Sense of Soil

An inquiry into agriculturally relevant perceptive categorization of soil in the Middle Bronze Age of West Frisia, Netherlands.

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June 6th, 2017
Final Version

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Chapter 1: Introduction

The closer soils are defined, it seems, the less likely we are to know them.
Bill Mollison 1988, 182

1.1: Research Problem

I will begin by positing that the following is an obstacle to archaeological research: potential nuances of small-scale farming in prehistory are likely lost to archaeologists who are personally inexperienced with subsistence living. Without a breadth of agricultural knowledge, it is challenging to understand the extensive possibilities for and reasons behind regional differentiation in food production, farmyard organization, animal husbandry, and local ecological constraints. When archaeologists work to understand prehistoric agriculture they often look to social evolution, population change, environmental and climate fluctuations, and technological advancement to understand *why* innovation and transformation occurred (Barker 1985, 257). When researchers try to explain *how* agricultural practices were applied, they must use historical sources and experimental work to explore phenomena such as crop yield, fertilization, land needed for foraging animals, or the ratio of crop and meat consumption to wild foraging (Fokkens 1998, Barker 1985, Pryor 1988). These features, and therefore how we define farming in the Bronze Age (BA), are essential when interpreting prehistoric culture and society as defined by the archaeological record.

Infrastructure development in the Netherlands since the Second World War has been constant; in the process, frequent Bronze Age excavations have been carried out, most which remain partially published and largely unstudied (Fokkens and Arnoldussen 2008). The subsequent needs for consistency in approach and more comprehensive methodologies have resulted in a concentrated effort in the past two decades to reconsider archaeologically-recovered data. A major focus of contemporary research is to approach new excavations from the perspective of landscape archaeology, so to incorporate all possible components of the prehistoric lifestyle. Through this framework, a “wandering farmstead” model has been presented (e.g. Fokkens and Arnoldussen 2008) for the Netherlands as a whole, which includes dynamic settlement and house locations that habitually moved short distances. However, excavations in West Frisia showed anomalous results, perhaps because of frequent geological fluctuations. This area shows unchanging settlement patterns that include ditches that demarcate houses and arable fields (Fokkens and Arnoldussen 2008, 10). These inconsistencies are evidence of differing settlement systems and agricultural practice within small geographic areas, and therefore present a need for a detailed understanding of how landscapes were conceptualized and decisions were made regarding land use.

Agricultural land use models that describe Bronze Age West Frisian farming face considerable challenges in their attempts to estimate yield and use levels for all farming related activities. Research questions often focus on land capacity and available flora for grazing, such as pasture, forest undergrowth, grassland, etc. (Fokkens 1998, 143). Conclusions are drawn from historical or experimental methods and they are surprisingly inconsistent. As an example, estimations of crop yield in West Frisia vary from 1:3 to 1:59 depending on the use of experimental methods or historical sources from the Middle Ages (Fokkens 1998, 141). These inconsistencies permeate the archaeological record of agriculture and obfuscate small-scale differences in farming and farm-related settlement structure. Van Amerongen (2016), Van Zijverden (2017), and others through the *Farmers of the Coast* project have recently undertaken a thorough reconstruction of the West Frisian BA landscape, using extensive floral and faunal remains from the plethora of available sites. Combined with detailed estimations using subsistence farming strategies, this work attempts to recreate the farm-centric lifestyle and organization of the area and reconsider relationships between settlement and natural landscape. Within these reconstructions there lies an attempt to address a conundrum; in order to understand BA farming we must incorporate our knowledge of a farmer’s decision making and land use, and therefore our interpretations of early agricultural practice are formulated through a convoluted synthesis of contemporary agricultural practice and archaeological evidence. More explicitly, our knowledge of how farmers choose and work with their land is a combination of ‘scientific’ agricultural data and ethnographic interpretations of subsistence communities, and there is, at best, a muddled understanding of how research can translate between and incorporate these two methodological approaches.

Additionally, the terminology of “farm” and “farmstead” potentially limits research by confining potential land use areas within projected boundaries. This problem has been dealt with to some degree by answering questions like: ‘Is there a template for a Bronze Age Farmstead?’, ‘Is the structure of the Bronze Age farmstead tied to agricultural processes?’, Or ‘Why did Bronze Age farmers choose one place over another?’ (Arnoldussen 2008, 14). Unfortunately, these questions are answered with a continuation of the modern notions of a farmstead, farmyard, and farm. As summarized in the conclusion of his PhD dissertation, after an extensive effort to answer assorted farmyard related queries, Stijn Arnoldussen states:

> Archaeology has taken a concept that not only derived from a domain of knowledge which is based on observative and historic research, but moreover a concept that within that domain is concerned with relations between architecture and the spatial distribution of human behavior, both of which are topics rather than data sets in archaeological research. Arnoldussen 2008, 429

Therefore we must ask, how does one interpret agricultural practice without using preconceived spatial definitions of a farm? Arnoldussen provides two helpful constraints in regard to this task. First, we must allow BA house sites to speak for themselves rather than using contemporary farm organization as structurally predictive models. Second, research should incorporate the concept that Bronze Age farmers were “knowledgeable landscape readers that incorporated or sometimes copied landscape traits” (Arnouldssen 2008, 429, 421). In what follows, I will venture to understand possible perspectives of farmers within the constraints of sense-based knowledge. As shown by Arnoldussen, reconstructions of the past have trouble explaining small variations between sites when interpreting these variations through a modern notion of farming. To confront this problem, I will propose an understanding of the land based on perceptibility, and, to exemplify this, provide an alternative method for defining soil type and composition as it is relevant to agriculture. My aim is to propose a methodology that can attempt to answer *how* farmers dealt with the necessity of small-scale adaptation to their immediate environment. This methodology could then be applied to understand *why* regional differentiation occurred between agricultural land use decisions.

Research in regard to agricultural choices, especially crop choices, focuses on four main components. (1) the overall availability of plants, (2) the environment, (3) social-economic factors, and (4) cultural influences (e.g. Chevalier *et al.* 2014). Together these emphasize technical, efficiency based, and economic methodologies. The most obvious and easily measurable of these factors is climatic, and, more specifically, numerous sites in Western Europe show obvious crop choices based upon soil type, such as sandy areas exhibiting a lower diversity of crops than loess areas (Bakels 2014, 103). In general, there is an established link between how past people perceived their environment and how they chose to use the land around them (Chevlaier *et al.* 2014, 6), but it is based on a technical analysis of material characteristics within the constraints of archaeology's reconstruction of the Bronze Age economy. Van Zijverden (2017) describes this problem with the example of data driven predictive modeling, which acknowledges a relationship between human activity and landscape characteristics. In the Netherlands, predictive modeling generally illustrates this relationship by describing correlations between soil composition and known archaeological sites (Van Zijverden 2017, 122). These models, however, are hugely affected by regional relevance, post excavation methodologies, and the personal research goals of supervising archaeologists. Just by looking at the questions asked when trying to determine plant and land choices shows a plethora of methodologies each attempting to answer a different question. These questions include inquiries about cultural materialism, human biological determinism, social categorization, environmental constraints, material availability, or localized cognition of the environment (Chevalier *et al.* 2014, 4). The resulting attempts to pick and choose the most relevant question divides agricultural data into minutely technical, specialized, and incompatible methodologies such as, archaeobotany, ethnography, experimental archaeology, historical study, pollen analysis (Chevalier *et al.* 2014). The Netherlands are an exemplary case study of how these methodologies are applied in landscape archaeology in an attempt to describe agricultural practice and land use decisions in the past.

Existing research in the Netherlands shows a consistent emphasis on large scale landscape research that allows for a uniquely detailed analysis of settlement patterns and land use through quantifiable ecological measurements and historical and experimental sources. The quantity of ecological data available, combined with a diverse natural environment over a relatively small area, allows for comparative evidence for various settlement and cultural patterns (Kooijmans et al. 2005, Fokkens and Harding 2013, 550).

It is important to mention that landscape-centric methodologies include barrow locations as well as agricultural and homestead organization. A specific example can be found in the Oer-ij estuarine region. Therkorn (2008), in a discussion of potential traditions in the area, outlines a likely multi-use approach to the land. Because of the lack of distinguishing geographic features in the landscape of the low countries, there is a history of land manipulation for the purpose of barrows. These areas, however, are not set apart or spatially distinguished from places of day to day activities, such as agriculture, grazing, or livestock pens. Instead, mounds are potentially seen as an area that is not affected by seasonal change, unlike every other aspect of life (Therkorn 2008, 163). While this thesis does not focus on burial practices, this pattern is an interesting introduction to the relationship between soil, geography and land use. Without geological formations, land differentiation seems to have been understood through other criteria as well as artificially manipulated and then reinforced.

1.2: Research Aims

The aim of this thesis will therefore present the possibility of reconsidering soil composition data, as it is relevant to agriculture, under categorizations that will be formulated with human based perception. To exemplify an application of this methodology, I will apply it to the archaeological record of agricultural land soil composition in the MBA of West Frisia. To describe the outlined problem in more detail, I will focus on one issue: how to identify what perceptive knowledge farmers is relevant to land and soil use, and how is this compatible with Western science? Humans consistently categorize their environment, and the answer to this question will present an alternative method to identify the agricultural relevance of soil composition data.

To begin to answer this question, I will make a basic assumption that Bronze Age farming is a craft and can therefore be understood and explained within the parameters of craft theory. Farming is a skilled understanding of a raw material and the actions undertaken to manipulate that material, in this case soil, and craft theory functions under the assumption that the ‘hard’ scientific measurable quantities as known by an archaeologist can be reconsidered with the use of perception and sense based categorization. Perceptive categorization in turn represents the perspective of a craftsperson (Kuijpers 2014, xiii). Kuijpers labels these “perceptive categories”, and this thesis will work to develop perceptive categories within soil identification. Kuijpers (2014) defines perceptive categories as characteristic of data that are measurable with the senses and are *relevant* to a craftsperson (Kuijpers 2014, xiv). Kuijpers’ application of these perceptive categories is focused on metalworking, and I will use this general concept to reorganize soil land composition values. I will identify these perceptive categories through ethnographic sources and an analysis of modern craft farming, just as Kuijpers (2014) is able to define the perceptive categories of metalworking through an in-depth analysis of modern craftspeople’s relationship with their material.

Farming as a whole is an complex series of mental and physical action. Therefore, dividing farming into step by step technical action and parsing out each process within those divisions, and then going through the process of relating perception to agricultural practice is immensely complicated. To manage this task, I will turn to the simplest form of technical analysis; the *chaîne opératoire*. Ingold (2003) defines craft as an activity that occurs through an engagement with a material; a combination of mechanical operation and care, judgement, and dexterity; and the creation of a narrative quality regarding the craft. While Ingold does not personally espouse the use of the *chaîne opératoire* because of its restrictive nature, if I define soil as the material in Ingold’s description, I can then apply the framework of a *chaîne opératoire* to farming land use processes. This structure uses soil as the raw material and land use as the finished product. I acknowledge the simplicity of the *chaîne opératoire*, but believe its linear ability to describe technical processes and choices is the most manageable tool in the initial analysis of a craft. In an effort to incorporate both contemporary soil science and perceptive categories into the *chaîne*, its construction will draw from known subsistence strategies, such as permaculture, and ethnographic sources concerned with ethnopedology. Permaculture and ethnopedology both describe a farmer's relationship with soil as congruous with a craftsperson's relationship with his material. A summary of the definition and relevance of ethnopedology and permaculture will be expanded upon in Chapter 3.

1.3: Research Questions

In an effort to approach the data in a manageable way, the following thesis will be a theoretical presentation of a methodology and will then give a possible application of this methodology and but will provide an example of how it might be applied in further research. I will use West Frisia as a case study for this application because the region has been consistently excavated for the entirety of the Twentieth Century, albeit with varying quality (Fokkens 1998, 13). Recently, a concentrated effort has been made to organize and understand the mass of data available from West Frisia, with a focus on population distribution, settlement typology, and landscape organization (e.g. Lohof and Roessingh 2014). Additionally, the Netherlands has both clayey and sandy soil that leads to a diversity of farming techniques over a relatively small geographic area, which provides an ideal case study to compare how soil differences might affect the *how* of land identification within a farming *chaîne opératoire* in the future.

