The Spatial Dimensions of Population Growth and Decline: Using GIS and Remote Sensing to Understand Landscape and Demographic History in Orkney, Scotland.

Tim Murtha, Pat Johnson, Jim Wood, and Stephen Matthews
Pennsylvania State University
University Park, PA 16802

Short Abstract:
Between 1750 and 2000, Orkney, Scotland underwent a major cycle of population growth and decline. After several hundred years of a stable population regime, the islands experienced significant population growth until 1850 (roughly), followed by severe decline. The modern demographic transition in Orkney, which contributed to this population decline, was atypical in several respects: it was late, the decline in fertility preceded that in mortality, and the transition was accompanied by massive net out-migration, all of which led to progressive depopulation of the islands. Our project is investigating these population dynamics within the context of significant landscape and environmental changes, influenced by a shift from near-subsistence farming to modern, commercialized livestock rearing. Here, we use historic cadastral maps, GIS, and remote sensing to interpret the spatial dimensions of these historic changes. We compare historic population patterns to changing patterns of land use and land cover in order to better understand the interwoven dynamics of population and landscape history from 1850 until today.

Draft: Dated 9/11/2009: Please do not cite or reference this draft. Final paper will be available at: https://www.larch.psu.edu/tim-murtha on 9.30.2009.

Introduction:

Between 1750 and 2000, the northern islands of Orkney (Scotland) underwent a major cycle of population growth and decline. After several hundred years of what was a presumably stable population regime, these island communities experienced sustained population growth between 1780 and 1850 (roughly), followed by severe population decline. The modern demographic transition in Orkney, which contributed to this population decline over the past century, was atypical in several respects: it was late, even by northern Scottish standards, the decline in fertility preceded that in mortality, and the transition was accompanied by massive net out-migration, all of which led to progressive depopulation of the islands.

The North Orkney Population History Project is attempting to understand these population dynamics within the context of the transition from near-subsistence farming to modern, commercialized livestock rearing. Unusual for historical demography, we are linking parish records, census data, and vital registers to historic archaeological and geospatial information on houses, farmsteads, and the past environment, as well as ethnographic/oral history material on local people's perceptions of change over the past 80 years or so.

In this paper, we use historic cadastral maps, GIS, and remote sensing to model the spatial and temporal dimensions of landscape history. We then compare and interpret how changing population patterns influenced and were influenced by historic land use and intensification patterns. We offer that information from historical demography can be more effectively integrated into broader anthropological and environmental research questions. We use these data to demonstrate that combining historical demographic data with historic cadastral data and remote sensing provides a unique method for linking land-use and environmental change with population dynamics on a landscape scale. Finally, we demonstrate how closely linked population history is to landscape history in Orkney.

Background:

The islands included in our study (Westray, Papay, Faray, Eday, Sanday and North Ronaldsay) form a natural cluster north of Mainland Orkney where the North Sea and the North Atlantic meet **(figure 1)**. A total of about 1300 people inhabit the islands today, substantially

fewer than the peak population of 6062 in 1861 **(figure 2)**. Today, settlement is somewhat discontinuous, with individual homes and farmsteads scattered across the landscape. Villages or towns are present on the two largest islands, Sanday and Westray, but the islands are dispersed and quite rural. Over the years, inhabited farmsteads have been improved but the great majority of modern farms are located on (Old Norse) named farm sites that predate the eighteenth century. Additionally, abandoned farms, inhabited up until the 20th century, still contain original farm buildings and farm features in various states of archaeological preservation. So, while in the last several centuries, individuals and families appear to be relatively mobile, farmsteads and their physical remains exhibit remarkable stability. And since farm names were used regularly in censuses, vital registers, rentals, tax rolls and other old documents, we can trace the movement of families across the landscape with relative ease for the entire period of our study (Note: as long as they remain in the known universe).

Until recently, agricultural production in Orkney was geared to meet household needs. This system relied on a delicate balance of grain production and livestock raising for household consumption needs and rent. And while the spatial patterns of agricultural production changed significantly in the 19th century, the core techniques and products did not change from the early medieval period until the mechanization of agriculture in the 20th century. However, significant reorganization of the spatial structure (in terms of size and distribution of plots) of agriculture took place in the 19th century, which made that delicate balance increasingly fragile and may have contributed to a reorganization of labor and settlement on the islands. One could also argue that these changes influenced the pace and structure of the subsequent population decline[1]. They also had a measurable effect on landscape.

Understanding these changes in the 19th century is a key component of our research and the starting point for this paper. The reorganization that occurred was largely the result of a previous period of economic growth that began in 1780. The boom, driven by kelp collection and processing, provided alkali for the British glass, soap, and dye-making industries on a

[1] The reorganization of agriculture essentially shrunk the amount of arable land and available pasture each household had access to, thereby creating a very strong incentive to out migration. Clearly this is an issue in many parts of Europe during the early part of the 20th century and a larger economic issue, but locally the conditions of agriculture were extremely fragile.

