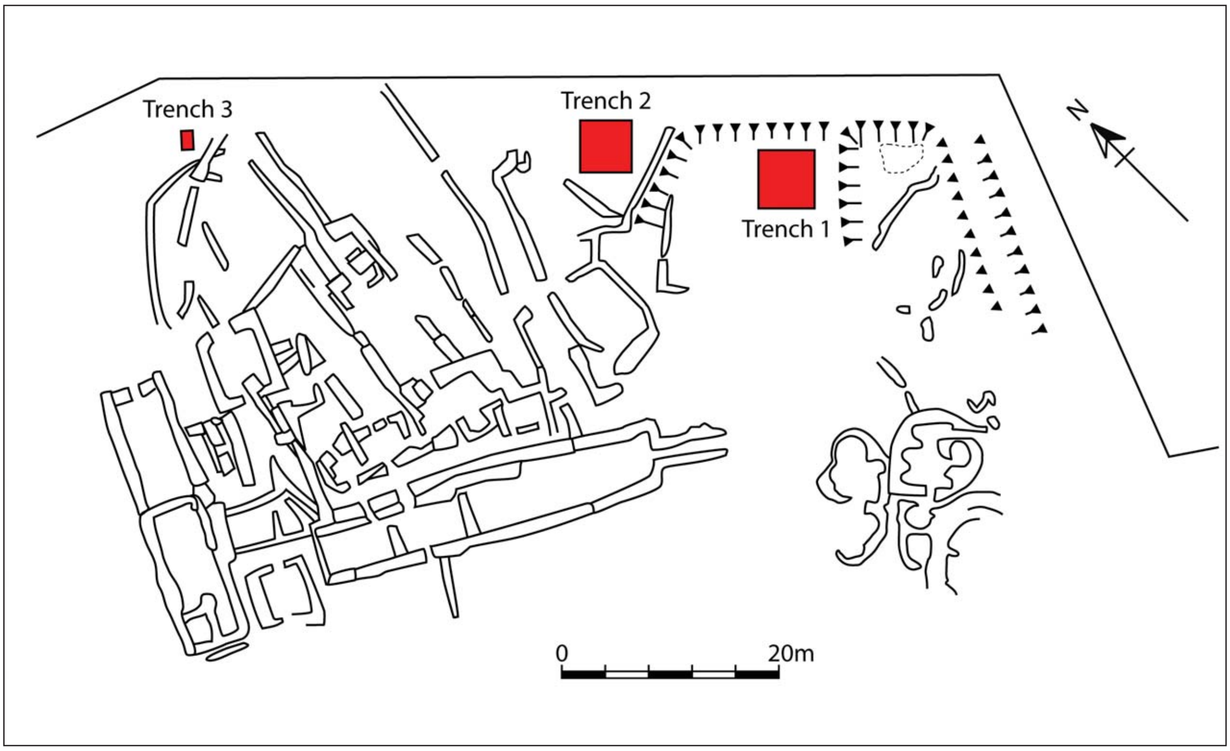

Figure 7. Location of the 2004 trenches at Jarlshof.

spp. (barley), with identifiable *H. vulgare* L. (hulled barley) occurring frequently in the samples and a few grains of *H. vulgare* var. *nudum* (naked barley) recovered from the cultivated middens (contexts [017], [018], and [019]). Grain preservation was variable; some grains were in a relatively poor state of preservation, being very abraded and clinkered, while others were quite well preserved. There are some very large grains, suggesting good growing conditions, though some other grains appear to have been harvested when still immature. Three samples contained cereal-sized culm bases (the base of cereal stems), suggesting that the cereal was being harvested by pulling rather than reaping with a sickle. This method is possible on light soils and allows the full length of the straw stem to be utilized, either as animal feed or for numerous other purposes such as thatching or rope for basketry. No other cultivated species were identified.

Weed seed assemblages from the samples in Jarlshof Trench 1 included weeds which are most likely to be related to arable agriculture such as *Stellaria media*, *Cerastium arvense*, *Fallopia convolvulus* (black bindweed), *Hypericum* sp. (St. John's wort), *Spergula arvensis* (corn spurrey), *Rumex* sp. (dock), *Montia fontana* (blinks), *Plantago lanceolata,* and *Ranunculus* sp. (buttercup). Other plants present as seeds included *Potentilla* sp. (cinquefoil), *Plantago* sp. (possibly *P. media* [lanceleaf plantain]), *Danthonia decumbens* (heath grass), other small grasses, *Cyperaceae* spp. (sedges), and *Empetrum nigrum* (crowberry). Roots identified as probably *Arrhenatherum elatius* ssp. *bulbosum* (onion couch) were also identified, as well as stems of other grasses and of *Calluna* spp. (heaths), Bryophyta (mosses), and fragments of Fucoid algae (brown seaweeds). Small fragments of amorphous carbonized material possibly originated from burnt dung or peat.