West Frisia is an ideal area of study for the methodology proposed in this work. Existing literature points to soils and environmental conditions as an integral component in settlement structure, land use, and even cultural differences. Favorable preservation and extensive data sets make West Frisia unique in its possibility for an in depth analysis of specific environmental conditions and their relation to land use and manipulation. Previous research has organized and defined specific characteristics of agricultural strategies, and has placed the region within greater trends in Bronze Age farming. West Frisia is therefore a exemplary case study to represent how agricultural models, through their technicality and efficiency based questioning, lack space to consider prehistoric farmers' meaningful relationship with the land within the context of agricultural practice. Specifically, van Amerongen's (2016) landscape reconstruction will be invaluable to my study, and her work will provide the pH values of arable land used throughout my methodology. According to her comprehensive description of arable field composition, we can see that arable fields were of “excellent quality… [with] exactly enough moisture, a pH of around 7, and a moderate to high nitrogen content.” (van Amerongen 2016, 330). In contrast to arable field quality, macrobotannical and fish remains from excavated sites in West Frisia indicate the possibility of varying ecological composition, such as adjacent brackish environments, around arable fields and within the environs of habitation areas (van Zijverden 2013, 167). These compositional characteristics are notably distinct within the ecological spectrum of West Frisia and the northern Netherlands as a whole, and therefore raise questions about the farmers’ ability to discern subtle differences in the soil that led to such ‘excellent’ fields.

Thus, my **research question** is: Why is perception, defined as any sensory input, relevant to agricultural soil identification as used in archaeology, and can perception be incorporated into soil typologies within the context of the ecological and archaeological record of the Middle Bronze Age of West Frisia, Netherlands?

1.4: Research Approach

The following chapters will work to answer the research question through a methodical approach to describing and then understanding farming as a craft, using MBA West Frisia as a case study for perceptively based methodological application. Overall, this thesis will propose a methodology and then will give an example test of the viability of perceptive categories as they might inform a archaeological study of prehistoric farming. This follows a approach that moves away from utilitarian data and relies on the discussion and organization of folk categories as cognized by the categorizers (Fowler 1977). I will consider perceptive categorization in the following steps, with a more detailed outline of the chapters presented below:

First: Soil typology and its problems are outlined as it is currently used in archaeology and the problems faced with formalizing sense based knowledge within the context of crafting are discussed.

Second: Relevant practices of tasting the soil from modern craft farming and ethnopedology are presented. This presentation includes evidence from modern craft farming and historical ethnographic sources to construct a *chaîne opératoire* that organizes the technical process associated with the identification, manipulation, and use of a soil in regard to agricultural practices.

Third: The viability of incorporating perception into pH based soil categorization as relevant to farming is discussed. Overall perceptively based categorization of soil pH is shown as a more meaningful, relevant relationship between farmers and their farmscape [a term that will be introduced in Chapter 3] than the technicality of currently used soil classification in soil science and archaeology.

These aims will be achieved through 6 Chapters. Through describing how land use is studied in archaeology, the first chapter shows gaps in research when it comes to farmers' perception of their craft, and presents farming as a craft that can be studied as such. It then summarizes one way of incorporating farmers perception through using perceptive categories to describe land composition as it is relevant to agricultural craft.

Chapter 2 gives a background on archaeology in West Frisia, and a description of current soil typology and its applications and uses in archaeology when studying agriculture. It then presents problems with this structure and introduces the purpose behind the alternative disciplines described in Chapter 3

Chapter 3 gives a background on craft theory and use of perception. It then discusses ethnographic examples of agricultural craft that incorporate perception.

Chapter 4 creates a farming *chaine opératoire* so that farming can be structured with craft theory. It then discusses the ecology of West Frisia and why pH is an exemplary soil composition characteristic to show the relevance of perception in West Frisia and in agriculture.

Chapter 5 presents empirical study of perception and sense categorization and outlines definitions of pH taste from food science. It then contextualizes these thresholds within the ethnographic evidence given in pervious chapters and hypothesizes perceptive categories of soil pH as relevant to agriculture.

Chapter 6 concludes this thesis by recapitulating the overall argument and evaluating my approach and discusses the need for further empirical research to determine taste-based perceptive categories. Overall, this chapter summarizes my research in a way that discusses its applicability for further study as potentially comparable across additional environmental variables, greater time-periods, and geographic areas.

Chapter 2: Archaeology, Soil, and Agriculture

Current trends in the Netherlands

Introduction

This chapter will be divided into two sections: First, I will give a detailed explanation of farming practices in The Middle Bronze Age of West Frisia to introduce archaeological research as it interprets agricultural land use within specific ecologies. Then, I will summarize the background of soil typology as it currently related to agriculture, specifically how soils are categorized in the Netherlands, and how that categorization came about. Overall, this chapter will outline the gaps in current methodologies that fail to represent a farmer's meaningful relationship with the land, and will discuss problems with the current top-down approach to soil science and its applications in archaeology.

2.1: Agriculture in Middle Bronze Age West Frisia

The Bronze Age in the Netherlands is defined at its advent with the first importation of Bronze, and following periods are generally differentiated with pottery and mortuary patterns (Arnoldussen and Fokkens 2008). This thesis will focus on the Middle Bronze Age, which falls within the boundaries of 1800 to 1100 BC. This period (officially divided into MBA 'A' and MBA 'B') is characterized by burial mounds with circular ditches, transitioning to post circles as well as settlements that include houses with three isles and "Kummerkeramik" pottery (Arnoldussen and Fokkens 2008, 19).

As a result of recent work by Roessingh (in print), Van Zijverden (2017), and van Amerongen (2016), there has been a comprehensive reconstruction of the West Frisian Bronze Age settlement and subsistence farming structure and environmental conditions. Van Amerongen's (2016) summarizing reconstruction of the landscape and subsequent model for agricultural organization and hypothesized use incorporated all available archaeological data from past excavations, as well as additional data from contemporary excavations. This research relies on a thorough reconstruction of the landscape through crop weed data to illustrate environmental characteristics. The following section will outline general conclusions drawn from pervious research into West Frisian farming strategies in the Middle Bronze Age.

In regard to crop husbandry, van Amerongen (2016) concluded that BA farmers in West Frisia made obvious selections about what types of crops to plant and what land was viable for agriculture. In general, farmers chose specific crops (mainly emmer wheat and hulled barley), which shows that an active decision was made about what plants to use, as other crops were contemporarily available in adjacent locals. Additionally, arable land was supplemented with fertilizer, which likely included waste from both houses and animal excrement (van Amerongen 2016, 3:67). Animal husbandry supplemented crop husbandry for food procurement, and animals were also used for work, transport, and for additional material resources (van Amerongen 2016, 5:71). These diverse subsistence strategies, in combination with wild plant gathering and hunting, resulted in mixed subsistence farming that relied on intelligent use of the environment. Further comparisons made by van Amerongen (2016) to other sites in the Netherlands, as well as sites in Denmark and Sweden, show that there were obvious variations in agricultural strategies between these geographically similar locations, that are defined by elevation, various levels of salinity, and proximity to coastline (van Amerongen 2016, 9:1).

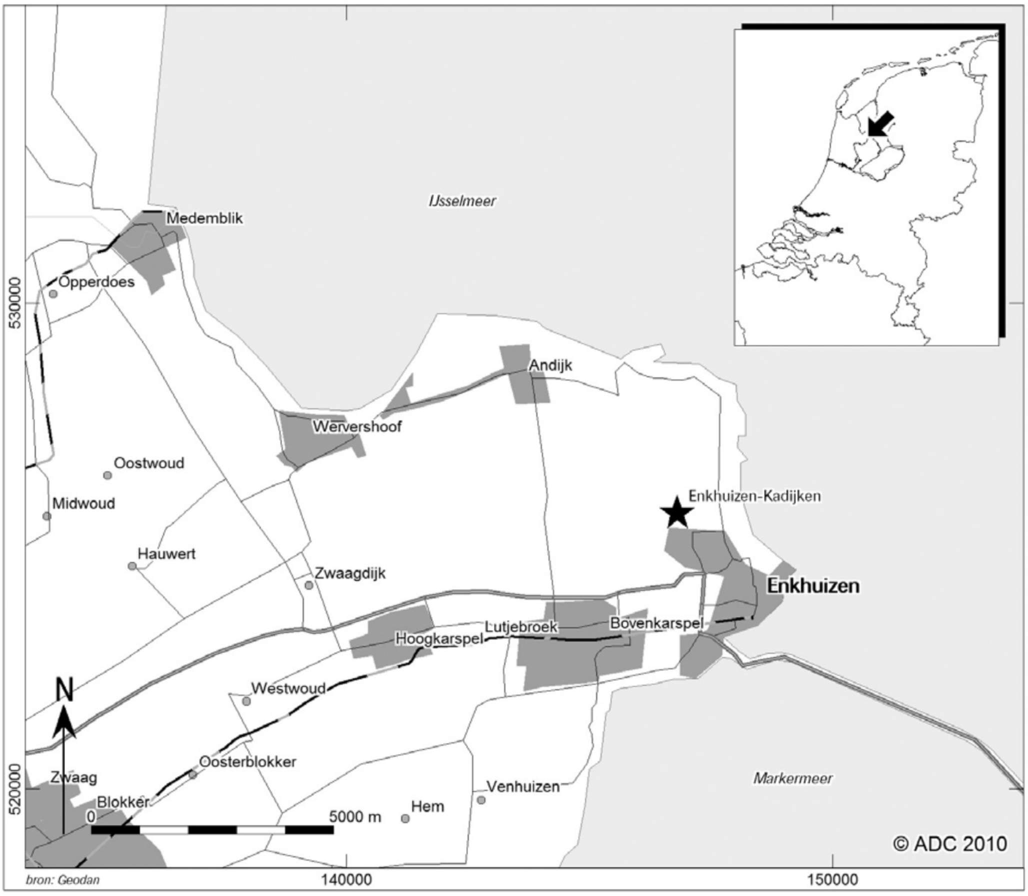

Figure 1: Archaeological sites in West Frisia. (Lohof and Roessingh 2012)

To exemplify the methodologies applied in West Frisia, I will provide an example of two sites discussed by van Amerongen: Bovenkarspel-Het Valkje and Enkhuizen Kadijken (Figure 1). These two sites are notable for having the highest diversity of data available among other excavations in West Frisia and are best suited to a comprehensive study of farming related activities and decision-making. Together they are representative of how comprehensive landscape reconstruction occurs in MBA archaeological research, and how landscape reconstruction and analysis relies on western soil typologies that differentiate minute, technically determined compositional values. The following paragraphs will give a very brief summary of literature regarding these sites, with a focus on data that relates to farming activity.

Middle Bronze Age occupancy began at both Bovenkarspel and Enkhuizen between 1600 and 1500 BC. Habitation occurred both on lower clayish areas and higher sandy ridges and it is possible that, because of their proximity, these settlements were linked. Houses were often rebuilt on the same spot, and although the exact life span of these houses is unknown, we can assume that houses were in the same place for around 150 years (Lohof and Roessingh 2012, 66). The houses throughout West Frisia show a consistent style and therefore fit under a proposed typology for the region (Arnoldussen 2008, 195). Both sites show evidence of cattle stalling and dairy production, although the two sites have different estimates for percentage of dairy consumption as part of the overall diet, which illustrates the possibility that, despite their proximity to each other, these sites might have had different subsistence strategies (Lohof and Roessingh 2012, 69).

Through assorted comprehensive and multi-disciplinary approaches to landscape and subsistence reconstruction, we are able to reconsider the overall subsistence lifestyle of these communities and the environment in which they were situated. Overall, the landscape was a “patchwork of lakes, marshy grasslands, dry arable fields alternating with patched of woodland and shrubs” (van Zijverden 2013, 167). Bovenkarspel and Enkhuizen fit within this model and are part of an area that was densely populated and had a profound impact on its environment. The diversity of subsistence strategies matched the diversity of the surrounding habitat, and people lived relative healthy lives through successful exploitation and interaction with the surrounding flora and fauna. Resource use and management was organized cyclically, with subsistence tasks differentiated into annual repetition of actions that were appropriate within the constraints of seasonal climatic fluctuations (van Amerongen 2016, 10:2).

