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LANDSCAPE PATTERN AND CHANGE THROUGH INTEGRATION OF REMOTE SENSING AND STONE WALL FEATURE IDENTIFICATION

Rebecca J. Trueman
University of Rhode Island, rjtrueman529@gmail.com

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LANDSCAPE PATTERN AND CHANGE THROUGH
INTEGRATION OF REMOTE SENSING AND STONE
WALL FEATURE IDENTIFICATION

BY

REBECCA J. TRUEMAN

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE
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OF

REBECCA J TRUEMAN

APPROVED:

Thesis Committee:

Major Professor Yeqiao Wang

Peter V. August

Roderick Mather

Nasser H. Zawia

DEAN OF THE GRADUATE SCHOOL

UNIVERSITY OF RHODE ISLAND

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ABSTRACT

Stone walls are relics of an agricultural civilization that once flourished in New England. By identifying the locations of both historical and present day stone walls, compositions of post-agricultural landscapes common across the New England region can be assessed with inclusion of historic human-land use interactions. I selected the town of New Shoreham, known as Block Island, as the study site for this thesis. Block Island is located approximately 14.5 km south of the Rhode Island mainland. The Island has rich land use history which resulted in an extensive network of stone walls still present across the landscape. Through visual image interpretation of 0.5 ft (0.1524 m) resolution orthophotography collected in the spring of 2011 and a historical topographic map from 1900, I created two datasets of stone walls containing total lengths of 260.6 km and 349.1 km, respectively. Analysis of these two datasets allowed for a temporal analysis to then creation three additional datasets containing stone walls between 1900 and 2011 which were matching, removed and built.

The presence of stone walls on Block Island was quantified in connection to ancillary Geographic Information System (GIS) data, representing both natural and anthropogenic classifications of the landscape. The natural landscape is represented by land use and land cover (LULC) available for 1988, 1995, 2003/04 and 2011. Data of LULC were further quantified for land cover change frequency (LCCF); the number of land cover changes occurring within each 45 m pixel between 1988 and 2011. The anthropogenic landscape is distinguished by the parcel boundaries for New Shoreham as of 2013 and protected open space as of 2013.

The 2011 dataset of stone walls was quantified for stone wall distribution among each land cover class for the temporal range, finding a higher abundance of stone walls within agricultural lands for 1988 and 1995 and urban lands from 1995 through 2011. The 2011 stone wall dataset was also quantified for distribution among each land LCCF class to find a higher proportion of stone walls contained within lands with the greatest frequency of land cover change. A strong relationship exists between the coincidence of stone walls and the boundaries of land parcels. Approximately 81% of parcels are in part bordered by a stone wall from the 2011 dataset. Additionally, over 50% of the lengths stone walls within the 5 datasets of stone walls are bordering parcel boundaries, with the more current datasets of 2011, matching and built having over 80% of their lengths adjacent to the boundaries of 2013 parcels. Lastly, at least 37% of the stone walls current as of 2011 are expected to remain untouched due to being contained within land designated as protected open space.

Stone walls represent a human component, among the many broad factors which generate the composition of landscape mosaics. By utilizing abilities of GIS technologies to identify stone walls for a large geographic area, this research models initial exploration of the relationship between this historical feature and the landscape it continues to reside within. Additionally, this work adds justification to continue the integration of remote sensing technologies and human's cultural histories in studying driving factors of land cover change and anthropogenic landscape characterization.

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PREFACE

This document follows the standard thesis formatting requirements defined by the Graduate School of the University of Rhode Island.

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CHAPTER 1

INTRODUCTION

Overview

There are many unknowns pertaining to the land use history of New England prior to European settlement when the Native Americans occupied the lands, as well as what conditions truly define the natural environment prior to human alteration of the landscape (Foster, 1998 and Hammond, 2002). However, there is a clear distinction in the time period between pre- and post- intensive human-landscape interaction; when lands within New England were settled by Europeans and management of lands became well established on an annual basis. The documented record of human history dates back to include this relatively recent period of intensive human land use, allowing for studies which involve assessment of temporal trends in land development and alteration.

Geographic information systems (GIS) have emerged as useful tools in addressing landscape-level research questions (Turner et al., 1996). A GIS allows for integration of remotely sensed data in conjunction with ancillary data. Specifically, it is with use of a GIS that location-based data can be visualized and analyzed. Collections of remotely sensed ground imagery have been acquired throughout the past century and continue to advance in both data volume and data quality. Additionally, public interests in the field of historical landscape ecology continues to grow as seen through the pursuits of environmental organizations to use knowledge of past land use in conservation initiatives; in several cases relying on data available as a

result of the synthesis between GIS and human history (Hammond 2002). The abilities of spatial data analysis will greatly enhance the underlying purpose of this research, by allowing for an integrative method between knowledge of historical human land use and the temporal characterization of land. More specifically, a GIS will assist in identification of stone walls and exploration of the connection between stone walls and the natural and anthropogenic landscape.

The scope of this study is to assess the ability of human land use interactions to persist. Stone walls are indicators of human land use and through their identification I in turn identify locations influenced by the era of human settlement and agriculture. Additionally, by completing a temporal assessment of stone walls I am able to assess stone walls approximately two centuries after their initial mass creation. First, both current and historical distributions of stone walls were determined. These data were then be compared with a temporal compilation of the natural landscape as based on land cover classifications from 1988 to 2011, and the human defined landscape as based on property ownership as of 2013 and lands in protected open space as of 2013. This integration will further study these historical features by assessing the spatial relationships between the temporal distribution of stone walls and the present and more recent landscape in which they reside.

Stone walls have previously been considered as a factor in studies pertaining to historical land use and change (Cronon, 2011) as well as landscape characterization (Wessels, 1997). However, few landscape studies solely focus on stone walls as features in their own right. Specifically, the temporal distribution of stone walls and the spatial connection between these features and the present day landscape. Through

making use of GIS technologies, stone walls are able to be temporally identified with historical data and aerial imagery. This identification allowed for this research to focus on both temporal change to the distribution of stone walls and an initial assessment of the relationship between stone walls and the more recently characterized landscape.

Hypothesis:

1. The temporal pattern of stone walls can be determined through use of historical maps and remote sensing data.
2. Present and more recent characterizations of the landscape can be assessed with inclusion of the temporal placement of stone walls.

History and Function of Stone Walls

In present day New England, stone walls are the most noticeable relics existing as evidence of the historical agricultural civilization that once flourished between the 18th and 19th centuries. Stone walls exist in New England as products of the integrated histories of nature and humans. There were several factors which lead to the formation of stone walls. Additionally, the function of these walls has changed over time.

Stone walls are composed of till stones. These stones are a product of New England's geologic setting. The Laurentide Ice Sheet retreated from Rhode Island about 20,000 years ago (Boothroyd, 2002). This glacier completely reworked the New England landscape, burying an abundance of ablation till under the surface at varying depths. Additionally, the New England climate has seasonal temperature variations which result in yearly cycles of ground freeze and thaw. The combination of these geologic and climatic factors allowed for the process of frost heaving to occur which

results in the surfacing of buried till stones through swelling and settling of the surrounding soil.

Due to large scale agricultural practices under way in the late 1700s and early 1800s, these stones began to emerge on the soil surface at a high rate. This emerging was predominately a result of the forest clearing taking place which was the first major anthropogenic interaction to result in soil destabilization (Thorson, 2009). However, use of plows enhanced the mechanisms causing stone surfacing by increasing the water holding capacity of the soil allowing for a greater magnitude of frost and thaw to take place.

Every spring these till stones emerged throughout fields and pastures in substantial quantities. To rid the fields of stones they were stacked around the boundaries of fields and properties and eventually formed into walls and fences. This was a process which was completed with use of tools to break and shape the stone, oxen to haul piles of rock and human labor to pick the rocks and form the walls. The overarching reason for the creation of stone walls was to serve as “linear landfills” (Thorson, 2009). At first, most stone walls were formed in conjunction with existing wood fencing. However, as settlements expanded and both resources and social mentalities changed, so did the function of stone walls.

After initial settlement people lived in communes where lands and property was shared, but after time people saw the value in personal property ownership and had the desire to clearly define their property boundary from that of their neighbors. Additionally, there was a need to create fences for the purpose of keeping animals in the confines of their owner’s fields and out of the fields of nearby farmers (Allport,

1990). Good fences make good neighbors became a common sentiment among New Englanders (Frost, 1914). Coinciding with these changes was also a reduction in the abundance of available forest resources, which at first were seemingly endless. Fences first built by the settlers were made mostly of wood. However, wood fences would easily rot and need to be replaced. By the mid-1800s forest abundance in New England was at a minimum of about 20% (Bellemare, 2002). Additionally, New England was dominated by fields, pastures and woodlots (Foster 1998). Ultimately it was the combination of factors: the seemingly endless amount of available stones, the increased need to fence one's property from their neighbor, the breakdown of wood fences and the reduction of available forest materials that led to the increased reliance of stones to be shaped into stone fences.

As the function of stone walls increased so did the value placed on them. The blueprint for building a stone wall would vary based on its purpose. Some stone walls were formed with additional precision such as wall ends separating a path or property as well as those more likely to be seen by those visiting from out of town. Some walls served as property boundaries while others were built to hold sheep and cattle (Allport, 1990).

In a day an individual could build about 5 m of wall while a team could form up to 60 m (Thorson 2009). It has been estimated that in 1871 there were 406,422 km (252,539 miles) of stone walls existing within the northeast (Allport, 1994 and Thorson, 2009). At this time farming was beginning to decline in New England and farmers were moving both to the mid-west where soils and equipment were better for

intensive farming and into cities where the industrial revolution created opportunities (Jeon, 2014).

In the years since agriculture decline, old pastures and fields have been overtaken by second growth forest and expanding urbanization. However, the stone walls remained and the same walls remain to this day; except for those which were altered from natural mechanisms or due to human interference. These stone walls still identify distinctions in property boundaries and land use; the latter likely a result of the former. Additionally, stone walls have continued to be built but their function is generally for aesthetic purposes to highlight property (Allport, 1990). Stone walls also serve the function of creating their own environments at a local scale where they provide habitat and refuge for small mammals, repositories for nuts and seeds and a microclimate conditions for young low lying vegetation to settle (Thorson, 2009 and Collier, 2013). Stone walls are a part of a social value that exists for many native New Englanders. A value transcended from our ancestors that serve as a reminder of a time filled with challenges, hardship and most importantly opportunity and perseverance.

The Landscape and Anthropogenic Land Use

A landscape is a product of multiple factors pertaining to natural abiotic and biotic conditions as well as human interactions, specifically anthropogenic land use (Turner, 2001). The combination of these factors results in the landscape as a mosaic of patches. These patches can then be studied as based on their structure, function and change which is what landscape ecologists focus on for the purpose of assessing how the configuration of landscapes results in ecological processes over time (Turner, 2001).

Humans have long been an integrated part of the environment and human manipulation of the landscape has lasting effects (Foster, 1998 and Turner, 2001). The task of deconstructing a temporally rich and complex landscape and identifying change through time is fundamental to the understanding of past human activity (Lock et al., 2002). Additionally, studies in ecosystems must consider the legacy effects of historical human land use (Foster, 1998 and Motzkin, 1996).

Previous studies of historical anthropogenic land alteration as based on examination of records, documented recollections, and *in situ* research has led to a much fuller comprehension of the present day landscape configuration and how the land cover mosaic has transitioned over time as based on both natural and human disturbances (Foster et al., 1998). Investigations of land use history have increased knowledge on the development of vegetative land cover, response of vegetative communities to both novel and natural disturbances, and new perspectives to be used in landscape management (Foster, 1992).

Specifically, in New England, various studies have assessed consequences of historical agricultural land use through characterizing temporal structure and function of these landscapes. Studies focused on soil structure and chemical composition, vegetative composition, and resistance to disturbance, determined that past land use does influence compositions of subsequent landscapes (Foster, 2003 and Flinn, 2005).

While initial site conditions can be a defining factor in determination of land cover, land ownership can also play a crucial role by altering the spatial extent of land use (Foster, 1992). Social and economic considerations are among the most important

drivers of landscape change, yet few studies have addressed both economic and environmental influences on landscape structure, and how land ownership may affect landscape dynamics (Turner, 1996).

When stone walls were originally placed on the landscape they formed borderers around fields and properties. This notation is still very evident within the study site. Through a simple overlay of the parcel boundaries in New Shoreham and present day aerial imagery, stone walls clearly coincide with these boundaries. This initial relationship makes clear that the interaction between nature and humans, which characterized the historical anthropogenic landscape, resulted in landscape alteration which has persisted in some capacity to the present day and promotes further investigation.

Remote Sensing

The acquisition of land cover imagery using remote sensing began with aerial images captured by planes pre-1900's and made huge advances in the 1970's with use of satellites to capture multi-band imagery of the globe. Commonly acquired are ground reflectance values in the red, green, blue and thermal bands of the electromagnetic spectrum but there are several other possibilities. Through post-processing and rectification, data are delivered to the user as pixelated images in which each pixel's location is associated with its x-y location on the ground and the size of each pixel correlates with the resolution of the receiver which acquired the data. Collection of both aerial and satellite imagery has continued to advance in detail by means of increasing number of spectral bands, resolution and positional accuracy.

Remote sensing data acquisition has ultimately resulted in a collection spatial data containing several decades of land cover and equally essential recent high resolution data sets. The consortium of federal agencies, which produce high resolution imagery of the Earth's surface, do so in part to assist in studies which focus on land cover change (US EPA, 2014). Available data used by those in the field of remote sensing for landscape analysis, has greatly enhanced scientific understanding of environmental change.

The use of satellite-based remote sensing data has been determined to be a cost-effective approach to document changes over large geographic regions (Lunetta, 2004). This can be more recognized through review of temporal land cover change studies (Yang et al., 2014). In this study, classification and determination of landscape change occurred through use of the pre-classified land cover imagery derived from aerial photographs. "Aerial photographs provide the largest source of information available today for research of long-term vegetation dynamics, and are the only source of information on vegetation dynamics that combines high spatial resolution, large spatial extent, and long-term coverage (Kadmon et al., 1999)." In today's world of remote sensing, aerial photography is just one of the many sources of data which researchers can use for landscape studies. The integration of data captured through Light Detection and Ranging (LiDAR) as well as unmanned aerial vehicles (UAVs) into landscape analysis could have major implications on research findings; advancing the scope of studies both in depth and spatial extent.

METHODOLOGY

Study Site: New Shoreham, Rhode Island

I selected the town of New Shoreham, also known as Block Island, as the study site. Currently, the Island is located 14.5 km south of the Rhode Island mainland. Geologically, New Shoreham is located just north of the Late Wisconsinan terminal moraine that retreated approximately 18,000 years ago (Boothroyd, 2000). While the Island had been inhabited by the Manisseans, a Niantic tribe of the Native Americans, for at least two centuries prior to European settlement, the first documentation of the Island was written by Giovanni da Verrazzano in 1524. The Island was officially settled in 1661 by a group of 16 men from the Massachusetts Bay Colony (Rosenzweig et al., 2000). Block Island is an ideal study site for assessing the connections between the historical anthropogenic land use and characterizations of the temporal landscape.

The general patterns of land use history on the Island was very reflective of mainland New England. This includes inhabitation by settlers from Europe, massive forest clearing and intensive agriculture and husbandry (Livermore, 1886). Combined factors of geologic history and human land use history resulted in the creation of stone walls on Block Island, just as in other areas which also contain stone walls throughout New England.

While New Shoreham does possess a similar characterization and history as the mainland, there are variations related to New Shoreham's island geography. Initially, Block Island was covered in dense forest. However, these resources quickly dwindled for their use for fencing, building materials and fuel (Livermore, 1886). It is

evident that these original forests never recovered so between initial loss of timber and 1750 residents were unsure of their future on the Island (Livermore, 1886). However, in 1750 peat became a valuable fuel source with coal becoming viable in 1846 (Livermore, 1886). Other main resources valuable to the productivity of the Island include seaweed for fertilizer and the fisheries (Livermore, 1886). New Shoreham has an extensive record of its history. This includes a complete knowledge of settlement, land distribution, establishment of organizations, agricultural practices, day to day culture and social etiquette. By choosing Block Island as the study site for this thesis research, the full assessment of a geographically separate area can be studied.

Recently, Block Island has been named by the Nature Conservancy as one of “The Last Great Places” in the Western Hemisphere, increasing the spotlight on this 6,200 Ha Island (Paton et al., 2001). This recognition only worked to enhance the culture of tourism which accompanies the Island every summer. Additionally, there are over 10 environmental organizations which together conserve and protect over 40% of the Island’s land (The Nature Conservancy, 2014). These facts exemplify this site as an area of scientific interest.

From a remote sensing standpoint, Block Island is an ideal location for conducting this research. Not only is there an extensive spatio-temporal dataset exists for Block Island but the land cover on Block Island also has its advantages for stone wall identification. Over 15% of the area on Block Island is maintained as areas of pasture and open fields. Additionally, the abundance of forest regrowth that took place throughout New England didn’t occur on Block Island and therefore, areas of regrowth are not as densely concentrated. Both of these factors increase visibility of

stone walls within the aerial photography. The most important factor to the selection of Block Island is the Island's clearly abundant concentration of stone walls; representative of the landscape of the southern New England region. In 1886 it was estimated that over 482 km (300 miles) of stone wall were contained on Block Island (Livermore, 1886).

Data Sources

Imagery

Imagery acquired and available from the Rhode Island Geographic Information System (RIGIS, <http://www.edc.uri.edu>) database for the years 2003, 2008 and 2011 was used for identification of stone walls and the creation of the 2011 stone wall dataset. The 2003/04 true color digital orthophotography was produced at a 0.6 m pixel resolution with map accuracy for a 1:5000 scale of plus or minus 3-5 meters. The 2008 imagery was available from RIGIS through ARCGIS' Online server for viewing. These data were collected at a 0.10-m pixel resolution. The 2011 digital Orthophotography was collected at a 0.15-m pixel resolution and compiled to meet a 0.762 m (2.5 foot) horizontal accuracy at 95% confidence level based on NSSDA (National Standard for Spatial Data Accuracy) testing guidelines. The 2011 orthophotography was the initial imagery used in stone wall identification (Figure 1) and the other datasets were used for verification and to add in stone walls missed. The 2008 imagery is of a higher resolution than the 2011 and therefore, stone walls are more visible particularly under canopy. In addition, use of Google Earth allows for ground views of areas which was specifically helpful for identification of stone walls around roads and other man-made landscape features.

Land Cover Data

The RIGIS database contains land cover maps for the years 1988, 1995, 2003/04 and 2011 derived from image interpretation and classification processes. LULC data was classified with a minimum mapping unit (MMU) of 0.5 acres. The MMU refers to the smallest size area entity to be mapped as a discrete area (Saura, 2002). These land use and land cover maps were used in this study to complete a temporal analysis of land cover change. Data are characterized to the U.S. Geological Survey's classification system (Anderson et al., 1976). All four datasets are available as an Anderson Level III classification.

Additional Datasets

Determination of the distribution of historical stone walls was based on the information presented within a historical topographic map from 1900 provided by the Town of New Shoreham (Figure 2). Also, provided by the town was the parcel boundaries dataset current as of 2013 (Figure 3) and protected open space data current as of June 2013 (Figure 4).

All data were either downloaded in or re-projected to the NAD 1983 Rhode Island State Plane Foot Coordinate System (Table 1). The RIGIS database is an online service used to obtain data for this project. The RIGIS database is freely accessible to the public and allowed for analysis at the appropriate scales of this study.

Identification of Stone Walls

Methods to the practice of feature identification vary based on the quality of data utilized and purpose of identification. Common practice to identification involves digitization of features by manual delineation through user visualization and pattern

recognition. Visualization of the data is a powerful way to utilize perception of the human eye for detection of features on the landscape, especially at the size of narrow linear, man-made features. Other method of automatic extraction were explored but since accuracy was a high priority for this study, delineation was adopted to identify and extract stone wall information contained within the dataset of 2011. Due to the high spatial accuracies of the 2011 orthophotography stone walls are able to be clearly visible in open fields, urban areas and under canopy (Figure 5).