'commercial scale', but also required a great deal of labor. Due to this economic impetus, much of Orkney experienced a near doubling of population between 1780 and 1830 (Sparks 2007; Thomson 1983, 2001). The kelp boom persisted in Orkney until 1830, wherein the British government lifted several tariffs on the importation of alkali, sending the price of kelp spiraling in Orkney and leaving the islands with large pools of labor on a relatively un-intensive agrarian landscape.

After the kelp boom crash, landlords struggled for a couple of decades to manage their lands without any viable export. Following reorganization principles from mainland Scotland and beginning around 1840, landlords initiated a substantial period of farm reorganization, enclosure of common pasture, construction of new drainage systems and a general intensification of production **(figure 3)** (Sparks 2007). This period was accompanied by moderate population growth, until 1880 when prices of grain and cattle experienced a downturn. From 1880 until today, the northern islands have witnessed sustained depopulation. 1880 (roughly), therefore is a critical period of time and likely relates (roughly) to the peak period of population and land use in Orkney[2]. During the 20th century, agricultural production in Orkney has become increasingly specialized. The mechanization of farms, increased export of resources, and depopulation has resulted in an agrarian landscape wholly dominated by livestock production[3].

Modern depopulation and commercialization of farming in Orkney have also been accompanied by unique land cover changes (at least by Scottish standards). In the latter part of the 20th century, there was an increase in smooth grassland and a decrease in arable land. Smooth grassland, which includes pasture and land used for silage, grew from 12% to 47% of Orkney's land cover between the 1940's and the 1980's (Lee 2007). Conversely, arable land, fields specifically devoted to temporary crop production decreased from 35% to 25%. All

[2] Before undertaking this study, we presumed that the peak period of occupation would have been directly related to the peak period of land use. Interestingly, this does not seem to be the case

[3] Agriculture is dominated by beef cattle production and supplemented by patches of sheep production.

grassland, which includes rough and intermediate grasslands or those not devoted to pasture and silage[4], grew from 27% to 66% of land cover (Mackey et al 1998).

These patterns are considerably different than those observed throughout mainland Scotland. Scotland as a whole witnessed increases in urban land (46% growth), arable land[5] (11 % growth), forest and woodland (>600% growth), while smooth grassland decreased by 11%. Heather and mire, which decreased by roughly 25% throughout Scotland, only showed modest decreases in Orkney (Mackey and Shewry 2003) **(figure 4)**.

To understand the interwoven landscape and population histories, we combine demographic information with geo-referenced historic cadastral and estate maps **(figure 5)**, local physical landscape data (such as soil and physiographic data), and remotely sensed data, including: historic and modern air photos (1985), and low resolution landsat (ETM and ETM+) imagery in order to model and interpret the landscape history of Orkney as related to land use/land cover. Adapting research methods used to interpret historic land use in Norway (Domaas 2007), we compare population change to changes in the quantity and quality[6] of land under cultivation. Simply, we are making a first stab at evaluating landscape history and environmental change in Orkney as it relates to historical demography.

We are addressing three questions in this paper:

1. *What areas in both quality and quantity were taken under production when population peaked in Orkney, during the 19th century? Also, what was the ratio and acreage of arable, pasture, and natural land.*
2. *How did these patterns change between the 19th century and today? Specifically we model land cover/land use for 1860, 1880, 1900, and after 1985.*
3. *How do these changes compare to Orkney's population history?*

There are six islands included in our overall study **(figure 1)**. While they are connected by regional demographic, social, and economic trends, each offers distinct environmental, social, and demographic patterns that we will expand this study to in future analyses. For this study, the

[4] These figures also include smooth grassland.
[5] There was also an accompanied 50% reduction in hedgerow length throughout Scotland.
[6] Primarily measured as pasture vs. arable.

specific area of interest is the island of Westray. We chose Westray primarily because of the availability and completed-ness of data[7]. To complete this study we used on two primary sets of data **(figure 6)**:

1. ***Historic Demographic Data compiled from census records and registry data from 1851 until the present.*** *These data provide us with the population history information for comparison.*
2. ***Land Use/Land Cover Data compiled from:***
    a. ***Historic cadastral maps from 1882, 1901, and prior to 1882.*** *These data provide us with the field boundaries and land use data for the period when Orkney's population was at its historic peak. Also, the pre-1882 map helps us to interpret the specific land use patterns observed in 1882 and 1901.*
    b. ***Modern land use patterns*** *interpreted from remote sensing, including aerial photos and LandSAT data. Physical landscape features derived from remote sensing and modern soil survey maps. Physical measurements including slope and aspect were derived from a DEM. These data are different from the LCS88 data produced by Scottish Natural Heritage, although the LCS88 was used to inform the coding.*