Therefore, farming practices in MBA West Frisia can be likened to contemporary definitions of mixed-subsistence farming (van Amerongen 2016, 56). As an agricultural system, mixed-subsistence, especially in a volatile ecological zone such as West Frisia, possibly requires the greatest amount of perceptive land knowledge; with a diversity of farming options available and a fluctuating climate, farmers are forced to continuously adapt to their environment and to understand minute ecological changes that might effect their craft (Mollison 1988). And yet, rather than addressing farmers’ perceptive and holistic relationship with the land, archaeological research uses soil typologies and ecological proxies that are formulated with technical, scientific definitions of landscape and land categorization. This is understandable, as the disciplines of western agricultural science and pedology are detailed, universal, and scientifically proven, but can these categorizations accurately reflect perceptively-guided choices made by farmers within a specific ecological zone? As outlined in my introduction, I will work to answer this question through one component of farming craft: land identification. Even more specifically, I will focus on soil identification as an illustration of how perception can be incorporated into our understanding of farmers' soil knowledge as relevant to agriculture. Thus, now that agriculture in the MBA of West Frisia has been introduced, I will focus on how the soil typologies used by archaeologists were created and how they relate to agriculture.

2.2: Soil Typology and Agriculture

This section will give a short introduction to soil research in the Netherlands and outline the existing relationship between agriculture and soil typology. Therefore, it is necessary to provide a background on soil science in the Netherlands and its relationship with agriculture. The following section will give an overview of both general classification systems and classifications used in the Netherlands, with a focus on how these classifications relate to agricultural land use.

In recent years there had been a concentrated effort to normalize soil classification systems to create world-applicable soil maps, especially in the context of agricultural viability and sustainable land development and use (FAO.org). The Food and Agricultural Organization (FAO) of the United Nations is the most comprehensive of these projects, and I will use the soil proprieties described in their overview of world soil classification as representative of a standardized relationship between agriculture and soil classification.

The FAO was founded in 1945 by the United Nations as a systematic response to epidemics of hunger, malnutrition, and food insecurity (FAO.org). Within this mission is an effort to globalize land use knowledge and create universally accessible information of soil properties as they relate to food production. There are numerous applications of this project, including simulating programs that predict crop growth and viability based upon soil composition values that can be entered into a program. For example, the FAO provides 'Ecocrop', in which you can "[e]nter information about your local climate and soil conditions, such as temperature, rainfall, light, soil texture, depth, pH, salinity and fertility. Ecocrop then identifies plant species with key climate and soil requirements that match the data you have entered” (http://ecocrop.fao.org). Another example is ORYZA, an “ecophysical model which simulates growth and development of rice including water, C, and N balance” (https://sites.google.com/a/irri.org/oryza2000/home). With these programs, farmers and researchers can determine soil properties and climatic factors and then obtain a prediction of how plants will grow or what ecological changes are necessary to grow their desired crops.

These models, and the FAO soil classification system, include pH as a relevant chemical property in soil taxonomy. Soil pH, a measurement of hydrogen ion concentration, has a direct relationship with land fertility, and can be a deciding factor in plant growth and agricultural viability (FAO.org). As described in the *Field Book for Describing and Sampling Soils,* the FAO suggested publication field guide, pH is identified in soils using a pH meter with 1:1 water:soil or 1:1 soil:$CaCl_2$ (Schoeneberger *et al.* 2012). The suggested testing system is shown to be accurate to a tenth of a percent of pH value, but the field guide warns that values may very depending on time of year, recent rainfall, or other climatic conditions and suggests retesting throughout the year to realistically identify soil pH. By all authorities, pH is seen as an integral component of the relationship between soil classification and fertility. The methods for identifying pH, however, use chemically based tests that are scientifically accurate but are only useful within the parameters of the tests available to farmers. Without a pH meter or knowledge of chemical reactions, farmers would be unable to determine soil pH within the FAO system.

The FAO system is fairly recent, and the Netherlands, the geographic area used as a case study for my methodology, has its own soil classification system that was used pre-FAO and is still used today. The Dutch Soil Classification System was formalized in the 1960’s after yeas of inconsistent and mostly physiographic soil mapping. The classification system was developed using “inherent soil properties” (Hartemink and Bakker 2006, 2) and move away from a geologically based taxonomic system. With this transition, agricultural viability became a component of category differentiation through the naming of groups and subgroups. Soil appellations were comprised of geographic location, historical reclamation uses, relationship to bodies of water, or the primary use of the land, such as ‘weide’ for pasture or ‘akker’ for arable land (Hartemink and Bakker 2006, 3). Thus, current soil types and soil maps as used in archaeology are formulated with some recognition of land use as a deciding factor in classification. However, as names for soil types were given post-classification, agricultural association arose when soil typologies were standardized and needed universally applicable terminology associated with each geographically and compositionally unique soil type.

Therefore, there exists a scientific taxonomy of soil composition that relates to agricultural land use. Universal soil classification systems, such as those created by the FAO, and soil classification guides, such as the USDA field guide, provide a structure for farmers to 'scientifically' analyze their soil and contextualize it within research that pertains to agricultural science and land fertility. These structures are based on an ability to scientifically measure compositional values, and because they are methodologically consistent in their application and incorporate agricultural land fertility, they can act as a "conceptual grid for cross-cultural comparisons [in reference to all examples of scientific biological categorization]" (Medin and Atran 1999, 4). Both the FAO universal system and the Dutch classification acknowledge a deep connection with agriculture. This connection, though, is constructed through modern knowledge of soil composition and fertility as it is understood through empirical research. Thus, the simplicity of perception is overruled by the complexity of our scientific knowledge of soil composition. An example of this can be seen in the most basic of pedological identification structures: soil versus sediment. In non Western-scientific contexts, there is no concept of a soil horizon, and the process of creating a soil profile is non existent; sub-surface sediments are irrelevant. each exposure of soil is qualified uniquely, resulting in a consistent "disinterest in soil genesis" (Sillitoe 1998, 191). Put generally, "technical classification [such as the FAO] rests upon the character of a three- rather than two-dimensional taxonomic entity" (Williams and Ortiz-Solorio 1981, 358). Ethnopedological taxonomies do not differentiate between soil and sediment, and instead are perceptively based descriptions of exposed soil, and, as such, are 'two-dimensional'. While they ignore sub-surface sediments, farmers might have additional categorizations of soils with characteristics ignored by pedologists, such as the ownership of the land or its use (Talawar and Rhodes 1998, 11). To pedologists, these cultural criteria may appear irrelevant to the chemical properties of the soil, while to farmers, who have no knowledge (or interest) in sub-surface sediments, differentiating soils from sediment becomes superfluous.

Another example of the dichotomy between pedology and agriculturally relevant perception based classification can be seen through efforts to define boundaries in soil type. Pedologists are forced, through the necessity of exact classification, to delineate exact boundaries where they do not exist. A farmers' perceptive categorization can define a soil by, "modifying… descriptor terms, so the soil here may be 'some of this and a little of that' where as the one over there is 'less of this and more of that' and so on" (Sillitoe 1998, 191). These soils are thus defined uniquely as they are directly *relevant* to the definer. This contrasts the appellations given by systems like the FAO, which, while having some basis in perceptive reading, are defined explicitly. An example taken from van Zijverden (2017) shows the soil map of Ente (1963) with an overlay of Bovenkarspel site features, and in its description includes a depth differentiation in sediment and soil type such as, "thick (25-60 cm) (silty) clay loam soils overlying (20-30 cm) sandy loam to loam, sometimes underlain by (silty) clay loam" (van Zijverden 2017, 94). Therefore, contemporary classification is overly specific and problematic when describing soils identified only with perception and within the context of agriculture. This thesis will use pH as an example of these dichotomies.

The issues of a sliding scale in landscape differentiation has already been posed in terms of the perceptive-science relationship as applied to the environment. Popa and Knitter's (2016) paper in particular attempts to integrate what is perceivable with the senses and precise measurable data on geomorphology to reconstruct the 'perceived landscape'. My methodology is significantly less complex than this, as the main purpose of Popa and Knitter's work is to incorporate fuzzy logic into landscape categorization. Understanding that the definite lines as seen in precise measurements are not discernible by human senses, they attempt to translate between the environment (exact geomorphic measurements) and the landscape (the environment as perceived by humans). While applied to slope angle rather than soil composition, Popa and Knitter's work argues that 'hard' boundaries in landscape categorization ignore the main component of what differentiates landscape from environment: human perception (Popa and Knitter 2016). This acknowledges the essential incorporation of perceptive categorization in landscape reconstruction, which I argue is missing from soil categorization.

With the initial assumption that farmer's interact with the land in much the same way that a craftsperson interacts with their material, this brings my research question to the forefront; How can farmer's perception be incorporated into sufficiently established soil classifications that are ubiquitous across research disciplines? The answer to this question lies in ethnographic examples of craft farming, both contemporary and historical, where farmers rely on their perception of the farmscape. Overall, this methodological thesis will seek to establish that perceptual data, such as taste, will always be necessary and relevant to archaeological discussion of soil science in the context of agriculture.

Conclusion

As shown by the gaps in the FAO system, and exemplified by the possibilities in Popa and Knitter's work, methodologies that acknowledge the importance of perception can give archaeology new insight into spatial organization in the past. This process will incorporate numerous disciplines in attempt to match the formidable 'scientific' backing of existing soil classification. While formalizing systems of biological cognition is daunting, Medin and Scott concisely summarize that, "a cognitive science of folk biology that combines and integrate the strengths of its constituent subfields holds great promise for understanding how people cognize the natural world" (Medin and Atran 1999, 7). With this in mind, the following chapter will discuss methodologies in archaeological research that incorporate perception, and then introduce the other disciplines that I will use to consider how humans senses can be incorporated to soil classification within the context of farming.

Chapter 3: Perception and Archaeology

A presentation of methodologies for reconsidering material categorization, and a discussion of farming as craft

Introduction

A perceptive categorization of soil relevant to the archaeology of agriculture could be achieved by conceptualizing farming as a craft and by defining soil typologies in perceptible terms. This chapter provides potential avenues towards these categories. It is broken into two sections: its first part surveys existing applications of perception and sense in archaeology and craft theory (esp. per Kuijpers 2014), outlines the methodological framework previously used to formulate perceptive categories, and discusses its limitations. This survey forms the scaffold of my methodology, elaborated in chapter 4.

As craft theory relies on contemporary understanding of the skills of a craft, this chapter's second section will discuss disciplines that value the perception of the craftspeople. In the context of agriculture, these are ethnopedology, a cross-disciplinary research that studies 'indigenous' agriculturalists' knowledge and use of soils (Wilshusen and Stone 1990, 104), and permaculture, a comprehensive 'craft farming' framework used worldwide that builds agricultural practice in connection with regionally specific natural systems.

3.1: Perception Based Methodologies: Craft Theory in Archaeology

3.1.1: Craft Theory

Describing skill and craft in prehistory is a complicated and problematic challenge for a discipline that is divided between epistemologies that focus on either practical or cultural ontologies (Dobres 2010, 104). Practical reason research focuses on what we are able to understand about technology in the past from our knowledge of present technology, and generally assumes the equivalence between these. On the other hand, cultural reason ontologies see technology as inextricable from practice and culture (Dobres 2010).

Choosing one of these strategies over the other is arguably unproductive, because researchers must either disregard rigorous scientific research in favor of cultural reason, or ignore the integral relationship of technology and culture in favor of practical reason. Choosing either side of this argument means ignoring vital aspects of opposing methodologies and, in a effort to address this issue, some contemporary research tries to bridge the gap between these two opposing epistemologies. Craft theory utilizes methodologies that attempts to unite ‘hard’ empirical, archeological facts with ‘soft’ perceptively based and embedded experiences, and thus gives a possible solution to divergent epistemologies. It is these endeavors that will inform the following thesis, and exemplary literature is outlined below.