Stone Walls and Land Cover Change

To assess temporal distributions of stone walls on the landscape, determination of the temporal distributions of land cover classes and quantification of the frequency of land cover change was completed. To determine distributions of temporal land cover, the four sets of pre-classified land cover data from 1988 to 2011 were normalized. To best represent the variation in the datasets and for simplification purposes of this research, all land cover classifications were normalized to an Anderson Level I (ALI) (Table 2). Datasets were originally classified to a MMU of 0.5 acres. To be conservative all LULC datasets were converted to a resolution of approximately 45 m to represent the size of the MMU. Temporal distributions of stone walls for each of the 7 land cover classes for each dataset within the temporal range were quantified by calculating the length of stone wall within the area of each land cover class.

Temporal frequency refers to the rate at which change events occur; ecosystem and/or anthropogenic (Lunetta, 2004). Land cover classification datasets for 1988, 1995, 2003/2004 and 2011 normalized to an AL1 coding were used to quantify land

cover change frequency (LCCF). Mapping units from each date were subtracted from the preceding date in the series (e.g., 1995 minus 1988, 2003/04 minus 1995 and 2011 minus 2003/04). Raster images were then reclassified to a 0 or 1 where a 1 represented any value other than 0 (i.e. change occurred). Mapping units were classified as based on the amount of times each mapping unit changed by performing summation of the resulting reclassified raster files. The final raster of change contained classes with values ranging between 0 and 3, where a 0 represents no change in land cover between 1988 and 2011 period and a value of 3 represents change occurring between each time period. Distributions of stone walls for each LCCF class were quantified.

Since little is known about the geographic range in influence stone walls may exhibit in a landscape, another assessment was done at a more local scale. This could assess if stone walls are more likely to be contained in areas with less overall temporal land change due to the expected outcome that lands around stone walls change less than those not adjacent to stone walls. To do this comparisons were made between the magnitude of LCCF around stone walls to areas where stone walls are not present to assess the connection between stone walls and frequency of land cover change at a more local scale. To do this stone walls from the 2011 dataset were converted to points by separating stone walls into individual line segments and adding a point in the center of each stone wall. Those points were then buffered by 15 m. Then a random point dataset was created containing the same amount of points (3,135) at least 30 m away from any stone walls to ensure there would be no overlap in buffers. Random points were buffered 15 m. The raster dataset of LCCF was used to obtain information within the areas defined by the stone wall buffers and the random stone wall buffer

individually. Total frequency values within the buffers were summed and normalized by area of land within each individual dataset.

Stone Walls and the Human Defined Landscape

Stone walls were assessed with 2013 parcel boundaries for the town of New Shoreham. Coincidence of stone walls for 2011 and present day parcel boundaries was quantified by determining which parcel boundaries are adjacent to a stone wall within 3 meters. Then determined was the total individual parcels involved in this intersection. Also, quantified was the amount of stone walls within each of the 5 datasets (2011, 1900, Matching between 2011 and 1900, Built after 1900 and Removed after 1900), which are bordered by a parcel boundary from the 2013 dataset. The protected open space dataset current as of 2013 was integrated with the 2011 stone wall dataset. The abundance of stone walls contained within these areas was quantified.

Ground Truthing

Ground truthing of stone walls took place on Block Island during the summer of 2014. This occurred with use of a 2008 Trimble GeoXT running Terrasync Pro 5.6 with an accuracy of <1meter differential correction. The approximate vertical and horizontal distance that stone walls were set away from the receiver was set for additional location accuracy. Most of the stone walls surveyed were located along roads where I was able to easily find and record their locations. Additionally, I was able to access several stone walls located in Lewis Farm which is contained in protected open space in the southwest corner of the Island. The software Terrasync Pro 5.6 was used to convert the features collected into a shapefile which could be

exported and read by ESRI's ArcMap. An accuracy assessment was done to determine the accuracy of the 2011 stone wall dataset based on the stone walls identified in the field which were not within the dataset. However, since I was only able to survey a sampling of the stone walls, I was not able to determine which stone walls in the dataset are not located on the ground.

RESULTS

Temporal Distribution of Stone Walls

Amounts and locations of stone walls on Block Island was determined for both the year 1900 and 2011. A 1900 historical topographic map was used to identify the 1900 distribution of stone walls (Figure 2). Dashed lines of stone walls were manually digitized from the topographic map to create a standalone dataset containing 349.1 km of walls (Figure 6). Determination of stone walls as of 2011 was completed through visual image interpretation and pattern recognition of the 2011 orthophotography, 2008 aerial imagery and online resource checking with use of Google Earth. Stone wall abundance as of 2011 totaled 260.6 km (Figure 7). This resulted in a stone wall density of 14.2 km/km² and 10.6 km/km² for the 1900 and 2011 datasets respectively.

Identification of stone walls current as of 1900 and 2011 into two separate datasets allowed for determination of changes to stone walls between the two dates. Matching stone walls totaled 195.8 km (Figure 8), stone walls built between 1900 and 2011 totaled 65.3 km (Figure 9), and stone walls removed between 1900 and 2011 totaled 153.3 km of wall (Figure 10). Distributions of matching and removed stone walls are spread throughout the extent of the Island with no evident spatial pattern. The built stone walls showed a clear connection with roads. Within the dataset, 27.1 of the 65.3 km (43%) of built stone walls are parallel and within 10 m of current roads on the Island.

Stone Walls and Temporal Land Cover

Land cover classifications at an AL1 coding system for 1988, 1995, 2003/04 and 2011 are illustrated in Figures 11-14 respectively. From 1988 to 2011 the total land cover change as based on distribution of the 7 AL1 land cover classes is approximately 31% (Table 3). That is the sum total of change by taking the absolute value of the difference in percentage between 1988 and 2011. This is comparable to the total change for all of Rhode Island quantified in the same way which was also approximately 31%. In New Shoreham urban land was the most abundant land type which also increased from ~25% in 1988 to ~37% in 2011. This is comparable to the state of Rhode Island as a whole which contained ~27% urban land in 1988 and increased to ~28% in 2011. However, the dominant land cover in Rhode Island is forest with ~44% in 1988 and increasing to ~58% in 2011. New Shoreham contained ~19% of forest land in 1988 which increased to ~22% in 2011 (Table 3). In year to year trends are broken out into a bar graph and line graph to show that throughout the temporal range urban, forest and water increased while agriculture, bushland, wetland and barren lands decreased (Figure 15 and Figure 16 respectively).

The distribution of stone walls for each land cover class for the temporal range was quantified (Figure 17). Distribution of stone walls from the 2011 stone wall dataset generally mirror distributions of land per each land cover class (Figure 18). However, through a calculated z test for 2 population proportions there are significant results to support that stone walls are more abundant in some land cover classes while less abundant in others throughout the time range. Specifically, the analysis did find a higher abundance of stone walls within agricultural lands for 1988 and 1995 and urban lands for 1995 through 2011. Additionally, found was that a lower proportion of stone

walls was contained within LULC classes of wetlands, water and barren land for 1988 through 2011 (Table 4).

The land cover change on Block Island during the temporal range was assessed to determine total LCCF for each 45 m pixel. The assessment of LCCF determined that approximately 54% of the land had no change in AL1 coding, 44% of the land had changed once, 2% of the land changed twice and almost 0% of the land changed between each date assessed (Table 5, Figure 19 and 20). Similar to the analysis with stone walls and LULC, the distribution of stone walls per LCCF class match up very well to the percent of land per LCCF class. However, a z test for comparison of percentages found significant the difference between the amount of stone walls and the amount of land within the LCCF class of 3, indicating a greater abundance of stone walls within this class (Table 5).

To assess LCCF at a local scale around the stone walls a comparison was done between buffered areas containing stone walls and absent of stone walls. There was no difference found between the magnitude of land change around the stone walls as based on a 15 m buffer and the magnitude of land change around 15 m buffers absent of stone walls (t-test, $p= 0.520$, Table 6, Figure 22). This buffer was somewhat arbitrarily chosen as based on the total land area of the Island and size buffers that would allow for a good representation of areas absent of stone walls to be compared.

Stone Walls and the Anthropogenic Landscape

The parcel dataset current as of June 2013 contains 2,208 individual parcels with an average parcel area of 1.2 ha. Within the 2013 parcel dataset, 1,788 parcels (81%) are in part bordered by a stone wall from the 2011 dataset (Table 7, Figure 23).

About 234 km of stone wall (67%) from the 1900 stone walls dataset (Figure 24) and 208 km of stone wall (80%) from the 2011 dataset border a parcel boundary within the 2013 dataset (Figure 25). 158 km (81%) of stone walls from the matching stone wall dataset (Figure 26), 79 km (52%) of stone walls from the removed stone wall dataset (Figure 27) and 54 km (83%) of stone walls from the built stone walls dataset (Figure 28) border parcel boundaries from the 2013 dataset. See Table 8.

Through use of the 2013 protected open space map (Figure 4) the current abundance of stone walls contained within these areas of conservation was quantified (Figure 29). There are 12 organizations who own almost 35% of the land on Block Island as of 2011 (The Town of New Shoreham GIS Database, 2014). Within this protected open space there is approximately 37% of the stone walls as of 2011.

Ground Truthing

Through use of a 2008 Trimble GeoXT 26.88 km of stone walls were ground truthed (Figure 30). Of the 26.88 km of stone walls, 23.29 km were identified in the field and within the 2011 stone wall dataset. 3.59 km of stone walls identified in the field were not found within the 2011 stone wall dataset leading to an overall accuracy of 86.6%. (Table 9). It was not determined which stone walls were inaccurately included within the 2011 stone wall dataset. However, there were no stone walls in the dataset not also located on the ground in the specific areas surveyed.

The majority of the stone walls identified in both the field and within the 2011 stone wall dataset are contained within the AL1 classes of urban, agriculture and forest (Table 10). The majority of the stone walls identified in the field but missed within the 2011 stone wall dataset are also contained within the AL1 classes of urban,

agriculture and forest (Table 10). Land use classes are based on the LULC data normalized to an Anderson Level 1 from 2011 (Figure 14). Additionally, 12.12 km (45.09%) of the stone walls surveyed in the field are within 7.5 m of roads from the 2014 RIGIS roads layer emphasizing the ease of access to these walls as compared to walls on private lands and under canopy (Table 9).

DISCUSSION

Conclusions

Successful identification of stone walls for two dates allowed for creation a temporal dataset of stone walls for the extent of New Shoreham, Rhode Island. By assessing both the natural and anthropogenic landscape, connections were found to exist between the presence of stone walls and characterization of the temporal landscape. Specifically, the distributions of stone walls and the spatial distributions of temporal land cover, LCCF, parcel boundaries and protected open space.

Through use of the 1900 historical topographic map to identify the historical distribution of stone walls, the assumption is implemented that all of the stone walls for that time period were designated by a dashed line within the map. Metadata does not exist to know the procedure the cartographer used in the map creation. This adds to inaccuracies especially when considering if there were stone walls along the roads. The roads within this map are marked with a solid line. If stone walls were also contained along roads but not designated within the map, the total amount of stone walls would increase to be closer to the 1886 estimate of 482.80 km (300 miles) (Livermore, 1886).

The 2011 stone wall dataset has an accuracy of 86.6% as based on ground truthing stone walls with Trimble GeoXT. This high accuracy can be partially attributed to the method I used to identify stone walls within the aerial imagery. The manual process of digitizing stone walls, while time consuming, was used to result in as few missed stone walls as possible as well as less change of false recognition of

stone walls, a common result from a classification model. Additionally, inaccuracies within the 2011 stone wall dataset are more likely to be confound to stone walls under forest canopy, not visible within the imagery. Approximately 45% of the stone walls ground truthed were along roads due to ease of access, emphasizing the importance of using remote sensing for large scale stone wall identification. Due to time constraints and physical access to lands on Block Island the potentially missed and incorrect stone walls are a reasonable tradeoff to creating a dataset with ground surveys. Additionally, the missing stone walls from the ground truthed survey could be simply added to the 2011 database.

Use of the 2008 imagery assisted in identification of walls under canopy, because the 2008 dataset is of a higher resolution than the 2011 and therefore, enhances the ability to identify stone walls. However, this adds the assumption that a stone wall existing in 2008 was present in the 2011 dataset. It became evident that stone walls were both moved and built not only between 2008 and 2011 but also from 2003 to 2011. An example is shown in figure (Figure 30) in which a stone wall is not present in 2008 and then appears to have been built in 2011, possibly moved from the location shown just south in the imagery. With inclusion of the 2003 orthophotography, the influence of urbanization in not only removal of forest cover but also removal of a stone wall existing under canopy is visualized (Figure 31).

Since the accuracy of the 1900 is not known, neither is the accuracies of the datasets for matching, built and removed. It is important to mention that over approximately 43% of stone walls within the dataset of built stone walls are located parallel to roads. It is very likely that these stone walls were in existence in 1900 but

were not distinguishable on the topographic map. This point would also lead to inaccuracies of the other stone wall datasets as well.

The distribution of stone walls per land cover class to that of the percent of land per land cover class is very similar. However, there is instances in which the percentages of stone walls compared to the percentages of land per land cover class is significant, suggesting that there is more stone walls within agricultural lands from 1988-1995 and urban lands from 1995-2011. Additionally, there is less stone walls present in water, wetland and barren lands for the whole date range of 1988-2011. The distribution of stone walls per LCC frequency class and land per LCC frequency class is also very similar. However, a comparison of percentages found significant the difference between the amount of stone walls and the amount of land within the LCCF class of 3, indicating a greater abundance of stone walls within this class. It is important not to exaggerate the significance of the relationship between stone walls and land cover that is found in this study. While it is logical for there to be more stone walls contained within agricultural and urban lands than water, wetland and barren, ultimately Block Island is completely covered in stone walls. This makes it difficult to synthesize these findings into a conclusion; emphasizing the need to expand the scope of this study in both methodology and selection of sites.

At a local scale, the LCCF of areas containing stone walls was tested against areas absent of stone walls to quantify if stone walls were located in areas with less land cover change throughout the temporal range. No significant difference was found when comparing the buffer zones containing stone walls and zones absent of stone walls. However, it must be considered that the frequency of land cover change within

the time period of this study area was minimal as based on approximately 98% of the land being contained within the LCCF classes of either 0 or 1.

The choice in resolution of the LULC datasets is likely to have a relevant impact in the results of this study. LULC datasets were classified into an AL1 classification with a pixel resolution of ~45 m as based on the MMU of the original classification of 0.5 acres. The use of this large pixel size is likely to over generalize the detail related to land fragmentation and patches. Additionally, longer land segments could easily be removed by being consumed by neighboring land types. The detail expressed with use of a higher resolution could result in the land use frequency change quantified being greater, which would be more consistent with the 31% change found between land use classes from 1988 to 2011.

Connection has been found between stone walls and the human defined landscape by identifying the percent of current parcels surrounded by a stone wall and the length of stone walls which are surrounding parcel boundaries. Since 80% of the parcels on Block Island are at least in part bordered by a stone wall, it is evident that these features will have influence in some aspect to the majority of land owner. This influence could range from landscape maintenance to property monetary and aesthetic value to ecological characteristics of shrubs and mice populations. Additionally, datasets of stone walls which include stone walls from 2011, i.e. the 2011 dataset, matching stone walls and built stone walls have 80%+ and the stone walls contained within the older datasets of 1900 and removed contain 50%+ of their lengths bordering parcel boundaries in the 2013 distribution. It is likely that with the knowledge of parcel boundaries in 1900, the percentage of parcel boundaries bordered

by a 1900 stone wall would be determined to be greater for 1900 parcels than 2013. Through further assessments these local scale relationships as well as larger scale connections between temporal distributions of parcels and stone walls could become clearer.

Through quantifying the percent of current stone walls contained within protected open space, this study brings to light the role of conservation and specifically emphasizes the importance of humans to landscape change. Over 37% of stone walls as of 2011 were contained within protected open space. There is a clear value that the people on Block Island have for the land and a desire for lands to be conserved. So, be it on purpose or just as a side effect, the stone walls within this space are now also valuable.

Limitations

This land cover change study is inherently data limited for both aspects of data quantity and quality. By only using temporal land cover from 1988-2011, the land cover present in 1900 (the year of the first stone wall dataset) and from 1900 to 1988 is ignored. Also relevant to the limitations of this study, was the variation in the method to which the LULC data was originally classified. While data were classified with the most accurate methods of the time, the 1988 and 1995 datasets were classified through a manual process while the 2003/04 and 2011 datasets were classified through an automated model. This factor could have gone into creating inaccuracies within the land cover change analysis which follow through the remaining assessments which used this data; all analyses of the natural landscape. Through looking at the distribution of land cover classes for each of the four datasets it is apparent that the

years 1988 and 1995 are very similar while the class distributions for 2003/04 and 2011 are also very much alike, yet different from the first two dates (Figure 15).

While available, the land cover classification from 1962 was not used in this study. This map is a topographic map in which land cover classes were manually drawn in the form of polygons. It was very challenging to distinguish polygon boundaries from other symbolized features and therefore, would have contributed inaccuracies to the results.

While some relationships were found between the distributions of stone walls and both land cover classes and land change frequency for the date range, this study did not find a very strong relationship between stone walls and land cover overall. This can be attributed to both the resolutions of the available data assessed and data not assessed which may or may not be available. Additionally, assessing the land cover classifications at a 45 m resolution may have been an oversimplification to these data.

Future Considerations

It is suggested that this study be used as a model to be expanded to other areas which also contain stone walls. It would be specifically interesting to assess areas with fewer stone walls and which have experienced a high magnitude of land cover change, to compare to those areas with opposite conditions. This would greatly enhance understanding of the relationships between stone walls and the temporal landscape. Hence, expanding understanding of how historic land use interactions can persist. This model only uses an area in which stone walls are high abundant throughout and which has gone through minimal temporal land cover change in the more recent past. So

while the buffer analysis did attempt to isolate areas containing stone walls and those in which stone walls were absent, the study site itself limited the size of a buffer to 15m. By assessing areas with different characteristics the range of influence stone walls exhibit can become understood and accurately modeled. Additionally, findings from this study can be more fully understood with integration of other spatial datasets and qualitative historical information. This will allow for both the purpose of the current and the origin of historical stone walls to be better addressed, as based on both environmental and social factors.

Other considerations include the incorporation of stone walls into landscape ecological studies assessing factors which influence land cover change as well as studies within other environmental fields. By identifying locations of stone walls a standalone dataset exists that can become easily accessible. Stone walls can be studied as small mammal habitats and corridors by wildlife biologists and areas for breeding of beetles and ticks by entomologists. Hydrologists can assess the ability for stone walls to influence overland flow and infiltration. Additionally, through field research it has been noticed that stone walls are commonly overtaken by shrubs and this could also be assessed in relation to growth and spread of invasive species.

Conservation of Stone Walls

Through this study the relationship between stone walls and landscape characterization and change has begun to be assessed. There is much potential for this relationship to continue to be analyzed and understood in more depth based on the abundance of stone walls located with the study site and the remaining New England and adjacent states which have stone walls. Stone wall conservation will be a result of

human value placed on both stone walls and lands which happen to contain stone walls. As based on this study, there is a clear appreciation for both stone walls and lands. Additionally, the state of Rhode Island places specific value on stone wall conservation enacted through the RI General Law § 45-2-39.1 and RI General Law § 11-41-32 which give penalty to theft of a stone wall and RI General Law §44-3-43 which gives tax exemption to owners of certain types of historic stone walls (RI Gen L § 45-2-39.1 (2013), RI Gen L § 11-41-32 (2014) and RI Gen L § 44-3-43 (2014)). This leaves us in a position to suggest that the conservation of stone walls be considered within these studies because the preservation of these features will allow for not only the continued study of stone walls, but also for persistence of the relationships studies find between stone walls and their environment. Through more specific assessments of other factors relating to the conservation of stone walls including government regulations and future projections of land cover change, the persistence of stone walls can be better understood.