Methods

Without available aerial photography prior to the 1940's, we relied on a series of historic maps to generate past land use / land cover maps for Westray. Two sets of 1:2500 OSGB maps from 1882 and 1901 proved extremely valuable. These were enhanced by a review of a variety of detailed historic estate maps[8] **(figure 5)**. Using ArcGIS, the maps were scanned and georeferenced. Each feature (landscape and cultural) was digitized, geoprocessed, and geocoded. All of the maps are highly detailed and show not only individual farms, boundaries, agrarian improvements, and buildings, but also include information about land suitable for pasture

[7] In reality, the time allotted for this paper didn't allow for adequate comparative analysis.
[8] One map in particular, from 1859 provided an extremely useful survey for reconstructing land cover.

and arable land. Estate maps offer an extremely detailed description of land use and land cover, but unfortunately do not typically provide full coverage. Unlike the data for 1882 and 1901, we have incomplete coverage for 1859. For those areas of Westray without coverage in 1859, land cover and land use from 1882 was used as a substitute.

The maps were coded for three land use/land cover variables:

1. *Pasture Land*: Indicated on maps by hatching or coloring and typically associated with what would be considered intermediate grassland today;
2. *Arable Land:* Land improved for seasonal production of grains or turnips is typically enclosed and numbered; and
3. *Natural Land: Land in inaccessible areas such as cliffs or simply areas that were left fallow are indicated as cliffs, beaches, or wetland areas. While rough grazing could have occurred on these lands, similar to fallow lands today they are left as rough grasslands or heather and mire.*

Unlike traditional land cover studies that are typically focused on developed land change and loss or gain of natural habitat, we were not necessarily focused on accurately representing developed land or natural habitats. In other words, the data presented here may not be an accurate measurement of natural lands. Future work focused on different topics, such as the influence of these historic patterns on soil quality or habitat patterns would require a reassessment of natural land as described here (Domaas 2007). Past Land cover maps were generated for 1860 (roughly), 1882, and 1901. Interpreting 1985 aerial photos and LandSAT imagery from 1998 generated a modern LULC coverage. These data vary from the LCS88 data, in part because we could not distinguish between various grassland types for the historic periods. Population history was generated by linking published census data from 1851 to 1901 with civil registry data for the 20th century, (reported in Sparks 2007).

Results:

Land cover in 1860, roughly the peak period of population for Westray, was dominated by a relatively balanced distribution of pasture and arable land **(figure 7)**. Some parts of the landscape remained in natural conditions, but there is evidence of improvement of lands

accompanied by the partitioning of fields **(figure 8)**. Marginal lands, located on hill slopes and un-drained portions of the landscape were improved during this period, clearly associated with the adoption of smallholder principles from mainland. Decades later, many farmers considerd the 1850's and 1860's as the first modernization of farming in Orkney. In 1932, Corrigall reported that in the 1850s and 60s, *"…there came to the Orkneys large numbers of young men from Aberdeenshire and elsewhere, who took up farming on poor brecks [hills] or stiff clayey places, and although many of them did not enrich themselves, they undoubtedly showed the people here many better ways of farming and cropping the land"* (Corrigall 1932 in Lee 2007:98).

Between 1860 and 1882, Westray exhibits moderate change of both pasture and arable land. Arable land is slightly more represented, but because of the incomplete coverage from 1859 and the substitution of coding from 1882 the patterns are not significant enough to interpret change. However, between 1882 and 1901 significant improvement of lands and landscape change has occurred on Westray. Marginal lands, first improved in the 1860s and 1880s are expanded, such as those adjacent to hillslopes **(Fitty Hill shown in figure 9)**. Marshy areas are drained and squared to provide access to arable fields **(Rackwick shown in figure 10)**. And upland areas, previously left uncultivated are now squared and improved **(Rapness shown in figure 11)**.

Therefore, despite the arrival of improvement idea in the 1850's and 1860's, these data suggest that an extended smallholder influenced intensification of agriculture in the decades following the initial reorganization had occurred; And that this intensification was focused on improving previously uncultivable land between 1882 and 1901. This not only evident in the quantity and distribution of arable land, but the number of parcels (established by counting the polygons created by digitizing field boundaries). Between 1882 and 1901 a substantial number of new fields (or better, new field boundaries are constructed). Interestingly, the peak period of land use change corresponds to the beginning of sustained and severe depopulation **(figure 12).**

Between 1901 and the 1980's another shift in land cover and land use occurs, although the changes directly correspond to overall land cover patterns of change for Orkney as described by Mackey (Mackey et. al 1998). Westray exhibits two significant changes. First and most

significant is a decrease in the area covered by arable land cover/land use accompanied by an increase in grassland. Second, there is an increase in natural lands, which upon closer inspection indicates that marginal areas of Westray, brought under cultivation between 1860 and 1901 were left to grassland and subsequently have reverted back into more natural land cover[9].