3.1.2: Basics of Studying Craft

The basis of contemporary craft research, as it will be used in this thesis, is on what Dobres (2010) describes as an “ontological perspective on ancient technology… [that] specifically highlights the centrality of the (prehistoric) agent’s body in all ‘things’ technical” (Dobres 2010, 109). Therefore, bodily senses are vital to the the technical actions undertaken in craft work, and they inform skill levels and material comprehension, as well as the decisions made by craftspeople regarding their technical actions. Kuijpers (2014) builds upon and reconsiders previous discussions of crafting and defines technical skill with four characteristics:

1. Skill requires engagement with material
2. Skill depends upon the senses
3. Skill involves the body as a tool
4. Skill is apperceptive and requires both cognitive and embodied knowledge

(Kuijpers 2014, 28)

It is essential that research regarding craft and skill incorporates these considerations, since such an analysis has ramifications for comprehending how we might elucidate knowledge and action from archaeological evidence of technical activities. To do so, we must differentiate steps in craft work and then try to understand the possible decisions made at each step, and how skill is incorporated into those decisions. This analysis relies on a phenomenological (sense based) understanding of how a craftsperson interacts with materials, and how his or her technical decisions were informed by both discursive and non-discursive knowledge, otherwise defined as a conflict between idealist and materialist analyses (Kuijpers 2014, 12). These contrasting approaches either focus on the ‘hard’ empirical approach or the ‘soft’ perceptively based and embedded approach. An understanding of how to combine both equally necessary methodologies is integral to a comprehensive understanding of how skill is used in the past, and how we can understand archaeological data within this theoretical framework.

3.1.3: Chaine Opératoire: Comprehending Craft With Technical Steps

The archaeological record of farming has not yet been explored as a craft and therefore Section ii of Chapter 3 will describe which agricultural disciplines may provide a method of forming perceptive categories in line with craft theory. First, however, I will use an example of this theory’s application - the formulation of perceptive categories by Kuijpers (2014) as a tool to reconsider archaeological data in a sense-based and craft-relevant context.

In archaeology, the basic mode of analysis for understanding the production sequence of objects is the *chaîne opératoire*. *Chaîne opératoires* have been a consistent component of technology studies in archaeology since the 1980s, and their function and applicability has been discussed and reconsidered continuously since that time (Dobres and Hoffman 2010). Because of this established nature, an in-depth description of the uses, history, and applications of the *chaîne opératoires* is unnecessary here, and I will focus on describing how its specific structure is relevant to my research.

When trying to understand craft in the past, a description of technical steps is invaluable in identifying “the sequential technical operations by which natural resources were transformed into culturally meaningful and functional objects”. This technical knowledge therefore “permit[s] an understanding of the sequential physical actions and decision-making strategies by which matter was transformed into culture-bearing objects” (Dobres 2010, 125). By forming an understanding of human action by attention to the steps of material recognition and subsequent technical response, each step of the *chaîne* can be connected to the possibilities of underlying knowledge about the original material and knowledge that informs the decisions that regulate movement along the *chaîne*. Dobres (2010) summarizes this with:

> As an empirically-grounded analytic methodology, *chaîne opératoire* is an efficacious materials science entry point for identifying… real-world factors impinging on artifact design and manufacture and use as well as cognitive, symbolic and social factors shaping technological action. Dobres 2010, 106

As a result, this structure is uniquely suited to combining specific technical data from archaeological study and possible decision making that culminates in the actions undertaken by a prehistoric actor.

This methodology combines exact data with a contemporary understanding of the craft to reconsider what we know about how people recognized and manipulated materials. By incorporating perceptive categories into a *chaîne opératoire*, research can illuminate what decisions might have been made in the context of what was understood by prehistoric actors. This methodology has the potential to be applied in any context where a craft can be divided into technical steps, and will be exemplified here through an application to the craft of farming.

3.1.4: Perceptive Categories in Farming: Possibilities and Challenges

This discussion will rely heavily on the work of Kuijpers (2014), who formulated a methodology for defining perceptive categories as they correspond to different technical steps in the *chaîne opératoire* of Bronze Age axes. This work provides an illustration of how concepts might be created to discuss the agricultural *chaîne*. Overall, perceptive categories are created with the understanding that prehistoric actors would have been unable to differentiate as many compositional details as we are able to determine with contemporary science. The most important aspects of these categories are (1) their relevance to the applicable craft and (2) an ability to differentiate between categories with the senses.

Kuijpers' (2014) PhD dissertation is a comprehensive study of Bronze Age axes combined with an extensive analysis of contemporary metallurgists to understand how a skilled craftsperson might use their senses in the process of axe manufacturing. By comparing craftspeoples' 'soft' knowledge of the material to 'hard' scientific metallurgy compositional data, Kuijpers (2014) uses an established axe production *chaîne opératoire* to differentiate technical steps. These are supplemented with “perceptive categories”, created as a broader analysis of composition data and are only distinguished with qualities that can be perceived with the senses and are relevant to a metal worker, such as color or malleability.

With craft theory as an analytical tool to reconsider farming, it is necessary to incorporate our knowledge of how senses are used in farming to perceive and recognize the environment. The following sections will introduce agricultural analysis in literature that incorporates perception into farming practice, and will focus on soil identification within these practices.

The most challenging and problematic part of this framework comes in ‘translating’ between past and present actions in creating categories that are formulated with sense-based comprehension. Sense is inherently subjective, and we must understand it as such in order to accurately apply it constructs of the scientific method.

Therefore, the initial presentation of archaeological literature in Chapter 4 will the support the formulation of a farming *chaîne opératoire* in Chapter 5 using examples from archaeological evidence of subsistence farming. With the possibility of this sequential, craft based, organization of farming in mind, the two ethnographic examples of agricultural disciplines are discussed in the following sections. These disciplines, permaculture and ethnopedology, rely on ethnographic studies of agricultural knowledge to develop universal farming techniques. Because folk agriculture lies outside the realm of the western defined science, both disciplines incorporate perceptive land recognition. Additionally, because permaculture and ethnopedology exist within a western context, they base much of their analytical systems on an effort to translate between folk agriculture and agroscience. The result is a mass of literature that compares how craft farmers recognize the land with the analytical tools of agricultural science.

3.2: Farming as a Craft: Ethnographic Examples

Introduction

The methodology used to create perceptive categories relies on a compatibility between ethnographic description and experimental crafting and scientifically procured data. The agricultural practices, permaculture and ethnopedology, discussed in the following sections are presented as research environments for the study of ethnoscience. These agricultural disciplines exemplify how a farmer can cognize the soil, relevant to agricultural craft, within the constraints of what he or she can perceive. In this regard, they demonstrate exactly the compatibility between craft and science that perceptual categories rely upon.

Before introducing permaculture and ethnopeodology, I will introduce the specific terminology this thesis uses. Ethnopedology is one of the innumerable subfields within ethnoscience. Wilshusen and Stone describe ethnopedology as "[the] study of indigenous agriculturalists' knowledge and use of soils" (Wilshusen and Stone 1990, 104). Ethnographic study necessitates language that differentiates between the other and the scientist, and indigenous is the most common word used in ethnopedological literature. Permaculture is a conglomeration of agriculturally relevant land and ecological systems knowledge and was developed in the 1970's as a universal system design strategy for any farmer, worldwide (Mollison 1988). Therefore, while permaculture can arguably be included within the definition of 'folk' agricultural practice, it certainly does not fit under the premise of 'indigenous' agriculture. Thus, to sustain a discussion about both permaculture and ethnopedology, I will replace "indigenous" with "folk" whenever possible.

For spatial discussions throughout this thesis I will reconsider the constraints of farmstead/farmyard/farm terminology and redefine the whole system as a farmscape. 'Farmscape' appears to have first been used in the early 1990s in American agricultural literature and is described as follows:

> The farmscape, the land use system of a single farm, is an intermediate scale for studying biodiversity and ecosystem functions at the landscape level… Local experiences and farmer experimentation with biodiversity-based production systems exist in many farmscapes. (Smuckler et al. 2010, 81)

This term has been adopted in a non-archaeological context in North America by sustainably-minded farmers in North America to describe a whole-systems approach to farming. As my purposes cross over archaeological and agricultural purposes, I keep these various multiple significances under Morehart's (2010) broad definition of farmscapes as "the landscapes produced by agriculturalists" as differentiated from the household (Morehart 2010). This definitions implies all land used by farmers.

Archaeological analysis consistently uses historical and contemporary knowledge of subsistence farming, as well as experimental work, to understand and describe data that can illustrate an assortment of practices such as land use, diet estimations, animal husbandry demographics, storage needs, and crop selection. Two agricultural disciplines will be outlined in the following section. (1) Historical studies of subsistence farming as they are used to inform archaeological research and (2) modern farming frameworks that standardize general knowledge and land identification, manipulation, and use strategies. Because this thesis emphasizes soil as the resource, or raw material, used in the the craft of farming, the following discussion will illustrate how soil is understood and used within our contemporary knowledge of craft farming. Existing research based in 'hard' science is presented only when relevant to farming.

3.2.1: Subsistence Farming in MBA West Frisia

I am seeking to produce a craft theory approach to farming; this section discusses contemporary agricultural archaeological research to give the context that I will be working in. It is necessary to use the specifics of a time period, farming strategy, and ecological zone, to successfully implement a methodology. As previously introduced, the low countries in the Middle Bronze Age commonly practiced mixed-farming techniques, which includes a combination of crop cultivation and livestock raising (Arnoldussen and Fokkens 2008, 25). The analytical models for these areas generally focus on reconstructing the "cultural landscape", which has slightly differing definitions depending on use context, but will be used in this thesis as archaeological research that, "tries to investigate the ways in which people have structured the landscape in which they dwell and gave it meaning according to their cosmology" (Arnoldussen and Fokkens 2008, 8).

Research of this nature, in regard to specific farming practices, relies on data from historical subsistence farming and experimental yield, use, and organizational estimates. Experimental values that pertain to, for example, settlement layout or regional crop viability, are then compared to archaeological data in an effort to elucidate the practices that resulted in the existing archaeological record. Van Amerongen (2016) refers to the data from sources such as ethnography, archaeobotany, biology, and ecology as “proxies” which are then used to compare with relevant archaeological data. Therefore, in regard to crop husbandry and animal husbandry, van Amerongen is able to recreate possible parallels to prehistoric agricultural practices. This material is dealt with in detail in Chapter 4.

Modern taxonomies are built on a basis of chemistry and geography in an effort to standardize soil knowledge and understanding and discover “what is there” (Mollison 1979, 182). Despite this, soil science as a whole is a confusing discipline to specialists outside of the field because of the existence of numerous classification systems, and has been described as a “Babel tower” (Krasilnikov *et al.* 2009, 20). Comprehensive classifications include different standards on composition and therefore different identifications. In contrast, soil comprehension as it relates to farming and crop viability is well understood and recorded across geographic and cultural zones, as seen in the FAO classification system.

For the purposes of this thesis, I will focus on one specific contemporary farming practice. This contemporary discipline, called permaculture, will be used because of its generally applicable framework that, “contributes to an applied form of ecological literacy, supplying a popular and accessible synthesis of complex socioecological concepts” (Ferguson and Lovell 2014, 252). The scientific background of permaculture is therefore sufficiently abstract to create a general sequence of farming activity and a basis on which to define relevant aspects of soil composition, more specifically pH, as they relate to and affect agricultural decision making. The following section will more specifically define permaculture and introduce instance of taste perception in permaculture farming. The subsequent section will introduce ethnographic examples of perceptive land categorization as found within the discipline of ethnopedology.

3.2.2: Permaculture: A modern example of tasting the soil

One of the the foundational principals of permaculture is its ability to incorporates locally relevant environmental knowledge and an extensive compilation of regionally specific soil science with western agricultural science (Ferguson and Lovell 2014; Mollison 1988). To address Arnoldussen's criticisms of modern models, I will borrow specific aspects of permaculture to consider permaculture as craft farming in practice, rather than using permaculture to model MBA farming. Thus, permaculture will be used as a tool with which I will apply craft theory to farming, using pH identification as an exemplary study of this methodology.

Permaculture is a modern farming technique that combines agricultural science with an intense focus on a farmer's ability to adapt to and understand specific regional constraints (Mollison 1988).

> Permaculture is the conscious design and maintenance of agriculturally productive systems which have the diversity, stability, and resilience of natural ecosystems… the harmonious integration of the landscape with people providing their food, energy, shelter and other material and non-material needs.
>
> Bell 1992, 2

Permaculture is farming as learned through what Ingold refers to as the "education of attention" and an ability to adjust and adapt to one's materials and/or surroundings (Ingold 2003). The processes of design, maintenance, and learning and education make permaculture an excellent lens by which to see farming as a craft. In the farming craft, I interpret soil as the material upon/with which to apply one's skill. Much of our modern understanding of farming lacks this responsiveness to raw materials; it is seen as a universal food procurement system applied through space and time. The *Permaculture Designer's Manual*, a comprehensive disciplinary tome published by Mollison in 1988, devotes an entire chapter to soil composition as relevant to land fertility and agricultural viability. While permaculture publications have diversified greatly since then, and design strategies as presented in the original Designers Manual have been expanded upon (Ferguson and Lovell, 2014), this publication exemplifies general approaches to soil pH in permaculture's agricultural practice. The sub-section on pH describes pH measurements as vital to both soil and water science as they relate to farming (Mollison 1988, 198).

Overall, permaculture acts as a conglomeration of western agricultural science and diverse ethnographic agricultural practices as deemed relevant to efficient design systems. These practices, specifically land identification, are described using a combination of scientific measurement systems and western agricultural science [e.g. specific soil mineral compositions as they exist in different pH environments] and perceptively based interaction with the land [e.g. tasting the soil or using vegetative indicators to identify acidic or alkaline soils] (Mollison 1988, 198). I will specifically describe tasting the soil in permaculture as a method of pH measurement, as this is the basic concept used to consider perceptive categorization as presented in Chapter 5.

Tasting the soil to determine pH is a suggested practice in permaculture literature and instructional publications that present tasting as an alternative if scientific soil tests, litmus paper, or personal pH testing equipment is unavailable, or if famers are interested in a perceptive interaction with the land. Permaculture design guides provide extensive descriptions of how to use one’s senses to interact with and identify overall soil fertility, and guides (e.g. *Practical Permaculture*) suggest tasting the soil to identify pH and state that, “acidic soils tend to taste and smell sour, while alkaline soils tend to taste and smell sweet” (Bloom and Boehnlein 2015, 130). More informal resources, such as online interactive websites, magazines, informational documentaries, and conference proceedings, give specific techniques for tasting the soil to roughly determine pH[1]. These are general guidelines, however, and rarely go beyond an acknowledgment of the correlation between taste and pH. Soil taste descriptions might also incorporate assorted other possible factors in soil taste or mouth feel based on conjuncture by a specific farmer. An example from Logan (1995) references a farmer who describes his personal ability to differentiate soil pH with taste.

> A very acid soil would crackle like those sour candies that kids eat, and it had the sharp taste of a citrus drink. A neutral soil didn’t fizz and it had the odour and flavour of the soil’s humus… [a]n alkaline soil tasted chalky and coated the tongue. (Logan 1995, 14)

Perceptive categories as available at this point are broad approximations of the relationships between soil taste and pH, and involve the entire spectrum of taste and mouth feel available in the vocabulary of a farmer and lack empirical categorization. Therefore, in order to integrate perception and science there needs to be significant supplementary research to determine their exact relationship.

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[1] For example: Logan 1995, ediblegeography.com, vegetablegardener.com, cleanairgardening.com, treehugger.com.

3.2.3: Ethnopedology: Ethnographic perceptive land identification

In the context of archaeology, pedology is already a component of excavation methodology because archaeologists rely on stratigraphy and soil differentiation to guide methodological approaches. Thus, "pedological studies offer archaeologists answers to questions about the composition and potential uses of different soil types within an archaeological study area." (Wilshusen and Stone 1990, 104). Ethnopedology is doubly applicable in this sense as both an ethnographic discipline that can illustrate possible example of alternative cultural relationships with the land, and a supplement to the discipline of western pedology. Additionally, ethnopedological research was founded as a subset agricultural science in distressed ecological zones:

> Ethnopedology arose in the field of sustainable agriculture though a need to understand local agricultural systems as a contrast to western notions of sustainable land use. (Barrera-Bassols and Zinck 2003, 173).

Because ethnopedological studies are generally concerned with resource management in indigenous communities, researchers often use an integrated and comparative approach that identifies correlations between cultural and scientific information (Barrera-Bassols and Zinck 2003, 176). While it is impossible to obtain a full understanding of past people's soil knowledge, ethnopedology is vital to the approximation of possible perceptual categories and determination of how they are incorporated into land identification as a technical step within the framework of agricultural practice. Ethnopedology will provide evidence of craft farmers using their senses to systematically understand, define, manipulate, and use soils in the context of farming activity.

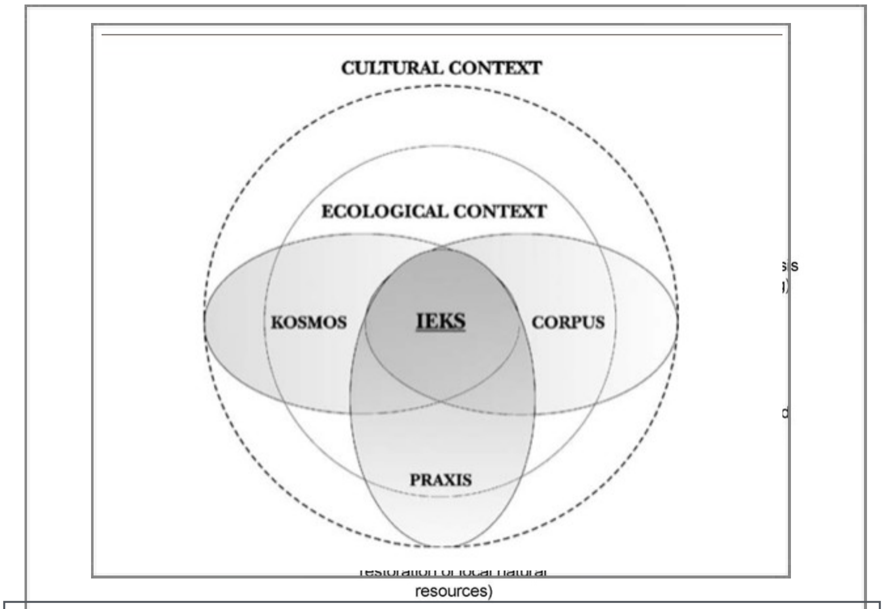


Figure 3: Domains that contribute to 'indigenous' environmental knowledge systems. (Barrera Bassols and Zink 2003)

Figure 2: Diagram of contributing disciplines to ethnopedology (Barrera Bassols and Zink 2003)

A number of researchers have worked to standardize ethnopedological theories and methodologies and their relation to scientific pedology and agricultural science, most notably in an exhaustive database compiled by Barrera-Bassos and Zink in 2003. Since ethnopedology, much like archaeology, is a field that combines a plethora of other disciplines, there is a consistent effort to compare different analytical approaches (Figure 2). According to Barrera-Bassol and Zink's (2003) summarizing research, there are three main theoretical and methodological strategies used to perform analyses of ethnopedological knowledge: ethnographic, comparative, and integrated. Ethnographic research focuses on cultural relevance and language uses, and it is generally not compared to scientific soil research. In contrast, comparative research's main purpose is to compare and contrast scientific soil information and generally results in a disregard for farmer's expertise and often assumes the superiority of scientific information over local Environmental Knowledge Systems. Integrated research is directly related to resource management and agricultural vitality and incorporates both soil science and local knowledge participation in an effort to successfully work with communities in a sustainable manner (Barrera-Bassos and Zink's 2003, 176).

Ethnopedology is based in what Barrera-Bassols *et al.* (2006) refer to as an "Indigenous Environmental Knowledge System" (IEKS), which is comprised of a combination of beliefs, cognition, and practice, or ‘kosmos, corpus, and praxis’ (Figure 3). When applied in archaeology, one can only addresses evidence of possible practices undertaken by prehistoric farmers, and therefore can only use tangible representations of soil comprehension from indigenous farming communities. It important to keep in mind, as Wilshusen and Stone (1990) outline, ethnographic studies run the risk of including anachronistic categories for the benefit of the researchers and which are randomly determined using “descriptive phrases… rather than discrete names” (Wilshusen and Stone 1990, 106). This presents the same problem discussed in Chapter 2 with boundaries as defined by the FAO; in an effort to draw clear lines between compositional values and descriptive terms, western scientists are liable to invent boundaries and delineate unnecessary appellations. It is easy to imagine a scenario where a scientist, based upon her knowledge of the chemical properties of the soil, is convinced that a soil in location A is different than location B. When asking a farmer to describe these different soils, the farmer will be compelled to provide an answer and will therefore simply describe possible differences, which will in turn become the ‘name’ of the soil in the eyes of the scientist. The ethnopedological studies used in this work have made an effort to present available information from farmers that show that indigenous soil understandings are consistently based upon a morphological understanding of the soil (Barrera-Bassols *et al.* 2006, 125). They are explicit about where these understandings are descriptive and where they are established taxonomies.

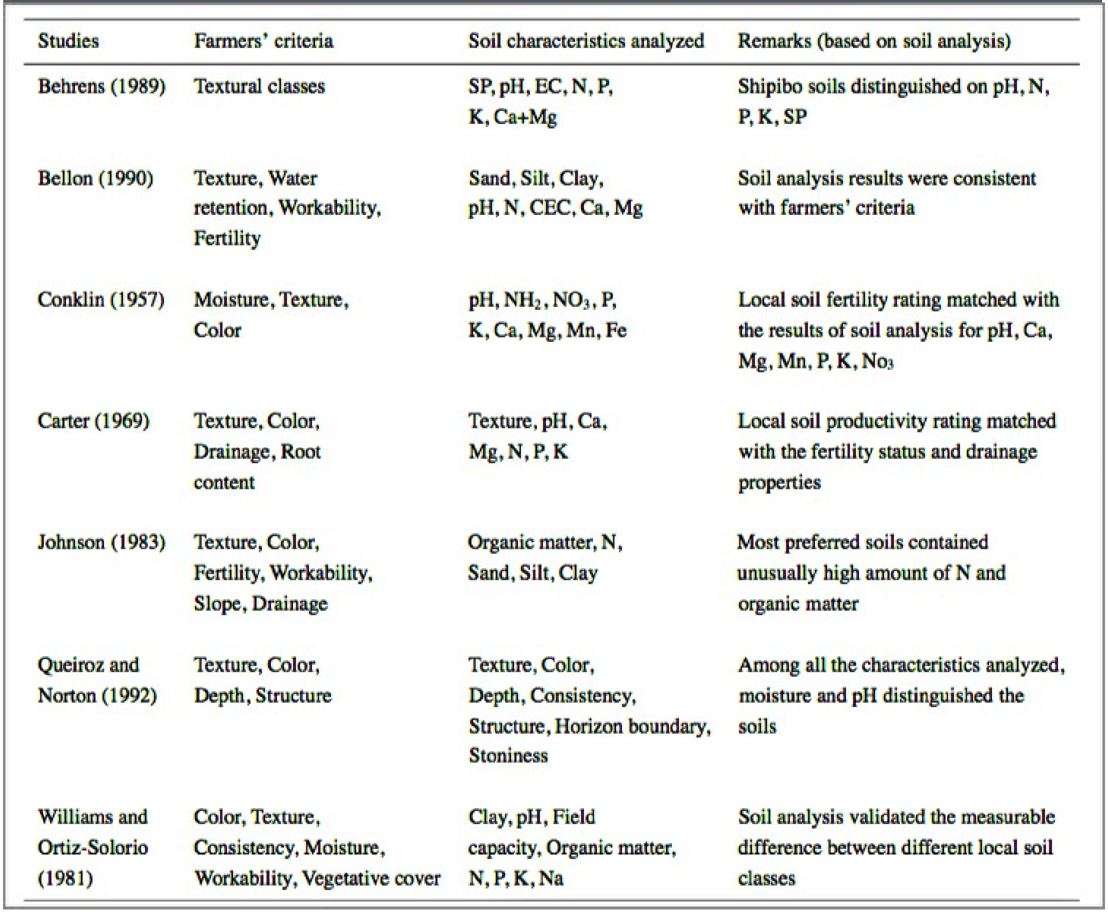
Barrera-Bassos and Zink (2003) consolidated all of the existing research on indigenous soil knowledge into one database, which includes 865 total references from 61 countries and 217 ethnic groups (Barrera-Bassos and Zink 2003, 171). The summarizing conclusions of their compilation provide an aggregation of evidence necessary to address the main issues of phenomenological approaches: variation in human experience and translatability between science and perception (Kuijpers 2014, 55). In Barrera-Bassols and Zink’s survey of existing ethnopedological studies, they determined four sets of classification criteria used by ethnic groups:

(1) Color (100%) and texture (98%)
(2) Consistency (56%) and soil moisture (55%)
(3) Organic matter, stoniness, topography, land use, and drainage (between 34% and 48%)

(4) Fertility, productivity, workability, structure, depth and soil temperature (between 2% and `26%)

Barrera-Bassos and Zink 2003

Table 1: Compositional comparisons from studies that correlate soil analysis for physico-chemical properties with farmers' soil classification criteria. (Talawar and Rhoades 1998, 8)

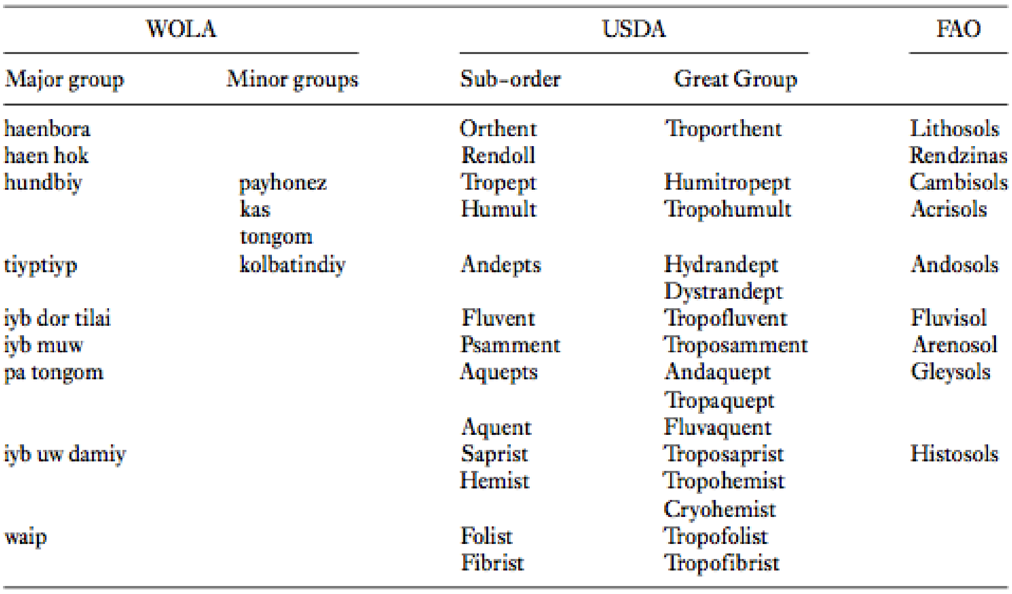


Studies	Farmers' criteria	Soil characteristics analyzed	Remarks (based on soil analysis)
Behrens (1989)	Textural classes	SP, pH, EC, N, P, K, Ca+Mg	Shipibo soils distinguished on pH, N, P, K, SP
Bellon (1990)	Texture, Water retention, Workability, Fertility	Sand, Silt, Clay, pH, N, CEC, Ca, Mg	Soil analysis results were consistent with farmers' criteria
Conklin (1957)	Moisture, Texture, Color	pH, NH_2, NO_3, P, K, Ca, Mg, Mn, Fe	Local soil fertility rating matched with the results of soil analysis for pH, Ca, Mg, Mn, P, K, No_3
Carter (1969)	Texture, Color, Drainage, Root content	Texture, pH, Ca, Mg, N, P, K	Local soil productivity rating matched with the fertility status and drainage properties
Johnson (1983)	Texture, Color, Fertility, Workability, Slope, Drainage	Organic matter, N, Sand, Silt, Clay	Most preferred soils contained unusually high amount of N and organic matter
Queiroz and Norton (1992)	Texture, Color, Depth, Structure	Texture, Color, Depth, Consistency, Structure, Horizon boundary, Stoniness	Among all the characteristics analyzed, moisture and pH distinguished the soils
Williams and Ortiz-Solorio (1981)	Color, Texture, Consistency, Moisture, Workability, Vegetative cover	Clay, pH, Field capacity, Organic matter, N, P, K, Na	Soil analysis validated the measurable difference between different local soil classes

Thus, ethnopedology has already formalized a substantial amount of folk soil comprehension and use strategies, which are entirely comprised of perceptively based definitions and decisions (Barrera-Bassos and Zink 2003, 178).

The relevance of ethnopedology lies in a comparison between these criteria and empirical soil classifications used by the FAO and other standardized systems. It has been shown that there is a correlation between folk classifications and chemical composition, which in turn translates to a correlation between folk and conventional soil typologies (Barrera-Bassola and Zink 2003, 179). But, as posed by Williams and Ortiz-Solorio, "[t]he question is not whether traditional cultivators perceive soil differences and integrate the into their agricultural systems, but

Table 2: A comparison of USDA and FAO soil appellations with those of the Wola people of the Southern Highlands Province of Papua New Guinea (Stillitoe 1998, 190)



WOLA		USDA		FAO
Major group	Minor groups	Sub-order	Great Group	
haenbora		Orthent	Troporthent	Lithosols
haen hok		Rendoll		Rendzinas
hundbiy	payhonez	Tropept	Humitropept	Cambisols
	kas	Humult	Tropohumult	Acrisols
	tongom			
tiyptiyp	kolbatindiy	Andepts	Hydrandept	Andosols
			Dystrandept	
iyb dor tilai		Fluvent	Tropofluvent	Fluvisol
iyb muw		Psamment	Troposamment	Arenosol
pa tongom		Aquepts	Andaquept	Gleysols
			Tropaquept	
		Aquent	Fluvaquent	
iyb uw damiy		Saprist	Troposaprist	Histosols
		Hemist	Tropohemist	
			Cryohemist	
waip		Folist	Tropofolist	
		Fibrist	Tropofibrist	

the nature of these perceptions and their adaptive significance” (Williams and Ortiz Solorio 1981, 358). What is interesting here is the difference between folk and conventional systems, and how these differences correlate with the use of soil as a material for a specific ‘adaptive significance’. As shown in Table 1, there is a significant overlap between scientifically measurable composition and descriptive ethnopedological criteria. Notably, there is a difference in criteria used by farmers based upon what is most relevant in the region discussed, and there is a correlation of sense-based criteria and compositional values, such as pH (e.g. Conklin 1957; Queiroz and Norton 1992), that do not have perceptive categorization within conventional soil classification.

There are more explicit comparisons, as shown in Table 2, between folk soil taxonomies and the FAO. These comparisons show correlation but not direct translation between named soils, and the difference lies in the relevance of soil composition. Wola appellations are given through perceivable characteristics and when a soil has a direct agricultural use, either positive or negative, and are therefore less detailed and precise than both the FAO and the USDA names (Sillitoe, 1998).

In their comparative study, Queiroz and Norton (1992) clustered both morphological and non-morphological characteristics of soil from the caatinga region of Ceara State in Brazil, and found that these clusters correlated with regional indigenous classifications. The morphological clustering, such as through color and texture, is in line with the consistency of morphological groupings in both folk classification and conventional pedology. Interestingly, according to conventional soil science, pH is not considered a morphological characteristic, and yet the clustering soil based on pH composition showed a “practically significant association between cluster membership and physiochemical soil properties” (Queiroz and Norton 1992, 303). Further empirical study of the relationship between pH and caatinga classifications is necessary to make a definite statement about farmers ability to identify pH. However, this correlation does show that a perceptive understanding of pH is possible if relevant to agricultural fertility. With this in mind, pH could feasibly fit under the imposed classification criteria of ethnopedology within: soil moisture, organic matter, drainage, fertility, productivity, or soil temperature. This relationship will be explored in Chapter 4.

Conclusion

This chapter began with an introduction to methodologies that incorporate perception into archaeology analysis of craft work and concluded with examples from agricultural disciplines that closely resemble the structure of skilled craft work. Existing research generally acknowledges a need for a sensory component in understanding soils and admits pitfalls of using only “formal logic” to interact with soils (Krasilnikov *et al.* 2009, 18). Ethnopedology has shown that humans interact with the environment conditionally, through “thought, knowledge, and language”, and more specifically, that they “do not directly respond to the environment, but rather to the environment *as they conceive of it*” (Brosius et al. 1984, 189). This point is outlined by an assortment of scholars who emphasize people-environment relationships. For example, Vayda and Rapport (1968) differentiate between the “cognized environment” and the “operational environment”, with the former reflecting people’s perception and the latter including all aspects of the environment, regardless of human comprehension (Brosius et al. 1984, 189).

As shown in ethnopedological studies, most soil recognition systems focus on dividing soils into all-encompassing categories based upon their most productive use, such as for or not for planting, for or not for building, and so on

(Wilshusen and Stone 1990, 107). Therefore, rather than trying to form perceptive categories for every possible soil characteristic that might have been relevant, this thesis will focus on categories that are relevant to farming and *also* available with archaeological data. As a farmer, perception of the environment becomes a unique relationship that creates a different reality, or cognized environment, than the operational environment as observed through scientific study. This chapter has shown the divergence of these two cognitions of the environment, and in order to reconsider the environment with a farmer's perception, I will present the technical structure of farming and turn to a specific ecology and agricultural community: West Frisia in the Middle Bronze Age.

Chapter 4: Environmental Variability

The Ecological Constraints of West Frisia, Netherlands

Introduction

Farming is skilled practice. In Chapter 3, I demonstrated the possibility of perception based land categorization with the analytical tools of craft theory and the empirical findings of ethnographic study. Chapter 4 has two major aims: first, to produce an agricultural *chaîne opératoire* in to structure the technical action of farming; second, to apply this *chaîne* to West Frisia. In agriculture, soil is shown to be particularly relevant to the vitality and fertility of the farmscape, and thus perception of the soil is integral to a farmer's skill. The final section of Chapter 4 shows that, in West Frisia's ecology, pH is an especially relevant composition property for agricultural viability. Therefore, perception of soil pH is proposed as an exemplary study for the applicability and relevance of perceptive categories.

4.1: The Craft of Farming: *Chaîne Opératoire*

While the specific model of a *chaîne opératoire* does not currently exist for farming, agricultural activity occurs in a sequential pattern that is conducive to this methodological framework. In the following section I will outline the steps of a sample farming *chaîne opératoire*. The most productive use of a *chaîne opératoire,* is to utilize its structure as a methodology that can predict the likely technical steps in a process (Kuijpers 2014, 51). Once these steps are established for farming they can be used to organize data in a way that is more relevant to the craft in question and the systematic understanding of a craftsperson. While this structure is consistently simplified and inherently "distorts the crafting process" (Kuijpers 2014, 53), it is its predictive nature that makes it interesting and applicable in the context of understanding perception as part of technical action.

The *chaîne opératoire* is a basic and easily manipulated structure. A farming *chaîne opératoire* will demonstrate sequential actions synonymous with the technical steps undertake by a farmer to engage with the land. The steps of the *chaîne* correlate to two main skill based material interaction processes: recognition and response to a material. The following *chaîne* will divide farming into the three steps: land identification, land manipulation, and land use. These are discussed below. While this is a simplified progression, its strength is its broad applicability across differing agricultural disciplines. I note that important skills in farming (like maintaining and harvesting crops) are excluded; their archaeological visibility is questionable, and further research into their position in the *chaîne* of farming is needed. However, their omission is not of immediate methodological relevance, for this thesis is concerned only with demonstrating the viability and relevance of perceptive categories in archaeology of farmscapes.

4.1.1: Sequential actions in farming

I. Land Identification

Land identification is a multistep process that is comprised of a farmer's assessment based upon sensory interactions with the soil through sight, touch, smell, and taste. In farming, chemical, climatic, and topographic analyses are invaluable to farming-related land use decisions (Mollison 1979). This initial understanding allows a farmer to engage with his or her land. This skill is vital to effective land management and agricultural viability and only after the recognition process can a farmer begin to productively work with land (Mollison 1979).

II. Land Manipulation

Once land has been identified and understood, a decision must be made about whether or not to add material or manipulate the preexisting environment in other ways. There are numerous actions that fall under the category of manipulation, such as fertilization, ploughing, irrigation, or grazing. In ethnopedology, fertilization is seen as a material addition to soil that is infertile, or 'cold', and is an involved process of 'heating' soil and bringing it to life in preparation for agricultural use (Barrera-Bassols *et al.* 2006). Physical manipulation of soil continues on the trajectory of preparing soil for agricultural use. Manipulation can encompass various forms of earth movement, but West Frisian MBA farming, as evident in the archaeological record, mainly included ard use as a form of soil aeration and fertility enhancement (van Amerongen 2016). Any type of ploughing (whether with an ard or traditional ploughing) can aerate soil and incorporate fertilizer, and increases soil fertility (Mollison 1979). Grazing can be either an intermediary step between land recognition and manipulation, or a final use decision. In the farming process, animal grazing is frequently used to clear and maintain land (Mollison 1979), and therefore be considered a component of active land manipulation.

III. Land Use

Land use actions are the final steps in this tripartite process of farming. This step is the culmination of the work done in the previous two steps and could include arable land, house sites, no use, or grazing. It is important to acknowledge here that land was likely not used for one single purpose of the entire course of the MBA. This thesis will instead look at overall trends in land used for agriculture as represented by what we can glean from archaeological data on arable land composition.

This sequential organization describes the *what* of farming, and will be used to focus on archaeological data that pertains to the step of land, and therefore soil, identification. By using this basic *chaîne opératoire*, soil composition values become a component of soil identification, and can be parsed out in a way that is relevant to the perceptual reading required to participate in skilled agriculture. To introduce the viability of a perceptual reading, one component of soil identification will be explored in more detail.

4.2: Soil as a Raw Material in a Farming *Chaîne Opératoire*

As shown in the introduction to land identification, there are multiple landscape and ecological characteristics that are relevant to farmers. Because of the topographic monotony of West Frisia, soil is generally considered to be a defining factor in land use and settlement locality (Arnoldussen and Jansen 2010, 149). Additionally, soil undergoes consistent compositional fluctuations due to the traditional nature of the West Frisian landscape (Arnoldussen and Jansen 2010). This thesis will therefore consider soil identification as the main component in the land identification in West Frisia.

The following section will discuss the ecology of West Frisia as represented in soil pH. pH is an exemplary compositional value to explore the translation between perception and science. In West Frisia pH data is indicative of environmental fluctuations that effect soil fertility. Additionally, interdisciplinary research shows a relationship between perception and scientific categorization of pH.

4.2.1: The Ecology of West Frisia: A basis for perception

Dijkema and Wolff's (1983) work - an analysis of the surrounding ecology outlines soil and vegetation succession and regression patterns (Figure 4) - is a helpful schematic of different soil types and how they transition through either human or natural impact processes. Additionally, van Amerongen's (2016) and Van Zijverden's (2017) reconstructions of the West Frisian landscape are outlined below to contextualize the environment in the MBA.

The land identification process, as relevant to West Frisia, involves actions that identify pertinent land characteristics. Soil composition is an integral part of this identification process, and perceptive categories will focus on how farmers recognize soil pH within the constraints of what is perceptible by humans. In order to successfully translate known perceptive abilities in soil identification into archaeological data, these categories will be based upon the available information from West Frisia. To begin this process the following section will outline the specific applicability of pH to agriculture in West Frisia and in comparative ethnopedological studies.

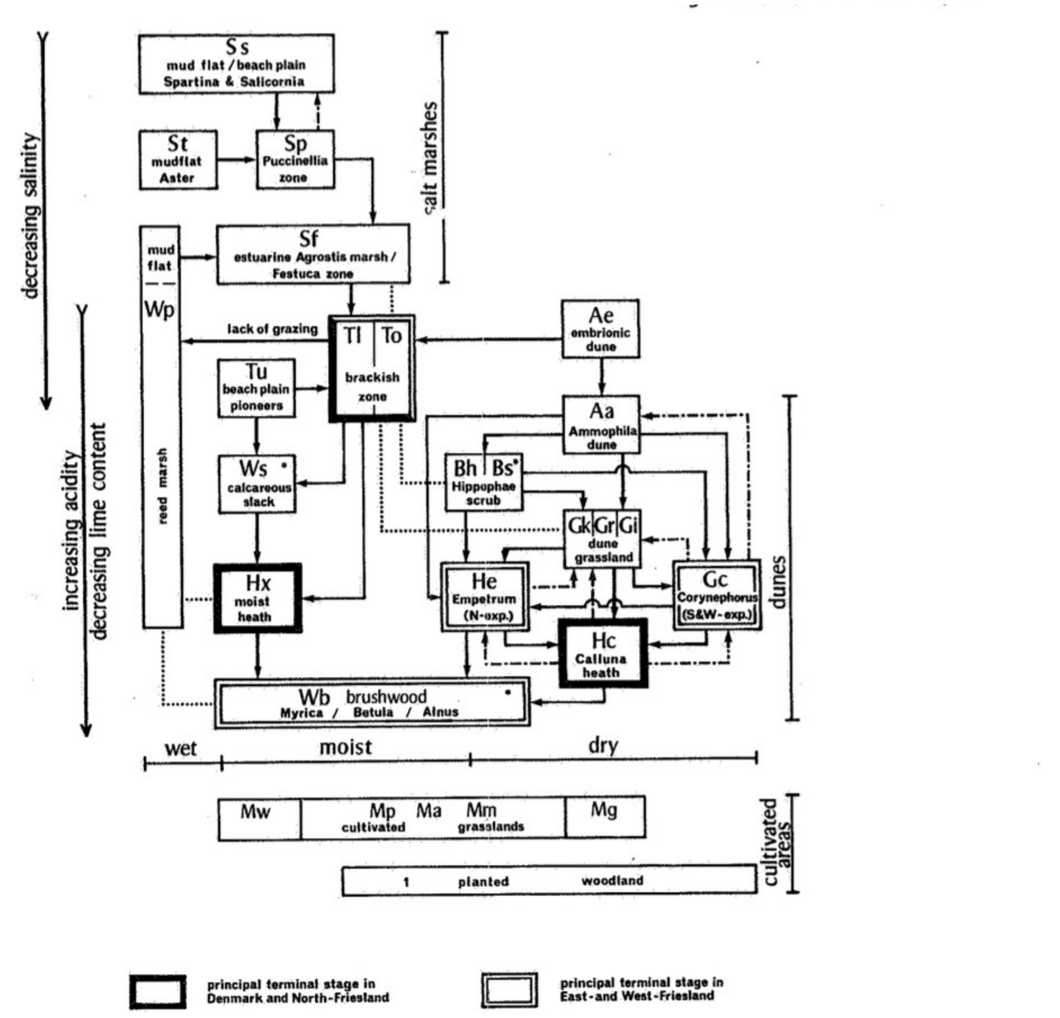


Figure 4: Succession and regression patterns of ecological environments and possible zone differentiation in the Wadden Sea and East and West Frisia (Dijkema and Wolff 1983)

Reconstructed soil maps of the area surrounding the sites used in this thesis show soil typologies, as differentiated with contemporary soil classification systems, that were available to West Frisian farmers. West Frisian soils include silty clay, kick clay, peat, sandy loam and loamy sand, transitional soils, loam soils, and clay loam soils. Contemporary soil maps are used to correlate between archaeological sites and soil type. Ethnopedological sources show that farmers consistently differentiate soils based only upon surface characteristics (Barrera Bassols and Zink 2003), and therefore, while subsurface soils and sediments are an important component of soil identification to a contemporary pedologist, only surface soils from arable land are perceptible and thus only these will be used to formulate perceptive categories.

Previous habitation models of the West Frisia Middle Bronze Age hypothesize that settlements only existed on sandy ridges adjacent to creeks, and propose that land fertility depletion and potential deforestation might have affected settlement movement and location choices. This argument is unsubstantiated, because a thorough understanding of soil composition, as it relates to settlement location and arable field use, was not completed before research projects conducted in the past few years (Arnoldussen 2010, 147). Overall, though, it is evident that varying moisture levels in West Frisian soils were directly related to fertility and land use through both nutrient saturation and sedimentation. Nutrient rich and organically fertile subsoils were established through periodic flooding (Arnoldussen 2010, 147), and a working knowledge of general moisture levels and the compositional effects of such variation would be vital to recognizing favorable agricultural conditions.

Table 3: Average land composition values from crop weed measurements from each sample, as compiled from van Amerongen's (2016) arable land composition data.

Site name followed by pit number	**Average pH as reconstructed from botanical remains found in arable land samples**
Bovenkarspel	
5	7
7	7
15	7
19	7
32	7
34	7
40	7
46	7
92	7
95	7
100	7
101	7
105	7
117	7

Table 3: Average land composition values from crop weed measurements from each sample, as compiled from van Amerongen's (2016) arable land composition data.

121	6.8
123	6.8
134	7
136	7
139	7
177	7
181	7
Enkhuizen	
1	7
3	6.75
12	7
21	7
40	7
44	7

The botanical and animal remains used in van Amerongen's (2016) reconstruction were collected from house ditches. Botanical remains are analyzed as having beed transported into the site by people, and therefore represent the environment directly surrounding settlements (van Amerongen 2016, 2:9). As shown in Appendix A, each pit is comprised of a number of botanical remains that were used to recreate ranges of possible land composition. Table 3 gives a example of pH values as reconstructed from house ditches at two sites in West Frisia. In order to consider these values as representative of arable land, and then consider them within the context of the greater environment of West Frisia, Table 3 shows an average of the range of pH values for each pit from all of the botanical remains as seen in Appendix A. As shown, soil pH for arable land remains consistent across samples and does not vary more than a quarter unit from a neutral pH of 7. Therefore, arable land pH values are consistent and will thus differentiated from the range of soil pH fluctuation in the overall ecology of West Frisia, presented in the following section.

4.2.2: Soil Composition and Agriculture

The main agricultural relevance of pH is the accessibility of assorted chemical elements based upon soil pH. Thus, pH identification is representative of soil health and nutrient diversity and can help to determine the potential species growth in a specific area. If soil pH is between 6.0 and 7.5, most domesticated agricultural plant species will grow, if pH is between 4.5 and 10, farmers can grow a smaller range of plants, but only if calcium is evident in the soil. If pH is below 4.5 or above 10.0, only specialized plants and bacteria can survive (Mollison 1988, 199). In an area where pH stays relatively constant, e.g. a very dry climate where soil leaching is less intense or an environment of soils with no sand and a high buffering capacity (U.S. Department of Agriculture), identifying soil pH would be less relevant to farmers, but in West Frisia, pH fluctuations have considerable ramifications for agricultural fertility.

Soil pH in West and Northern Friesland can range from 3.9 to 7.8 with more extreme acidification occurring through decalcification of brackish marshes (Dijkema and Wolff 1983, 124). Decalcification is a result of waterlogged soils with little aeration, and makes land unfit for arable use. The Netherlands is particularly susceptible to acidification of soils since, “fluctuating hydrological conditions cause intense decalcification of the soil” (van Den Berg and Loch 2000, 27). Therefore, the range of pH in West Frisia means that acidic soils would have been a continuous problem for agricultural fertility, and an ability to recognize acidity would have been a pertinent component of agricultural practice.

Ethnopedological studies show that the taste of a soil can be used as an identifying perceptive characteristic that is direct evidence for soil pH (Weinstock 1984, 146). In an exemplary study of traditional agriculture in Malaysia, Weinstock (1984) systematically compared farmer’s definitions of soil with pH measurements and determined a direct correlation between the defined taste of the soil and the soil pH. There are, of course, considerable ecological differences in average temperatures and elevation between Malaysia and West Frisia, but this study will be used as comparable to possible MBA perceptively based soil definitions in West Frisia through similarities in subsistence strategies and climatic moisture levels in both Malaysia and MBA West Frisia. The Malaysian farmers studied by Weinstock (1984) use a combination of swidden agricultural and field rotation and incorporate manuring into their land management strategies (Weinstock 1984, 149). These agricultural strategies are also evident in West Frisian in the MBA (van Amerongen 2016).

Soil moisture levels in West Frisia were reconstructed by van Amerongen (2016) based upon a range of moisture tolerance exhibited in botanical remains. Contemporary soil classifications include differentiations based upon particle and crumb size, which can determine permeability and moisture retention. Permeability can signify a variety of soil composition components and is a general representation of agricultural viability. Crumb size (texture) of a soil generally correlates with permeability - no crumb means extremely permeable (sand) and full cohesion means no permeability (clay). Knowledge of available water for plant absorption is based upon broad soil categorizations (sand, clay, aggregated loam) for no water storage to full saturation, and mixtures of these compositional factors would result in an assortment of water retention results. Neither end of the compositional spectrum (sand or clay) is ideal for agricultural use, since plants do not benefit from an extremely compact and cohesive soil or from an porous soil that does not hold water (Mollison 1979, 186). Additionally, medium crumb structure allows for nutrient and gas exchange and root penetration in the soil (Mollison 1979, 201). By interpreting soils as a material, the risk of acidification becomes the most relevant fluctuation in regard to pH and makes agricultural strategies comparable between Malaysia and West Frisia. As Weinstock (1984) shows, Malaysian farmers exhibit a necessary perceptible comprehension of pH levels based on taste when identifying agricultural land. This perception is relevant because of the possibility of fluctuating pH levels and the subsequent effect on a soil's agricultural viability.