TABLES

Table 1: Geospatial Data Sources

Name, year, format, resolution, coding and source of datasets used in this study.

<u>Dataset</u>	<u>Year</u>	<u>Format</u>	<u>Resolu tion</u>	<u>Coding</u>	<u>Source</u>
<i>Data for Stone Wall Identification</i>					
Digital True Color Orthophotography	2003/ 04	Raster	0.6 m (2 foot)	N/A	RIGIS
Digital Aerial Photography	2008	Raster	0.10 (4 inch)	N/A	RIGIS (online server)
Digital True Color Orthophotography	2011	Raster	0.15 m (6 inch)	N/A	RIGIS
Historical Topographic Map	1900	Raster	1.28 m	N/A	Town of New Shoreham, RI
<i>Temporal Land Cover</i>					
Land Use	1988	Polygon	0.5 acre	Modified Anderson Level 3	RIGIS
Land Use	1995	Polygon	0.5 acre	Modified Anderson Level 3	RIGIS
Land Use	2003/ 04	Polygon	0.5 acre	Modified Anderson Level 3	RIGIS
Land Use	2011	Polygon	0.5 acre	Modified Anderson Level 3	RIGIS
<i>Ancillary Data</i>					
Protected Open Space	2013	Polygon	N/A	N/A	Town of New Shoreham, RI
Parcels	2013	Polygon	N/A	N/A	Town of New Shoreham, RI
Roads	2014	Line	N/A	N/A	RIGIS

Table 2: Anderson Level 1 Classification

Land Use/Land Cover coding scheme for Anderson Level 1 (Anderson, 1976).

<i>Anderson Level 1</i>	
<u>Code</u>	<u>Description</u>
1	Urban/Built Up
2	Agricultural Land
3	Brushland
4	Forest Land
5	Water
6	Wetland
7	Barren Land

Table 3: Total Percent Change in Land Cover for Rhode Island and Block Island (1988-2011)

Change for each of the 7 land cover classes described by the Anderson Level 1 system (1988 to 2011).

Anderson Level 1 Class	Rhode Island			Block Island		
	Percent per Year		% Change	Percent per Year		% Change
	1988	2011		1988	2011	
Urban	26.84	28.29	+1.45	25.28	37.32	+12.03
Agriculture	7.16	5.39	-1.77	16.03	15.42	-0.62
Brushland	1.60	1.14	-0.46	19.75	10.55	-9.21
Forest	44.12	58.04	+13.92	19.00	22.04	+3.04
Water	5.59	3.95	-1.64	4.41	4.91	+0.50
Wetland	12.83	1.86	-10.97	6.17	4.31	-1.86
Barren	1.86	1.32	-0.54	9.33	5.45	-3.89
Total	100%	100%	30.75%	100 %	100%	31.12 %

Table 4: Temporal Land Cover Change and Distribution of Stone Walls (1988-2011)

Comparison of the amount of land in percent per each Anderson Level 1 Land Cover class to the amount of stone walls from the 2011 dataset in percent per Anderson Level 1 Land Cover class. LULC dataset resolution is ~45 meters. A two tailed z test for 2 population proportions was used to compare the proportion of stone walls within a given LULC type to the proportion of land within the same LULC type within a given year.

Anderson Level 1 Class	Year															
	1988				1995				2003/04				2011			
	% of Stone Walls	% of Land	Z score	P value	% of Stone Walls	% of Land	Z score	P value	% of Stone Walls	% of Land	Z score	P value	% of Stone Walls	% of Land	Z score	P value
Urban	29.46	25.29	1.533	0.126	31.95	27.39	2.051	0.040*	43.67	36.35	2.404	0.016*	44.96	37.32	2.076	0.038*
Agriculture	21.3	16.03	2.329	0.020*	21.48	16.14	2.334	0.020*	17.65	14.86	1.228	0.219	18.4	15.42	1.297	0.194
Brushland	21.7	19.76	0.824	0.412	20.45	18.61	0.750	0.453	10.74	10.69	0.022	0.984	10.4	10.55	-0.110	0.912
Forest	22.33	19.01	1.292	0.197	21.16	18.08	1.291	0.197	25.11	23.73	0.438	0.660	23.36	22.04	0.511	0.610
Water	0.91	4.41	-2.854	0.004*	0.88	4.39	-2.830	0.005*	1.12	4.94	-2.813	0.005*	1.11	4.91	-2.796	0.005*
Wetland	3.23	6.17	-2.060	0.039*	3.23	6.16	-2.035	0.042*	1.36	4.22	-2.142	0.032*	1.4	4.31	-2.189	0.029*
Barren	1.06	9.33	-4.526	<.001*	0.85	9.23	-4.683	<.001*	0.36	5.21	-3.500	<.001*	0.38	5.45	-3.597	<.001*
sum	100	100			100	100			100	100			100	100		

* Statistically significant at $P < 0.05$

Table 5: The Frequency of Land Cover Change and Distribution of Stone Walls (1988-2011)

Comparison of the amount of both land and stone walls contained within each land cover change frequency class. Classes were determined by calculating the amount of times the land changed between 1988 and 2011 resulting in a range of 0-3. Change values were determined based on 45 m resolution LULC datasets. A two tailed z test for 2 population proportions was used to compare the proportion of stone walls within a given land cover change frequency class to the proportion of land within the same class.

		<i>Land</i>		<i>Stone Walls (2011)</i>		<i>Z test</i>	
		Km²	%	Km	%	Z score	P value
Land Cover Change Frequency	0 Land Use Changes	13.14	53.61	130.93	50.42	0.1543	0.88076
	1 Land Use Changes	10.77	43.92	120.55	46.42	-0.2431	0.81034
	2 Land Use Changes	0.59	2.42	7.98	3.07	0.2521	0.80258
	3 Land Use Changes	0.01	0.06	0.22	0.08	-2.346	*0.01878
	sum	24.52	100	259.68	100		

* Statistically significant at $P < 0.05$

Table 6: The Frequency of Land Cover Change: Comparing areas with stone walls and absent of stone walls

15 meter buffers were created around points located on stone walls from the 2011 dataset. 15 meter buffers were created around an equal number of random points generated which do not overlap with the stone walls. Land cover change frequency information was obtained for each buffer. Areas per land cover change frequency unit were calculated and weighted by multiplying the area by the unit value (0-3). A two- sample t-test was performed on the weighted arrays. Differences in area are attributed to overlapping of buffers around random points which were then dissolved.

Land Cover Change Frequency Units	15 Meter Buffer Around Stone Walls		15 Meter Buffer Absent of Stone Walls	
	Km ²	Percent	Km ²	Percent
0 Land Use Changes	1.08	52.45	1.08	57.18
1 Land Use Changes	0.92	45.01	0.78	41.15
2 Land Use Changes	0.05	2.44	0.03	1.62
3 Land Use Changes	0.00	0.10	0.00	0.05
Total	2.05	100.00	1.88	100.00
Average Weighted Mean	0.0018		0.0015	
t-Test: Two-Sample Assuming Equal Variances	p=0.512			

Table 7: 2013 Parcels Coinciding with 2011 Stone Walls

Amount of parcel within the 2013 dataset which coincide with a stone wall within the 2011 stone wall dataset.

Parcels	2,208
Parcel Bordered in part by a 2011 Stone Wall	1788
Percent of Parcel Bordered by a Stone Wall in the 2011 Dataset	81%

Table 8: Stone Walls Coinciding with 2013 Parcel Boundaries

Length of stone walls within each dataset which coincide with parcel boundaries from the 2013 dataset.

Stone Wall Dataset	Total Stone Walls (km)	Stone Walls Bordering 2013 Parcel Boundaries (km)	Percent of Stone Walls Coinciding with Parcel Boundaries
1900	349.1	234	67%
2011	260.6	208	80%
Matching	195.8	158	81%
Removed	153.3	79	52%
Added	64.8	54	83%

Table 9: Field Validation of 2011 Stone Wall Dataset

Accuracy assessment of the 2011 stone wall dataset as based on field identification. Field work took place in the summer of 2014 with use of a GNSS Trimble.

	Stone Walls (km)
Stone Walls Identified in the Field	26.88 km
Stone Walls Identified in Both the Field and 2011 Stone Wall Dataset	23.29 km
Stone Walls Identified in the Field and not in the 2011 Stone Wall Dataset	3.59 km
Accuracy of 2011 Dataset	86.64%
Stone Walls Identified in the Field within 7.5 m of 2014 Roads	12.12 km
% of Stone Walls Identified in the Field within 7.5 m of 2014 Roads	45.09%

Table 10: Field Validated Stone Walls and Land Cover

Amount of stone walls identified through field validation within each Anderson Level 1 land cover class. Stone walls are split into those which were also identified within the 2011 stone wall dataset and those that were missed.

	Stone Walls Identified in Both the Field and 2011 Stone Wall Dataset		Stone Walls Identified in the Field and not in the 2011 Stone Wall Dataset	
	Km	%	Km	%
Urban	12.41	46.16	2.48	69.19
Agriculture	7.38	27.46	0.30	8.47
Brushland	1.54	5.74	0.10	2.71
Forest	4.84	17.99	0.60	16.76
Water	0.22	0.82	0.01	0.35
Wetland	0.48	1.78	0.04	1.12
Barren	0.01	0.04	0.05	1.40
sum	26.88	100.00	3.59	100.00

FIGURES

Figure 1: 2011 Digital True Color Orthophotography: New Shoreham, Rhode Island

Full extent of New Shoreham (Block Island), Rhode Island. Orthophotography was collected in the spring of 2011 at a pixel resolution of 0.5 feet.



Figure 2: 1900 Historical Topographic Map: New Shoreham, Rhode Island

Topographic map provided by the Town of New Shoreham, Rhode Island. Dashed lines symbolized in the map represent stone wall locations as of 1900.

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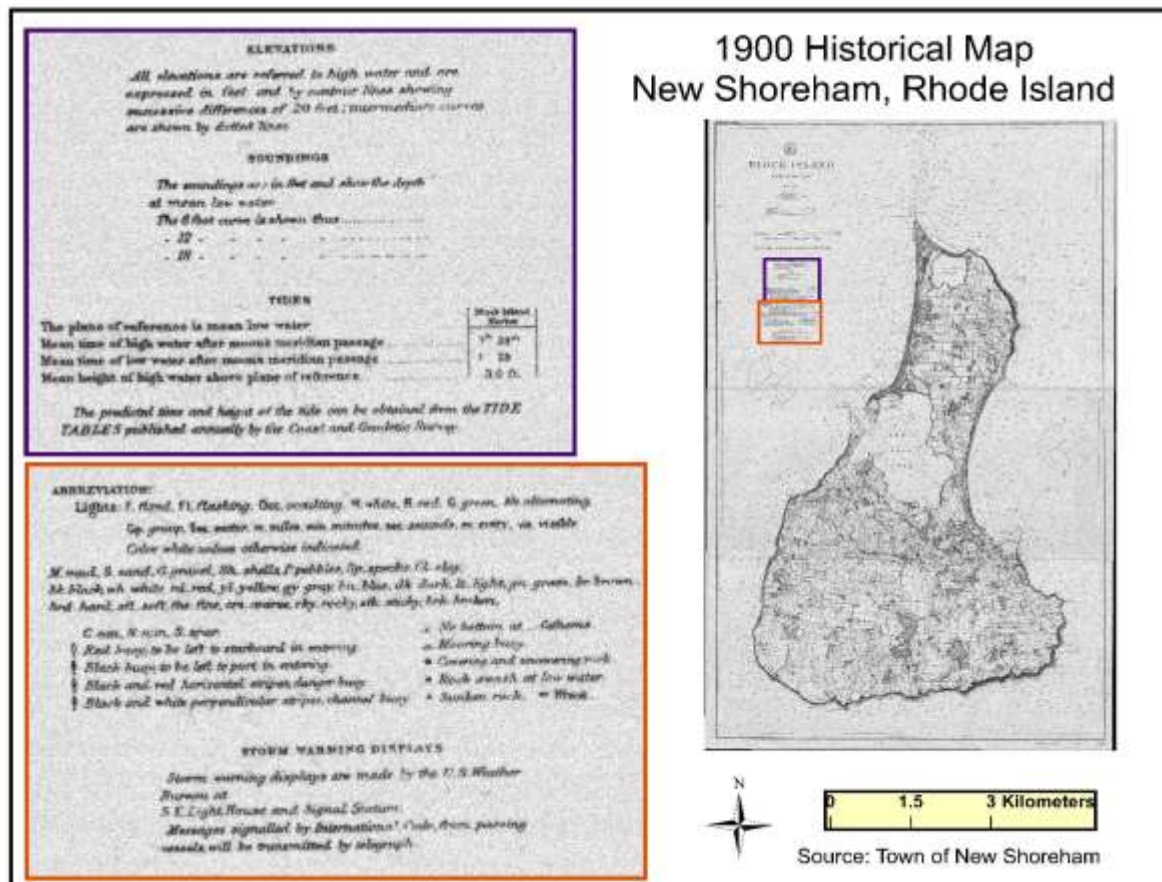


Figure 3: 2013 Parcel Distribution: New Shoreham, Rhode Island

Distribution of ownership boundaries current as of December 2013 provided by the Town of New Shoreham, Rhode Island.

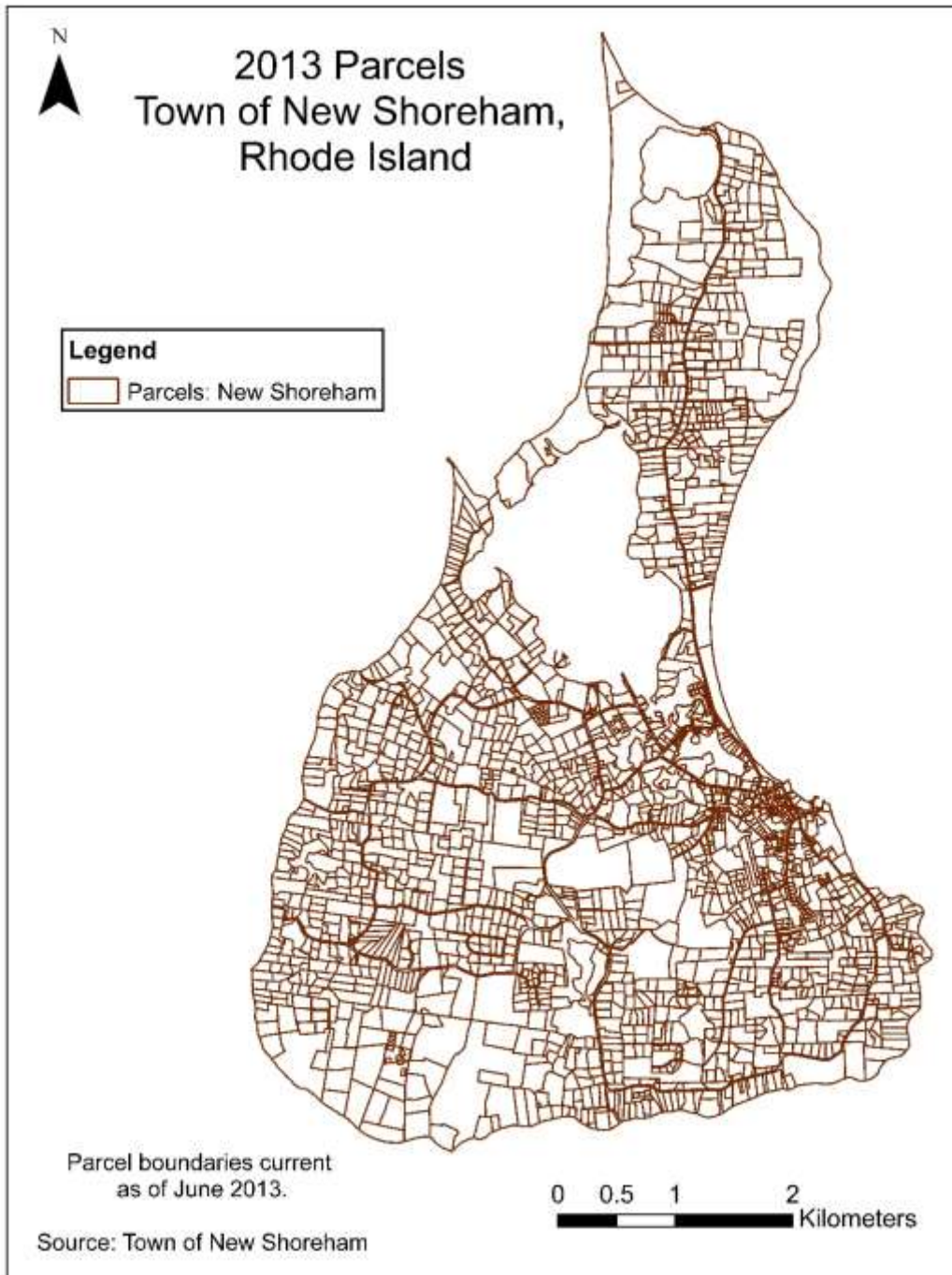


Figure 4: 2013 Protected Open Space: New Shoreham, Rhode Island

Areas of protected open space current as of June 2011 provided by the Town of New Shoreham, Rhode Island.

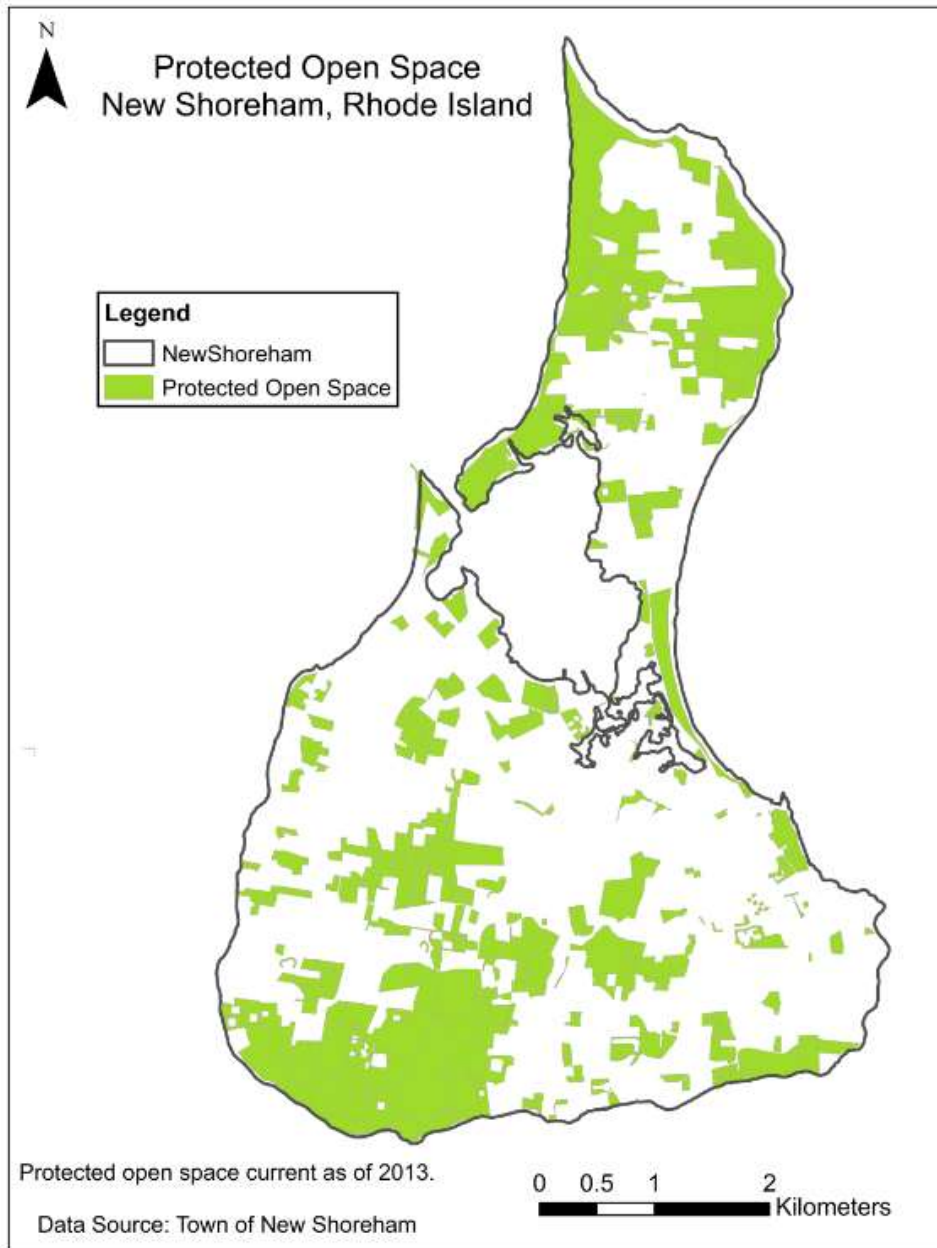


Figure 5: 2011 Digital True Color Orthophotography: Stone Wall Close Ups
Close ups of stone walls within the imagery.