Various explanations can (and have) be offered for the significant increase in grassland land cover for Orkney during the 20th century (see Lee 2007). But when these patterns are compared to population history, it is interesting to note that depopulation of Westray begins prior to the modern shift to grassland and actually is accompanied first by an *increase* in the quantity of arable land and arable fields. This is only then several decades later, followed by a sustained period of conversion to grassland and an overall decrease in arable land.

This grassland shift likely began around 1920 or 1930 as tenant farms became less profitable (Lee 2007). Most certainly, this shift was hurried by the mechanization of agriculture and the ability of small farms to capitalize[10]. It was a hotly debated topic in the 1920's when the choice between small and large farms was argued for and against in the *Journal of the Orkney Agricultural Discussion Society*. J. Johnston, clearly arguing the side of small farms, writes, *"Suppose we adopted large farms, what would happen to the many hundreds of acres now farmed by the smallholder? We all know that a very large part of it would revert to heather. There can be no doubt on this point. The crofter was the pioneer of Orkney farming. The big farmer would become famous in future generations as the farmer who conducted the great retreat, the retreat from the hillsides and uplands of our county."* (Johnston, 1927 in Lee 2007: 94).

As Lee (2007) correctly observes, the smallholder intensification of the previous decades was directly associated with the transformation of marginal lands to arable. And while Johnston's prediction of acres returning to heather didn't prove 100% accurate, it was insightful. The population decline and associated economic changes, including the mechanization of farms transformed the balance of land cover and land use in Orkney. At the turn of the century there

[9] Although these lands could likely be used for sheep grazing today.
[10] Eggs, eggs, eggs…

was roughly four acres of land (good or bad) per resident of Westray. Today, there are more than twenty acres of land per resident. In 1901 much of the landscape was arable, while today most of Westray is grassland.

It remains unclear if there is a direct influential relationship between population history and landscape history in Orkney and Westray, specifically. But these two issues are certainly entangled and perhaps both symptoms of larger historic economic patterns. A broader approach to our future analyses may help to better interpret these patterns. It will also provide us with the information to understand how each island adapted to these larger processes.

Future Directions

This is our first attempt to model landscape history in Orkney and compare it to the now well-documented population history. There are some clear future directions for the work.

1. To expand the historic land use/ land cover study to include all of the northern isles. This will not only allow us to compare how the variability in local environment influenced the spatial patterns or pace of landscape change, but also evaluate more localize trajectories of landscape change as related to the population decline **(figure 13)**.
2. To expand the analysis to include land use changes associated with other variables, such as the significant ecological change associated with peat excavation **(figure 14).**
3. To build a land cover/ land use coverage for the periods prior to 1860, relying on a patchwork of historic estate maps.

References:

Atkins, S. M., E. C. Mackey, and Scottish Natural Heritage. 1995. *The natural heritage of scotland : An overview*. Edinburgh: Scottish Natural Heritage.

Barclay, Robert S. 1965. *The population of orkney, 1755-1961*. Kirkwall Orkney: Kirkwall P.

Brennan, Ellen Rose. 1979. *Kinship, demographic, social and geographic characteristics of mate choice in a small human population*.

Domaas, Stein Tage. 2007. The reconstruction of past patterns of tilled fields from historical cadastral maps using GIS. *Landscape Research* 32, (1): 23.

Fenton, Alexander. 1978. *The northern isles : Orkney and shetland*. Edinburgh: Donald.

Lee, Jo. 2007. Experiencing landscape: Orkney hill land and farming. *Journal of Rural Studies* 23, (1) (1): 88-100.

Mackey, E. C., Mike Shewry, G. J. Tudor, and Scottish Natural Heritage. 1998. *Land cover change : Scotland from the 1940s to the 1980s*. Natural heritage of scotland. Vol. 6. Edinburgh: Stationery Office.

Mackey, Edward C., and Scottish Natural Heritage. 2001. *Natural heritage trends : Scotland 2001*. Perth: Scottish Natural Heritage.

Marwick, Hugh. 1952. *Orkney farm-names*. Kirkwall: W. R. Mackintosh.

Sparks, Corey Shepard. 2007. *Households, land and labor*, http://etda.libraries.psu.edu/theses/approved/PSUonlyIndex/ETD-2284/index.html.

Thomson, William P. L. 2001. *The new history of orkney*. 2nd ed. Edinburgh: Mercat Press.

———. 1987. *History of orkney*. Edinburgh: Mercat Press.

Tudor, G. J., E. C. Mackey, F. M. Underwood, and Scottish Natural Heritage. 1994. *The national countryside monitoring scheme : The changing face of scotland, 1940s to 1970s*. Battleby: Scottish Natural Heritage.

List of Figures: