Understanding lək̓ʷəŋən soils: The foundation of environmental stewardship in coastal anthropogenic prairies

by

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We acknowledge and respect the lək̓ʷəŋən peoples on whose traditional territory the university stands and the Songhees, Esquimalt and W̱SÁNEĆ peoples whose historical relationships with the land continue to this day.

Supervisory Committee

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Abstract

Long-term human habitation introduces morphological and chemical changes to soil as a result of cultural, economic, and stewardship practices. These cultural soils, or Anthrosols, are recognized globally. On the Northwest Coast of North America, Indigenous marine and terrestrial land stewardship practices are recognized on present-day landscapes. Increased awareness of these stewardship practices is informed by Indigenous knowledge, ecological legacies, ethnographic studies, and archaeological evidence. This research was undertaken to better understand how lək̓ʷəŋən (Straits Salish) stewardship of a cultural landscape affected the development of soil across a village-garden gradient. On Vancouver Island, British Columbia, Indigenous cultivation of culturally important root foods was interrupted by colonization and its pervasive effects, so an additional research aim was to investigate how cultural soils remain after being disconnected from traditional stewardship. There is a growing global understanding that Indigenous management of ecosystems plays a key role in ecological health. At the regional scale, Songhees First Nation are interested in learning about their soils to inform future restoration efforts and connect youth with their land and culture. The lək̓ʷəŋən Ethnoecology and Archaeology Project (LEAP) is a collaborative research project with the Songhees First Nation to learn more about the physical remains of lək̓ʷəŋən stewardship: soils are a key part of the project. Community knowledge, ethnographic sources, and ecological legacies informed the archaeological excavation and soil sampling in this research. Archaeological excavation was utilized to understand the pedologic and archaeological setting of the site. Soil samples were analyzed for physical and chemical properties to see if a statistical difference between on and off-site samples could be detected. Data from the archaeological excavation were recorded and interpreted. A gradient of influence does exist across the village-garden; the village has a strong physical and chemical signature that can be seen through archaeological excavation, macroscopic remains in the soil, and elevated levels of phosphorous, calcium, and soil pH. Results from the garden are less clear, previous ecological studies and archaeological surveys show evidence of lək̓ʷəŋən stewardship—culturally important plant species and burial cairns are present. However, within the soil, the macroscopic remains and soil chemistry signatures are not as strong as the village which indicates that the health of lək̓ʷəŋən gardens facilitates their continued ecological functioning which ultimately may obscure earlier soil signatures of stewardship. Archaeological investigation alone does not always show the full scope of Indigenous terrestrial management practices. Incorporating present-day community knowledge, ecological legacies of plant cultivation, and utilizing soil chemical data are important to understanding the interconnections between people and their environments across cultural landscapes. Current work on the ecological legacies of plant cultivation can be assisted by investigating the soil as a site that also undergoes co-development with Indigenous stewardship.

Keywords: Cultural soils, Anthrosols, Songhees First Nation, lək̓ʷəŋən stewardship, Indigenous terrestrial ecosystem management, British Columbia, ecological legacies, Indigenous Ecological Knowledge

Table of Contents

List of Tables

List of Figures

Acknowledgments

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Chapter 1: Introduction to cultural soils on the Northwest Coast of North America

Millennia of human habitation results in physical and chemical alterations to soil through intentional and unintentional actions such as living in houses and villages; growing, processing, preparing, and eating food; and the eventual waste management. Furthermore, these anthropogenic soils are recognized globally and their characteristics are variable based on the dominant human activity that caused their initial formation (Food and Agriculture Organization of the United Nations, 2015; Howard, 2017). Anthrosols, such as the well-studied Amazonian *Terra Preta*, are characterized by their darkly coloured productive soils which contain artifacts, archaeological features, and support culturally important plant species (Balée, 2013; Clement et al., 2015).

This present research project is among the few studies of Indigenous created soils on the Northwest Coast of North America (see Deur, 2000; Hoffmann et al., 2016; Trant et al., 2016), and the first to look at blue camas (*Camassia* spp.) cultivated soils in relation to an adjacent habitation site. Archaeologists in the region have typically approached archaeological sites as places of deposition—sedimentary accumulations of natural and human transported material—not as sources of soil that co-develop with Indigenous terrestrial management. These archaeological deposits, which may or may not contain shell midden can also be soils, characterized by their in situ formation to support the growth of plants, particularly for culturally important species. The development of human influenced or created soils on the Northwest Coast, as seen elsewhere in the world, parallels an increasing awareness of the significant role of Indigenous peoples in the management of their terrestrial ecosystems (Lepofsky et al., 2017; Trant et al., 2016; Turner et al., 2013).

Tl'chés is a place of particular importance for the Songhees First Nation which carries historical, cultural, and ecological knowledge that is important for community well-being. *Tl'chés* is an archetypal example of a cultural keystone place—where a continued connection to lək̓ʷəŋən ancestors is present and visible on the land (Cuerrier et al., 2015). This project is situated in a small prairie on the smallest of the three main islands that constitute the *Tl'chés* archipelago. This meadow was selected by the Songhees Nation as a research priority because it is situated between two plank house sites: one with a series of large rectangular depressions, and the other consisting of a raised house platform. The meadow between these archaeological houses has soils that support an abundant community of culturally important plants the lək̓ʷəŋən were known to cultivate: *Kwetlal*/ blue camas and chocolate lily (*Fritillaria affinis*). The two species of blue camas that grow on southern Vancouver Island are common camas (*Camassia quamash*) and great camas (*Camassia leichtlinii*). This field was identified by Songhees community members Sellemah/Joan Morris, and Cheryl Bryce, as a site of youth engagement and near-future ecological restoration (personal communication to Darcy Mathews, [April 19, 2016]). Both have also expressed the understanding that these soils, and what their ancestors did in the past to make them healthy and productive, is key to the restoration of traditional *Kwetlal* food systems. *Tl'chés* is part of Songhees Nation reserve land which was inhabited up until the early 1960's (Gomes, 2012). In the largely urban area of present-day Victoria, BC, it remains as some of the last undisturbed archaeological and ecological land in lək̓ʷəŋən traditional territory. This study of lək̓ʷəŋən soil on *Tl'chés* is part of the lək̓ʷəŋən Ethnoecology and Archaeology Project (LEAP), a collaborative research project directed by the Songhees Nation and Dr. Mathews.

What are cultural soils?

Cultural soils at their most broad definition are places that have empirical evidence of human activity ranging from habitation and agricultural sites to burial locations, and everything in between (Howard, 2017). The key features of cultural soils are that they are altered both physically and chemically as a result of human action (Holliday, 2004). Various perspectives exist about the degree and intentionality of human influence on cultural soil formation: some research contends that these are soils made by people while others refer to them as the by-product of human activity (Silva et al., 2021; Woods, 2004). Across the broad timespan that people have been interacting with their physical environments there are examples of people degrading (Butzer, 1982) and enhancing the productivity of the soil they rely on (Frausin et al., 2014; Schmidt et al., 2014).

Cultural soils that result from cultivation are legacies of how people intentionally or accidently modified their land in order to create more idealized conditions for their chosen resources. Soil change and improvement (or degradation) in quality can vary across space and time in response to complex cultural and environmental factors. These changes can contribute to lasting soil productivity which can include measures of increased topsoil thickness, improved water holding capacity, soil fertility, and maintaining or improving soil structure (Sandor & Homburg, 2017). Sometimes human manipulation of soil in the past has resulted in soil degradation, for example widespread erosion, soil compaction, and nutrient loss, which can take centuries or millennia to recover from (Butzer, 1982). Therefore, the creation of productive cultural soils involves creating the soil conditions necessary to benefit culturally important plants while also having the overlying cultural systems necessary to sustainably use the soil so that degradation does not occur.

This research project is focused on understanding changes that result from pre-industrial land use and soils that have formed from centuries-long practices of cultivation (Anthrosols) and does not consider the many recognized changes that result from modern industrial alterations to soil (Technosols). Technosols are distinguished from Anthrosols by their inclusion of modern, post-Industrial Revolution materials such as waste from mine spills or construction material (Food and Agriculture Organization of the United Nations, 2015; Howard, 2017; Naeth et al., 2012). *Tl'chés* does not have any Technosols and remains as some of the last intact soils associated with known cultivated fields and villages in lək̓ʷəŋən traditional territory. Cultural soils will be the term used in this thesis to describe lək̓ʷəŋən soils that have developed from terrestrial resource management practices because the term conveys the multiple practices that occurred, such as village life and cultivation, that may result in different signatures in the soil.

Initial usage of the term Anthrosol was vaguely defined and used mainly by social scientists (Holliday, 2004) but has developed into a formal classification in the World Reference Base system with defined physical and chemical characteristics (Food and Agriculture Organization of the United Nations, 2015; Howard, 2017). A key attribute of

Anthrosols is their association with past agricultural activities ranging from long-term gardening activities (e.g., hortic, plaggic, pretic Anthrosols) to more significant alterations to hydrological regimes (e.g., hydragric or irragric Anthrosols) (Food and Agriculture Organization of the United Nations, 2015). The six subtypes of Anthrosols reflect the understanding that varied human actions result in distinct changes to soil. The term Anthrosol continues to be used as a soil category but researchers also understand that human effects on soil do not display harsh boundaries; rather, a "directional grading of soil property changes" away from centers of human activity are present (Orozco-Ortiz et al., 2021, p. 1). In effect, we should consider cultural soils as a gradient of attributes across time and space, in their relation to archaeological sites.

Dark earth is a related term that conveys a similar meaning of soils formed through human intervention, but the term does not carry the same definition of being related strictly to agricultural practices or having defined physical and chemical characteristics. Colour alone is not enough to distinguish human-influenced dark earths—the high input of soil organic matter in darkly coloured soil profiles can originate from natural or anthropogenic sources (Rodionov et al., 2010; Weil & Brady, 2017). Archaeologists identifying and describing dark earths rely on common features such as their dark colour, chemical enrichment compared to non-altered soils, and the presence of artifacts in the soil. The dark colouration is often attributed to the presence micro- or macroscopic charcoal particles (Howard 2017, p. 149; Silva et al., 2021). In addition to these common features, a series of other attributes are variably reported— for example, an increase in cation exchange capacity, microbial activity, and trace elements (Lehmann et al., 2003).

Recognition of and attempts to study the ways in which past humans have altered soil have been around for decades. The work of Olof Arrhenius in the early 20th century was the beginning of phosphate study in archaeological research because of its elevated levels found at ancient settlements (Cook & Heizer, 1965; Lehmann et al., 2003; Wells, 2006). Another landmark study of soil chemical changes induced by human activity came from the work of Cook and Heizer (1965) who showed how human activity introduces elevated levels of carbon, calcium, and nitrogen at settlement sites. Anthrosols and related terminology have been around since the mid twentieth century (Holliday, 2004, p. 26) while dark earth emerged as a research topic in the late 1980s to learn more about the amorphous, urban deposits found in northern Europe (Courty et al., 1989) and the term continues to gain traction and wider application in research on human-produced agricultural soils.

Cultural soils are found all over the globe with increased recognition in regions with long established research programs leading to a greater acceptance of the ways peoples in the past have modified their physical environments. Two prominent examples of cultural soils are *terra preta* from the Amazon basin and European Dark Earths found across northern Europe (Acksel et al., 2019; Schmidt et al., 2014). Less well-known but equally informative examples include investigations of cultural soils in West Africa, China, and Puerto Rico (Frausin et al., 2014; Rivera-Collazo & Sánchez-Morales, 2018; Solomon et al., 2016; Zhang et al., 2003). In North America, cultural soils formed by Hohokam farmers are recognized as Irragric Anthrosols (Schaafsma & Briggs, 2007; Woodson et al., 2015). In many instances the formation and use of cultural soils is not just an activity of the past but continues to be a feature of contemporary life (Hilbert & Soentgen, 2021; Sheil et al., 2012; Solomon et al., 2016).

How do cultural soils form?

Long-term residency often results in sophisticated management systems with people and the physical environment in a continual feedback cycle. People can manage their physical environments in ways that do not cause degradation as a by-product of increased food production. Examples from societies around the globe show that past peoples were able to steward their physical environment in a way that safeguarded against degradation and in some instances those efforts even had the ability to enhance the functioning of select ecosystems (Trant et al., 2016). In instances where ecosystem enhancement was achieved the people and the ecosystem co-evolved to depend on one another in such a way that if people were removed from the equation the environment would not flourish as it had. A popular term in research is "cultural landscapes," Lepofsky et al., (2017) define them as landscapes with human intervention that are seen through evidence such as ecosystems with high numbers of cultural plant species, higher nutrient status in soils, and obvious markers of human habitation like archaeological sites (see also Cuerrier et al., 2015). These cultural landscapes contain eco-cultural legacies which are evidence of humans shaping their physical environments. Soils are a key aspect of cultural landscapes.

Advancements in how we recognize cultural soils have been assisted by intellectual and methodological advancements in soil science. Increasingly, humans are recognized as a formation factor in soil because they can alter existing soil and affect developmental factors, for example, reshaping topography and removing or translocating plants and animals (Howard, 2017). Humans, going back millennia, have exerted extensive change on their physical environments; however, modern effects of human impact on soil are a global concern as large-scale industrial activities cover more land surface and climate change destabilizes ecosystems (Erlandson, 2013; Sandor & Homburg, 2017; Stephens et al., 2019). The need for safeguarding soil can benefit from learning how past people have successfully managed their soil and provide lessons for localized contexts.

Types of cultural deposits on the Northwest Coast

Habitation sites are the primary location of cultural soils on the Northwest Coast but so far have been regarded by archaeologists as deposits or sediments that have been transported to the site. Employing the concept of anthropogenically modified soils discussed above, I suggest that deposits within and surrounding archaeological sites on the Northwest Coast can be conceptualized as cultural soils. In particular, habitation sites—especially villages that have long-term or intensive use—can be distinguished by the high density of cultural materials that remain in place and become part of soil development. These materials can include products of village life, for example, hearths, organic and inorganic refuse from meals, and whole or broken household goods or tools.

There has been little distinguishment between soils and sediments in field archaeology. Notably, Julie Stein pointed out the difference between sediments (deposits transported though natural or human action) and soils (in situ formation of organic and mineral material in which plants grow). Consequently, Stein challenged archaeologists to be more specific in our usage of terminology (Stein, 1992b; Stein & Farrand, 2001). The distinction is important from a geoarchaeological perspective when research tries to understand how a site formed but should be used cautiously when thinking about how people interacted with and stewarded their lands in the past. In these former habitation sites, the deposits of village life undergo in situ soil development as ecological processes continue to function. Throughout coastal North America these habitation and shell-midden sites are known to be sources of high nutrients that feed plant growth, and sources of increased biodiversity (Cook-Patton et al., 2014; Erlandson 2013; Sawbridge & Bell, 1972; Trant et al., 2016; Vanderplank et al., 2014). These are an undeniable type of cultural soil, but they are not the only example.

Coastal archaeological sites in British Columbia are sometimes associated with dark earths that field archaeologists have colloquially called “shell-less midden” (Darcy Mathews, personal communication, May 3, 2022). These areas of dark, “greasy” soils are often associated with shell-bearing sites but have little or no shell themselves. There are two contexts shell-less middens are found in; the first, is the basal deposits underlying shell middens and the second context is deposits horizontally associated with adjacent concentrations of shell. Darkened, shell-less basal deposits have been investigated in the Salish Sea region and can potentially be explained by carbonate leaching (Stein, 1992a, 2008), although this is not always the case (Sullivan, 1993). Shell midden has also been documented as material for terraforming landscapes in the Salish Sea (Grier, 2014; Grier et al., 2017) but that does not mean that all coastal archaeological sites are comprised only of shell bearing deposits. The site formation issues associated with the second, horizontal context of “shell-less midden” soils has not been fully investigated and they are still poorly understood. Consequently, they are easily missed or misidentified during archaeological investigations. This has significant implications for heritage management in British Columbia, as potentially cultural sediments and soils are not being adequately identified, investigated, and managed.

The lack of research on cultivated soils in the Northwest Coast parallels a larger issue: an incorrect and long-standing anthropological construction of non-agrarian Indigenous peoples (Deur, 2002a, 2002b). The colonial assumption is that Indigenous plant cultivation was not practiced on the Northwest Coast because it did not look familiar to the eyes of the European settlers. Settlers and anthropologists looking for cultivation in North America were evaluating it against standards of European cultivation, for example, large expanses of fields, and crops planted in rows (Deur, 2002a). Settlers and anthropologists recorded the importance and abundance of salmon and shellfish to support their view that Indigenous peoples did not need to cultivate plants because other food sources were prevalent. What resulted were colonial and academic narratives of the Northwest Coast based on limited observation and little to no input from Indigenous peoples stewarding their territories. These narratives were constructed and replicated by succeeding generations of settlers and researchers (Deur, 2002b). A new generation of academic research has sought to challenge these early and unfounded assumptions by documenting the many ways in which environments on the Northwest Coast have been shaped and managed by Indigenous stewardship (Deur & Turner, 2005; Lepofsky & Armstrong, 2018; Mathews & Turner, 2017; Turner et al., 2013).

This is exemplified in community-based work in estuarine root gardens where Kwakwa̱ka̱ʻwakw and Nuu-cha-nulth peoples cultivated Pacific silverweed (*Potentilla anserina*) and springbank clover (*Trifolium wormskioldii*). This practice has gained recognition in western research, initially through the work of traditional knowledge holders collaborating with Douglas Deur (Deur, 2000). In his PhD dissertation, Deur conducted an investigation of gardens sites across western Vancouver Island and was explicit in his investigation of the anthropogenic origins of the deposits, calling them "engineered environments" (Deur, 2000, 2005). This work—likely the first academic investigation of cultural soils on the Northwest Coast—remains one of the few regional studies to show how soils can be formed by Indigenous management. Indigenous construction of rock wall features in these gardens resulted in observable morphological, textural, and pH changes to the soil (Deur, 2000, pp. 248-249).

In addition to cultivated soils in estuarine gardens, is the recent work on Coast Salish gardens where wapato (*Sagittaria latifolia*) was cultivated in the traditional territory of the Katzie First Nation (Hoffmann et al., 2016; Lyons et al., 2021). Site DhRp-52, identified during the construction of the Golden Ears Bridge, which now crosses the Fraser River, is comprised of a wetland cultivation site with an associated stratified archaeological site on dry land (Hoffmann et al., 2016). The strong evidence for a cultivated garden includes: charcoal rich sediments, numerous fragments of cultivation tools (tips of digging sticks), and an engineered rock pavement made of fire altered rocks (Hoffmann et al., 2016). In addition to the garden was an associated complex of archaeological use-areas such as habitation features and midden deposits that are situated within the larger Coast Salish cultural landscape of the lower Fraser River (Lyons et al., 2021). Both estuarine gardens and wapato cultivation are wet sites where anerobic preservation of organic material is favourable and the use of constructed rock features enhances the ecological conditions necessary for targeted plant cultivation.

Indigenous cultivation of terrestrial root foods is equally well documented, particularly for the cultivation of blue camas (*Camassia* spp.) from Oregon to southern Vancouver Island. I outline this in further detail in Chapter 2. Unlike wetland root gardens, however, the ways in which cultivation could have resulted in the formation of a cultural soil has yet to be explored. The difference between wetland and terrestrial dryland cultivation is noted in the different preservation potentials of these environments. In dryland environments organic matter is likely to degrade and become reincorporated into the soil because of exposure to wet and dry cycles that breakdown the structure of remains. The lack of direct evidence of cultivation has been noted by regional researchers as a challenge (Lyons & Ritchie, 2017; Weiser, 2006) and the documentation of these sites is more likely to rely on proxy evidence such a plant processing features, archaeological finds of cultivation tools, and the occasional find of botanical remains in archaeological contexts (Weiser & Lepofsky, 2009).

Archaeological challenges to identifying cultivation sites and their cultural soils can be assisted by studying present-day plant communities, especially culturally important species. Ethnoecological studies are becoming well-developed on the Northwest Coast and the ecological legacies of many culturally important plant species are increasingly well understood (Turner et al., 2013). This advancement has resulted from collaborative projects between Indigenous communities and researchers where the project priorities and questions address community knowledge and goals. On *Tl'chés*, Songhees knowledge holders have identified the study site based on its cultural and ecological importance which formed the basis for this thesis.

Positionality

The privilege of doing this work and writing this thesis has happened alongside a state of assessing my relationship to the work and how my own learning has changed over the course of this study. I am a person of Euro-Canadian settler descent who was a visitor in lək̓ʷəŋən and W̱SÁNEĆ territories during my studies at the University of Victoria. My previous academic training is in archaeology, where I learned under a dual framework of understanding the extractive, colonial history of archaeology which contrasted with learning about the many ways in which Indigenous knowledge holders and allied scholars work to document the past in a way that is meaningful to descendant communities. An influential experience was my field school that the K'ómoks First Nation and Simon Fraser University partnered to run. This first, hands-on archaeological experience confirmed my interest in excavating but it was also my first view of how a project can be run with the purpose of answering questions determined in consultation with present-day communities.

Working under the LEAP project with Songhees First Nation allowed me to expand my knowledge further and provided the guidance of having a thesis that fit within the larger project goals of learning more about the deep history of *Tl'chés* for youth land-based education and near future ecological restoration. These overarching goals have shaped how I see archaeology and changed my perspective that it is not just an interest in the past but also an endeavour that connects the past to the present, and future. As a researcher I am continuing to learn how to occupy the space between becoming an academic 'expert' and learning there is so much importance in always viewing yourself as a novice where you can be open to correcting and re-assessing your knowledge.

Research questions: Evaluating blue camas garden soils

Blue camas research continues to deepen our understanding of Indigenous cultivation practices and the ecological conditions necessary for camas growth. However, to date no research has investigated the anthropogenic origins of soils associated with camas cultivation on the Northwest Coast. As mentioned above, the meadow studied in this thesis is located on *Tl'chés* and is situated between two lək̓ʷəŋən archaeological villages. Two research requestions have been developed to address how we may study the lək̓ʷəŋən origins of cultural soils resulting from root food cultivation (Table 1).

Table 1. Research questions addressing lək̓ʷəŋən soil development.

Research question	Source of data	Methods
Does a gradient of cultural influence exist as you move from the village to the meadow?	Field excavation data; soil profile description; soil chemistry	Excavation of evaluative units across village-meadow gradient; chemistry and soil morphology measured at each unit
Did lək̓ʷəŋən management of the *Tl'chés* meadow—traditional burns and cultivation—alter the soil in ways that are detectable after decades of interruption to traditional stewardship?	Field and laboratory data: texture; organic matter; nitrogen; carbon; pH; calcium; phosphorous	Chemical analysis of meadow soil; *t* test of results between on and off-meadow samples Research hypothesis: soils in the meadow would differ significantly from those found off-site

Thesis outline

This research began with a synthesis of the global literature on Anthrosol and dark earth soils to set the context for how soils associated with Straits Salish root foods might be affected by these cultivation practices. Chapter one has briefly addressed what the common features of cultural soils are and how they typically form. The chapter also reviewed some of the Indigenous cultivation practices that are known from the Northwest Coast of North America. The research questions and thesis outline are presented to orientate the reader to the structure of the thesis.

Chapter two provides the background context for the study including a review of ethnographically known Straits Salish land stewardship practices that potentially impacted soil through root food cultivation, as well as cultural practices such as village life, that may have intentional or unintended effects on surrounding soils. The physical environment of the region is discussed in addition to the physiographic and cultural context of *Tl'chés*.

Chapter three outlines the methodology developed in this project to answer the research questions. As part of this, I create a hypothetical model of proposed alterations to soil developed from ethnographic literature and previous studies of cultivation on the Northwest Coast (Table 2). Chapter four presents the results of the research and discusses their implications. The results are organized by the archaeological excavation data and then the results of the soil sampling from the meadow and off-site location. Through the discussion the results are analyzed and interpreted considering the ethnographic literature. Finally, chapter five summarizes and concludes the thesis.

Chapter 2: lək̓ʷəŋən land-use and its effects on soil, ecosystems, and landscapes

This project is centered in the lands of the lək̓ʷəŋən peoples, who are known today as the Songhees and Esquimalt Nations. lək̓ʷəŋən peoples and their neighbouring kin and nearby houses and villages, have been collectively called the Straits Salish (Suttles, 1974). They have a shared history going back millennia. Straits Salish includes peoples that share related languages, economies, and familial histories: but for all the overarching similarities, every individual house is an autonomous unit.

Straits Salish peoples occupied the full extent of their territories through seasonal movements. Strict borders were not a common feature in the Straits Salish world. As Thom (2009) describes, territories were defined by interrelated relationships, language, and sharing through established protocols that represent the region. Seasonal movements were anchored by time spent at seasonal camps and at larger winter villages. Focusing on the economic viewpoint, time at seasonal camps was used to gather foods and necessities for the year such as: shellfish, marine animals, and plants from terrestrial and marine ecosystems. Equally important were cultural activities that occurred throughout the year, but these are not covered in this thesis because of the focus on the development of lək̓ʷəŋən soils in a village–cultivated meadow gradient. The land-based practices related to this project are the cultivation of root foods, site-level burning, habitation, and food production. All these activities have the potential to leave tangible evidence in the soil.

With the arrival of European explorers on the Northwest Coast and the expansion of colonial endeavours, lək̓ʷəŋən stewardship underwent rapid changes that often resulted in root food meadows being appropriated for settler agriculture (Turner, 1999). Grazing from sheep, pigs and cattle reduced the cover of traditionally important plants and colonial administrators restricted lək̓ʷəŋən people from traditional stewardship through the outlawing of yearly burns (Turner, 1999). These changes meant that these culturally developed ecosystems were cut off from the lək̓ʷəŋən activities that sustained them. Small islands often became the only place people were able to maintain camas cultivation (Suttles, 1974; Turner, 1999). Today, habitat fragmentation and invasive species are among the many threats to coastal prairie ecosystems but restoration efforts and interest in re-establishing traditional cultivation are ongoing (Derr, 2014; Dunwiddie & Bakker, 2011; Hamman et al., 2011).

ləkʷ̓əŋən landscapes are historical landscapes, with a diversity of uses across space and through time (Mathews, 2014). ləkʷ̓əŋən practices leave both archaeological traces and ecological legacies that can be seen to this day. In the following two sections, I briefly outline aspects of ləkʷ̓əŋən life that may have had both intended and unintended consequences in the development and altering of soils. I divide these into two broad categories: domestic life and stewardship practices.

Domestic life

Chemical analyses of soil at archaeological sites has found that human habitation results in increased elements where people live, dispose of waste, and bring material for their use in building homes, manufacturing tools, and consumption. Pioneering work by Cook and Heizer (1965) demonstrated that accumulations of calcium, carbon, phosphorous, and nitrogen occur in habitation sites. They describe three main sources of additions as: unused portions of plants or animals used for foods, excreta and urine from humans and animals, and manure fertilizer when groups utilized domesticated animals. Not all of these sources are specific to the ləkʷ̓əŋən context and some are unknown but it is certain that there was established etiquette for what happened within the village.

Additional specific sources of calcium, nitrogen, and phosphorus come from bones and shells used in tool manufacturing, ceremonial items, and from processing, preparing, and eating food. Any tools or possession that were left at the village would decompose over time adding to chemical enrichments or if they happen to preserve, will be present as artifacts. Because concentrations of elements occur where material is deposited it is likely that berms around houses in the village would be sources of concentrations. Additionally, Suttles describes daily sweeping of Straits Salish plank houses (Stein, 2000, p. 63; Suttles, 1974, p. 258), meaning inside homes would likely have fewer particles and lower chemical enrichments compared to disposal piles. Hearths from inside homes would be sources of charcoal, ash, fire altered rock, and possibly food that was accidently carbonized. Interestingly, organic matter dissolves rapidly in acidic soil conditions like those found on the Northwest Coast (Smith et al., 2011), however, it has been noted by researchers that large accumulations of shell result in calcium enrichment and can lead to a more neutral soil pH (Cook-Patton et al., 2014; Trant et al., 2016; Vanderplank et al., 2014) which creates the conditions for greater preservation of organic materials.

lək̓ʷəŋən winter villages were often placed in front of camas prairies where root foods could be cultivated and protected (Suttles, 1974, p. 59). Camas and other root foods were processed close to cultivation sites using pit-cooks to prepare large quantities of foods before they spoiled so they could be dried and stored or to be served during feasts (Beckwith, 2004, p. 82). The preparation of pit-cooks involved digging a pit—which may be reused over time— lining the pit with rocks, generating a fire to produce coals, adding the selected foods, covering the pit and adding fresh water before letting it cook for several hours (Louie Pelkey to Suttles, 1974, pp. 61-61; see also Suttles, 2005). All the materials that went into pit-cooking have the potential to leave macroscopic remains, for example, carbonized botanical remains, fire altered rock, ash, and charcoal.

Stewardship practices: Cultivation, managing, and burning

Research of root food cultivation in the Salish Sea region is mostly centered around blue camas. Ethnographic and historic records mention the importance of camas bulbs to local First Nations and how important it was as a food and trade item (Turner & Kuhnlein, 1983). There is information on other plant foods that were eaten such as Hooker's onion (*Allium acuminatum*), chocolate lily, and bracken fern (*Pteridium aquilinum*) (Turner & Bell, 1971; Turner & Hebda, 2012) but there is less published research on these plants as cultivates. Pacific crabapple (*Malus fusca*) was a widely desirable food with recorded stewardship practices from Indigenous peoples throughout the Northwest Coast (Armstrong, 2017; Lepofsky et al., 2017; Wyllie de Echeverria, 2013). Another culturally stewarded plant was Scouler's willow (*Salix scouleriana*) which was integral to making reef nets for fishing (Claxton, 2015). All of these cultural plants are present in the meadow on *Tl'chés* (Gomes, 2012) and have been identified as likely candidates of Straits Salish cultivation practices (Turner & Peacock, 2005, p. 140).

Systems of ownership were developed by lək̓ʷəŋən people where some cultivated plots—usually the best and most productive—were privately owned by family groups while other plots were open to any person who sought to dig there (Turner, 1999). There are reports of boundaries being established around owned plots, which would serve to delineate plots and mark ownership especially of the highly productive plots (Beckwith, 2004). An important part of maintaining camas fields were to clear the land of large stones which would be piled at the field margins and over time "the piles of stones on the plots are the remains or 'markers' of the plots" (Christopher Paul to Babcock, 1967 as cited in Beckwith, 2004, p. 71). More durable forms of plot markers, like rock alignments, may survive until present but wooden stakes, low ditches, or mounds are likely to lose visibility without regular maintenance (Deur, 2002b; Lepofsky & Lertzman, 2008). Additionally, as Beckwith speculates plot boundaries may have been misidentified or overlooked by early settlers and "the stones eventually became overgrown or were cleared for agriculture" (2004, p. 72). Figure 1 shows a potential camas plot boundary identified by Dr. Mathews at the Rocky Point site on southern Vancouver Island.

Figure 1. Possible blue camas field stone clearing identified by Dr. Mathews at Rocky Point. Photo by: Darcy Mathews.

Camas blooms in the spring sending up beautiful purple flowers (Figure 2). As the months progress towards summer the flowers die back but a distinctive stalk remains above ground. Historically, during summer families would live near the camas meadows and traditionally the women of the family would go out and dig camas bulbs while men were fishing (Turner, 1999). There are some reports that selection criteria were used by the women to decide which camas bulbs to keep and which to put back in the ground until they were big enough to harvest. Pointed digging sticks were used to turn over the root mat in fields which allowed for the selection of desirable bulbs and aerated the soil making it easier to dig over time (Beckwith, 2004, p. 73).

Figure 2. Kwetlal (*Camassia* spp.*)* (left), Chocolate Lily (*Fritillaria affinis*) (right).

After the harvesting season was finished the camas fields were burned which is said to improve the productivity of the plants in following years (Turner, 1999). It is worth considering that camas fields were annually tended plots where weeding and selective harvesting occurred, these fields had an open structure with blue camas, root foods, and native grasses as the predominant vegetation. Yearly burning of this material would not have resulted in large fires, rather low-severity fires were occurring regularly. Soil charcoal produced from frequent, low-severity burns was likely microscopic because the vegetation would be almost fully consumed as these areas were dominated by small, highly combustible plants (Kira Hoffman, personal communication, February 4, 2022). It is low-intensity fires that have the greatest potential to improve soil quality by adding base elements to the soil (Turner, 1999) and freeing nutrients from organic matter and minerals that can be more readily absorbed by plants. Fertilization of camas fields was also accomplished by applying seaweed to the soil before burning at the end of the season (Suttles, 2005, p. 181). Suttles speculates seaweed as fertilizer may be a 20th century practice, however, the antiquity of using seaweed as a fertilizer in camas meadows has not been investigated. Introduction of new techniques to improve cultivation is a common feature of cultures, therefore, despite the possibility of the recent origins of seaweed application, it should still be regarded as a Straits Salish practice.

Site description: A lək̓ʷəŋən landscape

Located in the Salish Sea, *Tl'chés* (Figure 3) is an archipelago known in English as Discovery and Chatham Islands. *Tl'chés* is part of the broader lək̓ʷəŋən landscape that prior to colonization would include a portion of San Juan Island to the east and extended north and west to meet the territories of the W̱SÁNEĆ and T'Sou-ke Nations. *Tl'chés* is the lək̓ʷəŋən word for these lands meaning 'islands' (Bryce & Sam, 1997; Mitchell, 1968, as cited in Gomes 2012, p. 3). The research for this thesis was conducted solely on West Chatham Island (48°25'52.0788" N; 123°15'16.6788" W) but will be referred to as *Tl'chés* for the remainder of this thesis.

Previous work by the Songhees First Nation and Gomes and colleagues (Cuerrier et al., 2015; Gomes, 2012, 2013) have highlighted the importance of *Tl'chés* as a cultural keystone place—a centre of cultural knowledge, values, and relationships for lək̓ʷəŋən people for millennia. *Tl'chés* connects Songhees with their land and provides a tangible place for the community to connect with their history which is critical to a sense of identity and well-being. Concurrent with Songhees stewardship of *Tl'chés* are increasing ecological threats from invasive species and human impacts from trespassing, littering, and prohibited beach fires. Gomes (2012, p. 57) identified Himalayan blackberry (*Rubus armeniacus*) and agronomic grasses as the main invasive species affecting the southern meadow where this research was conducted.

Figure 3. Regional map of *Tl'chés* in relation to present-day city of Victoria, with inset showing location on Northwest Coast.

The open meadow on *Tl'chés* is bounded by shoreline bluffs on the south and east margins, and by bedrock outcrops and vegetation on the north and west margins (Figure 4). A thick border of Himalayan blackberry, oriented northeast to southwest separates the deep soil meadow from the rocky outcrop with shallow soil used as a control site. In addition to similar vegetation, the open meadow and control site are under the same biogeoclimatic ecological zone—Coastal Douglas-fir moist maritime (CDFmm)—and the same igneous and metamorphic geology (Clapp, 1913).

The southwestern extent of the meadow is delineated by five archaeological plank house depressions, the largest (Bighouse 5) being approximately 33 m long and 18 m wide. The closest plank house depression to the meadow is designated as Bighouse 1, and it is approximately 28 m long and 11 m wide (Figure 4). These houses are situated on a wind-exposed point of land facing west and south towards prevailing winds. The shoreline is also steep, exposed bedrock, rising approximately 4 m above sea level. The exposed and rocky site is an unusual place for a winter village, and its defensible location, with panoramic sightlines, and steep shore suggests this site is a small defensive site, but with large winter village-sized houses (Darcy Mathews, personal communication, May 17, 2022). Additional archaeological work is required to determine the site function and chronology; however, such defensive sites and features are regionally associated with the last 1500 years (Angelbeck, 2009). Furthermore, the presence of burial cairns, along the peripheries of the meadow are similarly associated with the last 1500 years (Mathews, 2014). There is a human-made platform at the southern tip of the island (Figure 4). The function of this platform is currently unknown, but the seaward side of the feature shows a stacked stone retaining wall. This location receives the most wind and sun on the island, and speculatively, it would have been a good place for fish drying racks in the summer. Spring and summer-caught fish were sun-dried on wooden racks (Suttles, 1974, p. 142). Such racks were also often situated in front of summer temporary mat houses for the fishing crews (Suttles, 1974, p. 164). There has not been any previous systematic archaeological inventory or subsurface testing at this meadow prior to the current study and these archaeological houses appear to be unknown to the Songhees community.

Figure 4. Aerial photo of archaeological village portion of the study area, looking east to Bighouses 1-5, and Platform feature. East Chatham Island is in the background. Photo by: Darcy Mathews.

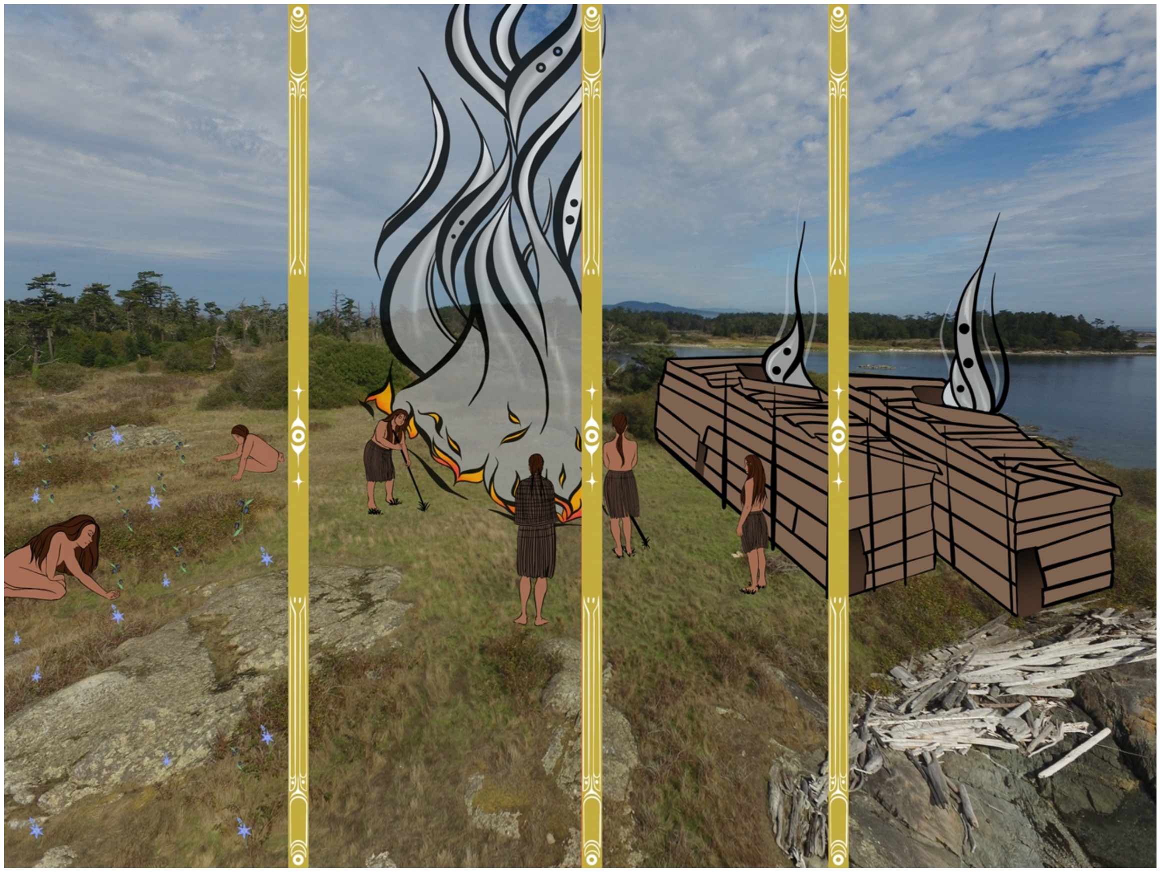

Figure 5. Songhees artist Jessica Joseph's illustration of the stages of lək̓ʷəŋən kwetlal stewardship beside the *Tl'chés* plank house village (Image used with permission).

My research project contributed to LEAP by studying the soils on *Tl'chés* to learn more about how they contributed to past blue camas stewardship, as well as how soils might inform present and near-future camas restoration, which is an expressed priority of the Songhees Nation. This provides a baseline of soil information for the community, as well as providing a historical framework for understanding the composition of lək̓ʷəŋən soils at a village-garden complex within this cultural keystone place. Figure 5 depicts the harvesting, traditional burning, tilling, and village life that were all part of lək̓ʷəŋən *kwetlal* stewardship, illustrated by Songhees artist Jessica Joseph. Although these activities would take place at various times over the season they have been included together in the illustration to show some of the activities that occurred in the *Tl'chés* meadow. The illustrated Bighouses are imposed over the plank house footprints visible in the field. This field was selected as a research priority by Songhees knowledge holder Sellemah/Joan Morris, who was born and raised at *Tl'chés*, on West Chatham Island. She was raised by her great grandparents Tom and Alice James, who lived in a house and small farm on the east side of the island, about 390 m NNW of the study site. Sellemah invited me, and welcomed me to *Tl'chés*, following lək̓ʷəŋən traditional protocols. The site was also selected as a research priority by Cheryl Bryce, a lək̓ʷəŋən knowledge holder, and the Songhees Nations Land Manager at the time this project started.

Physical environment

Below is a summary of some of the main processes of soil development that operate in this region. A lot of information has been written about prairie ecosystems both in the immediate study area and on the Northwest Coast of North America. There have also been some studies on the unusual dark soils that form around what is now known as Victoria, BC (Broersma & Lavkulich, 1980). Historically, researchers have viewed formation of the physical environment as a natural process that operates separately from human influence. However, more recent research challenges this human–nature dichotomy and is expressly interested in studying how cultural landscapes form through feedbacks of natural processes and human intervention (Armstrong, 2017; Fitzhugh et al., 2019; Lepofsky et al., 2017).

Climate and prairie ecosystems

Prairie ecosystems are fire-dependent systems that are broadly controlled by regional climate and Indigenous fire stewardship, principally frequent landscape-level burning. Coastal prairies and Garry oak (*Quercus garryana*) savannah ecosystems are recognized eco-cultural systems that people actively kept in an early successional, mostly tree-less state through periodic burning. Changing climate patterns from a cool, dry climate post-glaciation (approximately 10,000 years before present) to the current cooler, wetter climate favours vegetation succession and increased tree cover (Brown & Hebda, 2002). Researchers have demonstrated the regional pattern through charcoal and pollen in lake sediments as well as fire scars and other more interdisciplinary approaches (Gedalof et al., 2006; McCune et al., 2013; Pellatt & Gedalof, 2014). This helps identify large fires but many researchers acknowledge a challenge in recording small and low-intensity frequent fires is that they are difficult to detect using a single method approach and therefore need multidisciplinary methodologies.

Ecological succession of prairie ecosystems was first impacted by changes to traditional management (population decline, colonization, settler colonial outlawing of burning). This resulted in mostly tree-less prairies supporting greater populations of oak trees that could rebound because people weren't there to burn of seedlings before they could establish (Pellatt & Gedalof, 2014). Once Garry oak savannas became more prevalent it created conditions where Douglas fir (*Pseudotsuga menziesii*) could establish, because there was no landscape burning and Douglas fir is tolerant of shade. Sites with deep, moist soil conditions were often the first places appropriated for colonial agriculture. Today these sites need the most intervention to prevent succession because Douglas fir trees are encroaching on Garry oak savannahs and further reducing critical habitat for Garry oak and associated species (McCune et al., 2013).

Additional prairie ecosystems are often found on small islands, like *Tl'chés*, which have shallow, dry, and rocky soils. These shallow soils site don't always support oak trees or Douglas fir because the soil is not deep enough, but they do face threats particularly from invasive species, habitat fragmentation, and urban expansion (McCune et al., 2013). The southern meadow on *Tl'chés* reflects the regional pattern, of shallow soils supporting a suite of culturally important plants and invasive species (Gomes, 2012). Between the late 1990s and early 2000s a portion of the meadow on *Tl'chés* was burned by Songhees Nation to control the invasive vegetation, and regenerate cultural plants and traditional stewardship in the meadow (Gomes, 2012, p. 58). Reintroducing burning to these ecosystems is one restoration strategy aimed at conserving the remaining Garry oak and prairie ecosystems on southern Vancouver Island (Dunwiddie & Bakker, 2011).

Climate—measured by temperature and moisture—exerts some control over soil production. In general, a cooler climate such as that found on the Northwest Coast will facilitate an accumulation of organic matter and total nitrogen because decomposition and reincorporation of these material into the soil is relatively slow compared to warmer climate conditions (Jenny, 1994). However, this is just a general principle and the other soil forming factors—parent material, time, organisms, topography, and human influence—all affect formation and modify soil. The Southern Vancouver Island climate has been stable for several millennia and due to the rain shadow effect is described as generally being drier than the surrounding Northwest Coast with mild, rainy winters and semi-arid summers (Brown & Hebda, 2002).

Ecological legacies

Ecological legacies are evidence of prior disturbance—natural or human induced—that influence the present-day ecosystem. Cuddington (2011, p. 207) defines ecological legacies as "an indirect effect that persists for a long time period in the absence of the causal species, or after this species has ceased the causal activity." Indigenous stewardship on the Northwest Coast can have a positive influence on plant species diversity and functional trait diversity of ecosystems (Armstrong et al., 2021). The ecological legacies of lək̓ʷəŋən stewardship on the southern meadow of *Tl'chés* include populations of *kwetlal*/camas, chocolate lily, bracken fern, Hooker's onion, *q'əx̱mín/*Bare-stem lomatium *(Lomatium nudicaule)*, yarrow (*Achillea millefolium*), stinging nettle (*Urtica dioica*), crabapple, and Scouler's willow. Combinations of these species are present in anthropogenic prairies on the Northwest Coast (Weiser, 2006; Weiser & Lepofsky, 2009), and are indicative of the cultural landscape on *Tl'chés* (Gomes, 2012). The ecological legacies of these cultural plants were one criteria used in this study that defined the meadow boundaries on *Tl'chés*.

As described above, the cultivation and stewardship of camas has been widely documented. Other cultural plants known to be important sources of food, medicine, and material were not as extensively detailed in the ethnographic literature and the specific management practices of these plants do not have the same comprehensive detail as does camas stewardship. An exception is chocolate lily which overlaps with camas habitat in Straits Salish territory (Turner & Kuhnlein, 1983) and was likely cultivated along with camas bulbs. Dr. Mathews describes the chocolate lily population on *Tl'chés* as the densest he has seen on the Northwest Coast (personal communication, June 4, 2020).

Additionally, lək̓ʷəŋən families were known to own “specific beds of fern roots, which were passed down from generation to generation” (Mitchell [1968] as cited in Turner & Bell, 1971, p. 69). It is most likely that these were beds of bracken fern although it is possible that other species with similar ecological growing conditions were also present.

Underlying geology

The geology of southern Vancouver Island is made up of igneous and metamorphic bedrock overlain by unconsolidated sediments arising from periods of glacial and interglacial activity (Clapp, 1913). Early geologic maps of *Tl'chés* show the bedrock belonging to the Wark gabbro-diorite gneiss formation with a surface geology listed as rocky outcrop (Clapp, 1913). Surficial geology for southern Vancouver Island is mostly comprised of glacially derived gravel and sands with some areas of clay. These deposits can be several meters thick overlaying the bedrock and becoming the primary material soil forms upon, the characteristics of the parent material affect various properties of the soil, most importantly the texture of the soil which in turn influences drainage and movement of nutrients in the soil profile (Weil & Brady, 2017). Loosely consolidated sands and gravels facilitate drainage within soil which balances the supply of air and water necessary for plant life. However, a drawback with excessively drained soils is their potential to become very dry especially during the summer months when precipitation is low.

Pedogenic setting

In the Canadian System of Soil Classification, the soils around Victoria, BC, mainly belong to the Brunisol great group although Podzols are also common especially in more established forested ecosystems. Jungen and Lewis (1978, p. 112) note that Sombric Brunisols are found within Garry oak-grass ecosystems that have open, dry conditions. These soils have medium to coarse texture, low pH, and low-to-moderate base saturation (Jungen & Lewis, 1978). The Canadian Systems of Soil Classification also describe Sombric Brunisols as having a thick surface horizon and can display darkly coloured surface horizons (Soil Classification Working Group, 1998).

Despite climatic changes that benefit vegetation succession, the demonstrated influence of Indigenous stewardship maintained extensive prairie and Garry oak ecosystems. This indicates that at the broad scale, Indigenous stewardship of vegetation also affected soil development in the region. Vegetation type plays a major role in soil formation and actions to maintain an open prairie ecosystem will also be reflected in the soil. Researchers have shown that soil is relatively slow to develop and it can indicate former ecological conditions from decades previous even if the surface vegetation is different today (Hegarty et al., 2011).

What this indicates is that studying soil formation is complex because of the multiple factors that influence soil before, during, and after its formation. Hans Jenny's influential publication in 1941 recognizes five factors of soil formation: time, climate, organisms, topography, and parent material which interact to form many different soil types (Jenny, 1994). Researchers have also proposed that humans are a significant factor in soil formation (Howard, 2017, p. 1). Modern industrial activity is certainly noticed on soil and there are archaeological examples of people in early agricultural societies exhausting the soil after intensively using the land (Butzer, 1982).

These dark coloured soils on southeastern Vancouver Island have been recognized for a considerable amount of time but research has primarily been concerned with the classification of these soils within Canadian System of Soil Classification to assess agricultural and settler land-use planning. The first soil classification on southern Vancouver Island by Day et al., (1959) classify the coastal soils primarily as 'black.' This black soil classification overlaps considerably with the formerly extensive coastal prairies and Garry oak ecosystems found on southern Vancouver Island.

Chapter 3: Methodology

This research took a mixed approach of qualitative and quantitative methods. A synthesis of Straits Salish literature as it pertains to blue camas cultivation was combined with a literature review of anthropogenically modified soils to propose and assess hypothesized changes that would occur in a meadow that lək̓ʷəŋən people were cultivating for camas, chocolate lily, and other cultural plants (Table 2). In the literature on anthropogenically modified soils the search was narrowed to studies of soils cultivated by Indigenous and local people—some of the main criteria being that they were practices of people living in close relationship to the land—in contrast to modern soil alterations due to industrial activities of mining and large-scale agriculture. These hypothesized changes to soil were then evaluated in a lək̓ʷəŋən cultivated meadow on southern Vancouver Island.

Field research was based on Songhees First Nation reserve land which remains one of the few areas in the vicinity of Victoria, British Columbia not under urban development. Songhees expressed an interest in using an archaeological approach to learn more about the physical remains of their deep history on *Tl'chés*, the archipelago off southern Vancouver Island. In addition to archaeological remains, physical and chemical properties were being assessed that might distinguish cultivated soil from the soil located outside the boundaries of the site. This is among the first concentrated efforts of archaeological investigation in the meadow. The primary objective of this research was to test whether physical and chemical data from soil are useful tools for distinguishing cultivated soils in the Straits Salish region. As such, two research questions were developed (Table 1), the first question pertained to testing if a gradient of cultural influence could be detected in the meadow which was answered using methods described below. The second research question relied on using field data and statistical analysis to determine if lək̓ʷəŋən stewardship of the meadow resulted in detectable changes to the soil. The null and alternate hypothesis for the statistical analysis were:

> H_0 (null): No difference in the mean values of soil samples taken from the cultivated and off-site location for each of the following tests: Carbon, nitrogen, organic matter, pH, calcium, phosphorous.

H_1 (alternate): Mean value of soil samples within the meadow will be higher than the off-site location for: Carbon, nitrogen, organic matter, pH, calcium, and phosphorous.

Table 2. Model of lək̓ʷəŋən land-use and terrestrial resource management and their hypothesized effects on soil, potential archaeological indicators, and ecological legacies.

	lək̓ʷəŋən practice	**Hypothesized soil chemistry**	**Hypothesized soil morphology**	**Landscape & archaeological features**	**Ecological legacies**
Cultivation	• Clearing stones • Turning soil • Fertilization with seaweed[1]	Fertilization would increase: • nitrogen (N) • phosphorous (P) • calcium (Ca)	• Low soil compaction • Greater porosity • Finer grain-size[2] • Mixing of surface soil horizons[3] • Increased soil organic matter (SOM)	• Level fields[1] • Stone field clearing boundaries[1] • Less stony soil	• Concentrated populations of Camas (*Camassia* spp.), Chocolate Lily (*Fritillaria affinis*) • Other culturally important plants
Prairie expansion and maintenance	• Fire stewardship	Increased carbon from anthropogenic and natural fires	• Charcoal from woody vegetation during prairie expansion • Micro-charcoal from regular burning[2, 4]	• Burial cairns[5] • Stone markers for camas plots • Linear concentrations of field clearing stones	• Berries (*Vaccinium* spp., *Rubus* spp., *Fragaria* spp.)[7] • Camas and other liliaceous root foods • Bracken fern (*Pteridium aquilinum*)[7]
Pit cooking	• Cooking root foods with terrestrial and marine foods	Increased carbon (C) from: • Wood fuel • Carbonized root foods	• Charcoal from wood fuel • Ash concentrations • Carbonized botanical remains (e.g., camas, kelp, salal, grand fir, sword fern)[1, 6]	• Surface depression • Subsurface pit feature • Thermally altered rocks[1]	• Unknown, although possible vegetation changes
Habitation sites	• Building plank houses • Tool manufacture • Day-to-day cooking[6] • Waste disposal	• Elevated P • Elevated C • Possibly elevated N • Elevated Ca • Elevated pH	Shell-less midden (including house floors): • Few to no 'waste' particles due to daily sweeping[6] • Micro-charcoal • Lenticular ash deposits • Artifacts • Ecofacts	• Excavated house depressions • Berms of shell midden • Hearths	• Plants that favour disturbed soil: Thistle (*Cirsium* spp.), Stinging Nettle (*Urtica dioica*).

[1]Suttles 2005 [2]Lepofsky and Lertzman 2008 [3]Howard 2017
[4] Kira Hoffman, personal communication (Feb. 4, 2022) [5]Mathews 2014 [6]Suttles 1974
[7]Weiser and Lepofsky 2009

Field methods

Field work was conducted intermittently during June through early October in 2020 and late May through June in 2021. The work was conducted in three stages beginning with excavating the evaluative units which then informed the excavation of the unit in the lək̓ʷəŋən village. The third stage was collecting soil samples from within the village, field, and off-site to send to a laboratory for chemical analysis. Songhees interest in learning more about the soils in the field guided the work and in the 2021 season, Elders and youth came to participate in the excavation of the plank house. Archaeological excavation methods were used to capture data present in the lək̓ʷəŋən cultivated meadow for this project. The archaeological methods helped preserve information about lək̓ʷəŋən soil in the meadow. The soil description was paired with physical and chemical tests that are routine in soil description because changes in the cultivated soil were hypothesized to be microscopic rather than visible in the field. Field survey data and results from laboratory testing were combined to assess the cultural origins of the dark coloured soils found on *Tl'chés*. These darkly coloured soils have been noted throughout lək̓ʷəŋən territory (Broersma & Lavkulich, 1980).

Excavation of evaluative units

To understand soil properties in the meadow on *Tl'chés* a transect was established from the surface plank house depressions in the southeast heading to the northwest extent of the meadow which is being taken over by invasive species, particularly blackberry and ivy (*Hedera helix*). Evaluative units were placed in 20 meter intervals along the transect for a total of five units. The purpose of placing the transect starting at the plank houses was to test if a gradient of cultural influence could be detected in the soil. Literature on the chemical signatures of anthropogenic soils suggest that the greatest cultural signature would be located within higher use areas and decrease in magnitude further away from the centres of activity (Heckenberger et al., 2007; Middleton, 2004).

A second transect was placed perpendicular to the first running approximately southwest to northeast from the shore-edge to the inland edge of the meadow which was heavily overgrown with blackberry bushes. The current growth of blackberries forms an impenetrable barrier between the open meadow and the inland rocky outcrop (Figure 6) which determined the inland terminus of the second transect. The second transect also used 20 meter intervals determined by laser range finder to place two additional units at the furthest extents of the transect. The second transect crossed the first transect close to an evaluative unit (EU3) and this was used as the centre point for the second transect.

All units in the meadow were 50 cm^2 except for the unit dug in the plank house depression which was 1 m^2. The smaller size of the evaluative unit was chosen to get a view of the soil horizons and test for any archaeological material without disturbing too much of the meadow. Because archaeological material was expected in the plank house (Bighouse 1) it was decided to excavate a traditional 1 m^2 archaeological unit. The excavation of the Bighouse unit was also a community priority, since there is a desire to learn more about these older houses, and it provided an opportunity for Songhees youth to participate in the excavation. Apart from the blackened surface horizon, the soil outside the Bighouse was expected to be visually consistent with natural profiles. This study was interested in changes that occur in the A and B soil horizons, therefore the units were excavated to the C horizon were pedogenesis weakly affects the parent material (Day et al., 1959, p. 31). The C horizon was visually determined by excavating until the organic and mineral soil horizons terminated and gave way to deposits of sedimentary origin—rocks, gravel, sand, and clay.

The first two evaluative units (EU1 and EU2) were excavated to approximately 90 cm below surface and extended several centimetres into the C horizon. This ensured that the culturally sterile C horizon was reached and no archaeological sediments, artifacts, or features were deeply buried in the field. The remaining units were excavated just until the C horizon was reached, approximately 40 to 50 cm below surface. The C horizon was visually and structurally marked by a clear transition to a brown-orange coloured sediment dominated by boulders (>256 mm), pebbles (4-256 mm), and gravel (2-4 mm).

The evaluative units were dug in 10 cm arbitrary levels within stratigraphic units and screened through 2.8 mm mesh to separate any archaeological material from the soil and sediment. This mesh size was used to ensure that micro-remains, such as herring bones, would be captured in the study (Stewart & Wigen, 2003) although it is possible that plant macro-remains may still fall through. If any archaeological material—terrestrial or marine faunal remains, artifacts—was encountered, its location and depth within the unit was measured and they were collected. The memorandum of agreement between Songhees First Nation and the Mathews Ethnoecology Lab at the University of Victoria stipulates that all materials collected during study continue to belong to the Nation. Collected materials will be curated at the Royal British Columbia Museum, held in trust for the Songhees Nation.

Field notes of soil properties

Soil descriptions of each evaluative unit were compiled on the characteristics detailed in Table 3. The units were dug in arbitrary 10 cm levels within stratigraphic units and notes were taken of the stratigraphy being encountered. A full list of the criteria in Table 3 was recorded for each strata. Changes in strata were determined in the field by any major change in texture, structure, colour, archaeological material, or any combination therein.

A Munsell colour chart was used to determine colour in the field as strata were being exposed, differential moisture in the soil profile resulted in some colours being reported as either moist (m) or dry (d) in the descriptions. Munsell colour charts are the standard in soil analysis to record the hue (colour), value (lightness or darkness), and chroma (colour strength); the colour of the soil reflects soil composition and oxidation/reductions conditions (Food and Agriculture Organization of the United Nations, 2006, p. 33).

Soil compaction of each strata was measured using a soil penetrometer to determine the resistance of the soils and sediments, and given a qualitative description ranging from very loosely compacted to highly compacted. Typically, archaeological excavation in the region relies on an expedient assessment of compaction by the excavator, for example, low, medium, or, high compaction (Graesch et al., 2015). Compaction was measured for each strata with the aim of understanding whether differential compaction in lək̓ʷəŋən soils results from past practices, for example, greater compaction inside houses versus less compaction in the cultivated meadow.

Soil texture and the coarse fraction of the deposits were measured together for each strata. The limit between fine and coarse fraction of the deposits was set at 2 millimeters, any particle larger than 2 mm, for example, gravel sized or larger, comprised the coarse fraction of each strata and were not included in textural analysis. The coarse fraction was estimated by percentage of each coarse size class (gravel, pebbles, and boulders) and assessed for their angularity or roundedness which is indicative of depositional environment (Karkanas & Goldberg, 2007). The texture of the soil was estimated by tactile assessment of the proportions of sand, silt, and clay particles and the aid of a soil texture triangle to determine the category, for example, silt loam, loamy sand, etc.

Table 3. Soil description of physical properties in the field.

Characteristic		Example of description	Source
Soil structure		Granular, crumb, platy, blocky, prismatic, columnar	(Munsell Color (Firm), 2010)
Horizon depth		0-26 cm depth below surface	Tape measure
Colour		Hue, value, chroma	(Munsell Color (Firm), 2010)
Compaction		0.0 – 4.5 kg/cm^2 increasing in 0.25 kg/cm^2 increments	Eijeklkamp profile cone pocket penetrometer
Texture		Clay, silty clay, silty clay loam, silt loam, silt, loam, clay loam, sandy clay, sandy clay loam, sandy loam, loamy sand, sand	Soil texture triangle
Coarse Fraction:	Size class	Clay (<0.004 mm), silt (0.004-0.06 mm), very fine and fine sand (0.06-0.25 mm), medium sand (0.25-0.5 mm), coarse and very coarse sand (0.5-2 mm), gravel (2-4 mm), pebbles (4-256 mm), boulders (>256 mm)	Wentworth size class
	Composition (%)	Scale from 1% to 50%	(Munsell Color (Firm) 2010)
	Angularity	Very angular, angular, subangular, subrounded, rounded, well rounded	Powers scale of roundness
Sorting		Very well sorted, well sorted, moderately sorted, poorly sorted, very poorly sorted	Visual assessment using a sorting chart
Archaeological material		Shell, faunal remain, artifact, fire altered rock, charcoal, preserved botanical remains	-
Biological material		Ants, beetles, worms, roots, undecomposed plant matter	-

Soil sampling across the meadow

A stratified random sampling strategy was applied to the collection of soil probes. Two sampling zones were employed in this study. Zone A is the open meadow closest to the shore and between the house depressions and platforms. Zone B is the shallow-soil rocky outcrop inland from the meadow (Figure 6), which was intended as a control to compare against the physical and chemical characteristics of the cultivated field soils in Zone A. This stratified sample approach allowed for the targeted collection of soil probes from a pre-determined geographic extent while maintaining the collection of random samples necessary for statistical analysis (Drennan, 2010; Shennan, 1997). Twelve samples were randomly collected from Zone A and a further eleven samples were collected from Zone B in the rocky outcrop. Types of soil sampling are detailed below (Table 4).

Table 4. Types of soil sampling employed at *Tl'chés*, their location, and their purpose.

Test Type	Test size	Location	Purpose	Approx. Depth	Number of tests
Oakfield soil probe	22.8 cm long by 1.9 cm wide	Zone B: Inland rock outcrop	• Soil chemistry	15 cm	11
Eijkelkamp Bucket auger**	7 cm diameter	Zone A: Field Zone B: Inland rock outcrop	• Soil chemistry **Replaced probe to expedite sample collection	15 cm	12
Eijkelkamp Bucket auger	7 cm diameter	Zone A: Field at evaluative and excavation units	• Soil chemistry	15 cm	7
Evaluative Unit	50 cm x 50 cm	Zone A: Field	• Soil chemistry • Soil/sediment structure	Variable, excavated to C horizon	6
Excavation Unit	1 m by 1 m	Bighouse 1	• Soil chemistry • Soil/sediment structure • Radiometric data	47 cm	1

The random selection of testing location in the meadow was accomplished in QGIS by using a high resolution orthographic base map of *Tl'chés* overlain with a five-by-five meter squared grid. The grid map was numbered sequentially from left to right and top to bottom to assign a unique number to each square. A table of random numbers (Drennan, 2010, Table 7.1) was used to select the grid number that would be used for soil sampling. If the grid on the map contained a non-soil feature e.g., rock outcrop, then the next soil grid to the right was used for a sampling location. The Universal Transverse Mercator (UTM) location of each sampling grid was recorded and used in the field to locate the grid with an Arrow 100 GPS, accurate to approximately 20 cm.

The rocky outcrop sampling zone was modified from the procedure above because of the abundance of grid units that contained only rock. In place of pre-selecting the sampling locations the samples were collected in the field and their GPS locations recorded to map in QGIS. The area where samples were collected was influenced by the blackberry cover, surface bedrock, and the choice to get a geographic spread of soil probes from within the pre-determined boundaries of the rocky outcrop. The necessity of these decisions means samples from the control site are not truly random but for the purposes of this research there were no anticipated biases that would affect measurement of soil chemistry.

Collection of samples was accomplished with an Oakfield soil probe and an Eijkelkamp 7 cm diameter bucket auger to collect soil from the upper 10 cm of meadow and rocky outcrop. Initial soil samples collection used the smaller Oakfield soil probe but due to limited time in the field, the sampling instrument was switched to the Eijkelkamp bucket auger to expedite the soil collection. Despite the larger size of the bucket auger, an aggregate of soil was still collected for each sample. Multiple probes per sampling location were collected to get an aggregate sample for the measurement of soil chemistry which is known to be highly variable (Holliday & Gartner, 2007; Webster & Lark, 2018). This follows the procedure advocated by Asare et al. (2020) to even out any close-proximity spatial inequities in the soil chemistry. 750 grams of soil were required for the physical and chemical tests; to attain the required weight, between 20-30 probes were collected from the soil probe instrument while 4-8 probes were collected from the bucket auger. Measurements of the probe/auger and the hole after sampling at times measured up to 15 cm below the surface which reflected the compaction caused by using of the probe.

In addition to the randomly collected samples in Zone A and Zone B, soil samples were collected at each of the seven evaluative units. Since these seven locations were not selected randomly, they were not included in statistical analysis detailed below. The collection of soil samples from each of the seven archaeological units was utilized to align the results of the physical and chemical tests performed in the laboratory with observations of the soil properties described in the field.

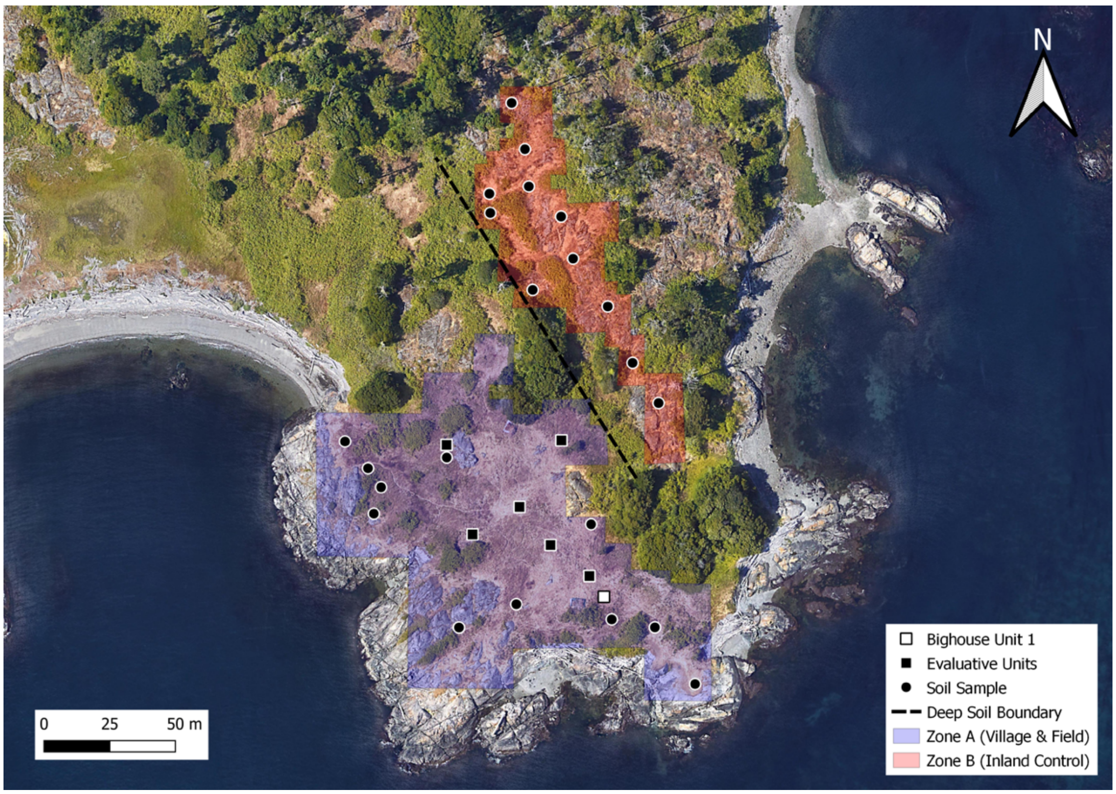

Figure 6. Map of the southern meadow on *Tl'chés*. Zone A (blue) indicates deep soil meadow and Zone B (red) indicates the rocky outcrop used as a control site.

Mapping extent of soil descriptive data using GPS and GIS

During the excavation and collection of soil samples locations were GPS recorded with an accuracy to 0.2 meters. The purpose of recording location data was to start defining the precise locations in the meadow where soil physical and chemical information was obtained. The locations were mapped to understand if soil properties existed across the meadow as predicted or if there was a unanticipated pattern of physical and chemical signatures. GPS data were entered into the open-source mapping software QGIS to generate a site map for the meadow on *Tl'chés* (Figure 6).

Community and youth engagement

The 2021 fieldwork season was enriched by community engagement and participation with the Songhees Nation as part of the LEAP project. Sellemah guided much of the fieldwork and was joined by Elder Frank George as youth excavated, screened soil for archaeological material, and learned species identification of some of the popular foods eaten by lək̓ʷəŋən people (Figure 7). The community engagement was also facilitated by the University of Victoria Living Lab—a collaboration between university professors and School Districts 61 and 63—which created opportunities for youth from the Songhees and Esquimalt Nations to participate in some of the excavation of Bighouse 1. Sellemah's teachings informed the fieldwork at *Tl'chés* and guided a pit-cook in May, 2021, to celebrate the end of the University of Victoria Ethnoecology Field School directed by the Songhees Nation and Dr. Mathews (Figure 8).

Figure 7. Songhees Elders guide fieldwork at Bighouse 1, while youth participate in excavation and archaeological screening. View NNW across to adjacent blue camas/chocolate lily meadow.

Figure 8. Author, Sellemah, graduate students Isabelle Maurice-Hammond and Cole Lysgaard (UVic) at *Tl'chés* (left), Living Lab member Desiree Jones and author making scow bread at *Tl'chés* pitcook.

Laboratory methods

Soil samples were collected in the field using the methods described above on June 23 and June 24, 2021. Each sample was approximately 750 grams of fresh soil labelled and sealed individually in a plastic bag. All samples were stored in a refrigerator at approximately 3° Celsius for five days. The samples were taken to the Government of British Columbia Analytical Chemistry Services Laboratory on June 28, 2021, for processing. After arrival at the lab the soil samples were oven dried at 30° Celsius, ground, and sieved to pass through 2 mm mesh (Kalra & Maynard, 1991). Tests were performed for soil texture, organic matter, pH, total carbon and nitrogen, and trace element analysis which are described in more detail below.

Soil texture

An accurate measure of soil texture is important in interpreting various soil functions such as porosity, nutrient holding, and suitability for plant growth (Weil & Brady, 2017). Indigenous cultivation of estuarine roots can result in soil texture changes (Deur, 2000) and is a possible signature of Indigenous cultivation more broadly (Lepofsky & Lertzman, 2008). This research sought to test if lək̓ʷəŋən cultivation of camas and other root foods resulted in changes in soil texture. Particle size analysis was performed by the Analytical Chemistry Services Laboratory by sedimentation rate with a hydrometer. A portion of the field sample was separated, placed in solution, agitated and then the settling rate was measured to determine the percentage of sand, silt, and clay. The procedure the lab follows is detailed in Kroetsch and Wang (2007). After receiving the percentages for each size class from the laboratory analysis I input the values into the United States Department of Agriculture (USDA) soil texture calculator to arrive at the name for the soil texture e.g., sandy loam (Soil Texture Calculator, n.d.).

The laboratory uses the Canadian System of Soil Classification (CSSC) particle size classes which closely approximate those of the Wentworth size classes used in the field to determine texture by hand. The CSSC and Wentworth size classes differ beyond the 2 millimeter limit which does not factor into the analysis of soil texture. Furthermore, the laboratory calculation of soil texture was done to complement the visual and tactile evaluation of soil texture conducted for each evaluative in the field. Tactile assessment of soil texture is frequently used in field archaeology and gives a reasonable estimate of soil texture; however, during a study of soil properties it was important to verify this by laboratory methods which provided the most accurate determination.

Organic matter

Organic matter is closely related to soil structure and influences nutrient availability, porosity, and water retention in soil. Archaeologically cultivated soils are frequently reported to contain higher levels of soil organic matter compared to their reference soils (Glaser & Birk, 2012; Howard, 2017; Kern et al., 2019; Zhang et al., 2003). Organic matter was evaluated in the lab based on Loss on Ignition (LOI), which measures the total composition of organic materials in soil (e.g., fresh and decaying plant matter, animal residues, soil microorganisms). LOI was the preferred method in this study because it directly estimates soil organic matter instead of other methods which estimate soil organic carbon from which a calculation of soil organic matter can be made.

Organic matter percentage was determined by LOI following a modified procedure detailed in Kalra and Maynard (1991, p. 25). The temperature was increased from 375° Celsius listed in the original procedure to 450°. Research by Ball (1964, p. 86) indicates that a firing temperature of 450° is still below the level where water can be lost from the clay fraction of the soil which would skew the measurement of organic matter. Five grams of prepared sample are placed in a crucible and heated to 450° Celsius for 16 hours. Weights of the sample from before and after heating are used to calculate the percentage of organic matter lost through firing.

pH

Soil pH is a standard procedure in soil analysis because of the importance pH plays in controlling chemical reactions (Hendershot et al., 2007, p. 173). This study used a measure of pH to understand soil conditions in the village and determine if a difference in pH was observed between the open meadow and rocky outcrop. Changes in soil pH—especially an increase towards alkalinity—have been noted by researchers studying soils affected by human settlement (Holliday, 2004, p. 302; Wells, 2006). Soils that may naturally be more acidic can benefit from human inputs that raise the alkalinity to levels more supportive of crop cultivation. On the Northwest Coast, shell-bearing site have also been shown to alter soil chemistry, including pH, resulting in greater vegetation cover and high species richness (Cook-Patton et al., 2014; Trant et al., 2016). However, prior to this project, it was unknown if substantial shell deposits were located around the lək̓ʷəŋən village, and to what extent anthropogenic shell deposits may be distributed in the cultivated field.

Soil pH was measured by combining a 1:2 ratio of air-dried soil with 0.01 *M* calcium chloride ($CaCl_2$), the solution is stirred and left for one hour before the pH is measured with a pH meter. The laboratory's procedure follows that detailed in Hendershot et al. (2007). Measuring soil pH in $CaCl_2$ solution offers the advantage of remaining consistent between field moist and air-dried conditions and is not affected by the soil solution ratio used. A consideration of pH measurement with $CaCl_2$ is that the results will tend to be lower by approximately 0.5 pH units (Hendershot et al., 2007, p. 173). Measurement of pH in water offers the advantage of being a closer approximation of pH in the field conditions however this study was more concerned with the consistency in measurement offered by using a $CaCl_2$ solution.

Total carbon and nitrogen

Measures of total carbon and nitrogen were selected to compare the values of both elements between the open meadow soil and the rocky outcrop. Carbon and nitrogen have been noted to increase in soils where human settlement occurs (Wells, 2006). Although measures of organic carbon and total nitrogen are more indicative of availability to plants this study was concerned with determining if a difference in total values of either element could be observed. Total value of elements has been suggested to be a better indication of human settlement because it is less affected by chemical cycling in the soil (Asare et al., 2020, p. 110). Total carbon and nitrogen were measured in the lab by dry combustion with an elemental analyzer to determine the percent of each element in the soil sample. The lab follows a modified version of the procedure detailed in Skjemstad and Baldock (2007). Total carbon and nitrogen included measures of organic and inorganic sources of each element.

Total elemental analysis

Trace element analysis has long been used in the study of archaeological soils to identify use-areas of sites and provide a means of chemically mapping sites (Da Costa & Kern, 1999; Glaser & Birk, 2012; Holliday, 2004; Wiedner et al., 2015; Zhang et al., 2003). Total element analysis has been suggested to be of greater value for geoarchaeological purposes because it is not as affected by chemical cycling in the soil compared to measures of plant available elements (Asare et al., 2020). The aim of this study was to determine if the total element concentrations of the open meadow soil (Zone A) could be distinguished from the shallow soils in the rocky outcrops of Zone B.

The sample was air-dried and separated by a 2 millimeter sieve before acid digestion of the soil following standardized procedures (Ministry of Environment, 2017; United States Environmental Protection Agency, 1998, 2007). One gram of prepared soil is digested in nitric (HNO_3) and hydrochloric acid (HCl) for two hours at a constant temperature of 95° Celsius (Ministry of Environment, 2017:C-23). The digested soil was then analyzed using inductively coupled plasma mass spectrometry (ICP-MS) and calculations of the elemental amount per kilogram of soil were made.

Significance testing of laboratory data

Samples collected within the boundaries of the open meadow soil totaled 19 and the rocky outcrop off-site totaled 11. From the meadow, seven of the soil samples were not collected by random selection and were not included in the statistical analysis. These seven samples were collected at each of the evaluative units to add soil chemical data to the physical descriptions to determine if a gradient of potentially culturally-influenced soil properties could be observed as distance increased from the village.

Initial exploration of the laboratory data from the soil samples was conducted following the statistical approach detailed by Drennan (2010) which began by constructing stem-and-leaf plots for each of the selected laboratory tests—texture, organic matter, pH, carbon, nitrogen, calcium, and phosphorous—to view the distribution of the values for the meadow and off-site samples. Box plots were generated to visually inspect and compare the centre, spread, and potential skewness of the data. The box plots and summary statistics of the soil probes were inspected to determine if their distribution met the assumptions for normality required for significance testing using the *t* test.

Positive skewness was anticipated in the data as it is very common with soil chemistry (Webster & Lark, 2019). Skewness was assessed to determine if the assumption of normality was tenable and if not, which data transformations were appropriate (Webster, 2001). If skewness was less than 0.5 no action was taken, if skewness ranged between 0.5—1 a square root transformation was applied, and if skewness was greater than 1 a logarithmic transformation was applied. In all instances of transformation it was applied to the meadow and control values. After assessing normality and applying transformations the analysis proceeded to compare the two sample means through significance testing using the *t* test. The decision to proceed with small sample sizes displaying only approximately normal distribution meant that the *t* test would be less able to detect any subtle changes in soil chemistry that may be present between the locations.

The research hypothesis was that the means of pre-selected chemical attributes would be different between the Zone A (meadow) and Zone B (control location). All statistical analyses, including the summary statistics, transformations, and unpaired *t* tests were performed in GraphPad Prism (Version 9.3.1 [350]) at the 95% confidence level. Tests returning a p-value greater than 0.05 were determined not to be statistically significant.

Soil signatures of lək̓ʷəŋən plant cultivation and stewardship

I developed a model to test signatures in field soils at *Tl'chés* that may be indicative of lək̓ʷəŋən cultivation and stewardship. This model is based on lək̓ʷəŋən ethnographies, previous regional and international archaeological work, and the work of ecologists and pedologists. These signatures were adapted as testable traits that may be discerned in the chemical and morphological structure of soils in the cultivated field and the plank house depressions (Zone A), to be tested against the soils inland from the field (Zone B). These hypothesized changes to soil under cultivation (Table 5) offer potential avenues to distinguish cultivated soils from non-cultivated soils as work continues to understand, protect, and re-implement Indigenous-led stewardship. In this study field data, results of physical and chemical soil tests, and the ethnographic literature were combined to assess if a distinction between open meadow and rocky outcrop soil could be made. These data were used to interpret what signatures of lək̓ʷəŋən soil management may look like.

Table 5. Testable traits of hypothesized changes to soil under root-food cultivation.

Soil nutrients	Porosity	Soil texture	Large stone removal	Soil pH
Beckwith, 2004: Proctor, 2013; Suttles, 2005	Proctor, 2013	Lepofsky & Lertzman, 2008	Suttles, 2005	Agee, 1993, cited in Beckwith 2004, p. 111

This research methodology sought to gather hypothesized changes to camas soil from the literature and begin evaluating some of those hypotheses in a known cultivated meadow. To assist the study, a framework of anthropogenically modified soil research was brought in. The global literature on Anthrosols and Dark Earths has steadily grown into developed programs that address various cultural signatures of cultivation. A prominent example is the development of Amazonian Dark Earth research that began as a little recognized phenomenon (late 19th century—1980s) until today where the last 40 years have seen an explosion of recognition and study of Amazonian Dark Earth (Woods & Denevan, 2009). The development of the ADE model was helpful in designing this methodology, but the purpose of this research always returned to the lək̓ʷəŋən-specific soil characteristics.

Chapter 4: Results and interpretation

The purpose of this study was to determine if the physical and chemical signatures in the soil could detect the legacies of lək̓ʷəŋən root food cultivation in one small prairie ecosystem at *Tl'chés*, despite interruption to traditional practice. The regional Straits Salish pattern of camas and associated root food stewardship began to shift with the onset of colonization around a century and a half ago. During the mid-to-late 1800s traditional blue camas cultivation transitioned to introduced plant cultivation in response to increased trade with colonizers (Lutz, 2008; Suttles, 1951). We do not know precisely when traditional root food cultivation in the *Tl'chés* meadow ceased, but it was likely the generation of Sellemah's great-grandparents, Tom and Alice James who raised Sellemah on *Tl'chés*. Sellemah and her family lived on *Tl'chés* (West Chatham Island) until the 1960s where they grew introduced vegetables and fruits near their home (about 390 m NNW of the meadow) (Gomes, 2012, p. 46). The ecological legacies of traditional root food stewardship remain in the meadow, albeit in a likely truncated form, in the densities and distributions of culturally important species like blue camas and chocolate lily. The landscape has significant residential archaeological sites on either side, and such gardens were ethnographically known to be associated with villages.

Research at *Tl'chés* indicates that cultural landscapes are complex and need multiple, interdisciplinary, and cross-cultural approaches to understand the kinds of past activities practiced there. Songhees community knowledge, ethnographic and archaeological studies, and ecological data all contribute multiple lines of knowledge about how lək̓ʷəŋən stewardship shaped the land. Soil chemistry and soil morphology (structure, colour, composition, compaction, etc.) analyses are relatively inexpensive additions to archaeological and historical ecological studies which can be used to learn more about the specific structural and chemical residues left behind on lək̓ʷəŋən landscapes where known activities occurred. In this research, I characterize the soil gradient, parallel to the shore and a gradient moving inland from the shore. The first gradient is located between the archaeological remains of a substantial plank house depression (Bighouse 1) and across the length of the adjacent meadow and its community of chocolate lily and blue camas. The purpose of this testing was to identify hypothesized changes in soil structure and chemistry between houses and fields, and these larger Evaluative Unit tests allow for a greater view of soil structure, horizons, composition, and potential archaeological materials or features. Smaller-diameter tests using a probe/auger were collected to get loose soil samples to run tests on the soil chemistry and compare the results between the village and cultivated field (Zone A) and the inland rocky outcrop (Zone B).

In this chapter, the results of the evaluative units across the village-garden gradient are presented with the results of the excavation unit within Bighouse 1. The description of every strata within each unit is presented and the accompanying results of soil chemistry (N, C, pH, Organic matter, Ca, P) are given (Table 13). Following this, the results of the comparison of soil probe/auger samples within Zone A (field) and Zone B (inland control) are presented by individual test. These are broken down into: texture, organic matter, carbon, nitrogen, soil pH, calcium, and phosphorus. The purpose of collecting soil data was to evaluate the model of lək̓ʷəŋən land-use and its effects on soil which was developed in Chapter 3 (Table 2). Based on the ethnographic data and knowledge derived from global anthrosol studies the soil chemistry was expected to be elevated in areas of cultivation and habitation. These data were used to answer the research questions developed, namely, if a gradient of cultural influence was present across the meadow and if lək̓ʷəŋən management of the meadow soils could be detected after decades of interruption to traditional stewardship. The results of all the field work and laboratory tests on *Tl'chés* are then discussed at the end of this chapter.

Results of evaluative units

A total of six 50 x 50 cm evaluative units were excavated in the Zone A cultivated field (Figure 9). The purpose of these tests was to describe the soil properties using the criteria in Table 3 (horizon depth, colour, compaction, texture, coarse fraction, sorting) and to assess the amount of macroscopic archaeological material in Zone A along two transects. The first transect ran shore-parallel between two archaeological habitation sites and the second was perpendicular from the shore to the inland bedrock outcrop. The following subsections detail the results of the meadow excavations at *Tl'chés* during the 2020 and

2021 field seasons. Full details of how the soil characteristics were described are found in Table 3. Determination of soil texture by hand was almost universally recorded as silt loam; upon receiving the laboratory results of the soil texture, all reported textures have been corrected to sandy loam[1].

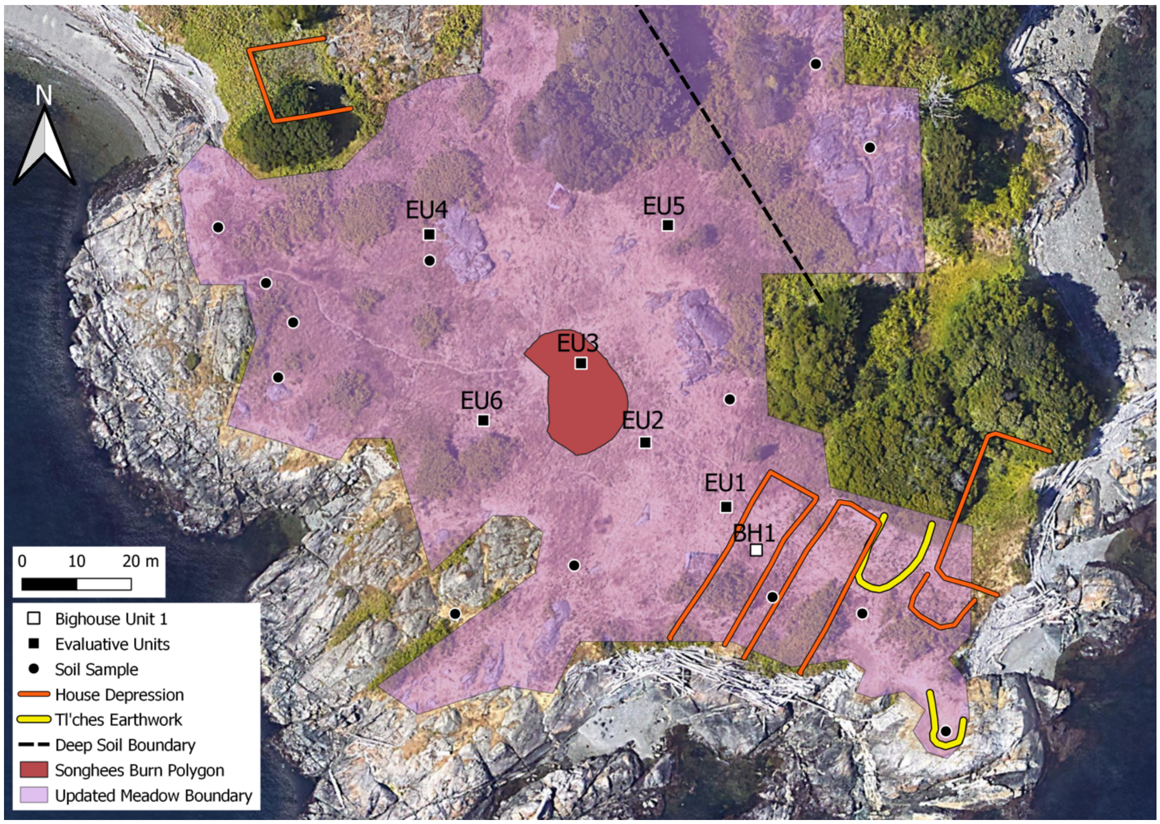

Figure 9. Close-up map of evaluative and excavation unit locations on *Tl'chés*.

Bighouse 1, Excavation Unit 1

This test was situated in the bottom footprint of Bighouse 1. Most of the margins of this archaeological plank house are visibly demarcated by a 25 m long, 14 m wide rectangular cultural depression (Figure 9). The lengthwise dimensions of the house outline are defined by 0.5 to 0.7 m high distinctive earthen ridges. There are two houses immediately adjacent and parallel to one another (Bighouse 1 and 2), and several more houses beyond

[1] Sandy loam and silt loam are comprised of similarly low quantities of clay particles (<0.004 mm) and both can range from approximately 75-100% silt particles (0.004-0.06 mm). The main separation between the two classes is in the content of sand; silt loam can have 0-45% sand, while sandy loam can have between 45-80% sand particles (0.06-2 mm).

these along the southern and southeastern edge of *Tl'chés* (Figures 4 and 9). The orientation of Bighouses 1 and 2 is atypical, in that the houses were usually oriented with one of the long sides facing the sea (Boas, 1890, pp. 11-12). Bighouses 1 and 2 are oriented with an end facing the sea. This may be to accommodate more houses in a smaller and more defensible space. Excavation Unit 1 was placed along the centre long-axis of the house, about half of the way inland from the present shoreline (Zone 9U E5364221.99 N481189.02). The intention was to identify a central hearth with radiometric data and preserved ecofacts. The excavation was conducted between June 10 and June 23, 2022. Basal deposits were not hit, and the test ended at 47 cm DBD (Figure 10; Table 6). The LEAP team will resume excavation in Autumn 2022.

Table 6. Summary of the soil and sediment characteristics of Excavation Unit 1, Bighouse 1.

Strat	Depth (cm DBD)	Munsell colour	Texture	Compaction (kg/cm^2)	Sorting	Coarse fraction	Archaeological materials	FAR (kg)
1	8-9	Dark reddish brown (5YR 2.5/2 d)	Sandy loam	0.0 very loose	Moderate	sub-angular 0.5% boulder, 3% gravel, 0.5% shell fragments	Ungulate bone (possibly sheep)	0.4
2	9-19	Black (5YR 2.5/1 d)	Sandy loam	0.25 loose	Moderate to poor	sub-angular 3% boulders, 15% pebbles, 5% gravel, 5% shell fragments	9 shellfish species, bone, slate debitage, bipolar core, slate lithic, charcoal	2
3	19-29	Black (5YR 2.5/1 m)	Sandy loam	0.75 loose	Moderate	sub-rounded to angular 3% boulders, 10% pebbles, 5% gravel, 5% shell fragments	7 shellfish species, bone, lithic, faunal claw (possibly raptor)	6
4	29-variable NW 37.5 NE 36.5 SE 35 SW 38.5 Center 37.5	Very dark grey (5YR 3/1 d)	Sandy loam	1.0 loose	Poor	rounded to angular 5% boulders, 7% pebbles, 5% gravel, 5% shell fragments	8 shellfish species, increased unbroken shell	6
5A	Variable - 41	Dark brown (7.5YR 3/2 d)	Sandy loam	0.75 loose	-	1% boulder, 5% pebble, 5% shell fragments	3 species of shellfish, charcoal and ash staining	2.5
5B	37-47	Dark brown (7.5 YR 3/2 d) mottled	Sandy loam	0.0 very loose	-	20% pebbles, 2-5% shell fragments	6 shellfish species, dog bone, unburnt Douglas	14

							fir bark, deposit mottled with charcoal staining/soil oxidization/hardened ash/crushed and burnt shell	
5B	47+	Unit continues but 5B was the last strata excavated in summer 2021.						

Figure 10. Profile photograph of Excavation Unit 1, Bighouse 1, south wall. Note the ubiquity of thermally altered rock and charcoal-rich soils/sediments. The age of the house is unknown; radiocarbon dates are pending for Strata 1 through 5B, described above.

Evaluative Unit 1

EU1 was placed on the transect approximately 20 meters northwest of the Bighouse Excavation Unit 1. Details of the soil properties are recorded below (Table 7). Strata 1 showed active soil fauna, numerous fine roots, and numerous Hooker’s onion bulbs (*Allium acuminatum* Hook.) growing in the surface horizon. The archaeological material in Strata 1 included a purple urchin (*Strongylocentrotus purpuratus*) spine found in the screen and FAR dominating the pebble size class. Strata 2 showed very small twigs (about 2 mm diameter), more onion bulbs, a clam shell fragment 12 cm below surface, and an unidentified bone fragment 16 cm below surface. FAR increased in Strata 2 and at

11 cm below surface depth the charcoal fragments increase in size. In Strata 3 there were fewer charcoal particles, little FAR, and at 35 cm below surface half a dogfish vertebra was found. Strata 4 and 5 showed no visible archaeological material (Figure 11).

Table 7. Summary of the soil and sediment characteristics of Evaluative Unit 1.

Strata	Depth (cm DBS)	Munsell colour	Texture	Compaction (kg/cm^2)	Sorting	Coarse fraction
1	0-8	Black (5YR 2.5/1 d)	Sandy loam	1.0 loose	Moderate to poor	sub-angular 5-10% pebbles
2	8-30	Black (5YR 2.5/1 d)	Sandy loam	1.5 loose	-	increase in pebble density
3	30-43	Very dark brown (10YR 2/2 d)	Sandy loam	2.75 moderate	Poor	sub-rounded 25% coarse sand, 3-5% pebbles, 5% boulders
4	43-59	-	Loamy sand	4.5 high	Very poor	50% pebbles 10% gravel
5	59-90	-	Sand	4.5 high	Moderate	3-5% boulders, 20% pebbles, 15% gravel, 10% coarse sand

Figure 11. Photograph of north wall in Evaluative Unit 1 with a gradual transition from dark surface horizon to underlying parent material.

Evaluative Unit 2

EU2 was placed on the transect 40 meters northwest of the Bighouse Excavation Unit 1. Table 8 details all the soils properties recorded. In Strata 1, soil fauna were active and numerous fine roots grew. Between 5 – 14 cm below surface there were three pieces of FAR and between 13 – 15 cm below surface depth charcoal was present in the screen. Strata 2 also had active soil fauna and medium-fine roots were present. In Strata 2, 3, and 4 there was no visible archaeological material present (Figure 12). In Strata 4 the boulder fraction (>256 mm) increased but the stones were highly weathered.

Table 8. Summary of the soil and sediment characteristics of Evaluative Unit 2.

Strata	Depth (cm DBS)	Munsell colour	Texture	Compaction (kg/cm^2)	Sorting	Coarse fraction
1	2-30	Black (7.5YR 2.5/1 d)	Sandy loam	0.25 surface to 1.0 at 30 cm	Well	sub-rounded 1% boulders, 5% pebbles
2	30-42	Very dark gray (7.5 YR 3/1 d)	Sandy loam	1.75 at 35 cm to 4.25 at 40 cm	Moderate	sub-rounded 5% gravel, 10% pebbles, 30% coarse sand
3	42-59	Between very dark grey and dark greyish brown (2.5YR 3/1.55 d)	Sandy loam	4.5 high	Poor	angular 10-15% boulders
4	59-80	Very dark brown (7.5YR 2.5/3 d)	Sandy loam	4.5 high	Poor	1-3% boulders, 15-20% pebbles mostly replacing fine fraction

Figure 12. Evaluative Unit 2 transition from blackened surface horizon to underlying parent material around 30 cm depth below surface. Photo taken when soil was dry.

Evaluative Unit 3

EU3 was placed on the transect 60 meters northwest of the Bighouse Excavation Unit 1. Details of the soil properties are recorded below (Table 9). Strata 1 had active soil fauna, fine and thick roots, and numerous onion bulbs. Between 5 – 10 cm below surface a small (3 mm) piece of charcoal was found in the screen. At 21 cm below surface Strata 2 was too cemented to dig with a hand trowel and was the shallowest unit in the meadow (Figure 13). There were a few fine roots (<1 mm diameter) in Strata 2 but no visible archaeological material.

Table 9. Summary of the soil and sediment characteristics of Evaluative Unit 3.

Strata	Depth (cm DBS)	Munsell colour	Texture	Compaction (kg/cm^2)	Sorting	Coarse fraction
1	4-17	Very dark grey (7.5YR 3/1 d)	Sandy loam	1.0 loose	Moderate	1% rounded boulders
2	17-21	Dark brown (7.5 YR 3/2 d)	Sandy loam	4.5 high	Very poor	15% boulders, 20% pebbles, 20% gravel

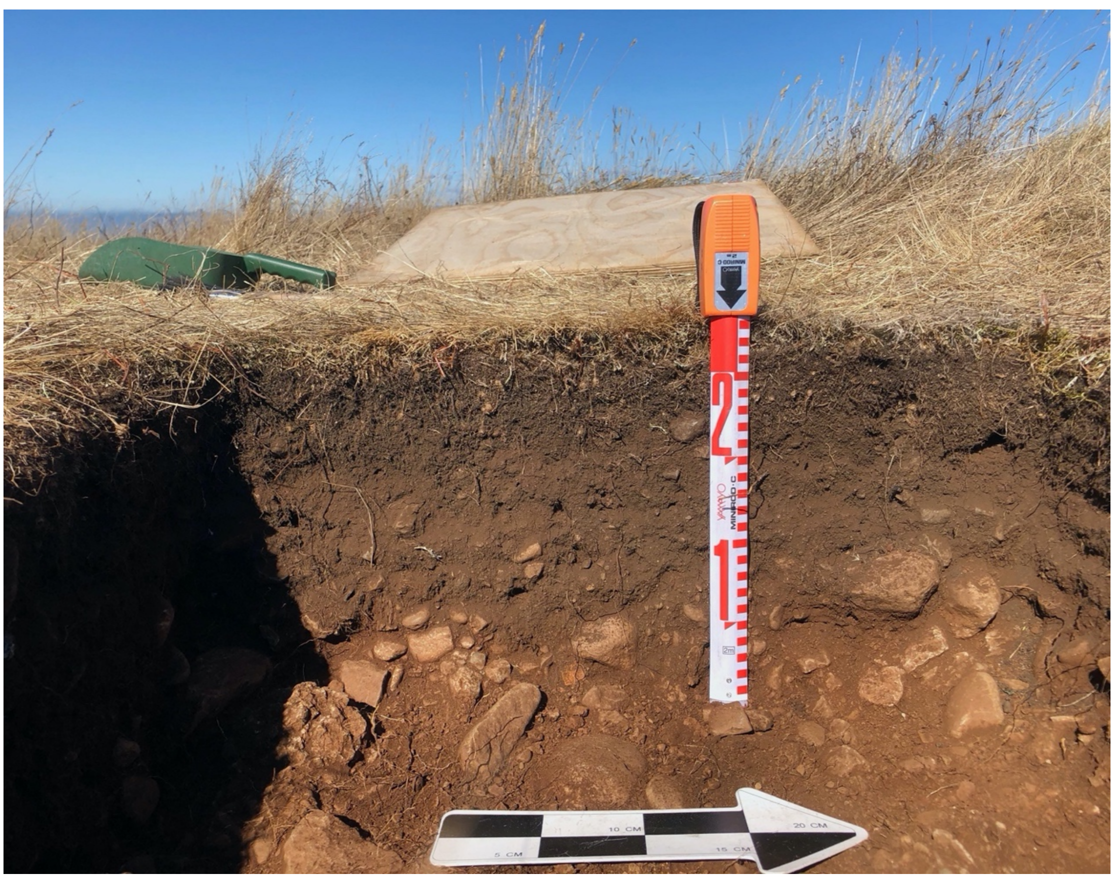

Figure 13. Evaluative Unit 3 showing shallow soil at the center of meadow.

Evaluative Unit 4

EU4 was placed on the transect 80 meters northwest of the Bighouse Excavation Unit 1. Table 10 details the soil properties recorded. Strata 1 showed a granular soil structure (2 – 5 mm diameter), active soil fauna, fine roots, blackberry roots, and a few onion bulbs. No visible archaeological material was present in any of the strata (Figure 14).

Table 10. Summary of the soil and sediment characteristics of Evaluative Unit 4.

Strata	Depth (cm DBS)	Munsell colour	Texture	Compaction (kg/cm^2)	Sorting	Coarse fraction
1	2-32	Black (7.5 YR 2.5/1 d)	Sandy loam	0.0 at surface to 1.5 at 30 cm Loose to moderate	Well	7% boulders, 3% pebbles, 3% gravel
2	32-50	Very dark grayish brown (10YR 3/2 d)	Sandy loam	4.0 high	Moderate to poor	sub-rounded 5% boulders, 15% pebbles, 10% gravel
3	50-57	Dark brown (10YR 3/3 m)	Sandy loam	4.5 high	Moderate	sub-rounded 1% boulders, 7% pebbles, 25% gravel

Figure 14. Evaluative Unit 4 transition around 30 cm below surface from black surface horizon to underlying parent material with larger boulders.

Evaluative Unit 5

EU5 was placed on the shoreline-inland transect 20 meters northeast from Evaluative Unit 3. Details of the soil properties are recorded below (Table 11). Strata 1 soil had a coarse (0.5 – 1.5 cm) granular structure with active soil fauna, numerous fine roots, and onion bulbs (Figure 15). Archaeological material in Strata 1 included a couple pieces of FAR found 5 – 6 cm below surface and a 2 cm piece of charcoal found in the screen from 20 – 25 cm below surface. Strata 2 had fine plant roots but no visible archaeological material.

Table 11. Summary of the soil and sediment characteristics of Evaluative Unit 5.

Strata	Depth (cm DBS)	Munsell colour	Texture	Compaction (kg/cm^2)	Sorting	Coarse fraction
1	4-28	Black (10YR 2/1 m) to very dark brown (10YR 2/2 m)	Sandy loam	1.25 loose	Moderate	sub-rounded 3% boulders, 7% pebbles
2	28-43	Dark brown (7.5 YR 3/2 d)	Sandy loam	3.5 moderate	Poor	sub-rounded 3% boulders, 15% pebbles, 20% gravel

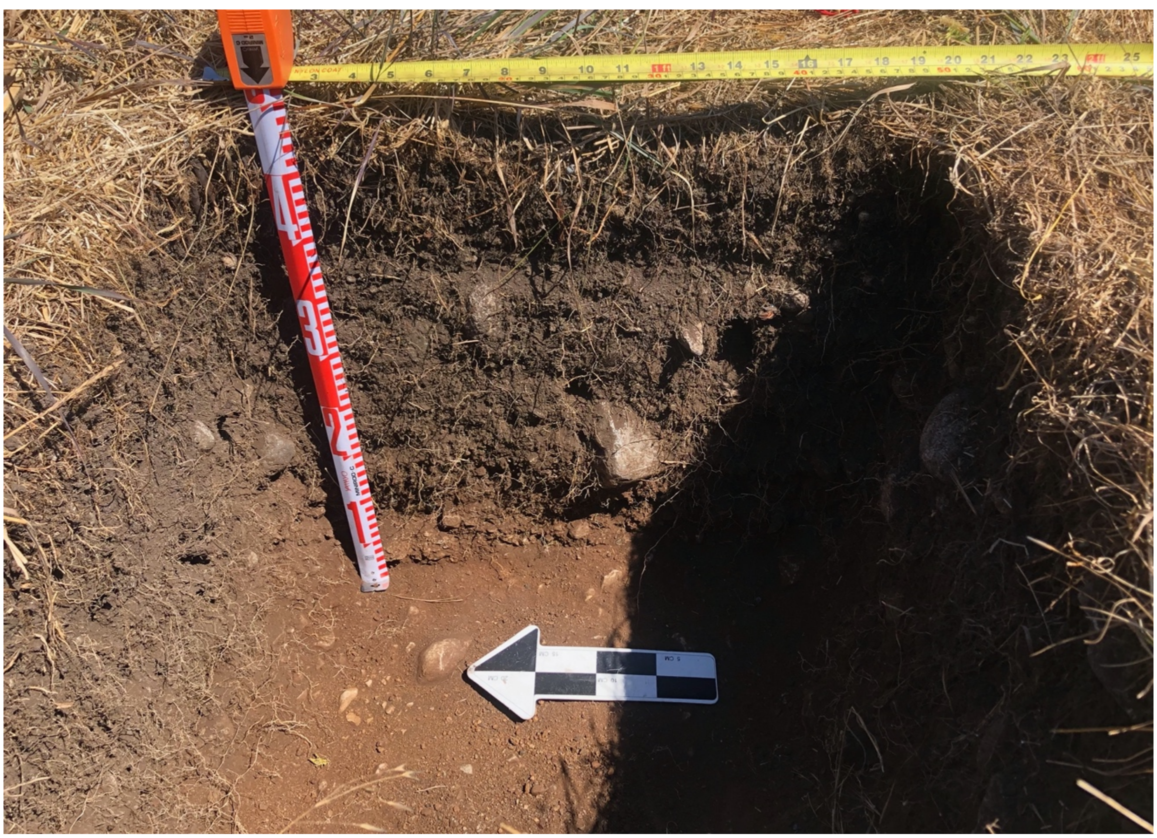

Figure 15. East wall of the soil profile in Evaluative Unit 5 showing dark horizon with rocky underlying parent material.

Evaluative Unit 6

EU6 was placed on the shoreline-inland transect 20 meters southwest from Evaluative Unit 3. Table 12 details the soil properties recorded. In Strata 1 the soil had a granular structure, active soil fauna, fine roots, onion bulbs, and chocolate lily bulbs. Three pieces of FAR rock were found in Strata 1 between 23 – 28 cm below surface. Strata 2 had fine roots and blackberry roots but no visible archaeological material (Figure 16).

Table 12. Summary of the soil and sediment characteristics of Evaluative Unit 6.

Strata	Depth (cm DBS)	Munsell colour	Texture	Compaction (kg/cm^2)	Sorting	Coarse fraction
1	5-39	Black (7.5 YR 2/0 d)	Sandy loam	1.0 loose	Moderate	sub-rounded 3% boulders, 5% pebbles, 5% gravel
2	39-42	Dark brown (7.5YR 3/2 d)	Sandy loam	3.0 moderate	Poor	sub-rounded 7% boulders, 15% pebbles, 7% gravel

Figure 16. East wall of Evaluative Unit 6 increasing boulders in the lower horizon.

Summary of Evaluative Unit Stratigraphy

Excavation Unit 1, in the Bighouse 1 feature (see above), had relatively higher concentrations of archaeological remains—including marine and terrestrial fauna, charcoal and ash in a hearth feature, artifacts, and a high density of fire altered rock (FAR). As hypothesized, the evaluative units indicated a decrease in archaeological material in the soil moving northwest, away from the Bighouse 1 village at the southeast margin of the meadow (Figure 17). The next evaluative unit (EU1) was approximately 20 meters northwest of Bighouse 1 and had noticeably less archaeological material—including pieces of marine fauna, charcoal, and some FAR. As distance increased beyond 40 meters from the village, about halfway across the meadow, the evaluative units showed two to three pieces of FAR per unit within the upper 28 cm of the profile (Figure 18). Beyond 60 meters from the village there are no longer any visible pieces of charcoal.

The charcoal particles found in the Bighouse Excavation Unit 1 were associated with a domestic hearth which would have been used for cooking and heating the home. It is possible that the macroscopic charcoal found in the upper strata of Evaluative Units 1 and 2 were translocated from the village hearths (e.g., wind transportation, trampling by people). As expected, very little macroscopic charcoal was observed in the field farther away from the houses, because fire stewardship in coastal meadows occurs in the general absence of coarse woody debris, coupled with the higher frequency of complete combustion characteristic of burning in grass-dominated meadows (Hegarty et al., 2011; McCune et al., 2013). Even in EU3, which is within the footprint of a small, prescribed fire conducted by the Songhees Nation between the late 1990's–early 2000's (Gomes, 2012, p. 58), no visible charcoal fraction was observed in the soil.

The Evaluative Unit testing showed the soil profiles to be relatively uniform across the meadow gradient away from Bighouse 1. In all the evaluative units the upper soil horizon showed colour with low chroma and value on the Munsell colour chart even when the soil colour was recorded on dry soil, in every profile the corresponding colour name was 'Black.' The two exceptions were the archaeological Bighouse 1 ('Dark Reddish Brown') and the shallow soil of EU3 ('Very Dark Grey') which are low on the chroma and value scales. These darkened surface horizons generally end at approximately 30 cm depth below surface and transition into a lighter orange-brown horizon becoming increasingly rocky with depth. One exception to the trend was Evaluative Unit 3, which extended only 20 cm deep from surface to parent material; this shallow soil unit is a high point in the meadow. All units surrounding EU3 have deeper soil profiles indicating that the meadow soil is deeper at the margins than in the centre.

Soil compaction in the meadow is very low in the surface horizon extending to a general depth of around 30 cm below surface. In all units the surface compaction was never greater than 1.75 kg/cm^2 measured with the soil penetrometer. Stoniness of the upper horizon was uniformly low, often not greater than 3% boulders (>256 mm) some of which were pieces of fire altered rock. Based on the excavation, characteristics of the meadow soil are consistent with the model of lək̓ʷəŋən land-use and stewardship (Table 2) including: darkened soil horizons indicating the presence of organic matter, few stones and homogenized soil in the upper horizon to a depth of 30 cm below surface, and low soil compaction.

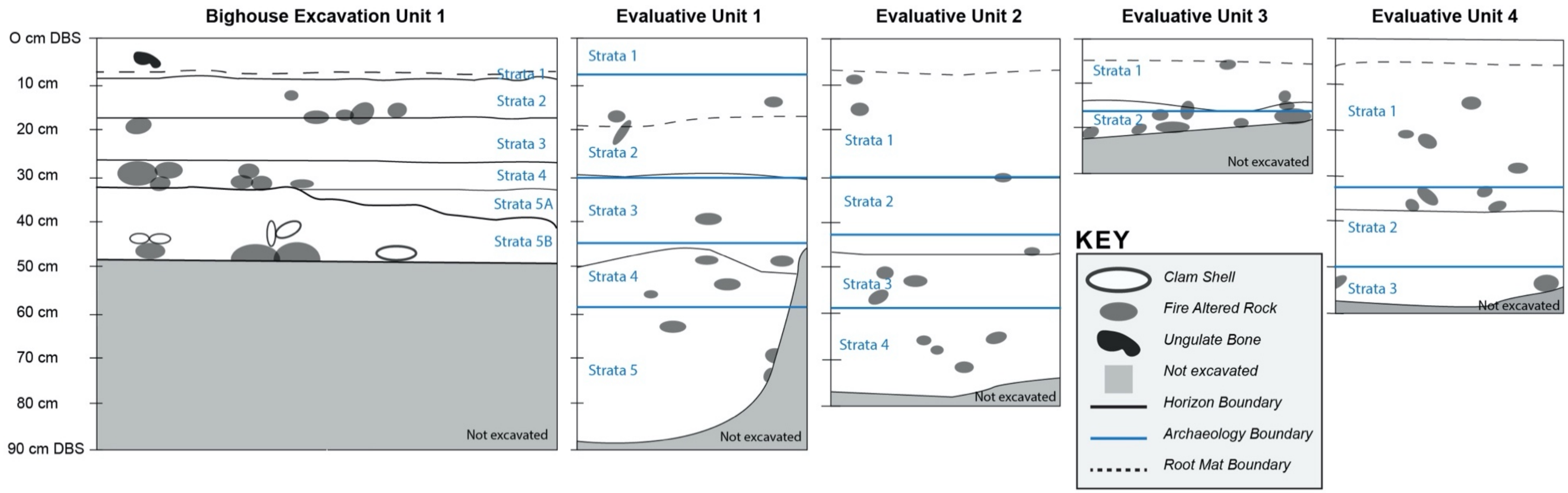

Figure 17. Transect of soil profiles across *Tl'chés* meadow. Left is the Bighouse excavation; remaining profiles are in 20 meter intervals northeast from the Bighouse.

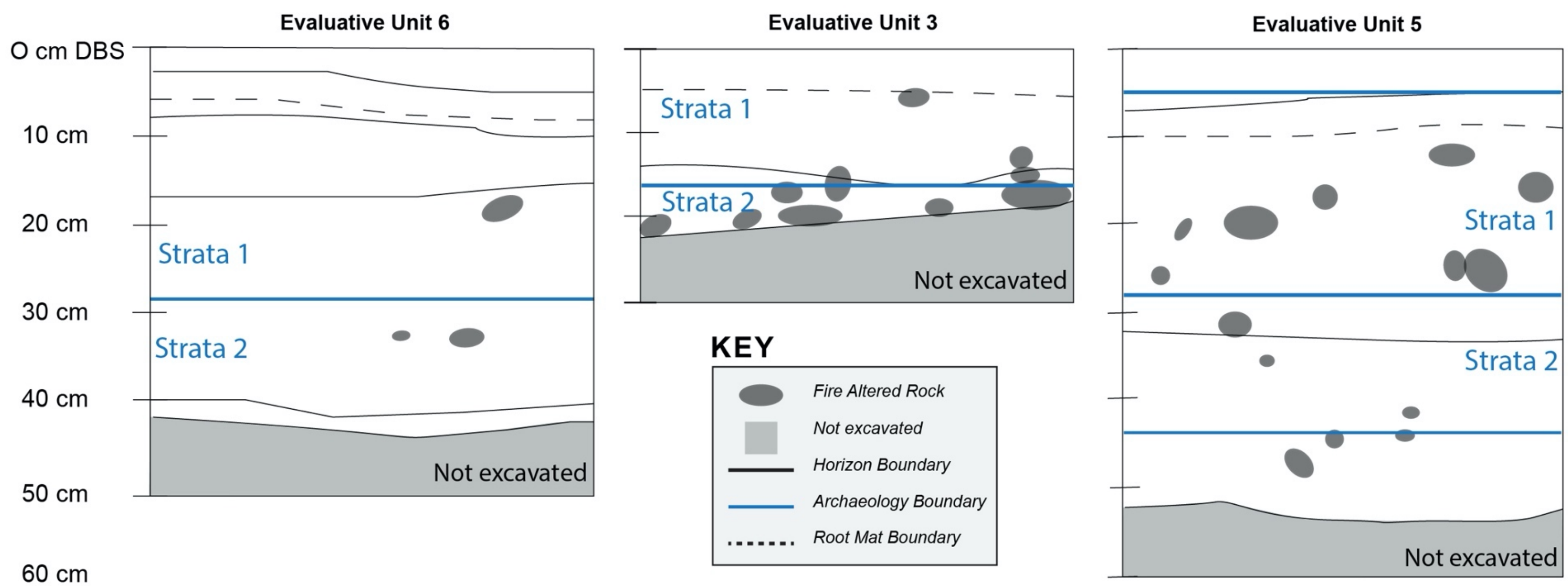

Figure 18. Transect of soil profiles from shoreline to inland. Evaluative Unit 6 is located near the shoreline; remaining profiles are in 20 meter intervals moving inland towards the meadow boundary.

Evaluative Unit soil chemistry

Bulk samples of soil were collected from the upper 10 cm at each of the seven units and tested for nitrogen, carbon, pH, organic matter, calcium, and phosphorous. The values recorded for each of the tests was higher in the Bighouse compared to the six other evaluative units which is consistent with other researchers finding that chemical signatures in cultural soils are elevated in high use areas, such as within villages (e.g., Griffith, 1980, 1981; Heckenberger et al., 2007; Middleton, 2004). Calcium and phosphorous are almost twice as high in the Bighouse. Nitrogen, carbon, and organic matter are around one and a half times as high within the Bighouse, and pH is one unit higher in the Bighouse (Table 13).

However, when the values for the Bighouse are compared to the bulk samples collected via probe/auger the elevated values are no longer apparent (Appendix A). In all the laboratory tests, none of the values from the Bighouse are the highest recorded across the *Tl'chés* meadow. Some soil probes showed unusually high values both within the deep soil meadow and the rocky outcrop areas, these are discussed in more detail below.

Table 13. Results of soil samples at excavation units. BH = Bighouse; EU = Evaluative Unit.

Unit	Nitrogen %	Carbon %	pH (1:2 $CaCl_2$)	Organic matter (LOI)	Calcium (mg/kg)	Phosphorous (mg/kg)
BH	1.4	18	6.0	32	28,000	5,700
EU1	0.54	7.4	5.2	16	14,000	2,300
EU2	0.68	9.3	4.9	17	12,000	1,100
EU3	0.76	10	4.2	21	8,300	1,400
EU4	0.62	8	4.8	15	11,000	1,400
EU5	0.74	9.7	5.0	18	9,700	1,300
EU6	0.57	7.6	4.8	15	9,900	1,100

Results of the soil probe sampling

After receiving the results of soil testing from the Government of British Columbia Analytical Chemistry Services Laboratory the numerical data from the soil probes were inspected for any skewness which could affect the comparison of means between the meadow and off-site samples. The outcome was that skewness was apparent in almost all measures: soil texture (sand, silt, clay) were the only tests that did not require transformation. Data that needed to be transformed prior to analysis by *t* test were assessed by their skewness values: 0.0-0.5 = no transformation; 0.5-1.0 = square root transformation; >1.0 = logarithmic transformation (Webster, 2001). These transformations were applied to bring a closer approximation of normality to meet the *t* test assumptions. Below details the results for each of the physical and chemical tests performed on the soil samples. Statistical analyses of the laboratory data were performed using a two-tailed independent *t* test with a significance level of 0.05. Box plots of significant results are shown in-text while non-significant results are in Appendix B.

Soil texture

Changes to soil texture, including a tendency towards finer grain-size are hypothesized effects of cultivation (Lepofsky & Lertzman, 2008). Measuring soil texture required the separation of the sand, silt, and clay fractions which were compared by *t* test separately. No transformations of the data were required for any of the tests; all mean and standard deviation values are reported on untransformed data. Despite a significant difference of silt between the meadow and rocky outcrop control area (Figure 19), the relatively proportions of sand, silt, and clay, are not as important as the combined values to determine soil texture. Figure 20 shows the soil texture for the meadow and rocky outcrop samples; considerable overlap between the two areas is apparent.

Sand: The 12 soil probes collected in the meadow ($M = 64.50$, $SD = 4.317$) compared to the 11 soil probes collected in the rocky outcrop control area ($M = 58.18$, $SD = 9.806$) did not show a significant difference in percentage of sand, $t(21) = 2.031$, $p = 0.0551$.

Silt: The 12 soil probes collected in the meadow ($M = 26.92$, $SD = 2.392$) compared to the 11 soil probes collected in the rocky outcrop control area ($M = 32.73$, $SD = 9.360$) showed a significant difference in percentage of silt between the two areas, $t(21) = 2.082$, $p = 0.050$.

Clay: The 12 soil probes collected in the meadow ($M = 8.792$, $SD = 2.299$) compared to the 11 soil probes collected in the rocky outcrop control area ($M =$

8.864, SD = 1.132) did not show a significant difference in percentage of clay between the two areas, $t(21) = 0.094$, $p = 0.926$.

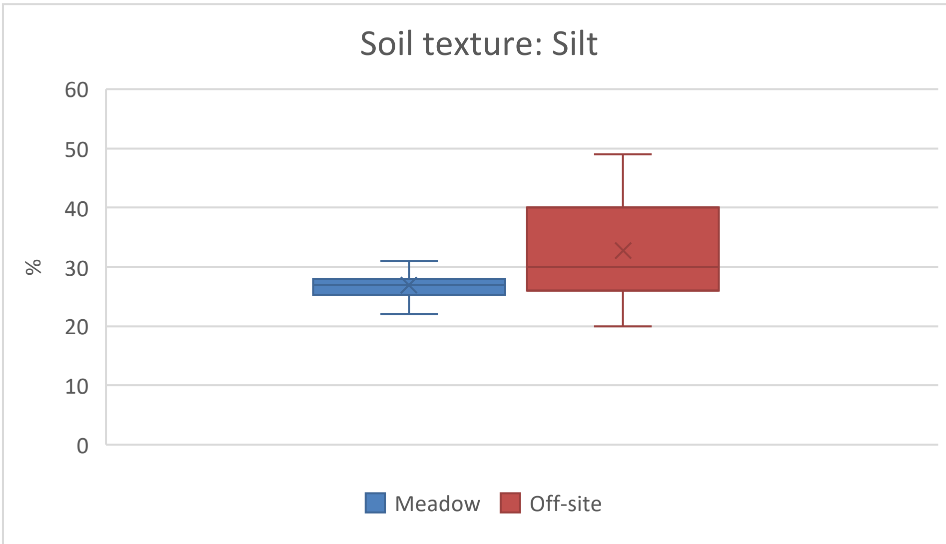

Figure 19. Significant difference in silt between meadow and off-site samples.

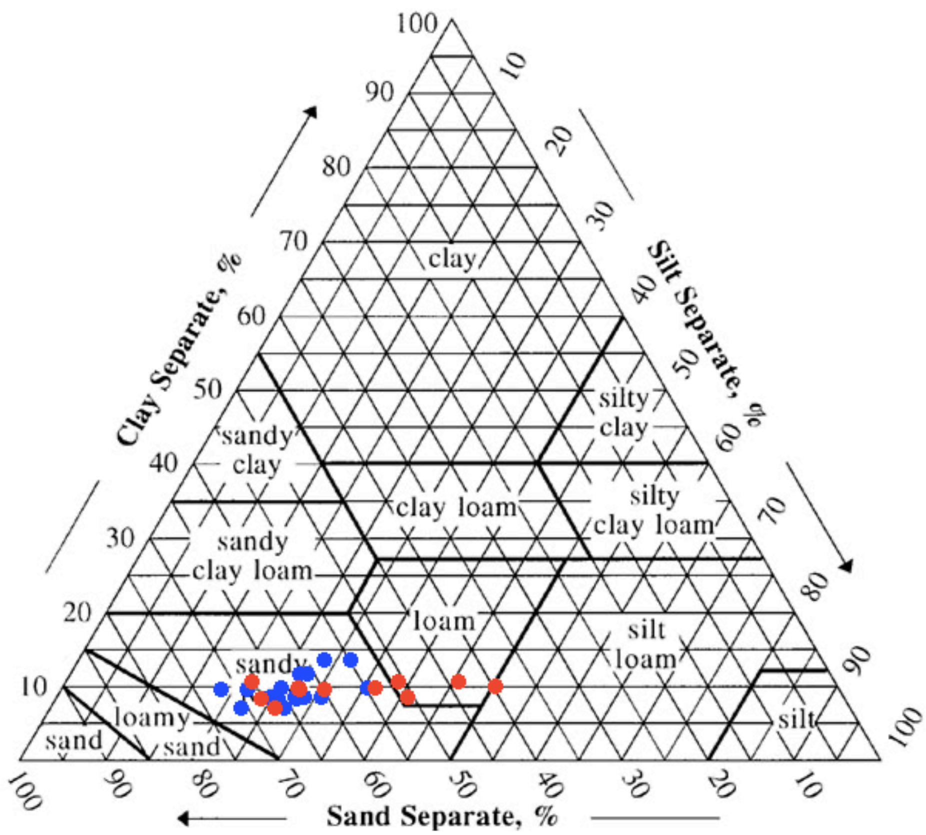

Figure 20. ***Tl'chés*** **soil texture. Blue = meadow samples (Zone A). Red = rocky outcrop samples (Zone B) (Soil Texture Calculator, n.d.).**

Organic matter

In the model of hypothesized lək̓ʷəŋən effects on soil, increased soil organic matter could potentially come from cultivation or as carbonized remains in habitation sites. A logarithmic transformation of the data was applied to correct the positive skewness that was present in the meadow samples (0.98) and the rocky outcrop control samples (1.13). The mean and standard deviation are reported for the transformed data. The 12 soil probes collected in the meadow (M = 1.318, SD = 0.116) compared to the 11 soil probes collected in the rocky outcrop control area (M = 1.331, SD = 0.137) did not show a significant difference in percentage of organic matter between the two areas, $t(21)$ = 0.252, p = 0.803. No clear trend appears in the measurement of organic matter, elevated levels were found around the plank house village, but equally high values were found within the meadow and rocky outcrop areas as well.

Total carbon

Increased carbon input to the site could come from multiple sources (Table 2), namely, landscape burning, pit cooking, and deposits from habitation sites. Total carbon values were slightly positively skewed for both the meadow samples (0.775) and to a lesser extent the rocky outcrop control samples (0.442). A square root transformation was applied to the data to address the positive skewness; mean and standard deviation values are reported for the transformed values. The 12 soil probes collected in the meadow (M = 3.345, SD = 0.517) compared to the 11 soil probes collected in the rocky outcrop control area (M = 3.488, SD = 0.546) did not show a significant difference in percentage of total carbon between the two areas, $t(21)$ = 0.645, p = 0.526. Values for total carbon were elevated in samples collected around the village but there were similarly high values found in the meadow and in the rocky outcrop.

Total nitrogen

Changes to total nitrogen at the site where habitation or seaweed fertilizer was applied may show increased nitrogen (Table 2). Measurement of total nitrogen was slightly positively skewed for the meadow samples (0.781) and for the rocky outcrop control samples (0.547). Because the data were only slightly skewed a square root transformation was applied to correct some of the skewness; mean and standard deviation values are reported for the transformed values. The 12 soil probes collected in the meadow (*M* = 0.965, *SD* = 0.148) compared to the 11 soil probes collected in the rocky outcrop control area (*M* = 0.951, *SD* = 0.186) did not show a significant difference in percentage of total nitrogen between the two areas, $t(21) = 0.207$, $p = 0.838$. High values of nitrogen were found at surface archaeological features but values that were similar or greater than those were also found in the meadow and rocky outcrop where no surface features are present.

pH

The effects of habitation and deposition of archaeological material around villages were hypothesized to raise soil pH. Values for pH were very positively skewed in the meadow (1.149) and slightly negatively skewed in the rocky outcrop control samples (-0.316). A logarithmic transformation was applied to address the more extreme positive skewness of the meadow samples; a consequence was that the transformation enhanced the negative skew of the control samples from -0.316 to -0.392 but this was still within the acceptable range of normality for performing a *t* test (Webster, 2001). Mean and standard deviation are reported for transformed values. The 12 soil probes collected in the meadow (*M* = 0.698, *SD* = 0.067) compared to the 11 soil probes collected in the rocky outcrop control area (*M* = 0.658, *SD* = 0.031) did not show a significant difference in pH between the two areas, $t(21) = 1.844$, $p = 0.079$. The highest values of pH were found within the village at the southeast of the meadow.

Calcium

Increased sources of calcium were identified as potentially coming from deposits around habitation sites (Table 2), for example, around Bighouse 1. The distribution of calcium was positively skewed in the meadow (1.431) and in the rocky outcrop control samples (0.074) so a logarithmic transformation was applied to the data to approximate a more normal distribution. The mean and standard deviation are reported as the logarithmic transformed values. The 12 soil probes collected in the meadow (*M* = 4.13, *SD* = 0.331) compared to the 11 soil probes collected in the rocky outcrop control area (*M* = 3.91, *SD*

= 0.039) showed a significant difference in calcium between the two areas, $t(21) = 2.189$, $p = 0.040$ (Figure 21). Three unusually high values of calcium were found where surface archaeological features are present, two of these were 7.5 times higher than the lowest calcium value.

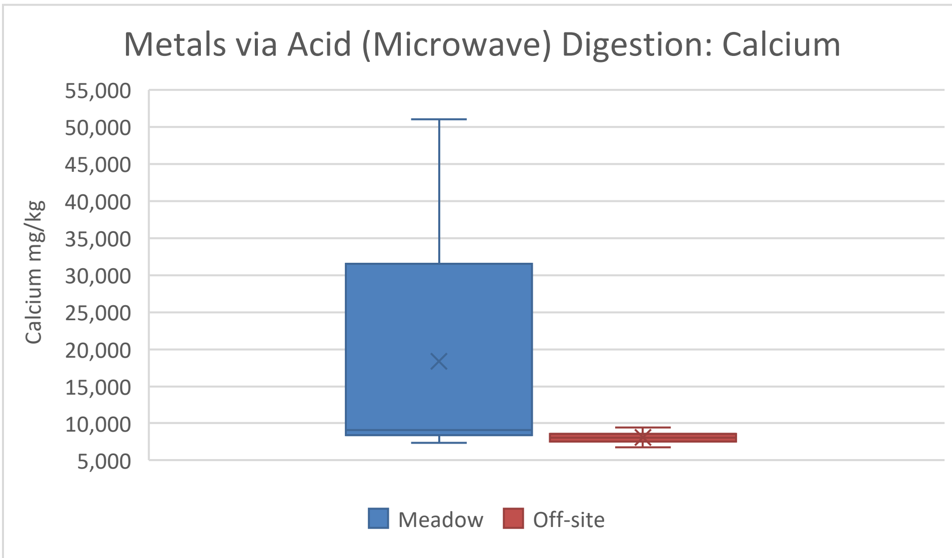

Figure 21. Significant difference in calcium between meadow and off-site samples. Box plot data is the untransformed values.

Phosphorous

In the model of hypothesized lək̓ʷəŋən effects on soil, increased phosphorous could potentially come from fertilization or habitation sites. Data for phosphorous showed positive skewness that was very pronounced in the meadow sample (2.054) and mildly present in the rocky outcrop control samples (0.6949). A logarithmic transformation was applied to the data to correct the positive skewness; the mean and standard deviation reported are for the transformed values. The 12 soil probes collected in the meadow (M = 3.422, SD = 0.407) compared to the 11 soil probes collected in the rocky outcrop control area (M = 3.380, SD = 0.185) did not show a significant difference in phosphorous between the two areas, $t(21) = 0.314$, $p = 0.757$. A similar trend to pH and calcium was noted for phosphorous where elevated levels of select chemical attributes were highest in areas that have surface archaeological features. A notable soil probe was from the platform feature on the opposite side of Bighouse 2 (Figure 22) at the southeast of the meadow which is almost 17 times higher than the lowest phosphorous value.

Discussion

In this study, I built a model based on ethnographic Straits Salish practices to look for and test potential soil signatures associated with root food and camas cultivation, including common practices such as burning, tilling, fertilizing, field clearing, and others (Beckwith, 2004; Suttles, 2005; Turner & Kuhnlein, 1983). I coupled this with the global literature on Dark Earths and studies involving the analysis of cultivated field anthrosols. I then derived a suite of field and laboratory methods to test the model using structural and chemical lines of evidence (Table 2). This research attempted to study these changes by utilizing an approach popular for anthropogenic soils—the collection of samples from within and off-site for statistical comparison (Asare et al., 2020; Cook-Patton et al., 2014; Sheil et al., 2012; Trant et al., 2016; Wells et al., 2013). As a first effort at identifying soil-based evidence of terrestrial Indigenous plant food stewardship in the Salish Sea, I was aware that the process would be challenging, and that results may not be straight-forward. As expected, the outcomes of this study are complicated.

First, I was not able to conclusively identify an inland control site against which to compare the soil chemistry of the deeper soil samples. The inland soil probe testing component of the study, around the bedrock exposures behind the village, was intended to function as a non-anthropogenic baseline for comparison with the deeper field soil chemistry. After conducting the field work and analyzing the results, I am not convinced that this inland site is non-anthropogenic, which I discuss below. Based on the experiences of others working on plant-based historical ecology, ethnoecology, and archaeology on the Northwest Coast, we know that ecological signatures of stewardship are complex. Further, even archaeological approaches and sites—offering perhaps the most concrete picture of past land use, are still not straight-forward. In landscapes with a deep and encompassing history of Indigenous life, finding soil control sites free from human influence seems similarly challenging as identifying control sites for studying the ecological legacies of plant stewardship.

Second, it is difficult to determine exactly what the soil effects of low-severity cultural burns are and how long they will last after a burn. Low-severity burns may affect mineral elements in the soil by increasing magnesium, calcium, and available nitrogen while also decreasing total nitrogen but repeated burning can also cause increase soil density which negatively impacts porosity (Agee, 1993) but these changes are highly variable. Agee also suggests that chemical changes are more likely than physical changes in the soil, and that higher-severity fires will have more noticeable and longer-lasting impacts while low-severity burns are more challenging to detect. In my study, I could not attribute changes in soil properties to a single lək̓ʷəŋən practice because many of the practices may have similar potential effects in the soil, for example, increased charcoal could come from habitation, prairie maintenance, cultivation, or pitcooking.

While more work must be done to make this approach viable, this research is the first time a study has tried to distinguish camas cultivation on soil properties and chemistry alone. I recognize that as such, this work is a single line of analysis, that must be combined with other lines of evidence and approaches, to better understand lək̓ʷəŋən cultural landscape stewardship. In the following sections, I revisit the research questions and discuss my results, with the above points in mind.

RQ 1: Does a gradient of cultural influence exist from the village into the meadow?

In this study material remains were present within the Bighouse village and up to 40 meters around the village. Beyond 40 meters the remains are limited to small amounts of FAR in the upper 30 centimeters of the soil. The profile of Bighouse Excavation Unit 1 shows that the deposits are quite distinct from the meadow based on their archaeological materials and are best thought of as sediments upon which soils are forming. Outside of the village the soil properties are consistent across the meadow. This indicates that known places of lək̓ʷəŋən use—cultivated meadows, are likely to be overlooked in instances where a quick archaeological determination of site boundaries is required on macroscopic remains alone. Without including Songhees community knowledge, ethnographic data, and plant surveys of culturally important species it would be easy to miss such sites, which continue to be significant places in lək̓ʷəŋən lives.

However, the assumption that material remains will only be found in village sites should not be taken for granted while working in camas meadows, there are studies that state that camas cultivation could also include processing at the site (Suttles, 1974), temporary camps (Weiser & Lepofsky, 2009), and plot boundaries marking ownership (Deur, 2002a; Suttles, 1974). All of these activities have the potential to leave archaeological remains in the form of roasting features, quantities of fire altered stones, botanical remains, and plot markers although the preservation of these are variable based on material. For example, wooden stakes outside of wet-site contexts degrade rapidly (Lepofsky & Lertzman, 2008). However, stone field clearing has been associated with blue camas cultivation sites at Rocky Point (Mathews, 2014), and the nearby Uplands Park, directly opposite *Tl'chés* in Victoria (Mathews et al., 2011). Furthermore, the burial cairns situated along the edge of the study area meadow appear to be part of a larger pattern in which burial cairns are associated with the edges of present-day blue camas distributions (Mathews, 2016).

Soil colour was consistent across the meadow between the village and field, generally the 30 cm below surface was black (Munsell soil colour chart) although the depth could vary by a few cm higher or lower depending on the specific unit. The upper 30 cm would include the digging stick depth for lək̓ʷəŋən cultivation. The only exception was EU3 in the centre of the cultivated field (Zone A), which was the shallowest unit. Here the upper horizon only extended 17 cm below the surface. Generally, the soil colour did become lighter with depth in all units, but this is expected and reflects the concentration of organic material found in the surface horizons of soil. Beckwith (2004, p. 28) speculated the black colouration of regional soils could be due to the presence of microcharcoal resulting from Straits Salish landscape burning practices. This could also be the case at *Tl'chés*, however, it would require soil micromorphological analysis to determine if microcharcoal is present.

No relationship between compaction and distance from the Bighouse was found although compaction did increase with depth below surface which is characteristic of soils. The surface horizon of the village and cultivated field showed uniformly loose compaction (never greater than 1.5 kg/cm^2) in the upper 30 cm of soil. The exception is EU3 which was greatly compacted 4.5 kg/cm^2 at 21 cm below surface where the underlying parent material is much closer to the surface. In a study on camas populations emulating traditional Straits Salish harvesting, Proctor (2013) found that experimental harvesting and a burn treatment did increase the soil porosity i.e., soil compaction was reduced. However, on *Tl'chés* it is difficult to determine if low soil compaction is only from lək̓ʷəŋən cultivation because soil texture, plant roots and active soil fauna all contribute to overall soil porosity and relative compaction. Cultural practice and ecological conditions represent complex interactions, and a more accurate assessment may be that long-term root food cultivation did not negatively affect soil compaction—which is a major concern when soil is continually used for cultivation.

Interestingly, the compaction of the Bighouse Excavation Unit 1 showed loose compaction—never greater than 1.0 kg/cm^2—continuing to a depth of 47 cm. This relatively loose compaction contrasts with other Northwest Coast studies which have investigated high compaction as evidence of archaeological house floors (Graesch et al., 2015). The lower levels of compaction found in the Bighouse could be due to the unit being excavated around a hearth feature which has deposits not commonly found on the rest of the floor (e.g., concentrations of charcoal, ash, and some shell material which would have been frequently disturbed as lək̓ʷəŋən families were cleaning up their hearths). The physical location of the archaeological plank houses suggest this may be a defensive site, and as such, may have only periodic, or perhaps short-lived occupation. The ongoing LEAP archaeological project will work to untangle the site chronology and history.

Soil chemistry values—carbon, nitrogen, organic matter, pH, calcium, phosphorous—were elevated in the Bighouse samples compared to the values at the other evaluative units. However, when the values of the evaluative units were viewed against the values reported from the soil probes the distinction became less clear. There was no apparent pattern to values for carbon, nitrogen, or organic matter which suggests that ecological, rather than, archaeological processes are regulating these soil properties on *Tl'chés* today.

Village and surface archaeological features show up very well chemically, particularly elevated calcium, phosphorous and pH that were found in soil probes taken from these features. The probes from around the village were higher than those within the house and likely align with the observation that elevated chemical levels are found in areas of refuse (Cook-Patton et al., 2014; Wells, 2010; Wilson et al., 2008). Straits Salish houses were known to be swept and kept clean on the inside with deposits being placed outside the house which can result in small berms being formed around houses (Suttles, 1974, p. 258).

RQ2: Did lək̓ʷəŋən management of the *Tl'chés* meadow—traditional burning and cultivation—alter the soil in ways that are detectable after decades of interruption to traditional stewardship?

Many of the selected physical and chemical attributes showed considerable similarity between the camas meadow and the rocky outcrop area. Based on these results, it seems likely that camas production extended across a greater area than I anticipated. In effect, there appears to be two basic landforms in which camas was grown on *Tl'chés*: 1) the deep meadow soil; and 2) the adjacent bedrock outcrops behind the meadow, which have small pockets of soil (Figure 22). The present-day dense blackberry distribution makes this transition between deeper meadow soils and shallow bedrock-defined pockets of soil more difficult to see. However, this idea is supported by the fact that when sampling in the rocky outcrop there were a few dried camas stalks, rock features that may be burial cairns, and one fruit tree like those found in the heritage orchard near Sellemah's childhood home. This distinction in growing areas echoes Beckwith (2004), who discusses actively managed and family stewarded sites—such as the deep meadow soil sites—in contrast to open/community spaces where families that did not owned camas plots were able to tend/harvest camas.

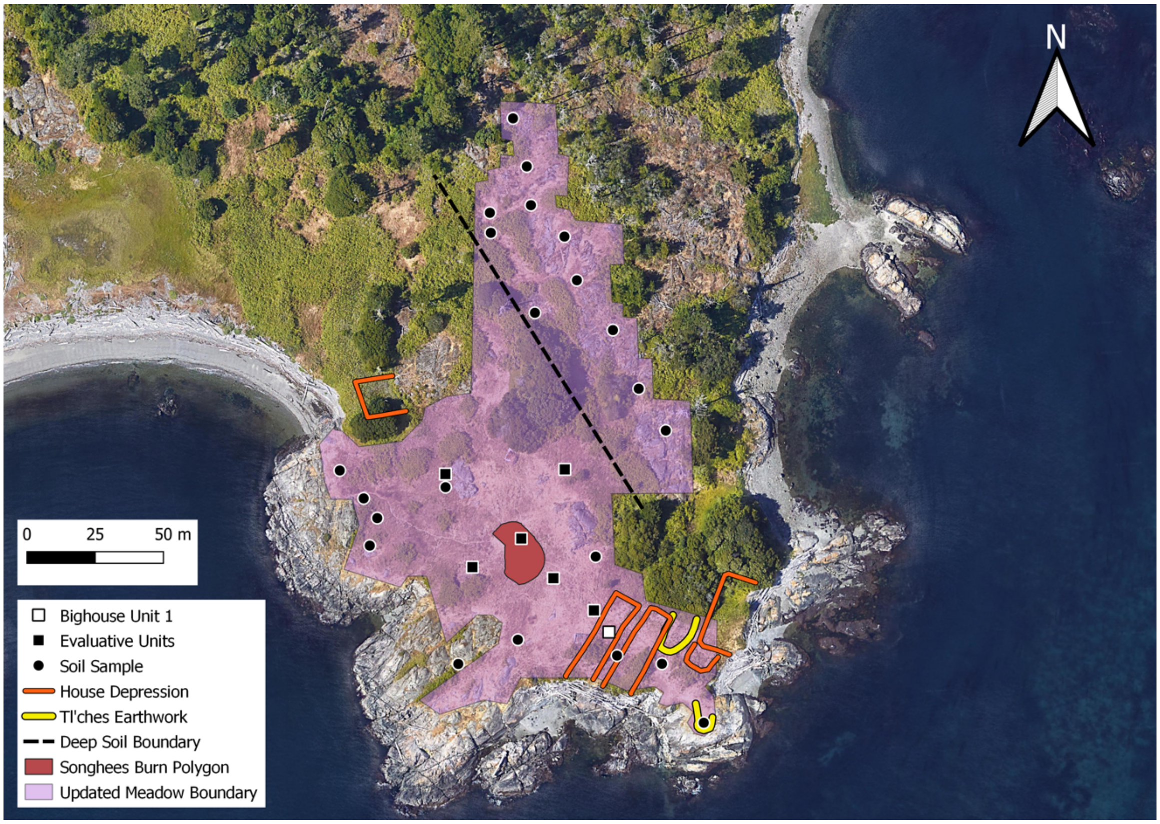

Figure 22. *Tl'chés* map showing updated boundaries and cultural features in meadow.

Texture

There was a statistically significant difference of silt, but this difference becomes inconsequential when all components of soil texture are combined. The soil texture on *Tl'chés* is sandy loam across the meadow and rocky outcrop (Figure 20). Lepofsky and Lertzman's (2008) assessment that a finer soil texture may be found in cultivated locations is more likely to depend on the specific cultivation practices—for example, traditional Northwest Coast estuarine cultivation is benefitted by the addition of material to increase textural diversity (Deur 2000). Soil texture is a resistant property of soil and is not likely to change unless there is intentional addition of diverse textural material or a change in depositional environment (Weil & Brady, 2017). After re-examining the ethnographic literature of camas cultivation, I would revise the textural component of my model. It does not seem likely that textural changes would result from turning the sod or burning. It is possible that these practices would impact the aggregation and structure of the soil while it is being actively cultivated but because soil structure is susceptible to rapid change it is unlikely changes would last long after cultivation ceases (Weil & Brady 2017, p. 148).

Organic matter

On *Tl'chés* similar values of organic matter were found in the meadow and the rocky outcrop areas. On southern Vancouver Island the soil organic matter content is already relatively high in Garry oak sites and is rapidly incorporated into the soil (Broersma & Lavkulich, 1980, p. 754). Rapid turnover of organic matter and interruption to cultivation may be responsible for the similar levels of organic matter between the two areas. It may also be that measuring soil organic matter through loss on ignition (LOI) is capturing more of the modern accumulation of organic matter which is relatively high in grassland environments (Weil & Brady, 2017, p. 560). It is possible that alternative tests of organic matter or sampling deeper within the soil profile would yield results more sensitive to a situation where people have not been actively cultivating for several decades.

Total carbon

There is considerable overlap between the total carbon values found in the camas meadow and the rocky outcrop area. Initial assessment of the carbon from the Bighouse excavation appeared to be elevated but when this was compared to values from the camas meadow and rocky outcrop there were several other samples that showed equally high or higher amounts of carbon. There does not appear to be any enrichment of carbon in the *Tl'chés* meadow indicating that current soil processes are responsible for maintaining carbon in the soil.

Total nitrogen

Total nitrogen is not distinguished between the camas meadow and rocky outcrop at the site. Areas where surface archaeological features are present do show higher values of nitrogen which could indicate that archaeological remains are providing an additional source of nitrogen to the soil. However, equally high values of nitrogen were also found near the margin of the meadow and in the rocky outcrop where no surface features are present indicating that archaeological remains may not be the only source of additional nitrogen at the site. Because of nitrogen's status as an essential nutrient for plant growth it seems unlikely that any changes from burning or cultivation would last long after stewardship has subsided.

pH

Comparison between the meadow and off-site did not meet the threshold for statistical significance. However, it was close (p= 0.0793), with the meadow samples having on average a higher pH. The source of the higher values of pH appears to be coming from the village where surface archaeological features are present. Apart from the village samples, the acidity of the rest of the meadow and the rocky outcrop are similar to those reported at another Garry oak grass site (Broersma & Lavkulich, 1980).

Calcium

Calcium was one of two statistically significant differences found between the meadow and the rocky outcrop, although it appears to be strongly influenced by the three extremely high values from the village (Probes 17, 18, 19). Studies of midden deposits found elevated levels of calcium come from marine shell deposits (Trant et al., 2016). Although the house depressions at the *Tl'chés* village do not appear to have substantial shell midden deposits (so far), archaeological shell does occur through the Bighouse Unit 1 house floor stratigraphy. Additionally, the high levels of calcium within the village appear to be counteracting the acidity in the soil from an average of 4.6 to around 6.4 pH. The localized change in soil pH may be enough to affect the preservation potential of organic archaeological material and change the growing conditions for vegetation that prefers more alkaline soils.

Phosphorous

There was considerable overlap between phosphorous values in the meadow and rocky outcrop despite extremely high values recorded in probes that came from the village. The highest value (Probe 19), located in the platform area of the village (Figures 4 and 9) is almost six times as high as the average for the meadow. The high phosphorous value in addition to a rock arrangement that appears to be a soil retaining wall on an exposed surface at the south end of the meadow could indicate that this location was used for fish drying racks (Holliday & Gartner, 2007; Stein, 2000; Suttles, 1974). Chemical signatures can be an excellent tool in archaeological interpretation, but they are better carried out with a larger scale archaeological excavation (i.e., they cannot entirely replace excavation). No subsurface testing of the southern platform feature was done during this thesis although it would be an ideal location for future investigation, and this research has flagged the platform as a high priority site for LEAP 2022 test excavation.

Summary of results compared to expectations of testable traits

To summarize, the results of this study were not always clear; some testable traits aligned closely with the model of ləkʷ̓əŋən stewardship detailed in Table 2. Some of the other traits were more complicated and support the idea that further work is required to refine this methodology. Table 14 provides the details of how the expected findings compared to the actual results of this study.

Table 14. Testable traits expectations versus study results.

Testable trait	Expectation	Result
Soil chemistry	Elevated C, N, Ca, P, and organic matter	• Carbon, nitrogen, and organic matter show no pattern • Calcium and phosphorous are higher around plank house village
Soil pH	Elevated pH	• Soil pH is higher around plank house village
Porosity	Low soil porosity	• Porosity is uniformly low across the village and surface of the meadow
Soil texture	Fine soil texture	• No detectable difference in soil texture between meadow and control
Large rocks in meadow	Few large rocks in upper horizons	• Infrequent boulders in the upper soil horizons
Colour	Low value and chroma	• Munsell soil colour dark (e.g., 'black', 'very dark grey') in plank house village and cultivated meadow

Study limitations

The biggest challenge encountered in this study was the selection of an appropriate control site. From the outset we knew working on *Tl'chés*—a cultural landscape on a small island—would present difficulties in identifying an area as a true control. We did not assume that any place on the island would be unused by lək̓ʷəŋən people, rather that some areas may have less modification to soil chemistry. The assumption made for this project that a rocky outcrop would be less intensively cultivated than a deep soil meadow turned out to be incorrect and does not reflect lək̓ʷəŋən land use as shown through the consistent measure of soil chemistry in both areas. Chemical attributes of camas fields will need more research done in multiple camas meadows to begin understanding what field conditions exist and if any discernable signatures of camas cultivation are present.

Studying variation of soil is difficult even under ideal conditions so the small area of the meadow on *Tl'chés* along with the proximity of the village introduced challenges in attempting to isolate cultivation practices. However, as stated previously *Tl'chés* is one of the few remaining places on southern Vancouver Island that is not directly impacted by urban development. Modern development often brings greater challenges because recent changes to soil chemistry are likely to mask earlier signatures. Studies of cultivation on the Northwest Coast note that stewardship was often meant to enhance natural environments, not outright change them (Lepofsky et al., 2017) and it appears that this is also the kind of subtle soil chemistry signal that this research detected.

Given that lək̓ʷəŋən stewardship—and Indigenous stewardship on the Northwest Coast more broadly—is proposed to minimize disruption of ecosystems and/or to maintain ecosystems at favourable life cycle stages then research project design becomes one of selecting an appropriate sample size to detect changes that may be present. A limiting factor in the statistical analysis of this study was the small sample size for the meadow (n = 12) and the rocky outcrop control area (n = 11) as well as having limited control types to experiment with. Having a larger data set gives more power to detect differences where subtle effects are hypothesized. However, the opposite is also true as pointed out by (Webster, 2001, p. 335) that if the data set is very large a statistically significant difference is much easier to detect, so caution is required before basing interpretations off statistical significance alone.

Chapter 5: Conclusion

This research aimed to understand more about lək̓ʷəŋən soils that develop under root food cultivation. It was important to take a landscape level approach to research on *Tl'chés* and include the village as part of the investigation. Because this is one of the first attempts in the region to consider the anthropogenic influences on soil as a line of evidence, the research sought to test if chemical signatures were a useful tool in identifying and understanding anthropogenic soils. Chemical tests were paired with descriptions of the macroscopic physical soil to determine if a gradient of influence existed between the village and the cultivated soil. While this approach detected the village deposits (which were already visible through surficial archaeological features), the portion of the study related to chemical signatures of root food cultivation was complicated by the fact that a true control site is likely not possible on this small island cultural landscape.

This research found that the boundaries of the current meadow should be reconsidered to include a much larger area on the southern portion of *Tl'chés* that was likely also under cultivation. The similarity between the deep soil meadow and rocky outcrop was evidenced by the consistent chemical patterns as well as burial cairns and culturally important vegetation that was noted in the rocky outcrop. The two areas may be better understood as two types of root food gardens, one in deeper soil areas and another in shallow soil bedrock defined basins. Defining hard boundaries around lək̓ʷəŋən cultivation sites continues to be a conceptual and research challenge, further complicated by invasive vegetation and changing ecological conditions.

Through this study, soil chemical analysis is a useful contribution to Northwest Coast archaeology. It is helpful in areas that already have clear signs of habitation—for example, within villages—but it also shows the potential of using chemistry in areas that don't have obvious macroscopic changes. The full potential of using this approach to study root food cultivation would be bolstered by additional studies in other cultivated fields to get a better sense of the range of chemical values that may be present. Ideally in contexts with better prospects for control sites—however, this is likely a perpetual problem in most contexts where Indigenous peoples have rich and deep histories.

Future research looking at the soil signatures of lək̓ʷəŋən stewardship should consider the ongoing changes in coastal prairie ecosystems that are dramatically shifting lək̓ʷəŋən cultural landscapes. Meadows are continually shrinking in size because of urbanization, vegetation succession—both native and invasive, climate change, and prohibition of traditional burning (Bachelet et al., 2011; Dunwiddie & Bakker, 2011). Applying a study approach of cultivation site versus control site will become increasingly difficult in urban areas as these ecosystems shrink. Understanding individual locations where cultivation was practiced is best accomplished through interdisciplinary projects that collaborate with local First Nations and can provide pathways for the protection of these sites.

Diversity has always been a feature of cultural landscapes meaning that clear boundaries between site and off-site cannot always be drawn. This challenges researchers to modify their approach to fit the landscape. Landscapes are used at multiple scales that form a gradient from highly detectable village centres outwards towards areas that appear to have little macroscopic remains but are still part of the cultural landscape. Integrating community knowledge of these areas with approaches such as soil chemistry can help researchers identify and move towards better understanding of these cultural landscapes.

One methodological approach to counteract the challenge of finding a control site is the use of soil micromorphology to analyze thin sections of soil under a petrographic microscope (Courty et al., 1989; Karkanas & Goldberg, 2007). Thin sections can be analyzed at several hundred times magnification to detect particles that are not visible by eye in the field (Goldberg & Berna, 2010, p. 58); this could be particularly helpful for determining the presence of micro-charcoal in lək̓ʷəŋən fields. Unlike loose samples collected for soil analysis, the micromorphology blocks remain intact so the context between soil constituents is preserved as it existed in the field. The primary purpose of using micromorphology is to disentangle cultural and natural inputs to the soil on the microscale and interpret their appearance (Courty et al., 1989). This was an approach initially considered for this project, but impacts of COVID-19 affected the timing, funding, and access to a micromorphology lab during the bulk of this research.

Studying human impacts to soil in root food meadows should be considered as part of a suite of methods that can be applied to identifying cultivation. For continuing work in cultivated meadows, it is important to incorporate local Indigenous knowledge and interests in all stages of the research process, especially the development of research questions. Integrating soil studies with programs of archaeological and ecological research will benefit each approach as it seeks to find physical signatures of stewardship that will accompany traditional knowledge. Research collaborations between First Nations and researchers are leading to a greater understanding in western science of the variety of Indigenous stewardship practices and how best to identify and protect these sites (Armstrong, 2017; Lyons et al., 2021). In many cases these are not just actions of the past but practices that continue to this day and in some situations are already being re-established.

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Appendix A: Results of soil physical and chemical data

Results of tests performed by the Analytical Chemistry Research Laboratory, Victoria, BC, summer 2021.

Analysis Report

BRITISH COLUMBIA

Ministry of Environment and Climate Change Strategy
Environmental Sustainability and Strategic Policy Division
Knowledge Management Branch - Analytical Chemistry Research Laboratory

Date In	28-Jun-21	**Final Report**
Date Out	10-Sep-21	**Data is reported on a 105°C dry weight basis unless otherwise indicated.**

Method	**Elemental Analysis via Combustion**			**Manual Meter**	**Muffle Furnace**	**Texture, Hydrometer**		
					LOI	**Sand**	**Silt**	**Clay**
	N	**C**	**S**	**I (1:2, soil:$CaCl_2$)**				
Units	**%**	**%**	**%**	**pH Units**	**%**	**%**	**%**	**%**
Estimated DL	**0.01**	**0.01**	**0.01**		**0.1**	**2**	**2**	**2**
Sample Identity								
tlc21p1	1.4	18	0.15	6.0	32	63	26	11
tlc21p2	0.54	7.4	0.067	5.2	16	73	18	9
tlc21p3	0.68	9.3	0.076	4.9	17	70	21	9
tlc21p4	0.76	10	0.08	4.2	21	68	26	6.4
tlc21p5	0.62	8	0.061	4.8	15	67	27	6.4
tlc21p6	0.74	9.7	0.073	5.0	18	56	35	9.1
tlc21p7	0.57	7.6	0.063	4.8	15	69	23	7.7
tlc21p8	1.1	14	0.11	4.5	26	62	30	7.8
tlc21p9	0.73	8.2	0.08	4.5	16	68	26	6.4
tlc21p10	0.8	9	0.086	4.5	17	67	26	7.7
tlc21p11	0.72	8.7	0.072	4.8	18	68	25	7.8
tlc21p12	0.68	7.9	0.062	4.6	18	64	28	7.8
tlc21p13	0.7	9.1	0.068	4.9	17	65	27	7.7
tlc21p14	0.83	10	0.074	4.8	20	66	25	9.1
tlc21p15	0.66	8.3	0.062	4.6	15	72	22	6.4
tlc21p16	1.1	13	0.11	4.2	21	65	27	7.8
tlc21p17	1.4	17	0.08	6.5	32	59	28	13
tlc21p18	1.5	18	0.13	6.3	33	56	31	13
tlc21p19	1.2	14	0.12	6.4	25	62	28	11
tlc21p20	1.6	19	0.17	4.1	39	41	49	9.3
tlc21p21	1.3	18	0.15	4.7	31	55	35	9.2
tlc21p22	1.3	15	0.11	4.2	28	45	45	10
tlc21p23	0.93	12	0.075	4.5	21	61	30	9
tlc21p24	0.9	11	0.059	4.7	19	52	38	10
tlc21p25	0.66	9.8	0.056	4.4	19	68	26	6.4
tlc21p26	0.62	11	0.064	4.9	18	64	27	9.1
tlc21p27	0.7	9.8	0.058	4.8	18	64	27	9
tlc21p28	1.2	15	0.12	4.1	25	52	40	7.8
tlc21p29	0.5	6.4	0.036	4.7	14	69	20	10
tlc21p30	0.58	9.8	0.063	5.0	15	69	23	7.7

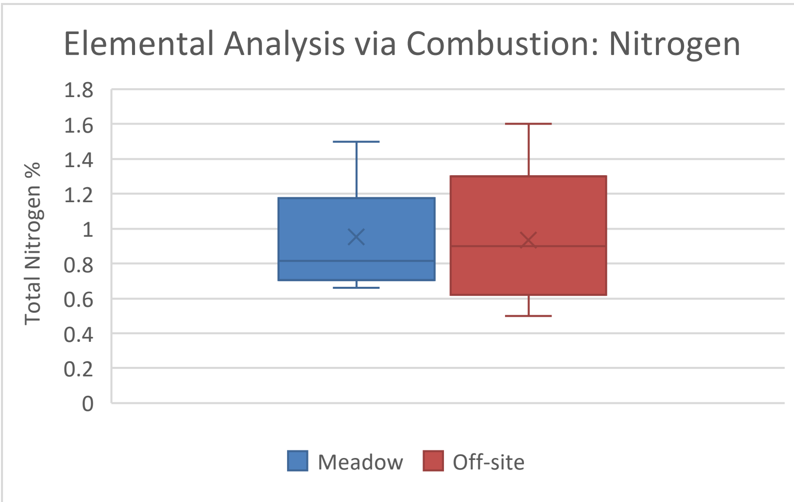
Analysis Report

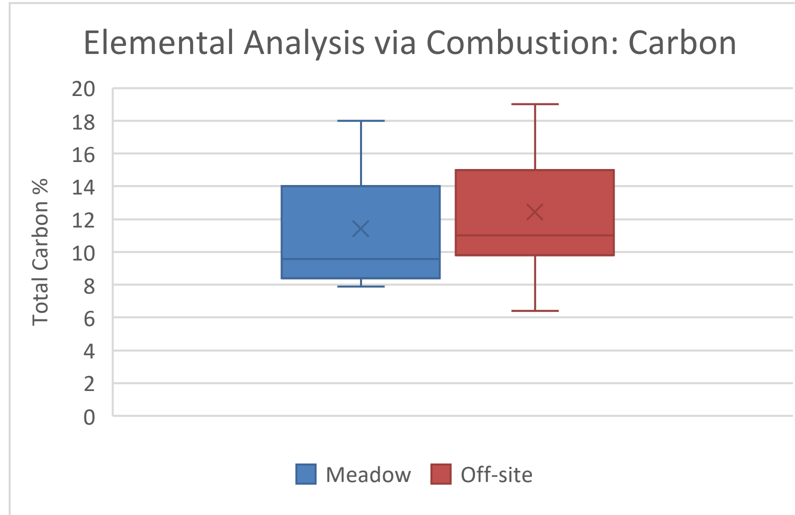
Ministry of Environment and Climate Change Strategy
Environmental Sustainability and Strategic Policy Division
Knowledge Management Branch - Analytical Chemistry Research Laboratory

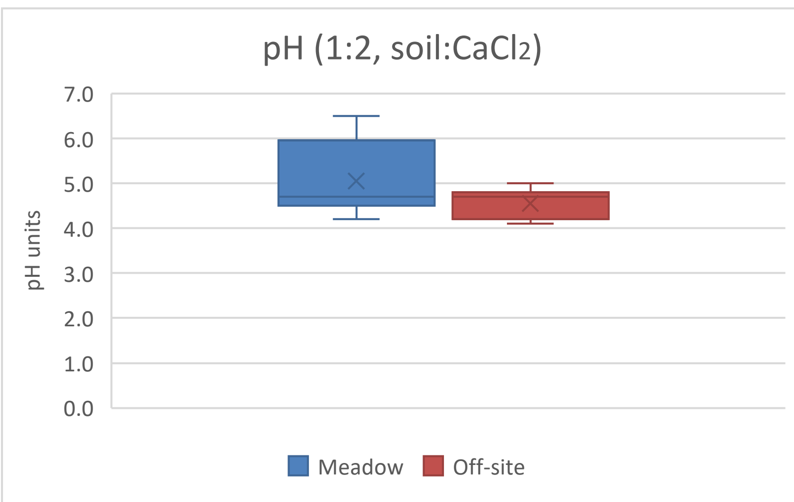
Date In	28-Jun-21	**Final Report**	
Date Out	10-Sep-21	**Data is reported on a 105°C dry weight basis unless otherwise indicated.**	

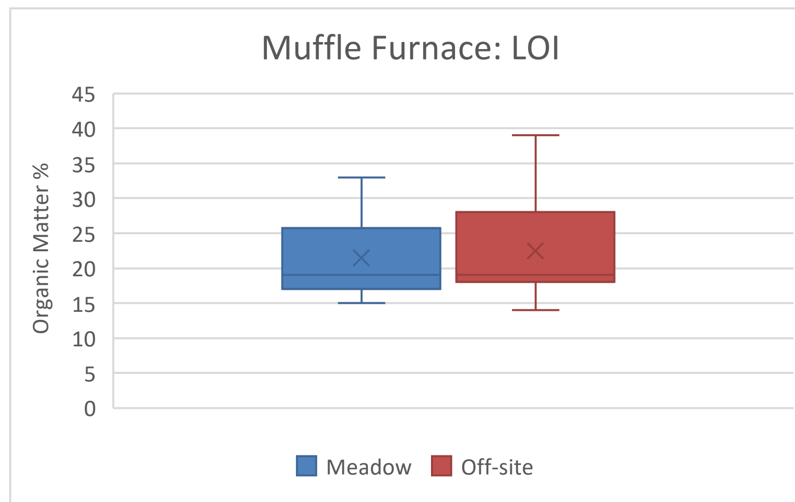
Method	**Metals via Acid (Microwave) Digestion - ICP-MS Analysis**												
	Al	**B**	**Ca**	**Cu**	**Fe**	**K**	**Mg**	**Mn**	**Mo**	**Na**	**P**	**S**	**Zn**
Units	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**
Estimated DL	**10**	**10**	**10**	**1**	**5**	**50**	**5**	**1**	**0.5**	**20**	**5**	**500**	**5**
Sample Identity													
tlc21p1	18,000	16	28,000	30	18,000	2,000	5,700	800	<DL	410	5,700	1,500	150
tlc21p2	23,000	<DL	14,000	21	26,000	1,800	7,000	930	<DL	330	2,300	550	80
tlc21p3	24,000	<DL	12,000	19	27,000	2,300	7,200	1,000	<DL	360	1,100	710	71
tlc21p4	28,000	<DL	8,300	18	26,000	2,200	6,600	730	<DL	560	1,400	730	66
tlc21p5	27,000	<DL	11,000	18	28,000	1,900	6,900	920	<DL	390	1,400	550	64
tlc21p6	27,000	<DL	9,700	22	28,000	2,300	7,000	1,100	<DL	430	1,300	640	64
tlc21p7	25,000	<DL	9,900	17	26,000	2,200	6,700	930	<DL	370	1,100	560	71
tlc21p8	23,000	<DL	8,300	21	24,000	1,900	6,000	880	<DL	440	1,700	990	63
tlc21p9	23,000	<DL	7,400	20	22,000	1,500	5,300	320	<DL	450	1,100	730	42
tlc21p10	23,000	<DL	8,600	21	23,000	1,200	5,200	340	<DL	370	1,200	830	45
tlc21p11	24,000	<DL	9,000	20	25,000	1,900	6,300	860	<DL	390	1,200	660	57
tlc21p12	24,000	<DL	8,600	20	26,000	1,800	5,400	700	<DL	340	1,500	590	56
tlc21p13	26,000	<DL	12,000	23	30,000	1,900	7,000	1,100	<DL	380	1,600	650	73
tlc21p14	24,000	<DL	9,800	24	25,000	1,900	6,100	830	<DL	330	2,500	740	88
tlc21p15	23,000	<DL	9,100	18	24,000	1,900	6,100	720	<DL	360	1,700	590	64
tlc21p16	24,000	<DL	7,600	23	24,000	1,800	5,000	470	<DL	500	2,900	1,100	67
tlc21p17	18,000	19	51,000	38	18,000	2,100	5,800	940	<DL	650	8,000	1,500	170
tlc21p18	19,000	14	38,000	37	18,000	2,200	5,700	930	<DL	620	10,000	1,500	170
tlc21p19	19,000	15	51,000	29	19,000	2,000	6,300	790	<DL	790	18,000	1,500	160
tlc21p20	20,000	<DL	7,900	26	18,000	1,100	2,500	720	<DL	920	3,600	1,200	89
tlc21p21	22,000	<DL	7,400	19	19,000	1,500	4,100	920	<DL	440	1,900	1,200	61
tlc21p22	26,000	<DL	7,500	24	20,000	1,000	2,600	530	<DL	1,000	3,800	960	65
tlc21p23	30,000	11	7,900	21	27,000	1,900	5,800	740	<DL	740	1,900	680	73
tlc21p24	32,000	<DL	9,400	36	26,000	1,500	4,300	1,400	<DL	1,100	4,500	590	110
tlc21p25	28,000	<DL	8,400	19	26,000	1,800	6,300	730	<DL	660	1,400	520	60
tlc21p26	28,000	<DL	8,100	19	25,000	2,000	6,800	880	<DL	640	1,700	580	72
tlc21p27	28,000	<DL	8,900	20	26,000	1,900	6,300	930	<DL	750	1,800	560	69
tlc21p28	29,000	<DL	6,800	21	24,000	1,700	4,000	740	<DL	990	4,200	1,100	73
tlc21p29	27,000	<DL	8,100	19	26,000	2,200	6,400	960	<DL	650	2,200	<DL	83
tlc21p30	25,000	<DL	8,600	20	24,000	2,200	6,700	1,500	<DL	730	1,700	530	81

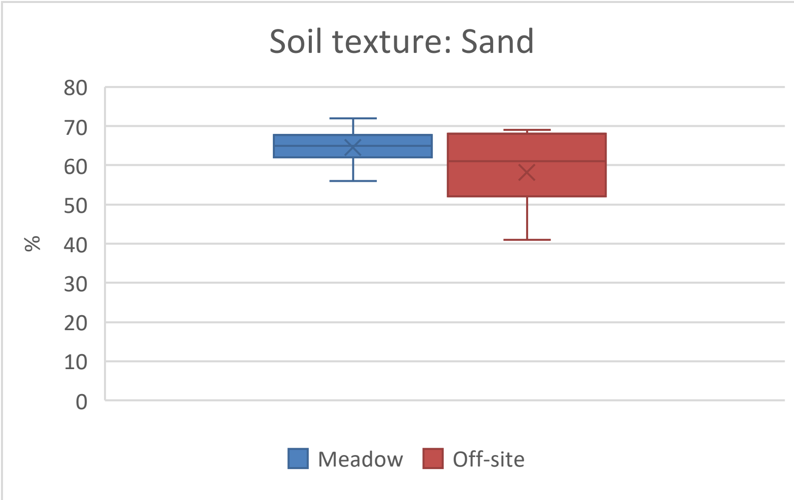
Appendix B: Box plots of non-significant soil sample results

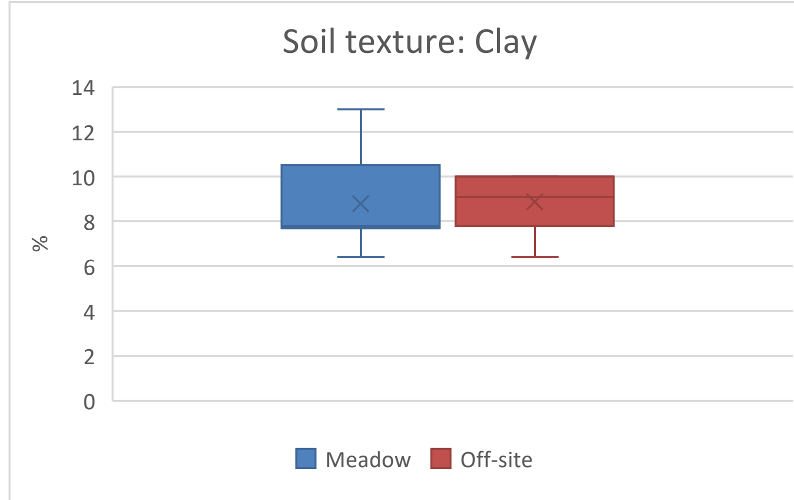


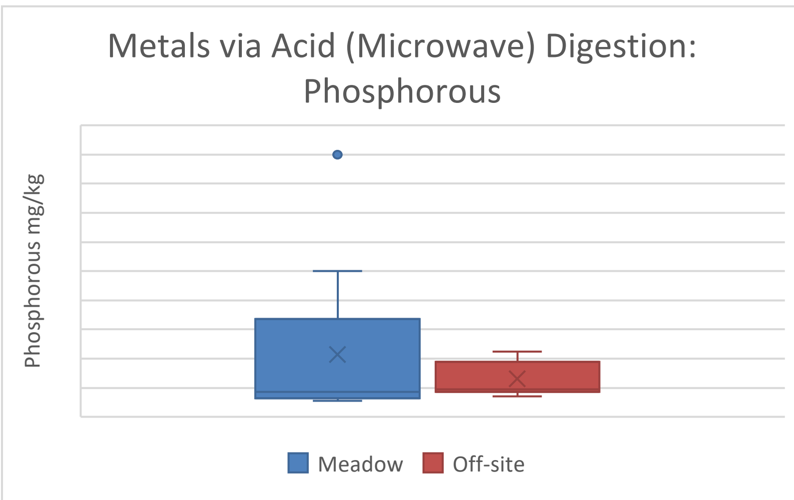







Soil texture: Sand
80
70
60
50
40
30
20
10
0
%
Meadow
Off-site


Soil texture: Clay
14
12
10
8
6
4
2
0
%
Meadow
Off-site


Metals via Acid (Microwave) Digestion: Phosphorous
Phosphorous mg/kg
Meadow
Off-site

Appendix C: Additional site photos of *Tl'chés*

Camas and chocolate lily bloom on Tl'chés. View SW towards Olympic Mountains.

Yarrow population near plank house village. Yellow lines show high points of house footprints. Archaeological equipment in centre is Evaluative Unit 1.

Screened soil from upper horizons of Evaluative Unit 1 showing charcoal and fire altered rocks.

Screened soil from Evaluative Unit 2 showing granular structure and onion bulbs.