Table 4. Jarlshof Trench 1 NISP (number of identified specimens).

	NISP	% NISP
Cattle	51	35.0
Sheep	76	52.0
Pig	15	10.0
Dog	1	0.7
Seal	2	1.4
Whale	1	0.7
Total	146	

Table 5. Bird bones from Jarlshof Trench 1. (Data from Nicholson 2005a).

	Trench 1
Large duck/small goose	1
Guillemot	4
Great Auk	1
Guillemot/Razorbill	1
Puffin/ Black Guillemot	1
Greater Black-backed Gull	3
Herring/Lesser Black-backed Gull	1
Medium-sized gull	1
Large-sized gull	3
Large bird	5
Medium bird	1
Small bird	1
Unidentified	17
Total	40

The animal bone assemblage from the middens in Trench 1, Jarlshof

The Jarlshof Trench 1 mammal-bone assemblage (ca. 650 fragments) was largely made up of indeterminate cattle- and sheep-sized fragments. Identification was difficult due to the highly fragmented nature of much of the bone (Table 4). Sheep, cattle, pig, seal, and dog were identified. A few fragments of cetacean bone were recovered. Due to the heavy fragmentation, only a few ageable and measurable elements were present for all three main domesticates. Neonate bones of all the three main domesticates were recorded, though cattle neonates were noticeably more frequent than those of sheep or pig, suggesting the possibility of dairying.

The bird bone from Jarlshof Trench 1 produced a relatively small number of identified bones (Table 5). In her report, Nicholson notes that the assemblage from these Neolithic/Bronze Age midden levels

Table 6. Fish bones from Jarlshof Trench 1. (Data from Nicholson 2005b.) nfi = not further identified.

	Trench 1
Eel, *Anguilla anguilla*	18
Herring/Sprat (Clupeidae)	87
Cod, *Gadus morhua*	16
Saithe, *Pollachius virens*	901
Pollack, *Pollachius pollachius*	4
Cod/Saithe/Pollack, *Gadus/Pollachius*	144
Bib/Pout, *Trisopterus* sp.	2
Ling, *Molva molva*	6
Torsk, *Brosme brosme*	1
Gadids (Gadidae), nfi	8484
Hake, *Merluccius merluccius*	1
Dragonet, *Callionymus lyra*	2
Garfish, *Belone belone*	1
Gurnards (Triglidae)	72
Butterfish, *Pholis gunnellus*	1
Sand eel (Ammoditidae)	3
Scad, *Trachurus trachurus*	5
Sea Breams (Sparidae)	4
Wrasses (Labridae)	4
Plaice/Flounder/Dab (Pleuronectidae)	5
Unidentified	40
Total	9801

resembles that of Tofts Ness, Sanday (Nicholson 2005a). As at Tofts Ness, gulls and auks dominated the Jarlshof assemblage.

Fish bones from Trench 1 were extremely well preserved (Table 6; Nicholson 2005b). The assemblages contained otoliths from cod family fishes (Gadidae) together with the abundant bones of small and tiny gadids (notably saithe) as well as the remains of other small fish including gurnards (Triglidae), sea bream (Sparidae), scad (*Trachurus trachurus*), and herring/sprat (Clupeidae).

Nicholson suggests that while sillocks (one year old saithe) numerically dominated the assemblage recovered from these prehistoric midden deposits, the tiny size of the individuals (under 20 cm and often under 15 cm long) when compared for example with the average gurnards, sea breams, and flatfishes (generally around 30–40 cm long fish at this site) suggest that they did not dominate the fish diet, which would have been quite varied (Nicholson 2005b).

The cultivation of the deposits in Trench 1 and Trench 2 is significant as this material is clearly domestic midden containing bone, carbonized plant material, and artifacts. The repeated sets of ard marks and the abraded nature of the pottery and bone indicate that this zone was used repeatedly over time. This excavation clearly confirms the cultivation practice suggested above for Tofts Ness.

This zone is perhaps best described as being a cultivated midden rather than a cultivated soil, representing a small heavily manured infield. The plump barley grains and weeds of fertile ground from samples taken from the successive midden contexts clearly illustrate the success of this strategy.