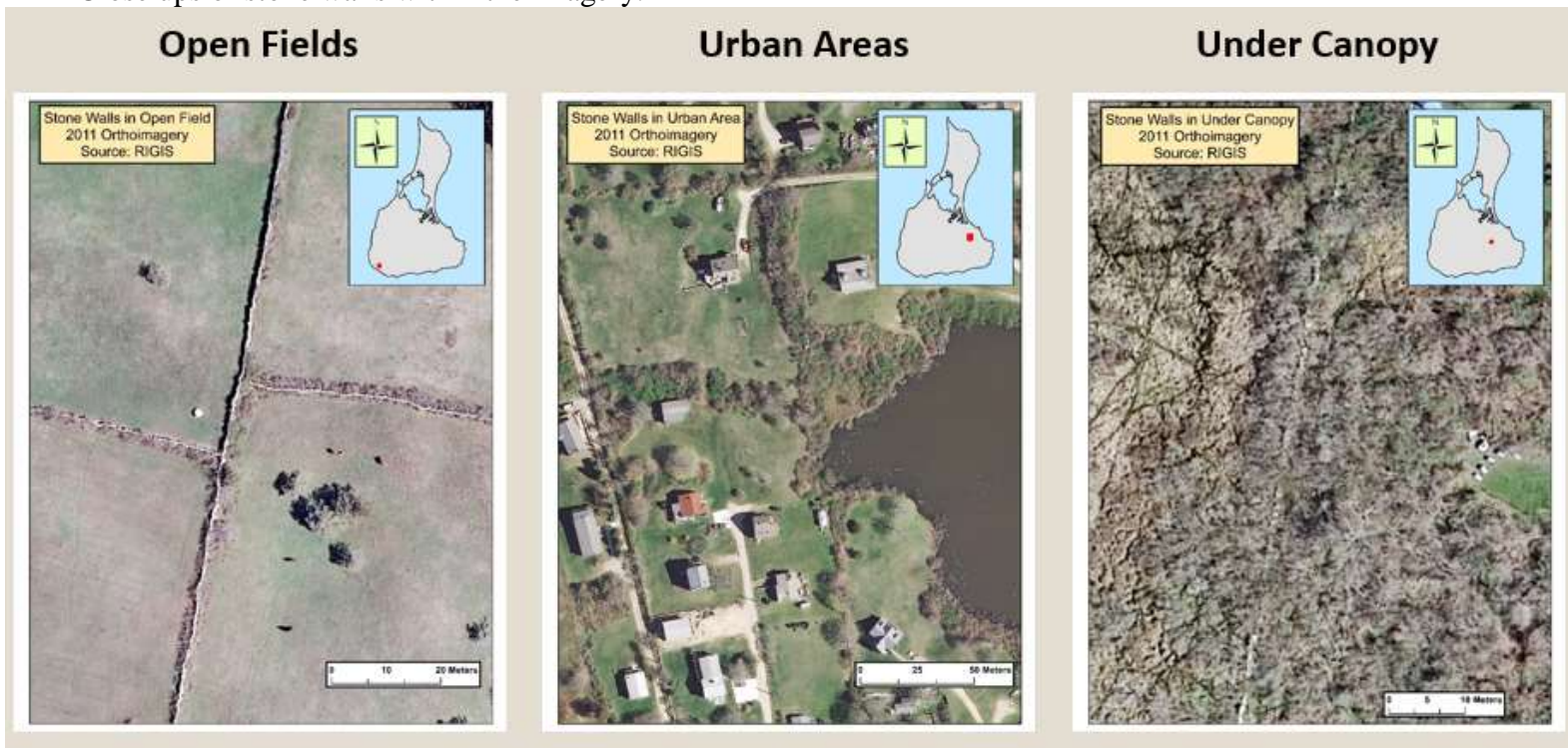


Figure 6: 1900 Stone Walls

Determined from the 1900 topographic map provided by the Town of New Shoreham, Rhode Island.

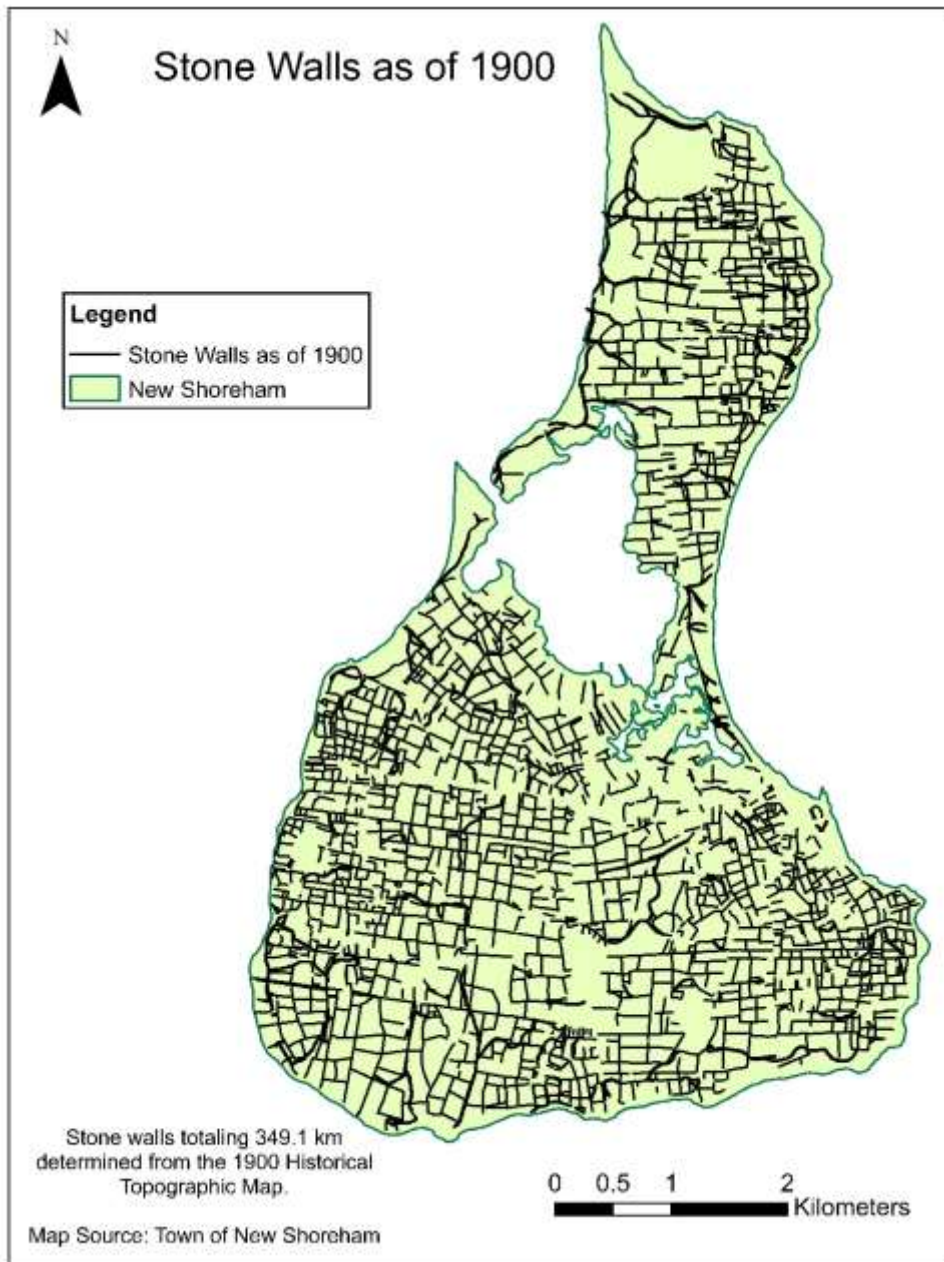


Figure 7: 2011 Stone Walls

Determined from the 2011 Orthophotography with validation from the 2003/04 and 2008 imagery from RIGIS and Google Earth.

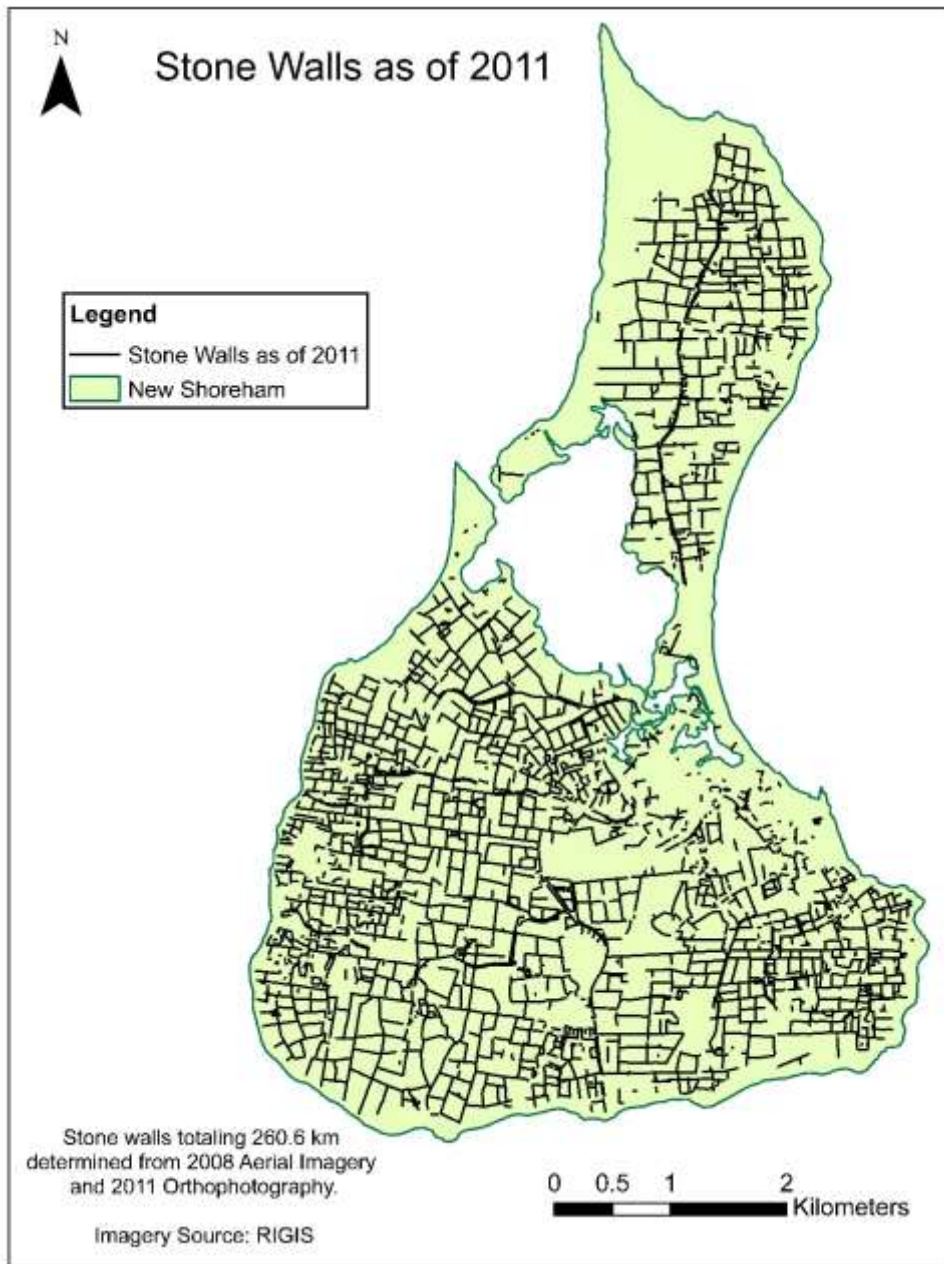


Figure 8: Stone Walls Matching Between 1900 and 2011

Stone walls which were present in the 1900 dataset and the 2011 dataset of stone walls.

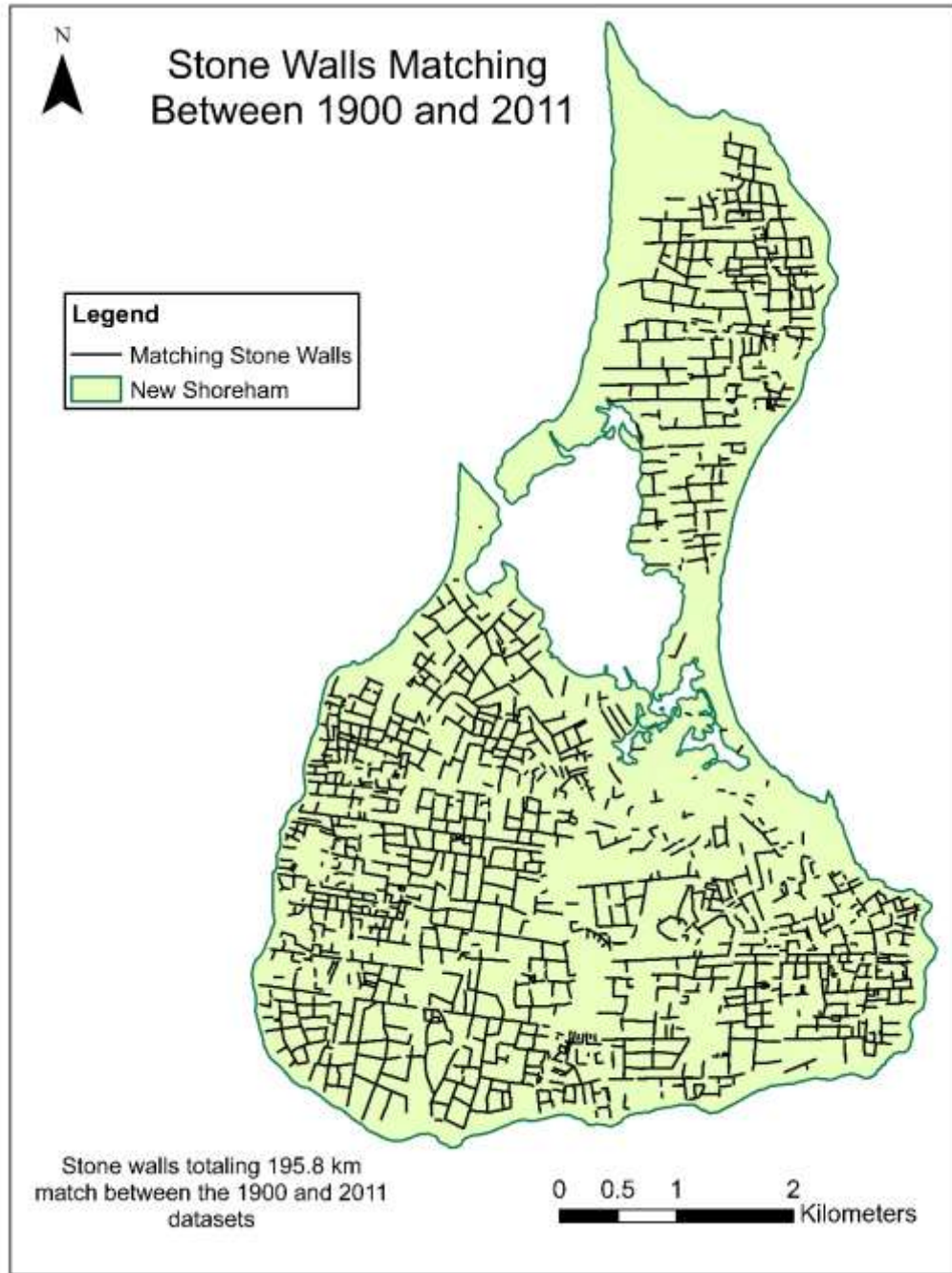


Figure 9: Stone Walls Built Between 1900 and 2011

Stone walls which were not present in the 1900 dataset and present in the 2011 dataset of stone walls.

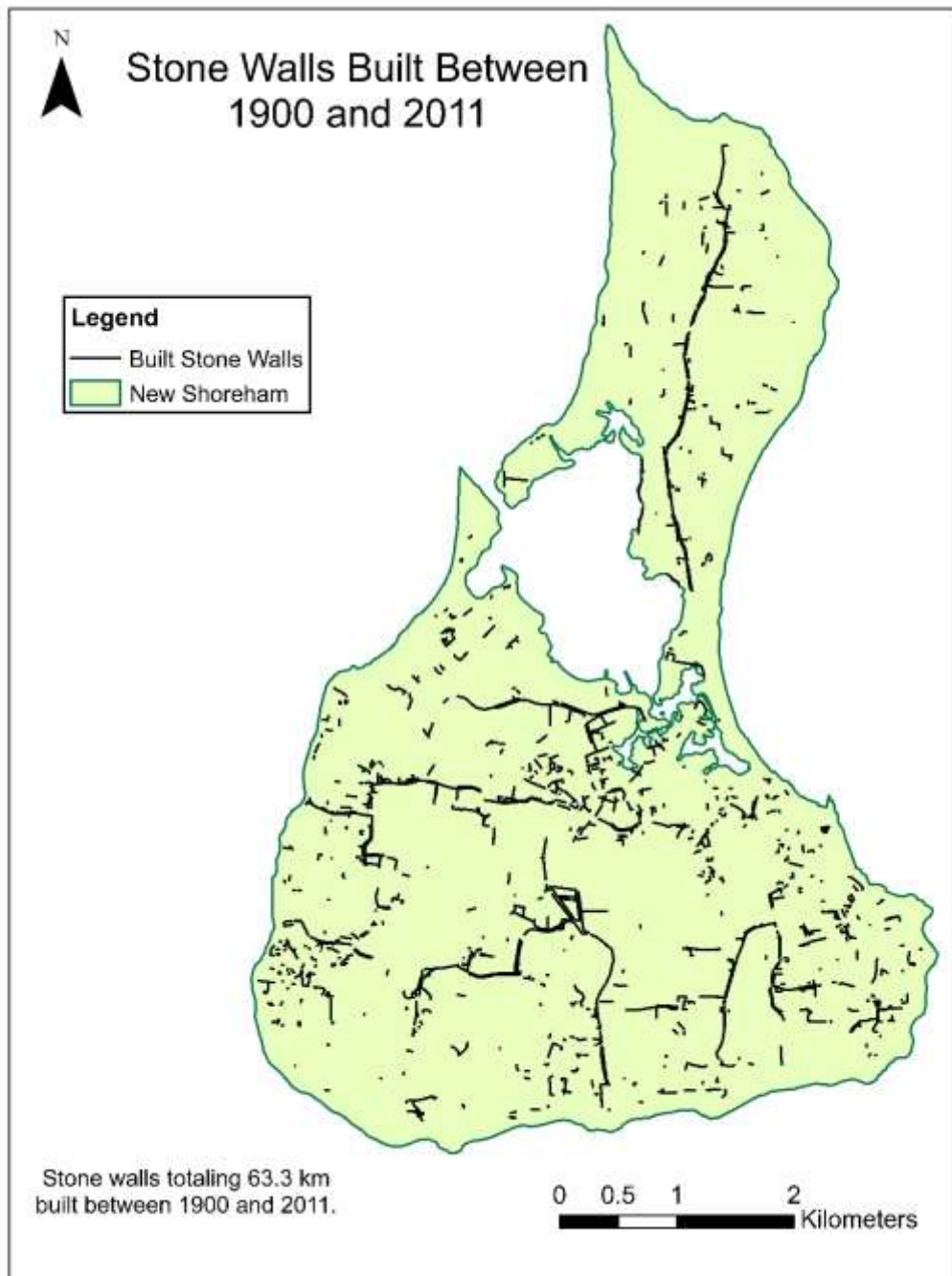


Figure 10: Stone Walls Removed Between 1900 and 2011

Stone walls which were present in the 1900 dataset and not present in the 2011 dataset of stone walls.

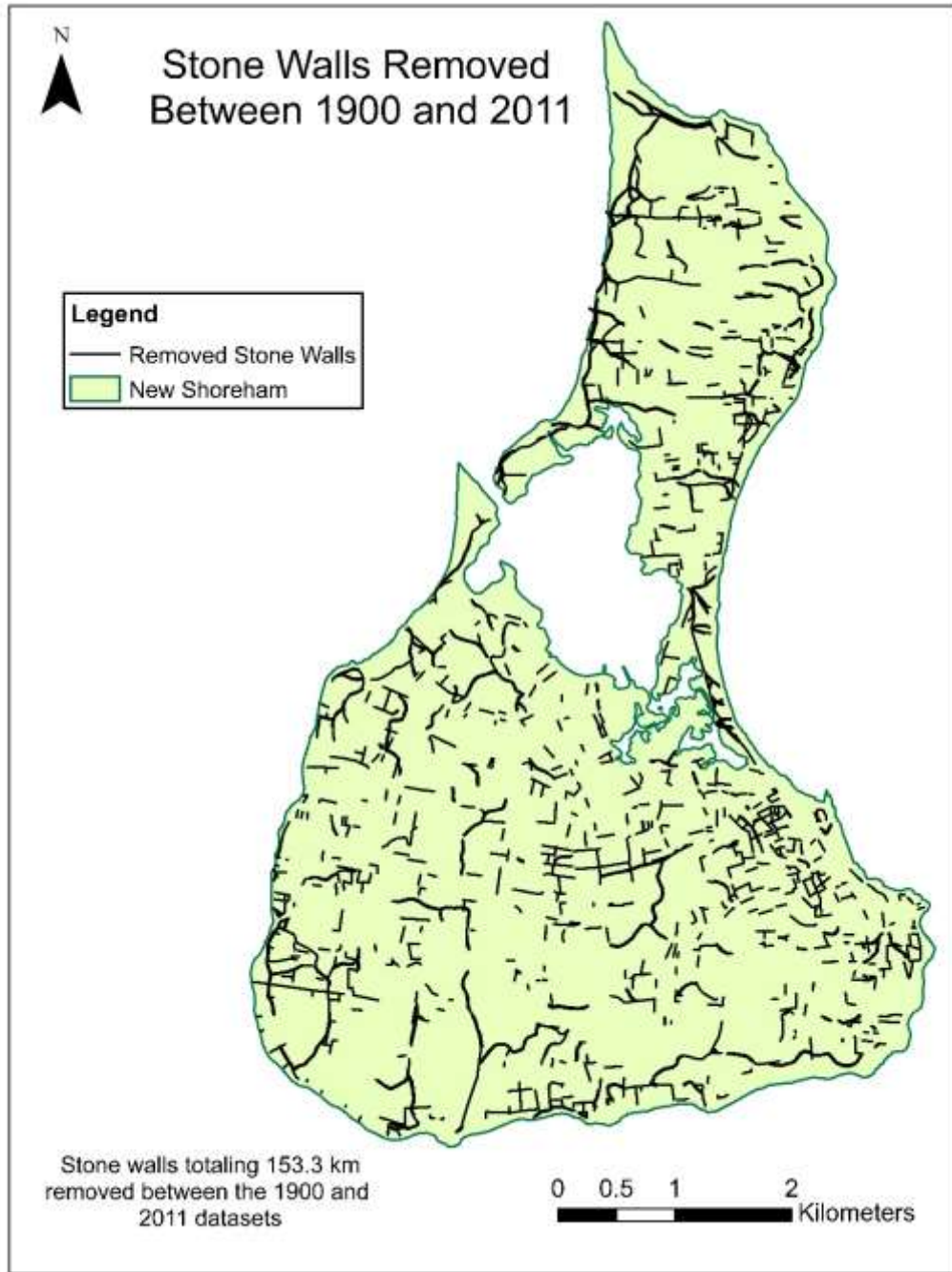


Figure 11: 1988 Anderson Level 1 Land Cover Classification
Pre-classified land cover from RIGIS normalized to an Anderson Level 1 Classification with 7 cover classes and 45 m pixel resolution.

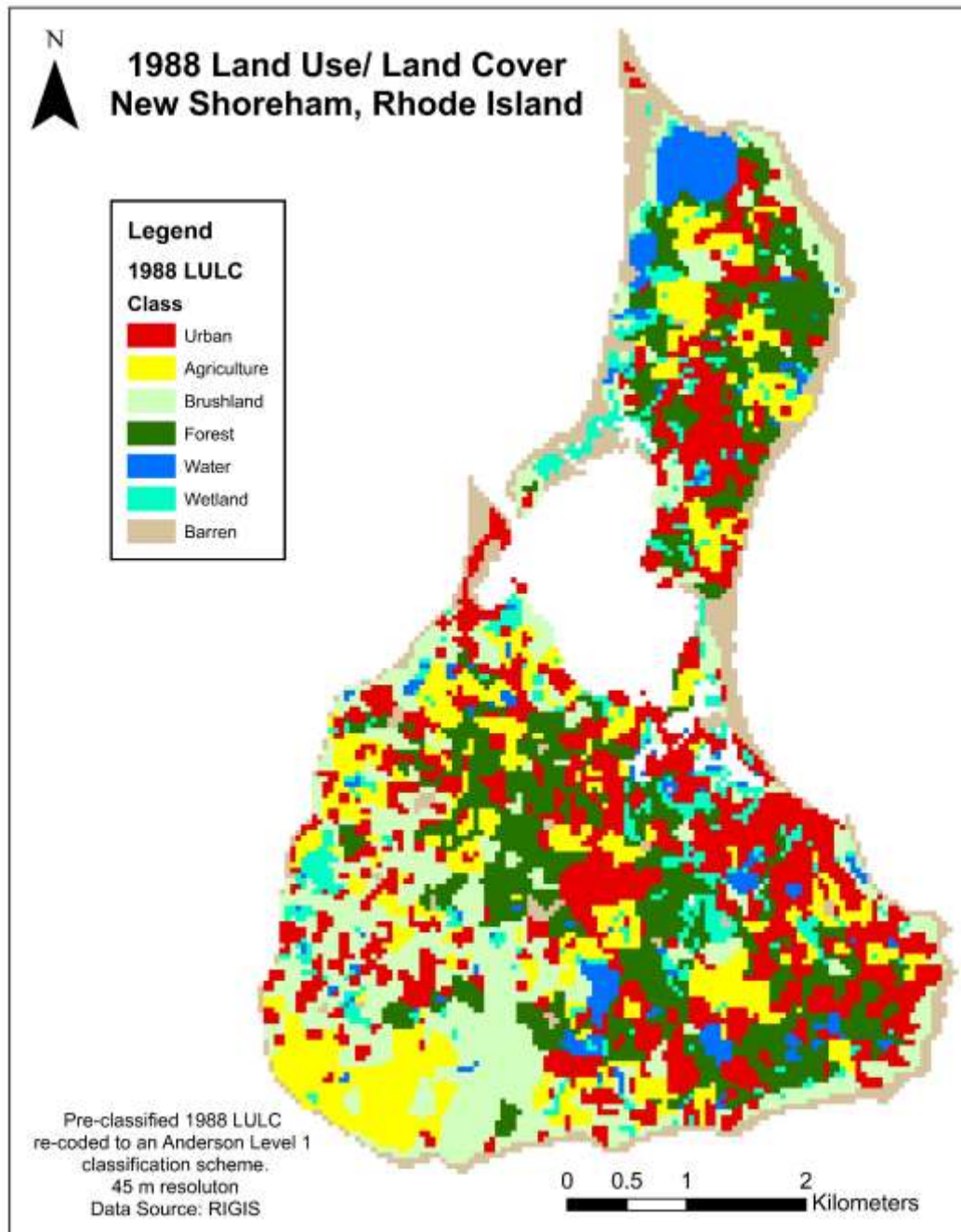


Figure 12: 1995 Anderson Level 1 Land Cover Classification
Pre-classified land cover from RIGIS normalized to an Anderson Level 1 Classification with 7 cover classes and 45 m pixel resolution.

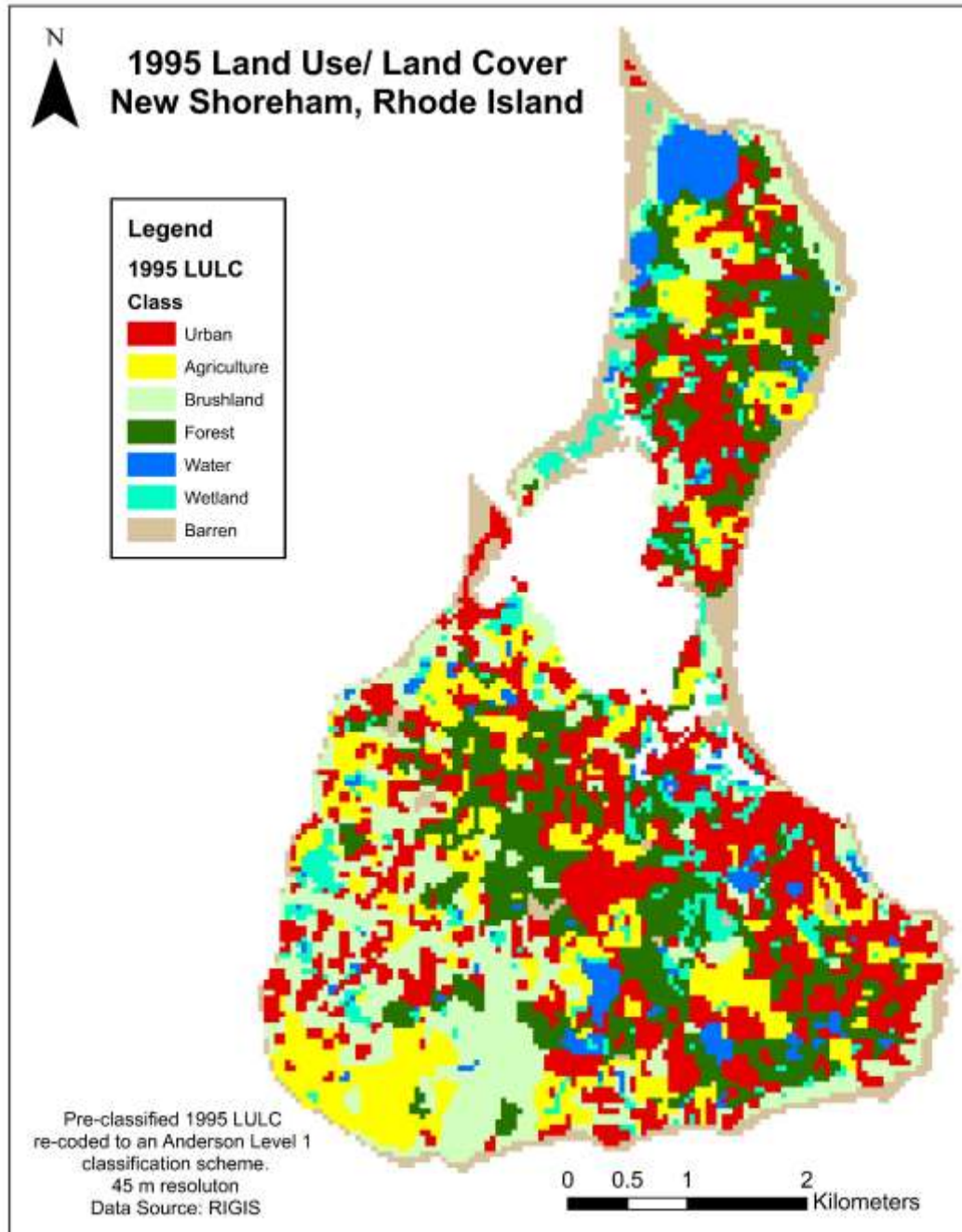


Figure 13: 2003/04 Anderson Level 1 Land Cover Classification
Pre-classified land cover from RIGIS normalized to an Anderson Level 1 Classification with 7 cover classes and 45 m pixel resolution.

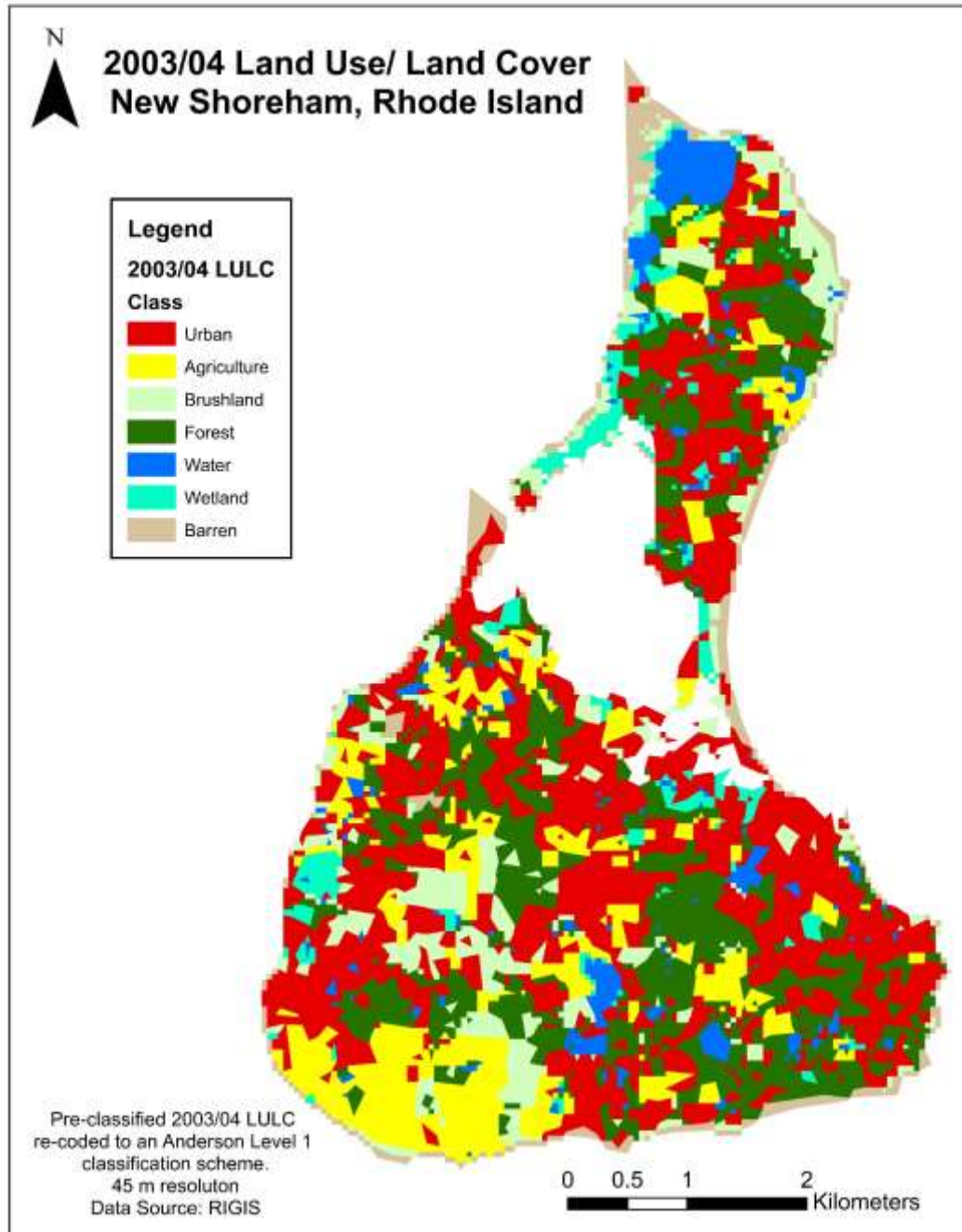


Figure 14: 2011 Anderson Level 1 Land Cover Classification
Pre-classified land cover from RIGIS normalized to an Anderson Level 1 Classification with 7 cover classes and 45 m pixel resolution.

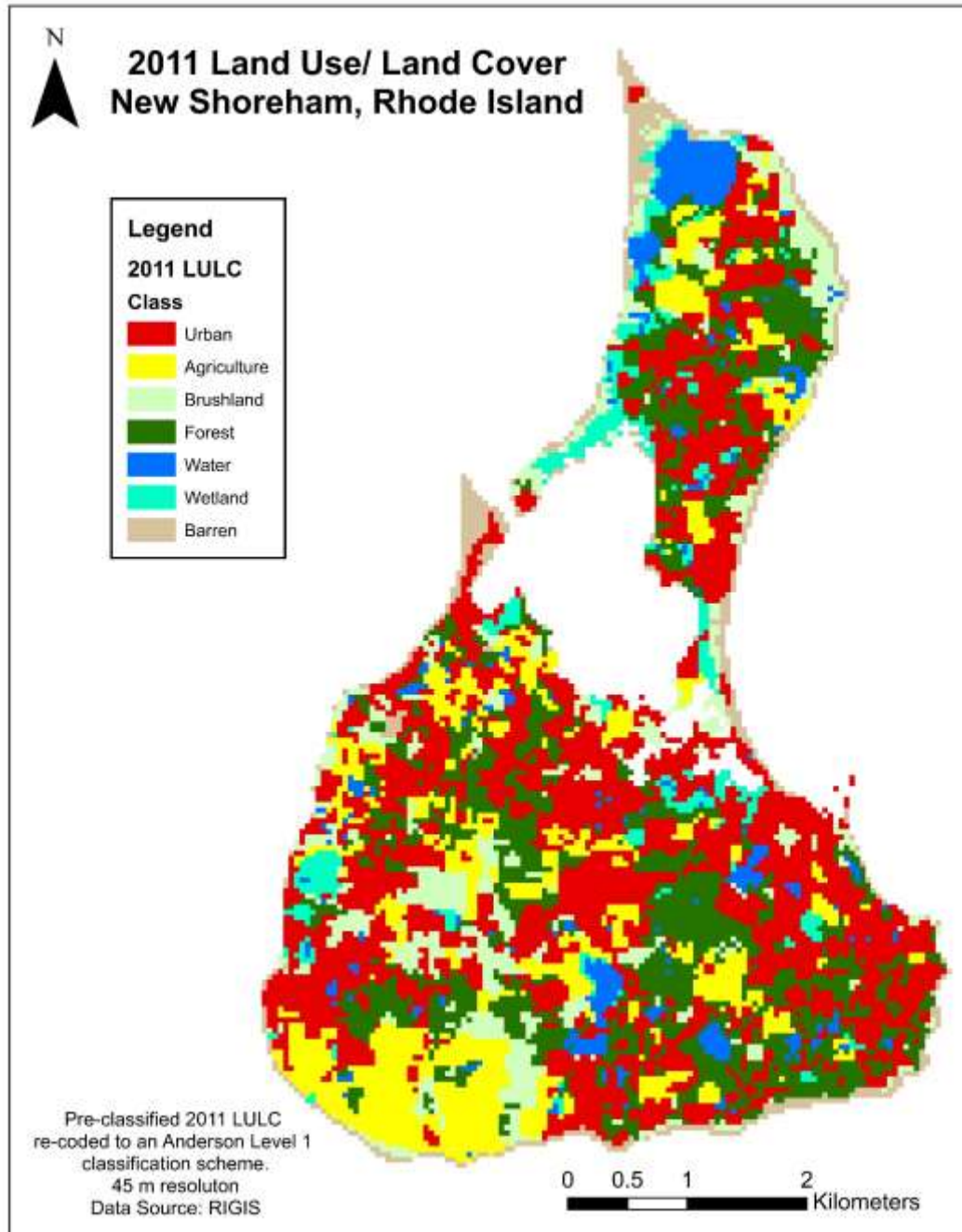


Figure 15: Percent of Land per Land Cover Class (1988-2011)

Bar graph from land cover classifications for 1988, 1995, 2003/04 and 2011 normalized to an Anderson Level 1 coding scheme. Values in percent's.