Continuity of Infield Management in Prehistoric North Atlantic Britain

The Bronze Age and Early Iron Age soils from Tofts Ness

Evidence from the Bronze Age and Early Iron Age buried soils associated with Mound 11 (Phase 4 and 6), Mound 4, and Mound 8 at Tofts Ness indicates a continuity in the intensive management of the arable resource. There seems to be an expansion in the Bronze Age with the creation of small arable infield plots, evidenced by the radiocarbon chronology for Mound 4 and Mound 8 (see Appendix 1). Although this practice provides strong evidence for continuity, the nature of the management appears to evolve during the Bronze and Early Iron Age. There is evidence for sand movement in this period, and this developmental change in soil management can in part be explained as a response to the changing environment. The manuring strategy at this time sees the application of podsolic turf from heathland (some of which is burnt). In the case of Mound 11, the soil was formed directly on machair sand.

Turf incorporated within the soil matrix may have been used within a complex cycle, having first been used as animal bedding before being composted and used as a manure (Bond 1995, Dockrill et al. 1994, Simpson et al. 1998a:743–4). The mineral components from these podsolic soils stripped from the heathland gradually increased the thickness of the soil profile. Cattle manure does not appear to feature as a manure additive, probably because it was a valuable fuel resource in an island landscape devoid of wood and blanket peat (Bond 1995:138). Ash and carbonized seaweed appear to have been applied to the soil. The evidence for seaweed is seen in both botanical samples and by the presence of burnt marine molluscs (Dockrill et al. 1994:115–72). Organic geochemical study of these soils indicates the addition of grassy turves (Bull et al. 1999:535–56). The evidence of sterol compounds in the soil suggests that human fecal material is present, although not a major element (Simpson et al. 1998a:743).

A radical change occurred at Tofts Ness in the middle of the first millennium BC due to massive movements of sand burying the Late Bronze Age soils (Fig. 4). This fundamentally changed the main mineral component of the soil matrix, which became calcite sand. Early Iron Age land-management strategies continued with a similar intensity of soil enhancement involving the application of a mixture of materials to the soil. This included the application of significant quantities of decomposing organic materials, indicated by the enhanced number of excremental pedofeatures modified by microbial activity (Dockrill and Simpson 1994:89). This material would help mitigate against the two main threats presented by the sand-based soils: susceptibility to drought and wind erosion.

Evidence from Old Scatness, Shetland

The excavation of another multi-period settlement mound at Old Scatness, South Shetland some 1.5 km northwest of Jarlshof (Fig. 6) has produced evidence for the continuity of these soil-management practices into the Middle and Late Iron Age (Guttmann et al. 2008, Simpson et al. 1998b). The site contains a ditch-defended Iron Age village surrounding a broch, or dry stone tower.

Investigation of the contemporary field system revealed a series of buried soils that had been created over a mineral sand, covering an extensive area around the site.

A number of complete profiles of these soils have been excavated to the east and in two sequences to the southwest of the site. Area L, to the southwest of the site, was typical, revealing an overall stratigraphic sequence of some 1.5 m (Fig. 9). The lower meter represented soils of the Iron Age. At least five different soils and two sets of ard marks were visible within this profile. This sequence was excavated by hand, and the soil from each stratigraphic context was sieved using a 5-mm mesh, which yielded evidence of artifacts (mainly abraded pottery).

The primary soil in this sequence, created directly on the sand, was a distinctive red, ash-based soil. This soil had been subjected to ard cultivation and was found to pre-date the construction of the broch, having a mid-first millennium BC date. This deposit was distinguished by both its fine particle size and its high total phosphate values (691–1516 mg P/100g), mirroring the ash middens found on site (Guttmann et al. 2005:59).

In the Middle Iron age, it seems that ash midden was no longer applied to the surrounding infield, but was stored within the settlement site. At this point, rich organics predominate in the list of material added to the soils and include animal manures and domestic waste such as flooring material (Guttmann et al. 2003:28). Clear visual evidence of organic flooring had been found in several of the structures from various phases of the site. This change occurs with the construction and first use of the broch and a significant build up of the soil (Dockrill et al. 2007a).

Discussion

This paper argues for a hypothesis that intensive soil management involving the use of midden to form small arable plots was current in the Neolithic and Early Bronze Age of the Northern Isles. These midden-rich arable plots increased the yield potential of the staple crop (six-row barley) even in bad years. The harvested barley is seen as a foodstuff that would have been an important, indeed crucial, energy source (Dockrill 1993, 2007a). As an economic resource, barley can be seen to have fulfilled an important role, a crop which could be "banked" in times of surplus to be used beyond its year of harvest to offset shortages in bad years.

The geographic position of the British North Atlantic islands ensures that poor years will be more common than in southern Britain. Settlement viability would have been achieved by a combination of factors that included a mixed economy in which there was potential to shift balances and a system of barley production in which yield potential in both good and poor years was maximized by the use of anthropogenic, intensive infield plots. The potential to store surpluses in good years of barley production would have been of prime importance; other products such as storable dairy products and dried or smoked meats might also have had a supporting role in offsetting shortages in lean years.

This research indicates that in the Neolithic and Early Bronze Age, the cultivation of midden spreads and the midden amendment of cultivated soils enabled the successful production of potentially high yields of six-row barley even in marginal locations such as Tofts Ness (Dockrill 1993). A special difference in deposition between pure hearth ash and the cultivated midden was noted above. The cultivated midden at Tofts Ness extended out east of Structure 1 and appeared to contain less ash and had a higher organic content. A similar spatial separation seems likely for the Jarlshof sequence and has been recorded at Skara Brae (Simpson et al. 2006). The burning of a peaty turf (sourced from around the freshwater lochs discussed below) would have resulted in the roasted iron-rich ash matrix of the Neolithic midden deposits at Tofts Ness, Pool, and Skara Brae. This interpretation is further supported by micromorphological analysis and the dominance of silt-sized mineral grains from the middens at Skara Brae (Simpson et al. 2006:229) This material, characterized visually by its distinctive reddish orange colour, accumulated and formed the core of the Tofts Ness, Pool, and Skara Brae settlement mounds in the Neolithic.

The enhancement of the soil matrix by fresh midden and manure would over time have protected the resulting soils from excessive drying and wind erosion as well as replacing the important nutrients needed for such intensive cultivation year after year. Manuring of the infield together with intensive weeding would maximize the yield return of barley (Dockrill 1993:161, 2002:156). The potential

Figure 9. The prehistoric ard marks and soil sequence below the post medieval sand (top) at Old Scatness (Area L). (Photograph © S.J. Dockrill.)

for the storage of surplus barley in the Neolithic is evidenced by the large cache of six-row barley recovered from the Neolithic building at the Ness of Gruting in Shetland (Milles 1986). There appears to be a continuity of the practice of intensive plot cultivation through the Bronze Age, which is directly related to the intensive creation and maintenance of anthropogenic soils such as those seen at Tofts Ness and Jarlshof. The calibrated radiocarbon dates from the settlement sequence at Tofts Ness and the prehistoric midden sequence at Jarlshof indicate both a continuity of practice and the longevity of the settlements, suggesting that their economic strategy was successful (see Appendix 1).

The relationship between intensive infield plot management and the storage of crop surplus can be expressed as a cyclic model (Fig. 10).

In reality, this cycle needs to take the aspect of time into account, and this model should be viewed as a spiral. The pictorial model should be thought of as a cross section through the spiral. The prime resource in the model is the manure and management, which with the invested labor, builds the infield resource year by year. Over time, the infield becomes an inherited resource. Judging by the archaeological evidence from both Jarlshof and Old Scatness, where soils were artificially created on sand, preexisting naturally formed deep soils appear not to have been an essential precursor for settlement. The economic stability generated by this model provides the catalyst for site viability and continuity. It can be argued that the continuity and success of these and other sites is due to this intensive form of cultivation and to the broad spectrum economy of which it is part (Bond 1998, 2003). Within this context, we are perhaps beginning to see that the maintained infield is an important resource generated by those working these "intensive garden" patches, which developed in depth and structure to become the inherited resource of the generations that followed.

Exploitation of a mixed, broad-spectrum economy (terrestrial and marine) evidenced by data from both the early deposits at Tofts Ness and at Jarlshof can be seen as providing sustainability for these marginal settlements. This economic strategy would provide a buffer in times of hardship, and its success can be measured by the long occupational sequences at these sites. Settlement viability in bad years is seen as having been achieved by both the use of stored barley and the greater exploitation of other resources within the economic system.

The stylized model of resource availability for Tofts Ness (Fig. 11) is not produced as a representation of the actual Tofts Ness landscape, but is an amalgam based on the Tofts Ness economy and a number of landscapes surrounding Orcadian Neolithic sites, including the settlement sites of Pool and Stove, which show similar resource potentials. Skara Brae, the World Heritage Neolithic settlement, shares a number of these key features including its coastal position and the presence of a nearby freshwater loch. The evidence for the creation of an infield around the immediate area of settlement has already been discussed above. The availability of water, often in the form of a loch, appears to be a key locational factor for early Neolithic settlement (Bond 1995:121). Freshwater would have been a vital asset, providing drinking water for humans and cattle. In the case of Tofts Ness, North Loch developed behind an ayre or bar of

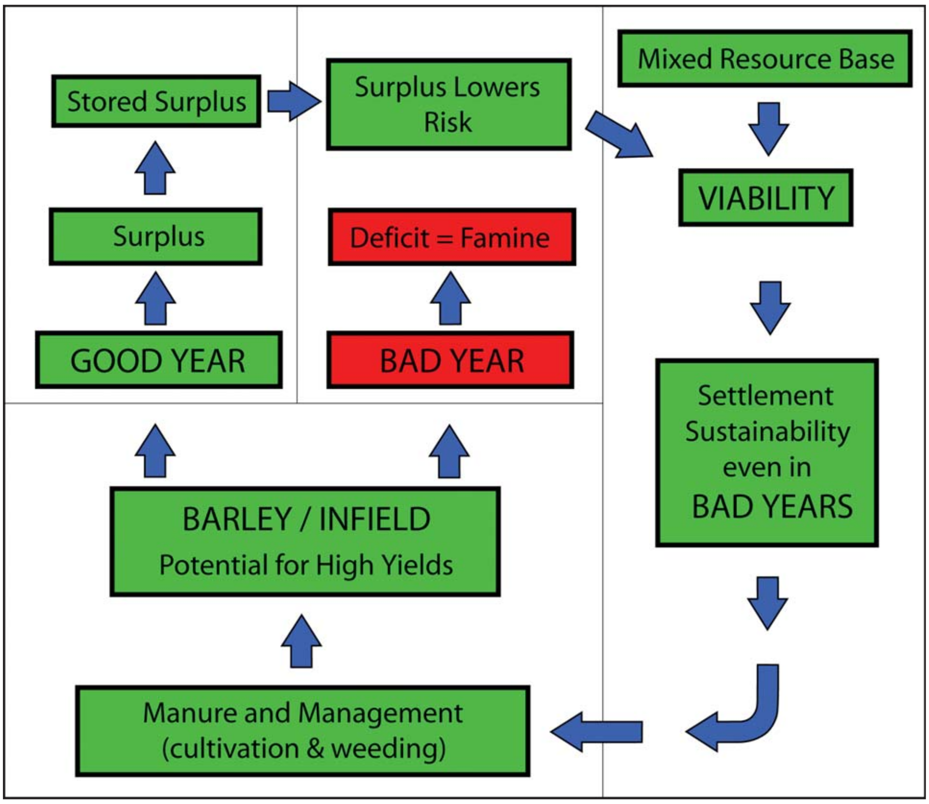

Figure 10. Cyclic model for intensive (high-yield) barley production on midden-manured small infield plots within a mixed-resource economy and the potential for settlement sustainability in bad years.

sand that contains the loch and a surrounding area of marsh. This area produces an iron-rich peaty turf, which appears to have been harvested as fuel (Dockrill 2007b:253–255). The loch and marsh would also have supported wild fowl at certain seasons, providing another food resource, which is verified in the Tofts Ness archaeological record.

The coast to the southeast of the headland at Tofts Ness contains a sandy bay, while low cliffs, shingle, and a wave-cut platform form the headland. This coastline provides a mixed set of economic resources that could have been widely exploited in the past for food products including limpets and other shellfish, seaweed, nesting sea birds, fish, and a range of sea mammals. This zone also provides a source of other materials including water-worn cobbles for tools such as pounders, grinders (pestles), and hammer stones, butchery knives made from flaked pebbles ("Skaill knives"), flint pebbles (worked into a number of different edged tools from scrapers to arrow heads), and pumice, which was used as an abrasive (Dockrill 2007c:38).

Measuring success: The later prehistoric infield

The same strategy employed in the Neolithic and Bronze Age can be seen within the Early Iron Age deposits at Tofts Ness and the Middle Iron Age deposits at Old Scatness. At Tofts Ness, the Early Iron Age infield appears to have been similar in size to that of the earlier phase and shows, despite the problems of windblown sand faced by the roundhouse occupants, a continuity in those soil-management practices of the Bronze Age, which had their origins in the Neolithic. Again the mixed economic resource base appears to have provided the ingredients for settlement sustainability. This settlement seems to have been marginal by Orcadian standards and, in contrast to the elite site at Old Scatness, was probably the home of the poorer end of the Iron Age social spectrum. The Early Iron Age roundhouse at Tofts Ness appears only to have been abandoned after a large windblown-sand event, which appears to have buried the infield and surrounding land surface.

A model for the Early Iron Age has been discussed by Dockrill (2002, 2007a:387–393), in which it was suggested that the intensive management of infield soils provided the potential for a barley surplus in good years. Storage of this surplus would have acted as a safeguard against years of poor harvest (Dockrill 2002:155–161).

Such storage of any barley surplus, either collected or exchanged within a barter economy for other services, could be redistributed to the bonded

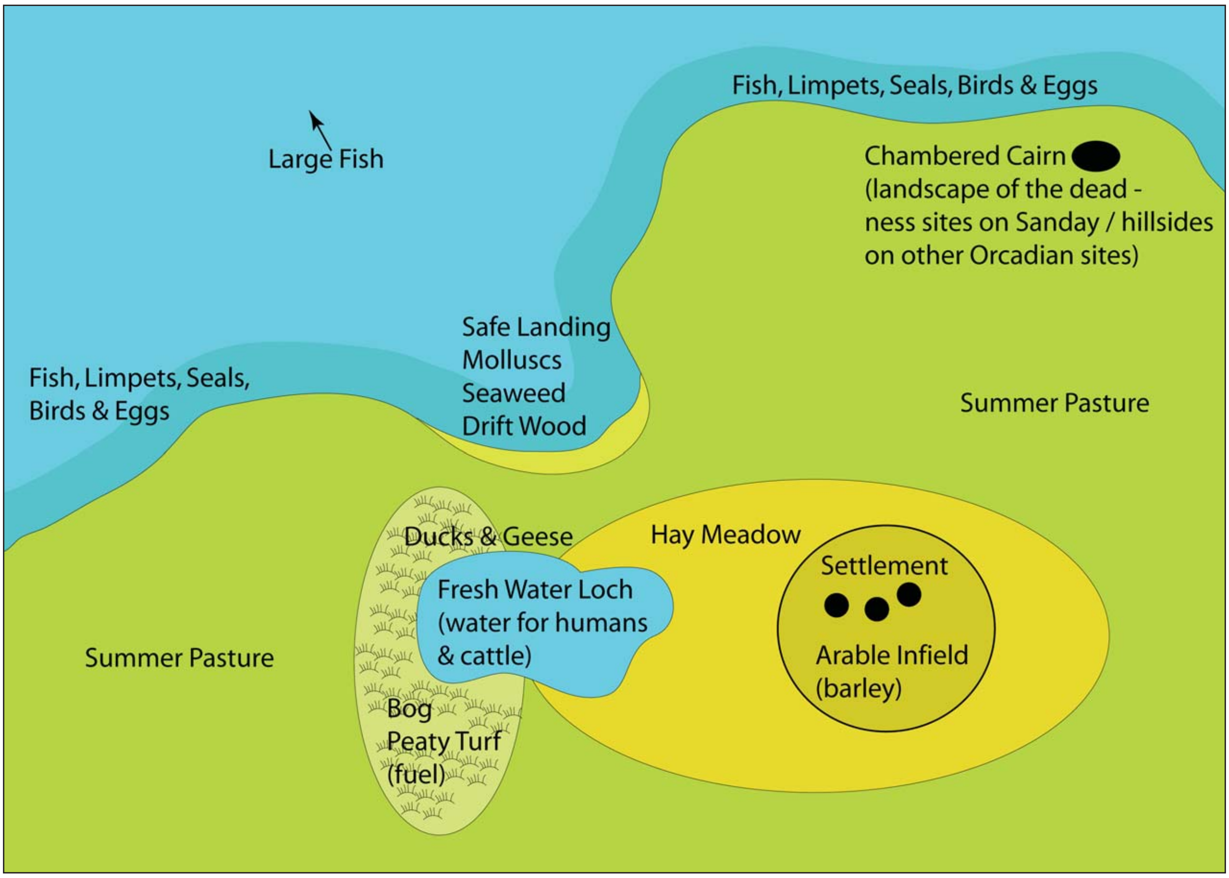

Figure 11. A stylised resource and landscape model based on the Tofts Ness data but incorporating the similar locational evidence from two other Neolithic settlements on the island of Sanday, at Pool and Stove.

client population and would have acted as an economic buffer in bad years. Such a model provides both wealth for the elite and the economic safeguard against poor years, which leads to social stability. The economic and social stability generated by this model for the Iron Age again provides a catalyst for site viability and continuity of a social system, binding the social elite to an underlying client population. That the system provided stability is shown by the long survival of the Tofts Ness settlement in such a marginal landscape. In the case of the settlements of Jarlshof and Old Scatness, their better positions gave them an even greater longevity.

Conclusion

The Neolithic adaptation to the Northern Isles owes its success to the full exploitation of the natural resources as well as the cultivation of barley and the husbandry of domesticates. The management of the infield to maximize yield, the potential to store surplus, and the ability to put a greater emphasis on the "wild resource" in time of famine provided these early farmers with both resilience and sustainability. Subtle changes in management occurred over time, with the application of manure and other amendments to combat soil changes. Because of this strategy, life was sustainable even in the face of massive environmental change to the infield soils, caused by events such as sand movement. This strategy provided sustainability and resilience for several thousand years; the agricultural system inherited by Iron Age peoples in this zone represents the success of this strategy and provided a means to procure wealth and status in these later societies, as seen by the Broch settlement at Old Scatness. It is not surprising then to find sites like Old Scatness and Jarlshof as early centers of Viking settlement, as these islands of inherited agricultural resource would have been highly attractive to the new settlers (Bond 2003).

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Appendix 1. Radiocarbon chronologies.

Site	Sample code	Material	Context	Description/phase	Uncalibrated BP	Calibrated age range 1-sigma (68.2%)	Calibrated age range 2-sigma (95.4%)	$\delta^{13}C$ ‰
Tofts Ness, Sanday, Orkney	GU-2209	Collagen from bone (*Bos*)	039	Phase 1, Area A, from ash floor surface in Structure 1.	4430 ± 70	3330–3230 BC (20%); 3170–3160 BC (1.7%); 3120–2920 BC (46.5%)	3340–2910 BC	-18.3
	GU-2210	Collagen from bone (*Bos*)	054	Phase 1, Area A, from primary cultivated midden.	4480 ± 70	3340–3080 BC (65.2%); 3050–3030 BC (3.0%)	3370–3000 BC (89.1%); 2990–2920 BC (63.0%)	-20.1
	GU-2205	Collagen from bone (*Bos*)	031	Phase 1.3, Area A, from primary midden.	4270 ± 50	3000–2990 BC (0.9%); 2930–2860 BC (53.8%); 2810–2760 BC (13.5%)	3030–2840 BC (72.9%); 2820–2470 BC (17.3%); 2730–2670 BC (5.2%)	-19.1
	GU-2366	Collagen from bone (*Bos*)	1013	Phase 1.3, Area A, from primary midden.	4350 ± 90	3270–3240 BC (3.1%); 3100–2880 BC (65.1%)	3350–2700 BC	-22.1
	GU-2367	Collagen from bone (*Bos*)	1022	Phase 1.3, Area A, from primary midden.	4220 ± 50	2910–2850 BC (26.1%); 2810–2750 BC (32.5%); 2730–2700 BC (9.6%)	2920–2830 BC (34.0%); 2820–2630 BC (61.4%)	-22.0
	GU-2368	Collagen from bone (*Bos*)	1111	Phase 1.3, Area A, from primary midden	4020 ± 70	2840–2810 BC (3.5%); 2670–2460 BC (64.7%)	2900–2300 BC	-20.9
	GU-2369	Collagen from bone (*Bos*)	1123	Phase 1.3, Area A, from primary midden.	4240 ± 80	2920–2830 BC (27.9%); 2820–2670 BC (40.3%)	3030–2570 BC	-22.3
	GU-2105	Collagen from bone (*Bos/ Ovis*)	005	Phase 2, Area A, from later Neolithic midden.	3650 ± 50	2130–2080 BC (18.9%); 2050–1940 BC (49.3%)	2200–2170 BC (1.6%); 2150–1890 BC (93.8%)	-22.6
	GU-2206	Collagen from bone (*Bos*)	033	Phase 2, Area A, from later Neolithic midden.	4160 ± 90	2880–2830 BC (13.7%); 2820–2630 BC (54.5%)	2920–2480 BC	-20.9
	GU-2362	Collagen from bone (*Bos*)	025	Phase 2, Area A, from later Neolithic midden.	4230 ± 90	2920–2830 BC (25.3%); 2820–2660 BC (42.9%)	3100–2500 BC	-20.8
	GU-2364	Collagen from bone (*Bos*)	194	Phase 2, Area B, from later Neolithic midden.	3550 ± 90	2020–1990 BC (4.7%); 1980–1750 BC (63.5%)	2140–1660 BC	-21.9
	GU-2104	Collagen from bone (*Bos*)	106	Phase 3, Area B, early Bronze Age midden infilling Structure 2.	3270 ± 50	1620–1490 BC	1670–1430BC	-22.1
	GU-2361	Collagen from bone (*Bos*)	012	Phase 3, Area A, from late midden.	3390 ± 60	1770–1660 BC	1880–1520 BC	-20.8

Site	Sample code	Material	Context	Description/phase	Uncalibrated BP	Calibrated age range 1-sigma (68.2%)	Calibrated age range 2-sigma (95.4%)	$\delta^{13}C$ ‰
	GU-2363	Collagen from bone (*Bos*)	191	Phase 3, Area B, from early Bronze Age midden.	3380 ± 70	1760–1660 BC (58.4%); 1580–1530 BC (9.8%)	1880–1510 BC	-22.3
	GU-2544	Peat	752	Phase 6, Area C, Early Iron Age from thin peat layer.	2470 ± 50	760–680 BC (22.9%); 670–510 BC (45.8%)	770–410 BC	-27.9
	GU-2183	Wood	SF3048	Phase 6.3, Area C, from floor deposit from Structure 5	2990 ± 100	1390–1080 BC (67.2%); 1070–1050 BC (1.0%)	1450–900 BC	-24.9
	GU-2208	Collagen from bone (*Bos*)	700	Phase 6.4, Early Iron Age, Area C, from midden material butting the rebuilt annexe wall.	2470 ± 50	760–680 BC (22.9%); 670–510 BC (45.8%)	770–410 BC	-21.4
	GU-2207	Collagen from bone (*Bos*)	575	Phase 6.4, Early Iron Age, Area C, from secondary wall core, Structure 5.	2510 ± 140	800–480 BC (62.1%); 470–450 BC (1.9%); 440–410 BC (4.1%)	1000–350 BC (93.2%); 300–200 BC (1.8%)	-22.0
	SRR-5256			Buried soil, Mound 11, depth 36-41cm.	2665 ± 40	890–875 BC (7.1%); 845–795 BC (61.1%)	910–790 BC	
	SRR-5247			Buried soil, Mound 11, depth 55-60cm.	3140 ± 40	1490–1470 BC (5%); 1460–1380 BC (63.2%)	1500–1310 BC	
	SRR-5244			Buried soil, Mound 4, depth 30-33cm.	2260 ± 45	400–350 BC (28.1%); 300–230 BC (39.4%); 220–210 BC (0.8%)	400–200 BC	
	SRR-5245			Buried soil, Mound 4, depth 50-53cm.	2980 ± 60	1320–1120 BC	1390–1020 BC	
	SRR-5242			Buried soil, Mound 8/1, depth 36-41cm.	1755 ± 45	AD 220–350 (66.6%); AD 370–380 (1.6%)	AD 130–400	
	SRR-5243			Buried soil, Mound 8/1, depth 108-113cm.	3440 ± 90	1890–1640 BC	1980–1520 BC	
	SRR-5248			Buried soil, Mound 8/2, depth 59-64cm.	2880 ± 40	1130–1000 BC	1210–920 BC	
	SRR-5249			Buried soil, Mound 8/2, depth 78-83cm.	3360 ± 45	1740–1710 BC (10.3%); 1700–1600 BC (53.0%); 1570–1560 BC (3.1%); 1550–1540 BC (1.8%)	1750–1520 BC	

Site	Sample code	Material	Context	Description/phase	Uncalibrated BP	Calibrated age range 1-sigma (68.2%)	Calibrated age range 2-sigma (95.4%)	$\delta^{13}C$ ‰
Jarlshof, Shetland	GU-12914	Charred barley	011	Upper midden band: dark sandy silt loam; middle context in a band of midden layers which seals and is sealed by windblown sand	3260 ± 35	1610–1490 BC	1620–1440 BC	-25.2
	GU-12915	Charred barley	017	Lower midden band: the upper part of a dark band of deposit with midden-like characteristics. Interpreted as the early midden, the upper part of which has been ploughed.	3370 ± 35	1740–1710 BC (8.6%); 1700–1620 BC (59.6%)	1750–1600 BC (87.2%); 1590–1530 BC (8.2%)	-24.3
	GU-12916	Charred barley	019	Lower midden: sandier layer of midden, under [017], sealing a ploughed midden layer [021].	3455 ± 35	1880–1840 BC (19.2%); 1820–1790 BC (8.8%); 1780–1730 BC (30.1%); 1720–1690 BC (10.2%)	1880–1680 BC	-25.4
Old Scatness Broch, Shetland	GU-11534	Sheep (*Ovis*) metatarsal	5265	Date of Broch construction	2225 ± 40	370–240 BC (11.3%); 310–200 BC (56.9%)	390–200 BC	-21.0
	GU-9871	Charred barley	2060	Dark brown buried soil	1900 ± 50	AD 20–40 (2.9%); AD50–140 (53.7%); AD 150–170 (6.2%); AD 190–210 (5.3%)	AD 1–240	-25.0
	GU-9872	Charred barley	2062	Bright brown buried soil	2185 ± 55	360–270 BC (36.4%); 260–170 BC (31.8%)	390–90 BC	-24.5
	GU-9873	Charred barley	2063	Bright brown buried soil	2230 ± 40	380–350 BC (15.0%); 300–200 BC (53.2%)	390–200 BC	-23.1
	GU-9874	Charred barley	2064	dark silver sands	2220 ± 55	380–340 BC (12.2%); 320–200 BC (56.0%)	400–160 BC	-22.8