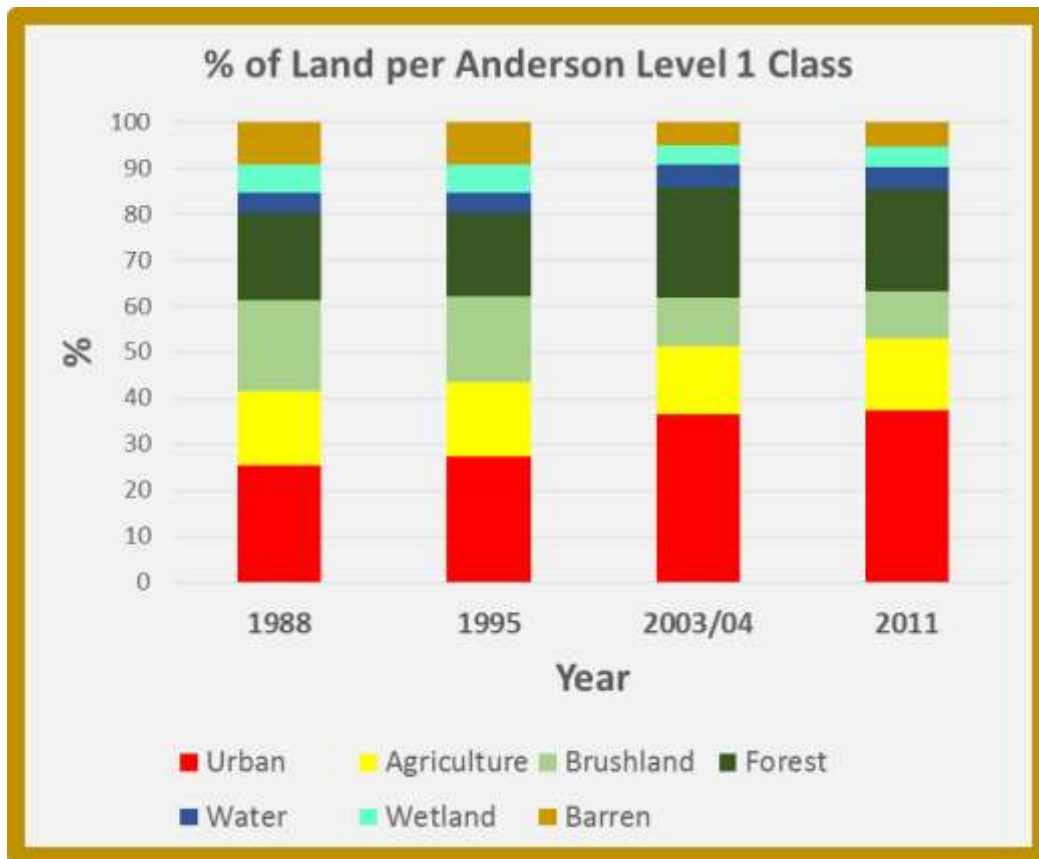


Figure 16: Percent of Land Change per Class (1988-2011)

Percent change of each Anderson Level 1 land cover class for each date (1988, 1995, 2003/04 and 2011)

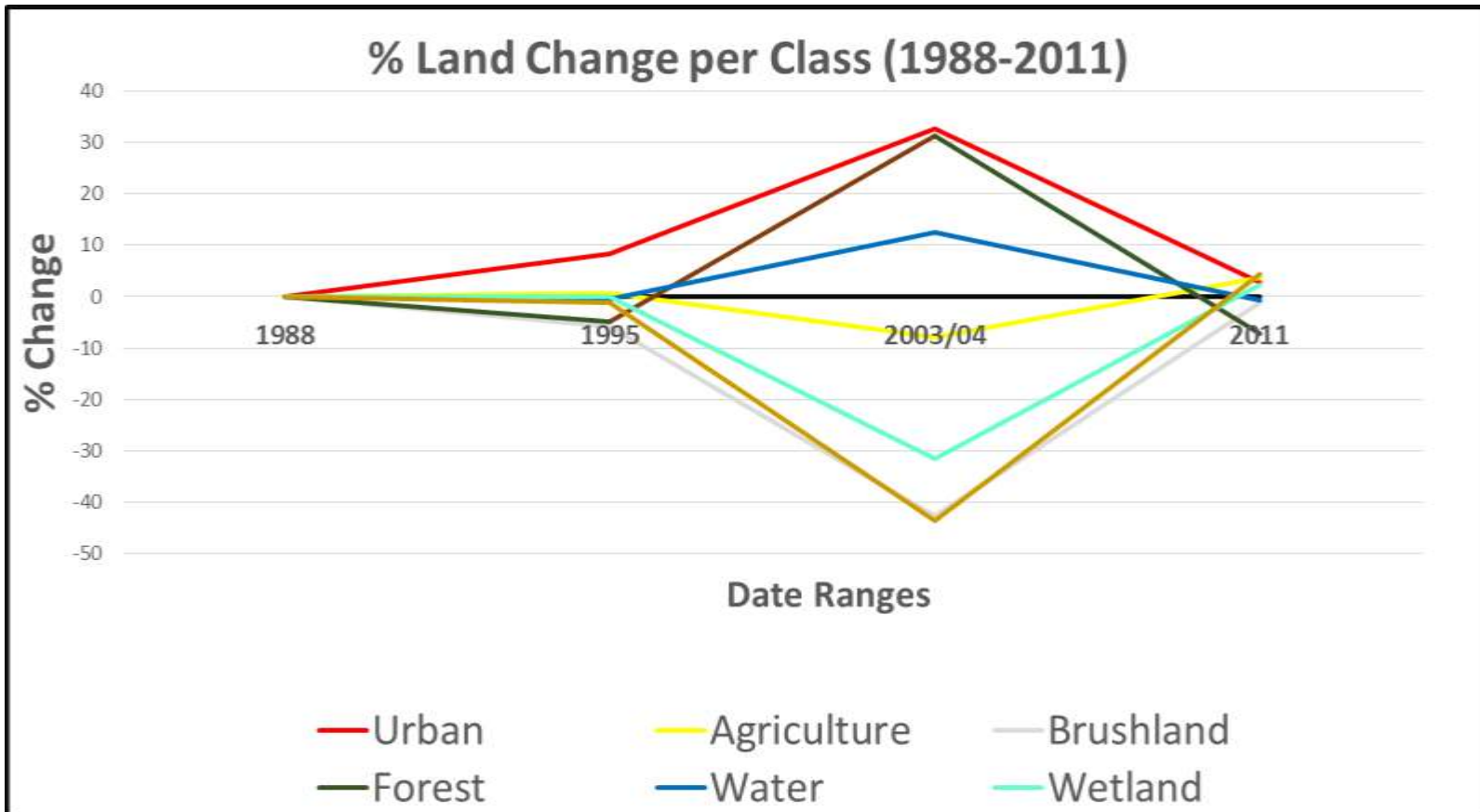


Figure 17: Percent of Stone Walls per Land Cover Class (1988-2011)

Bar graph of percent of stone walls from the 2011 stone wall dataset contained within each Anderson Level 1 class. Classes of land cover for 1988, 1995, 2003/04 and 2011 from RIGIS.

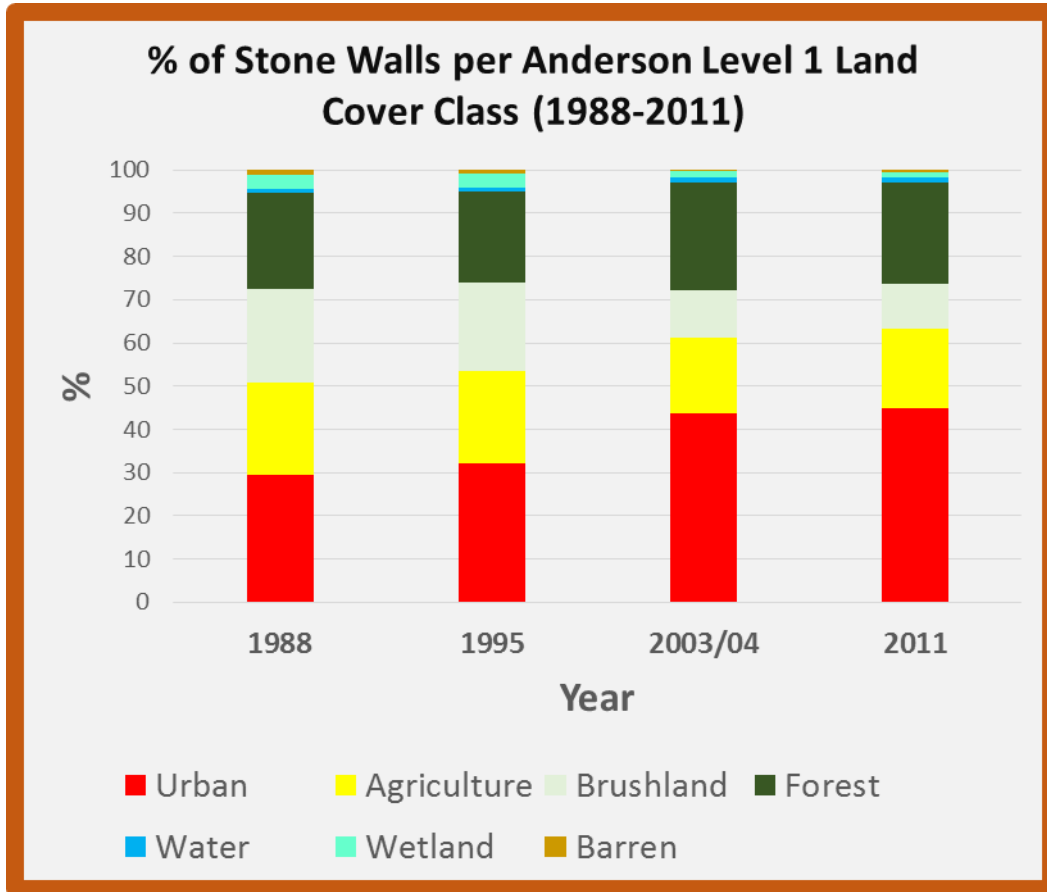


Figure 18: Temporal Land Cover Change and Distribution of Stone Walls (1988-2011)

Graph of the amount of land in percent per each Anderson Level 1 Land Cover class to the amount of stone walls from the 2011 dataset in percent per Anderson Level 1 Land Cover class.

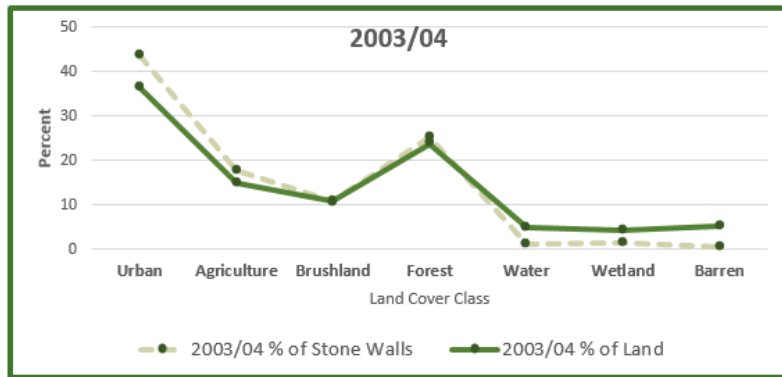
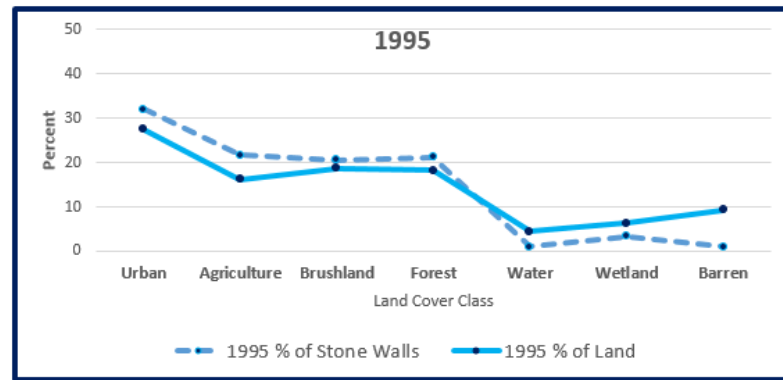
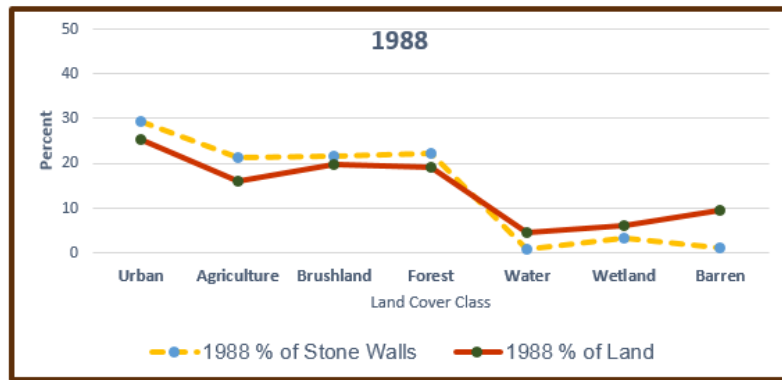


Figure 19: Land Cover Change Frequency (1988-2011)

Map determined through quantifying magnitude of change with use of the land cover classifications normalized to an Anderson Level 1 coding for 1988, 1995, 2003/04 and 2011. A 0 indicates no change from 1988 to 2011. 3 indicates a change between each date.

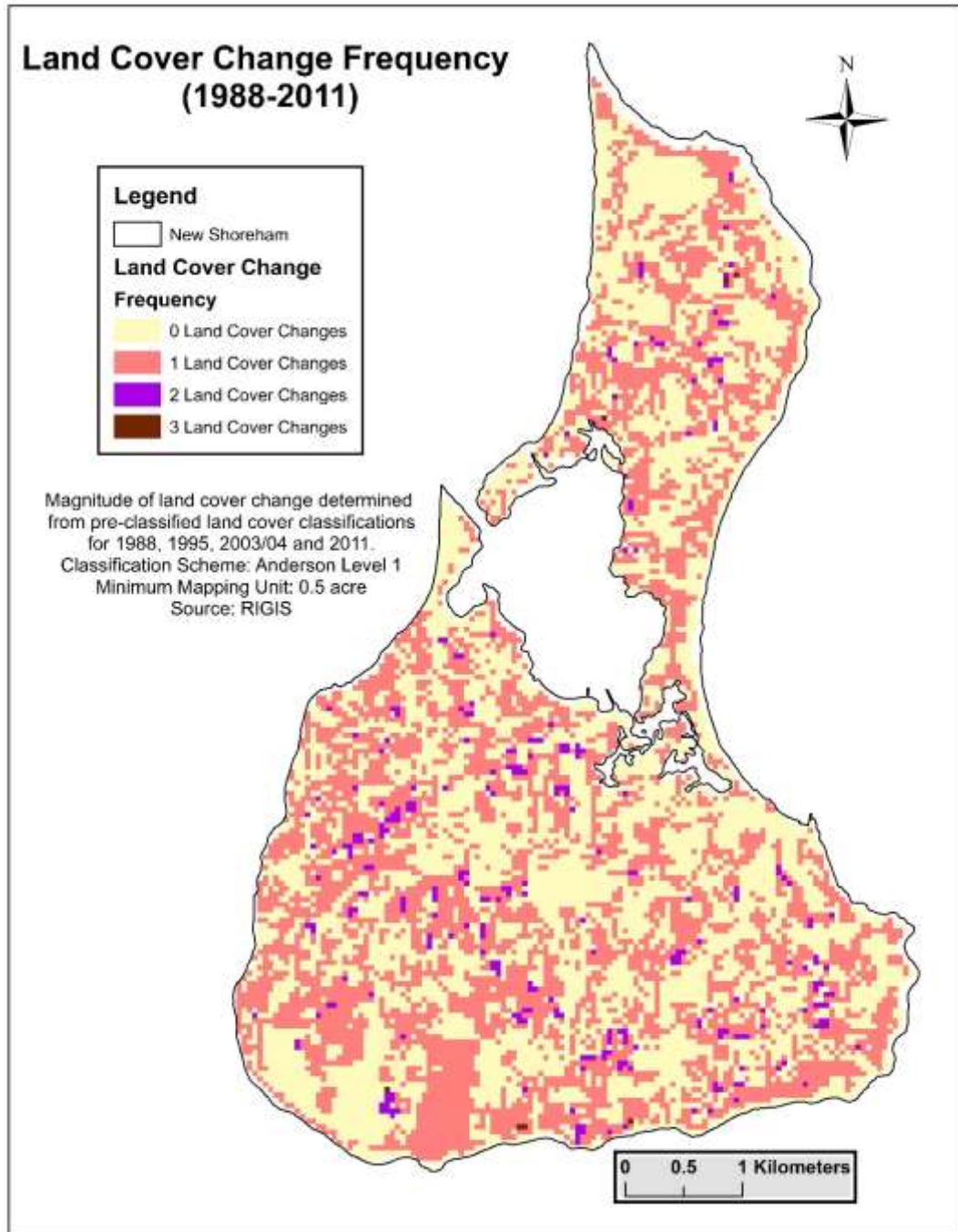


Figure 20: Land Cover Change Frequency (1988-2011)

Bar graph representing the percentages of land per each land change frequency unit.

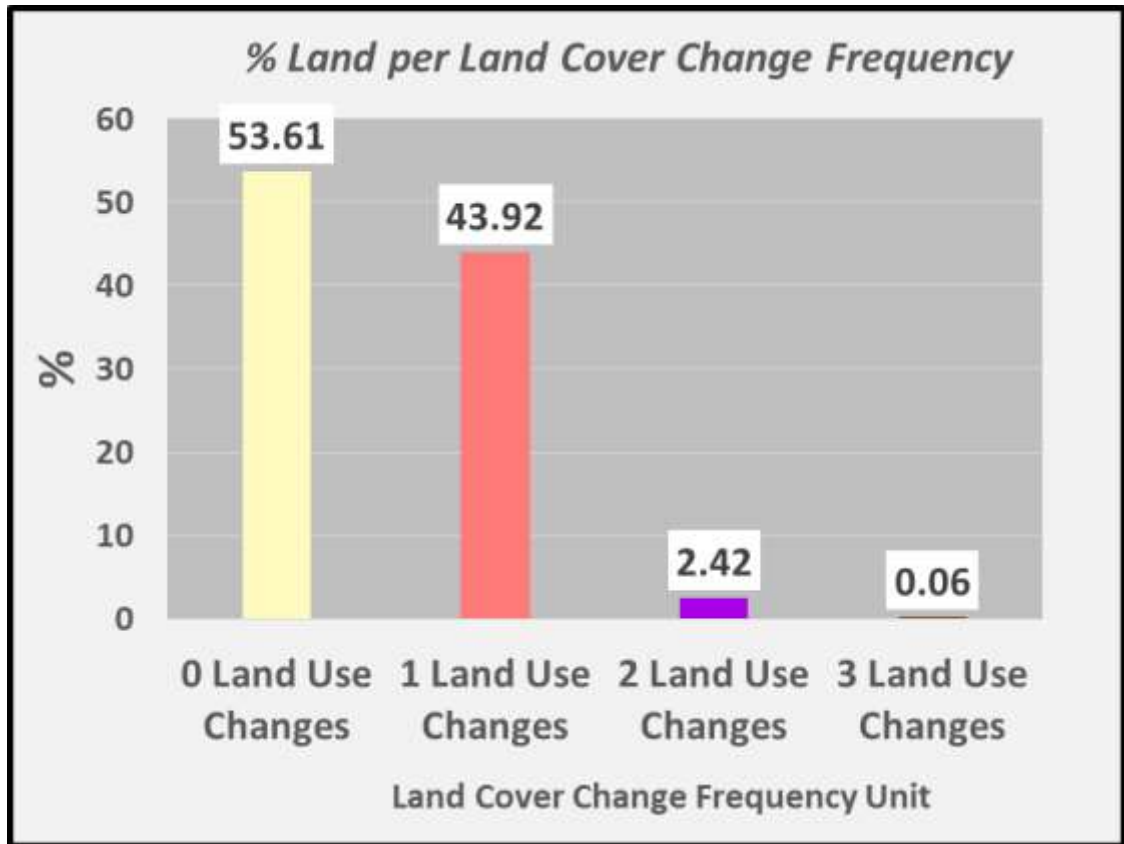


Figure 21: Stone Walls per Land Cover Change Frequency Class (1988-2011)
Bar graph representing the percentages of stone walls from the 2011 dataset within each land change frequency unit.

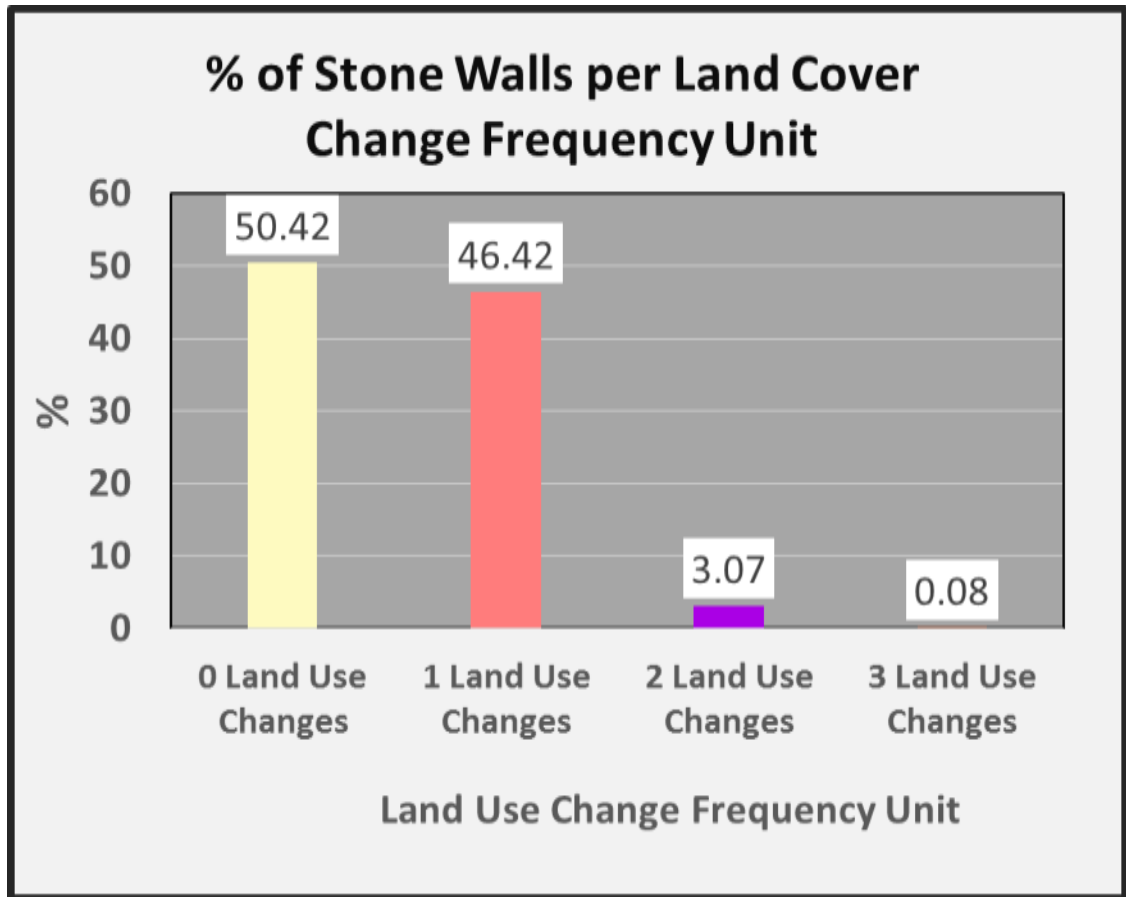


Figure 22: Land Use Change Frequency around Stone Walls

15 meter buffers were created around 3,135 points located on stone walls from the 2011 dataset. 3,135 random point were created 30 meters away from stone walls and 15 meters from the edge of the New Shoreham boundary. 15 meters buffers were created around the random points. Points from both sets were used to extract land change frequency information to determine if there is a difference between the frequencies of land cover change around stone walls compared to areas without stone walls.

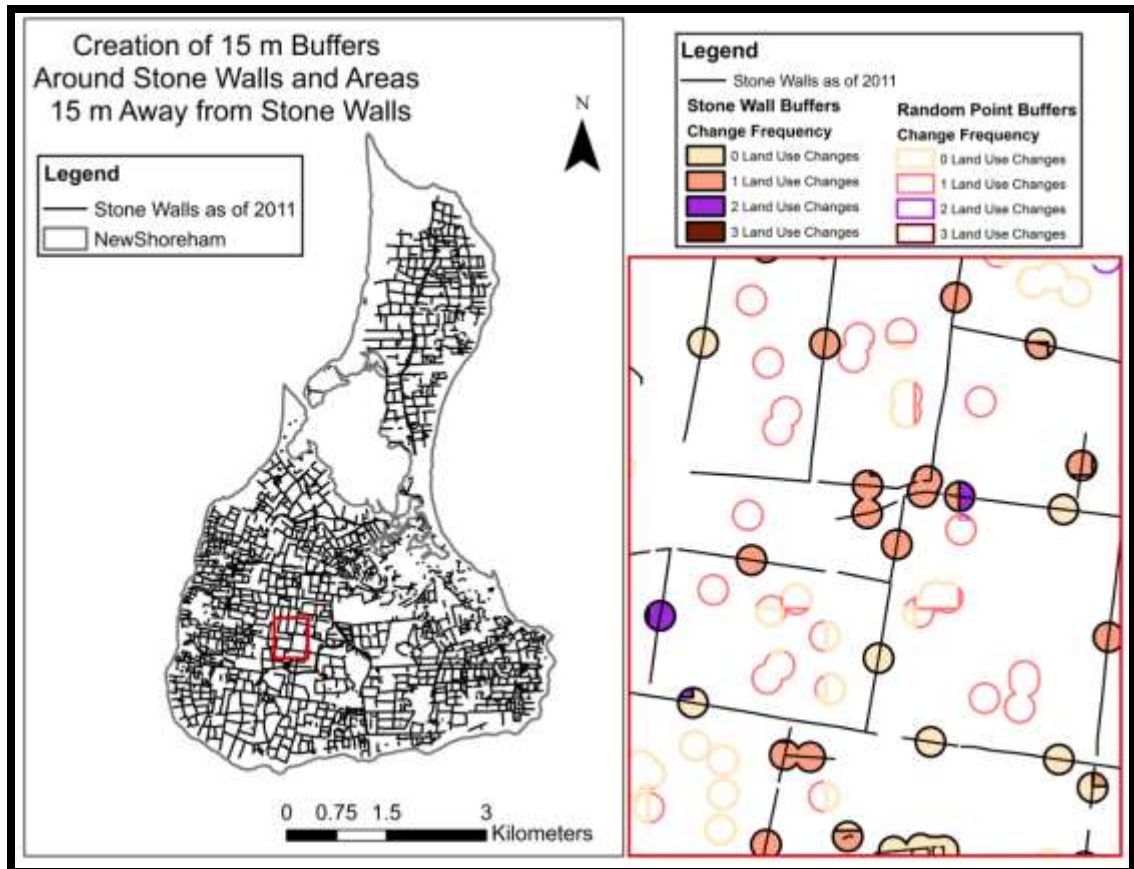


Figure 23: 2013 Parcels Bordered by a Stone Wall
Parcels which are bordered by a stone wall from the 2011 dataset.

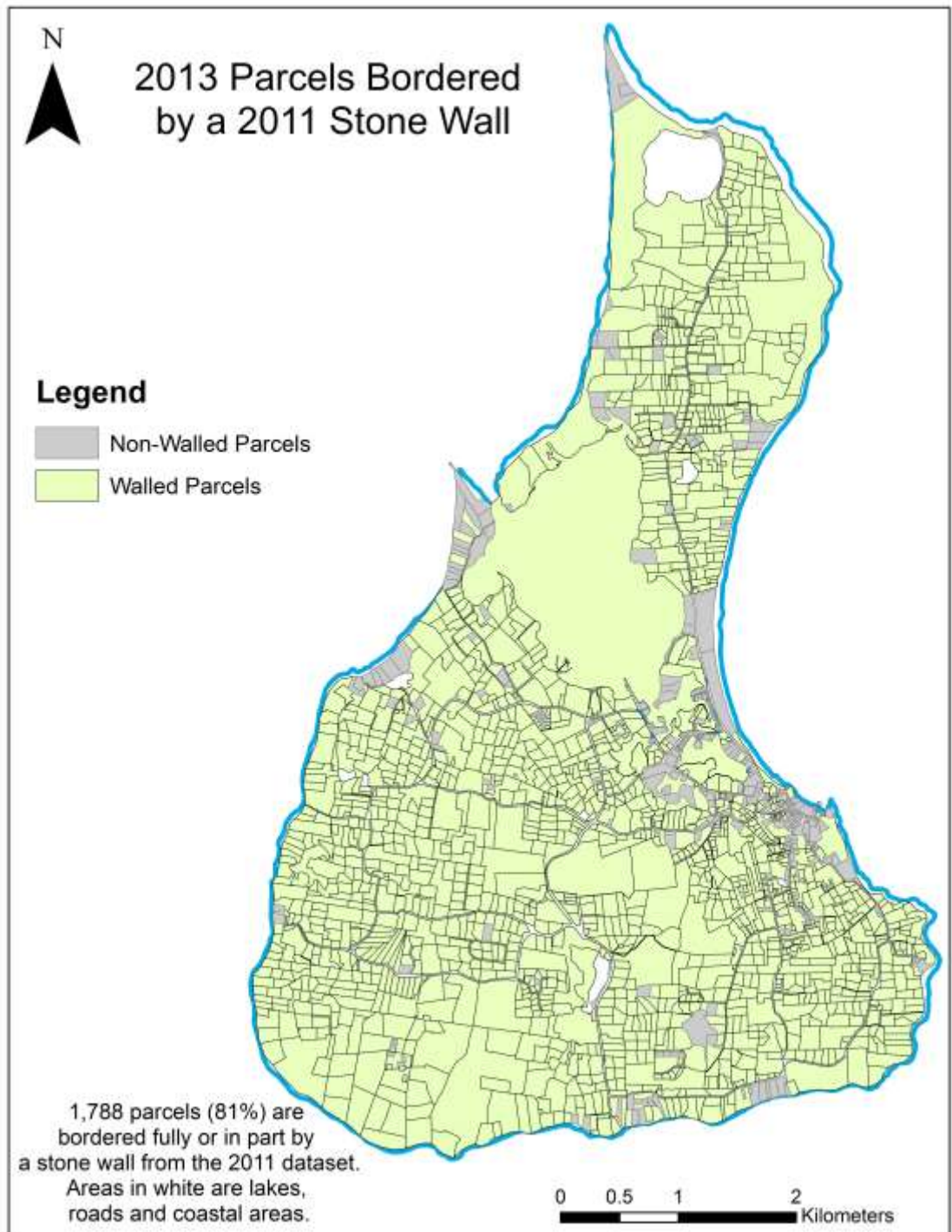


Figure 24: 1900 Stone Walls Bordering 2013 Parcel Boundaries
Stone walls from the 1900 dataset which borderer a parcel from the 2013 dataset.

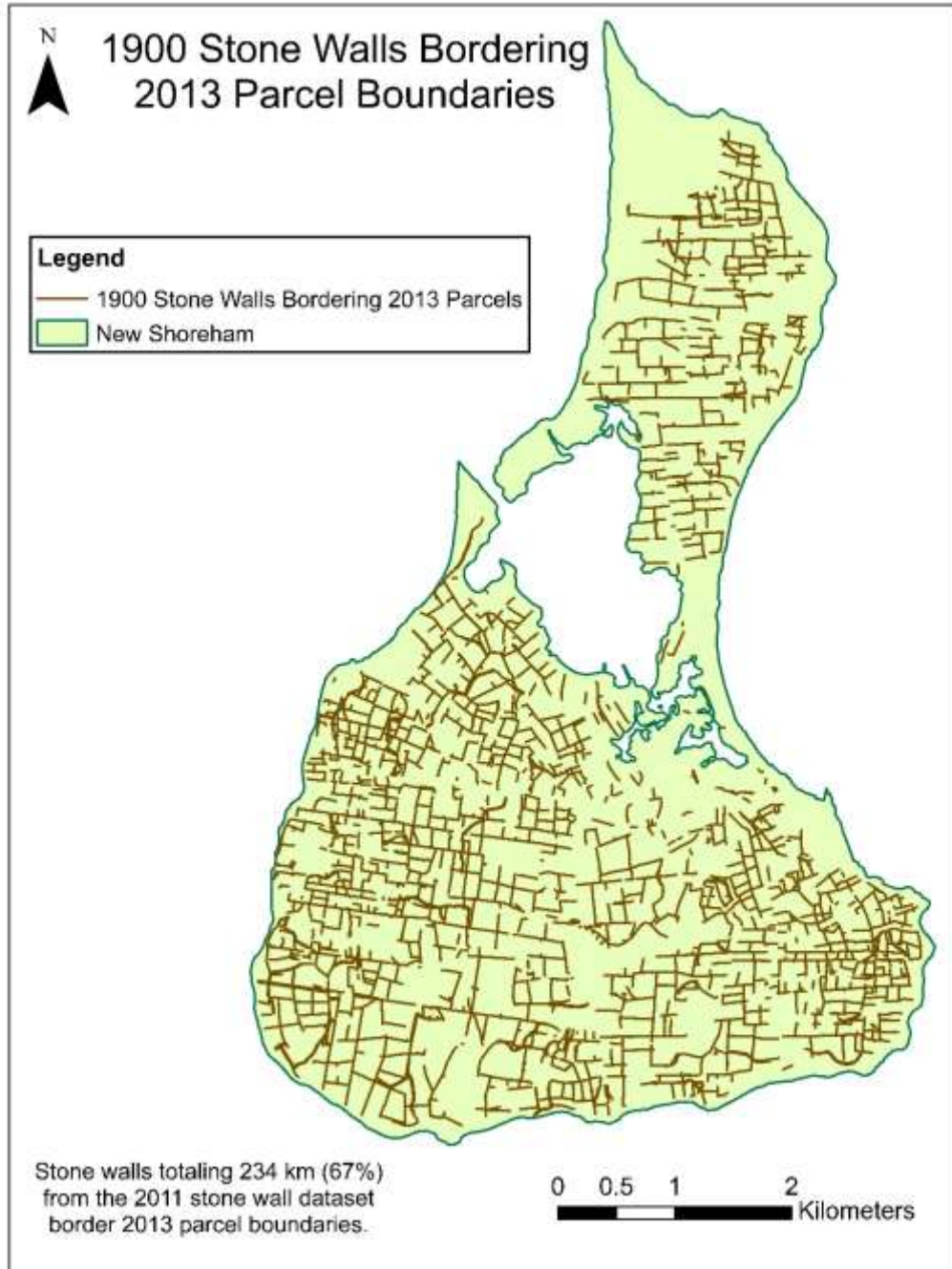


Figure 25: 2011 Stone Walls Bordering 2013 Parcel Boundaries
Stone walls from the 2011 dataset which borderer a parcel from the 2013 dataset.

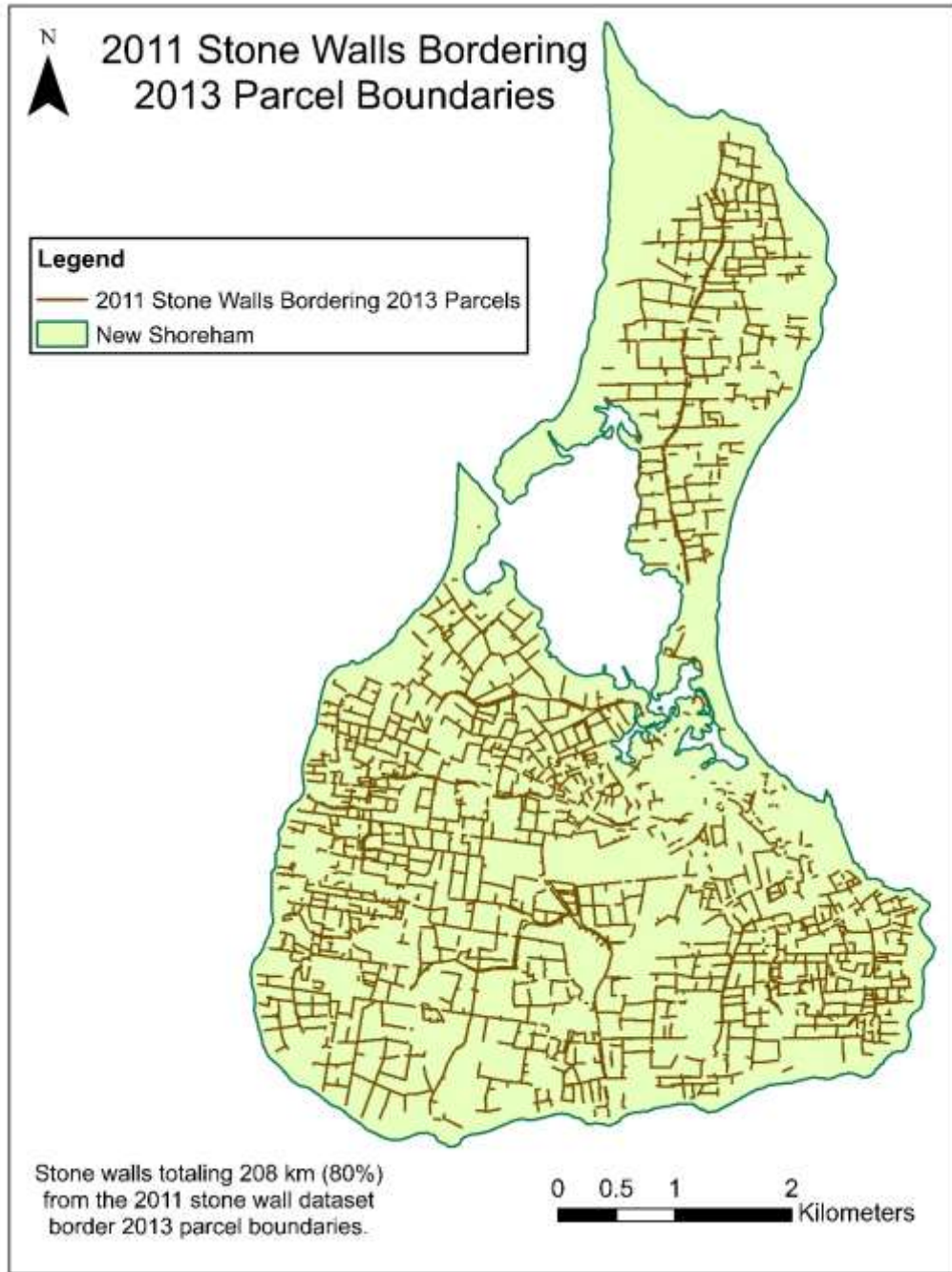


Figure 26: Stone Walls Matching Between 1900 and 2011 Bordering 2013 Parcel Boundaries

Stone walls from the matching dataset which borderer a parcel from the 2013 dataset.

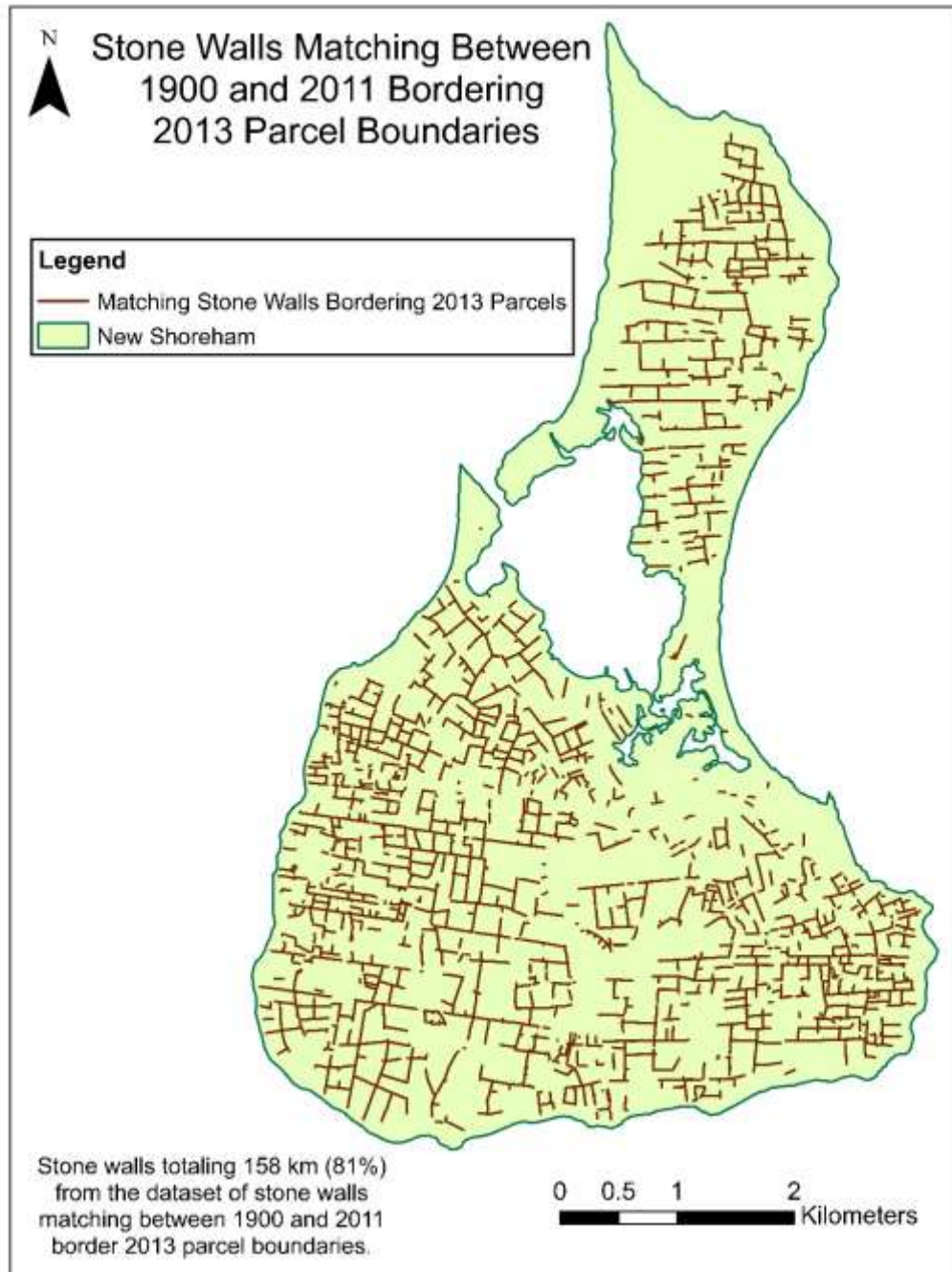


Figure 27: Stone Walls Built Between 1900 and 2011 Bordering 2013 Parcel Boundaries

Stone walls from the built dataset which borderer a parcel from the 2013 dataset.

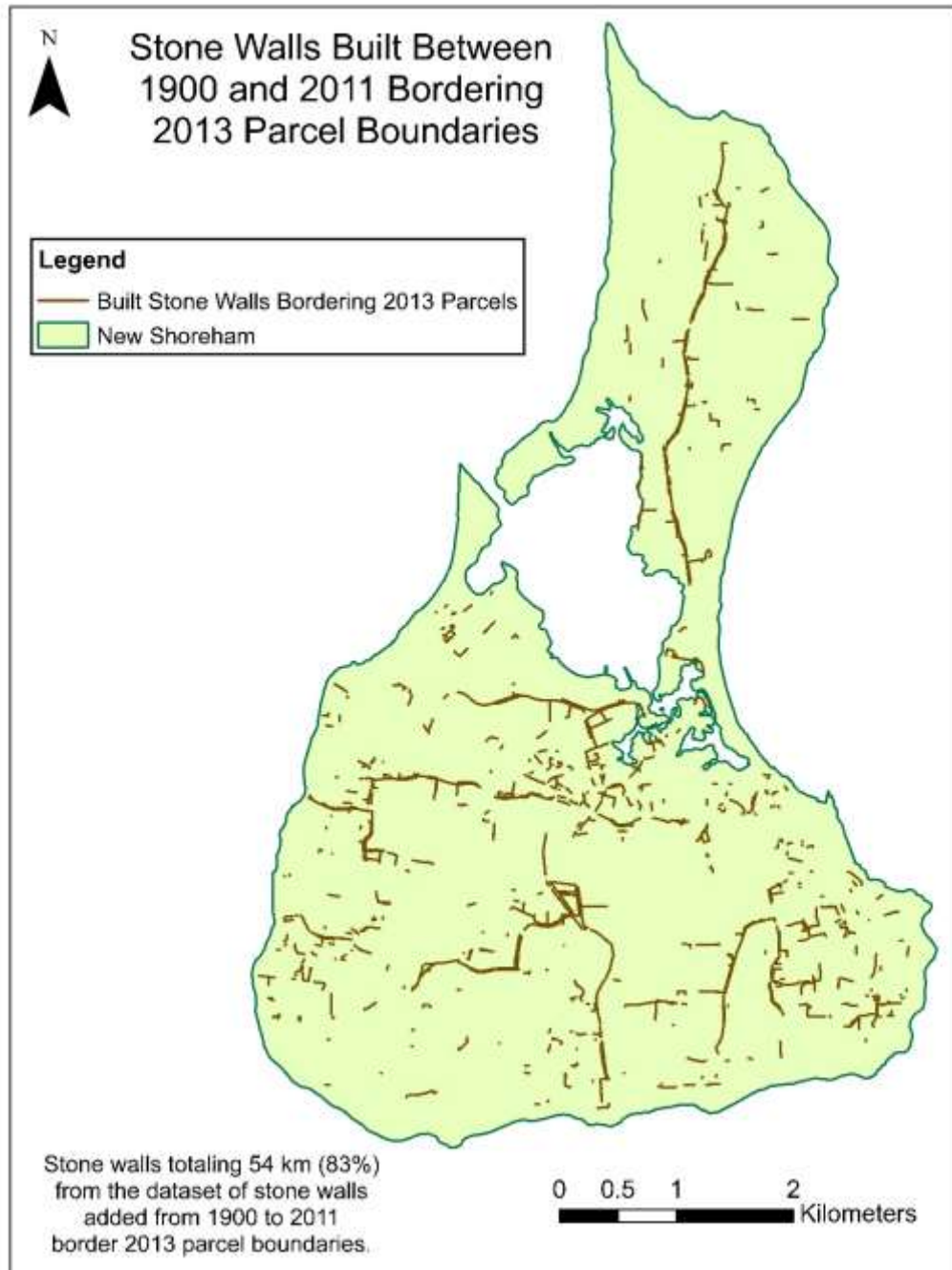


Figure 28: Stone Walls Removed Between 1900 and 2011 Bordering 2013 Parcel Boundaries

Stone walls from the removed dataset which borderer a parcel from the 2013 dataset.

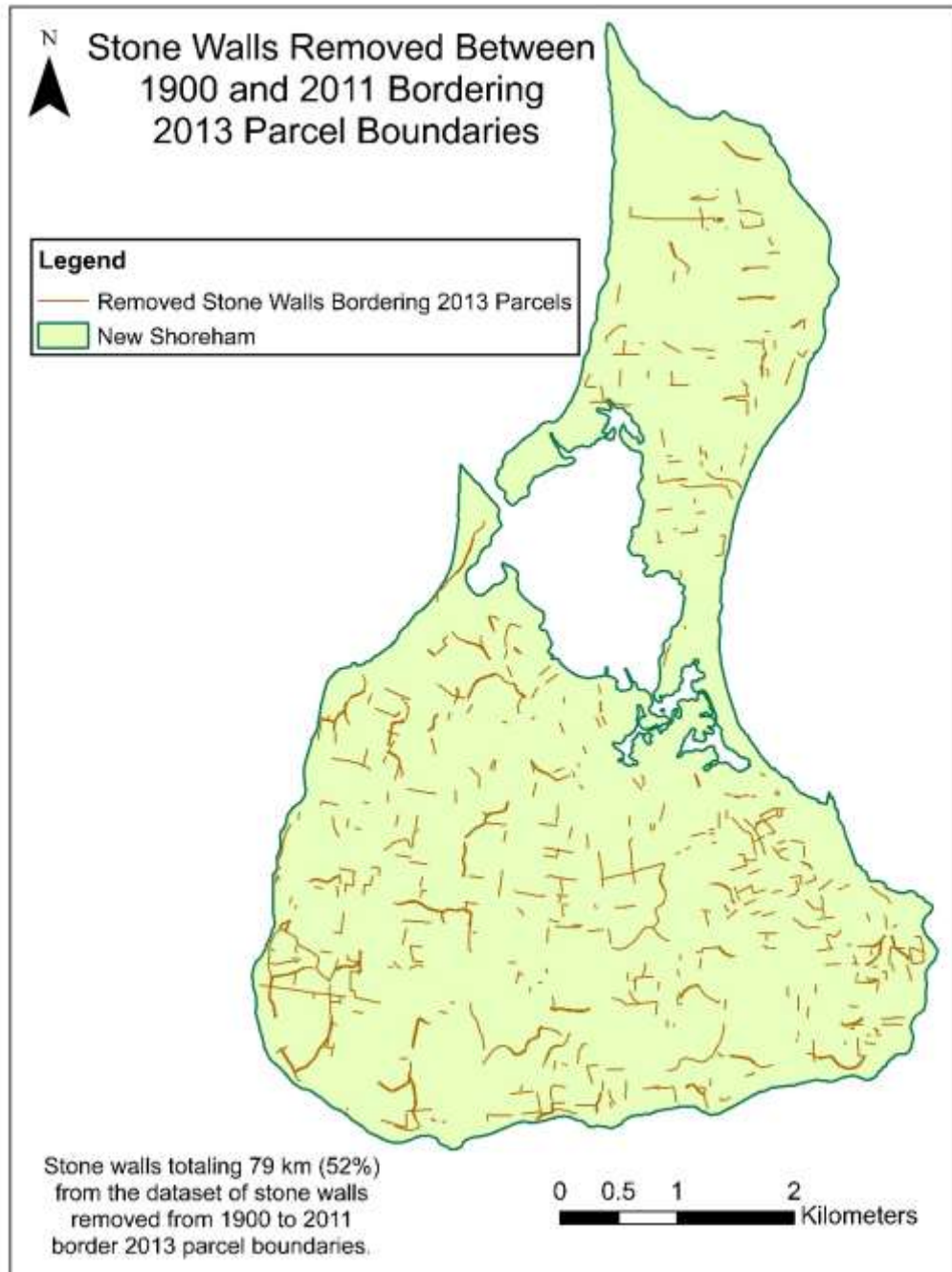


Figure 29: Stone Walls Contained within 2013 Protected Open Space
Stone walls from the 2011 stone wall dataset within protected open space as of 2013.

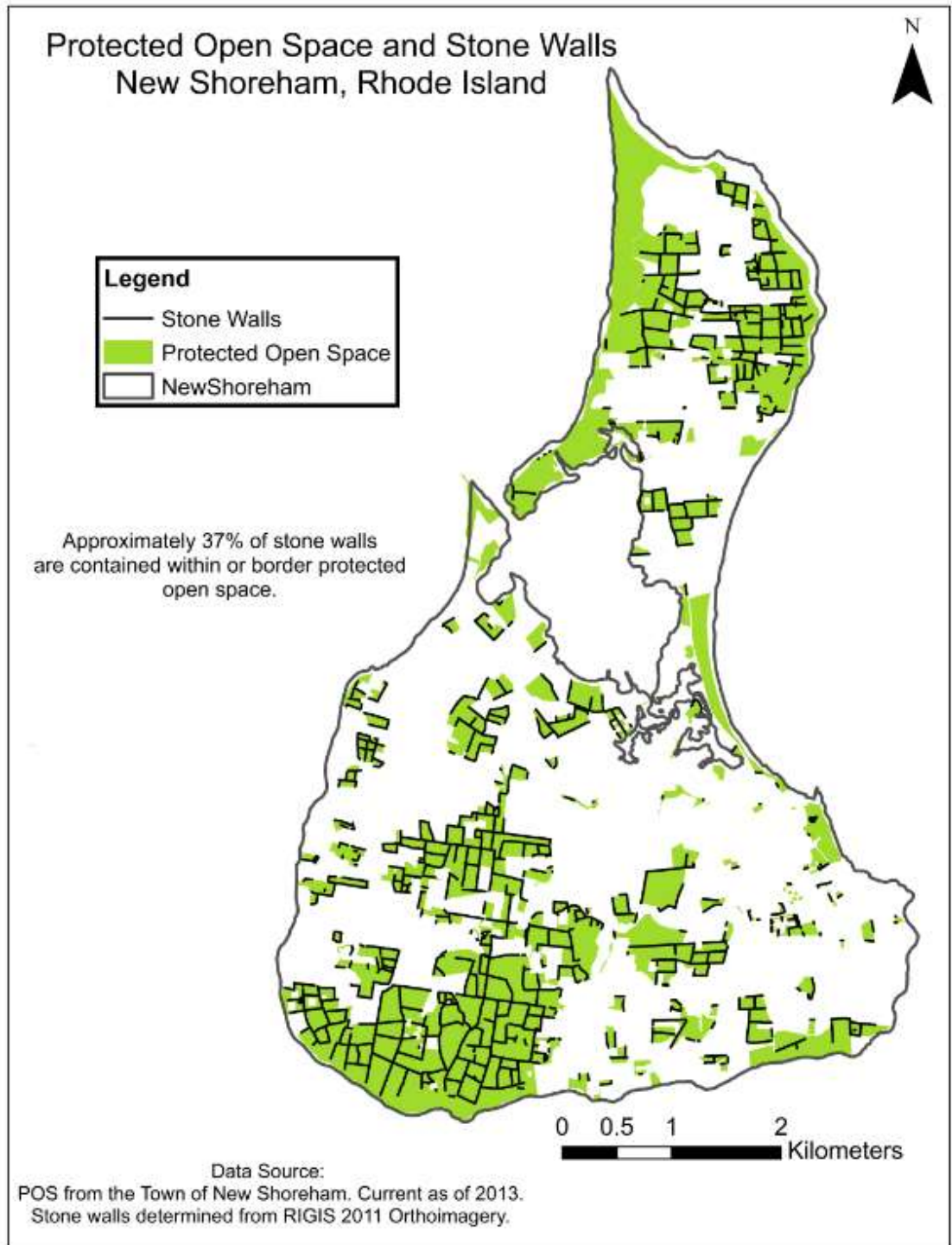


Figure 30: 2014 Ground Truthed Stone Walls

Stone walls ground truthed with use of a hand held 2008 Trimble GeoXT during the summer of 2014.

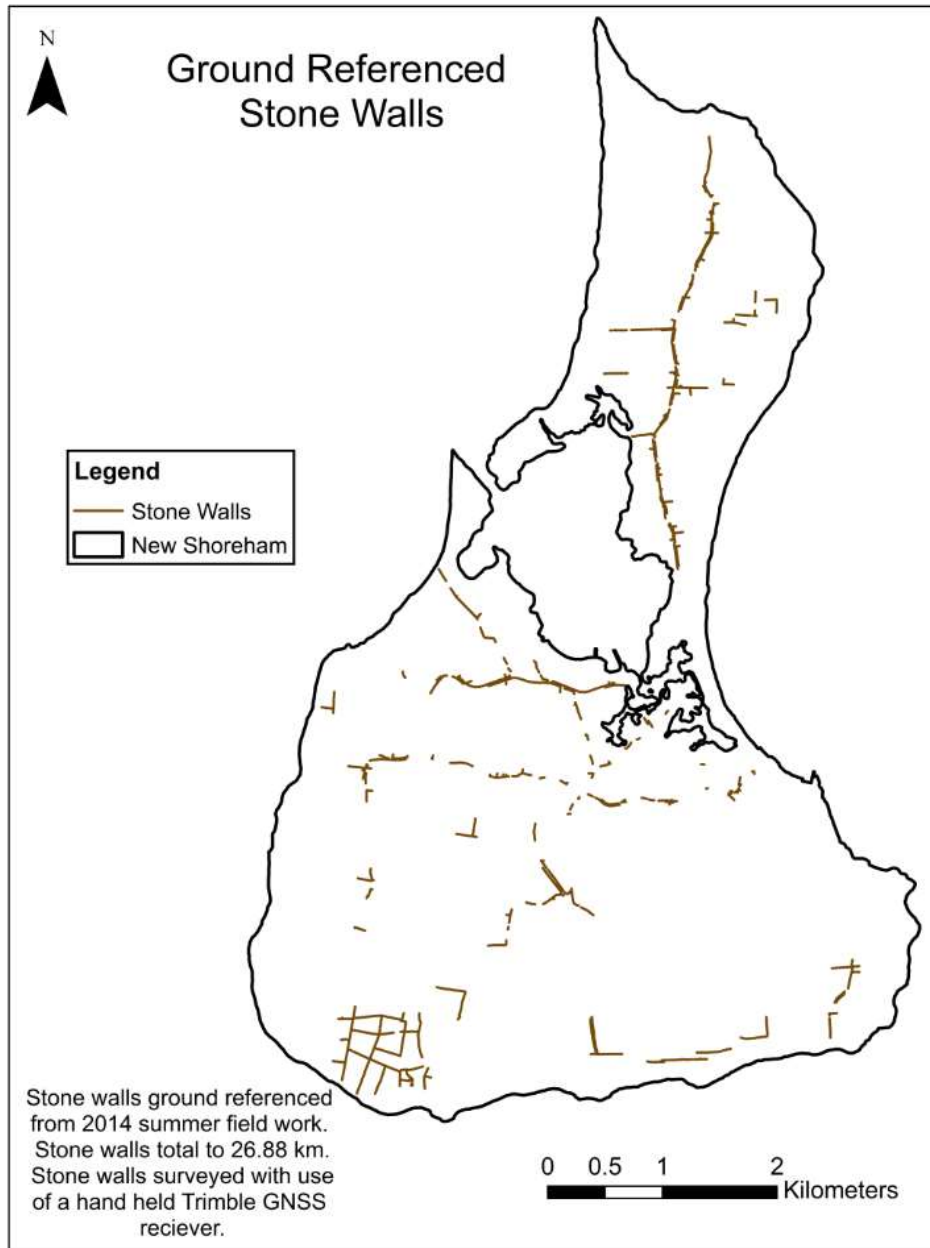


Figure 31: Change in Location of a Stone Wall from 2008 (left) to 2011 (right)



Figure 32: Change to a Stone Wall from 2003 (left) to 2003/04 (middle) to 2011 (right)



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