Permeability determines soils' ability to store both water and nutrients that are vital to plant life. Humus, decomposed organic matter in the soil, is an absorbent material and can absorb up to six times its weight in moisture and therefore increases a soil's ability to cache mineral nutrients. As described by Holmgren, "the differences between soils in their capacity to store water, nutrients, and carbon is the greatest single factor in the productivity of terrestrial ecosystems and agriculture" (Holmgren 2002, 37). I therefore argue that the compatibility of perceptive categories in these two agricultural communities is legitimate because moisture is a deciding factor in soil pH, and ecological zones that include a system of flooding combined with sandy soils (both Malaysia and West Frisia) show the highest risk for decalcification and subsequent acidification of soils. As a raw material of craft agriculture, soil pH for both communities becomes a deciding perceptive factor in a farmer’s land identification.

Thus, a soil’s permeability is representative of overall production potential and structural integrity. Ecological variability is an integral component in farming practices, and this variability directly affects farmers’ perception of the soil as it is relevant to their craft. With this in mind, I will consider how it is possible to incorporate this perceptive understanding into a technical analysis of farming practice.

Conclusion: A Farmer’s Perception of West Frisian Soil

Perceptive categories organize data in a way that shows how land was identified and farming occurred within the context of the overall environment of West Frisia relevant to its actors. The steps of the farming *chaîne* presented above show the *what* of farming activity. These steps will be supplemented below with a discussion of the *how* aspect of land identification. I have acknowledged soil taxonomies and western soil science as supporting scientific framework (Krasilnikov *et al.* 2009) and supplemented these with evidence from craft farming.

When identifying land to sow, farmer must make a choice from a number of available options. A soils’ ability to hold nutrients and water is the most vital aspect of its fertility; these factors are studied in pedology partially through in pH, but for [prehistoric] farmers they are manifest through perceptible features of the soil. Chapter 5 will study the relation of taste to pH as one example of the applicability of craft theory to agriculture. Overall, Chapter 5 combines a chemical approach to the definition of taste and the empirical correlation between the taste of soil and its pH.

Chapter 5: Sensing pH

The viability of categorizing the taste of soil pH through examples from food science

Introduction

The application of craft theory relies on the possibility of measuring or meaningfully quantifying human sensory perception. Methodologically, this is difficult. How are we to define something which is inherently subjective? Thus far, the perceptible characteristics of soil, especially the possible correlation between taste and pH, has been presented. In order to represent the feasibility of such a correlation from a scientific standpoint, Chapter 5 outlines empirical studies of taste perception categorization and shows evidence of this categorization from food science. In order to begin to apply sensation thresholds to the the ethnographic data from previous chapters and then create perceptive categories of soil pH as relevant to agriculture, the relationship between pH and taste must be determined. This chapter gives evidence of that relationship and describes how this could be applied in eventual categorization of soil taste as it pertains to pH.

5.1: Defining pH and Sense and Perception

The following section will give a short background on how senses are studied and how one can attempt to create categories that are based on how a human might recognize different tastes. I follow Medin and Atran’s (1999) compilation of articles in arguing that an interdisciplinary approach is necessary to incorporate ethnography into taxonomies of the natural world. They include: cognitive physiology, ethnobiology, and philosophy, but are inclusive of any relevant discipline. Overall, ethnopedology is concerned with the question of human mental representation of relevant sensation, a foundational issue in formalizing any perception-based categorization. The disciplines discussed so far; archaeology, permaculture, and ethnopedology, have give a theoretical argument for the relevance and possibility of perceptive categories.

Soil composition universality is affirmed by the ubiquitous FAO soil classification system that is methodologically applicable worldwide. The relevance of these soil typologies to the study of MBA farmers is partial, as they include land fertility as a component of taxonomies but base identification of soil types on scientific rather than perception based attributes. Acknowledging that understanding MBA farmers through contemporary pH science is anachronistic, it is necessary to reconsider soil taxonomies within the constraints of perception. The presented multidisciplinary necessity and feasibility of perceptive categories will now be supplemented with the empirical understanding of the taste-pH relationship. This foundation is based on physiological studies of sensation thresholds and, more specifically, on the discipline with the greatest interest in taste and pH, food science,. Incorporating empirical studies of this relationship, as well our ability to discern sensation thresholds, is the foundation for the feasibility of perceptive categories.

Much perception and sense research attempts to explain neural processes and how the brain responds to stimuli (e.g. Goldstein 1999). Goldstein describes recognition and perception as separate processes, with recognition as “our ability to place an object in a category that gives it meaning” (Goldstein 1999, 4). More explicitly, sensation occurs, perception is the chemical process of tasting, and recognition is the process of cognizing what that taste means.

Because of the subjectivity of perception, it is necessary to incorporate an understanding of how humans are able to recognize a change in what they are sensing; e.g. when something turns from warm to hot or from mild to sour. Linking soil pH to soil taste within the context of farming is an acknowledgment of human recognition. It is the chemical processes that are the basis of perceptive categories. Categories need delineated boundaries; perceptive categories need differentiation of sense. Accordingly, the subset of sense research most relevant here is into thresholds in psychophysical recognition, studying perception for recognition cusps to answer how humans differentiate changes in taste. Weber’s law, an attempt to determine Just Noticeable Difference[2] (JND) in human sensation provides an answer to this question. pH is a measurement of the concentration of Hydrogen ions (protons) in the solution (water based). pH is logarithmic so for every whole

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[2] Just Noticeable Difference is the smallest possible change in stimulus that is discernible by the observer’s senses (Goldstein 1999).

number that pH decreases, there is a 10x increase in concentration (Olmstead and Williams 2008). I will assume that through Weber Fractions, which show JND on a logarithmic scale, sensory perception of pH values can be correlated with the provided pH numerical scale, which represent in logarithmic changes in hydrogen ion concentration [e.g. hydrogen ion concentration in a solution between pH 6 and 7 increases by a power of 10]. This is represented in food science studies of pH-taste relationships, and are introduced in the following section. Therefore, perception of soil pH will be approximated through a comparison to these determinations of pH-taste relationships.

The main application of JND is that it is directly related to the intensity of stimulus. Weber determined this by observing subjects lift weights while attempting to notice an increase in heaviness. He determined that if the weight was light, the subject could identify weight change of smaller increments than if the weight was heavy. Light and heavy in this example have no value because it is the difference between them, not the actual measurements, that change the JND (Goldstein 1999, 10). The mathematical representation of this law is JND/S=K with JND as Just Noticeable Difference, S as Stimuli, and K as a constant value, and is known as the “Weber Fraction” (Goldstein 1999, 11). More recent applications to test the constancy of the Weber Fraction show that, as long as the stimuli does not approach the threshold too closely, it continues to be applicable (e.g. Engen 1972; Gescheider 1976). Therefore, one can approximate differences in perception if these differences are understood within the context of the concentration of stimuli.

JND thresholds as they pertain to taste are generally applied as a test of the viability of Weber Fractions (e.g. McBride 1983, Norwich 1987). Studies divide taste threshold testing into the four commonly identified tastes and associated solutions that are concentrations of chemical compounds associated with each taste; sweet (sucrose), sour (citric acid), salty (sodium chloride), and bitter (caffeine) (McBride 1983). Because my methodology pertains to pH, I will only discuss Weber fractions as they relate to the taste of sourness, or acidity. These boundaries will be discussed further in the following section as they specifically pertain to the formulation of perceptive categories.

Physiological analysis of taste perception is extraordinarily complicated, but the four “basic taste qualities” introduced above are recognized as universal categories of taste delineation (Goldstein 1999, 457). In order to create perceptive categories that describe how taste can differentiate between soils of varying pH, I will use taste science to define a relatively universal method that can measure at what point a person can taste something as ‘sour’ or ‘sweet’.

5.2: pH and Taste: Comparisons from Food Science

While there is little background on specific comparisons between taste and soil pH, there is an extensive amount of research, mostly in food science, to determine the relationship between pH and taste in controlled environments and lab-formulated solutions as they compare to foods. Publications in food science show a consistent relationship between the pH of a substance and taste (e.g. Da Conceicao Neta *et al.* 2007). This literature, when compared with Physiological studies of taste applicable Weber Fractions, show the possibility of direct translation specifically between sour taste intensity and pH, as seen in Figure 5. With this in mind, lab controlled taste associations could be used as a rough model that supports the basic assumptions of perceptive categories - that humans can physically taste differences in pH and recognize associations between taste difference and pH changes.

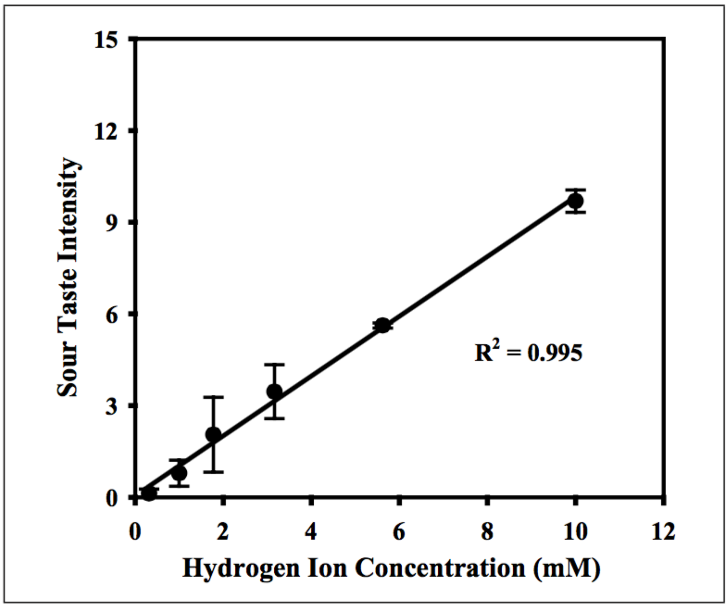

Figure 5: Relationship between sour taste intensity and Hydrogen ion concentration (pH) from .31mM [molar mass] to 10 mM (Da Conceicao Neta et al. 2007, 356).

There are an assortment of chemical compounds that might effect pH in soil. However, studies show that different organic acids (e.g. acetic, citric, malic, and lactic acid) have relatively similar effects on sour taste intensity as shown in an exemplary study by Da Conceicao Neta *et al.* (2007) that compared sour taste to assorted organic acids[3] and hydrogen ion concentrations. As shown in Figure 6, sour taste intensity increases linearly with both hydrogen ion concentration and organic acid concentration, and therefore it is the overall pH rather than the specific acid that determines sour taste intensity (Da Conceicao Neta *et al.*, 2007). This has been supported through studies that show measurable and correlating increases in pH and sour taste intensity (e.g. Lugaz *et al.* 2005; Makhlouf and Blum 1972; Plane *et al*. 1980). Thus, change in any acidic compound that changes pH is directly related to changes in an intensity of sour taste. This is an important factor in applying food science to soil, as there are numerous both organic and inorganic acids and alkalis that contribute to overall soil pH (Mollison 1979, 197).

Since pH and taste have a direct relationship, as exemplified in food science, and taste is used as a sensory tool to categorize soils within the context of

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[3] Organic acids contain carbon are often weaker and “contribute both hydrogen ions and protonated acid species to an aqueous solution” while inorganic acids are mineral based and release protons in aqueous solutions (Da Conceicao Neto *et al.*, 2007). Both are present in soil.

pH, as shown in ethnopedology and permaculture, it is feasible that soil categorization can incorporate perceptive criteria, specifically within the context of farming. To exemplify the possibility of creating perceptive categories, the first steps in this process have been taken to determine what the boundaries of human perception are when defining sour taste as it relates to pH. There is a necessity for sense-based typologies that are specifically relevant to farming, and while these categories need further empirical research, there exists a feasible structure for their establishment.

Conclusion

The perceptive based methodology outlined in this section is an attempt to consider the relationship between the methods of pedological categorization of modern scientific practices and methods a farmer might use. In acknowledging the anachronism of pH to MBA actors, this chapter examined the possibility of categorizing soils based on pH characteristics perceptible to a farming craftsperson.

A possible construction of such categorization, based at this point only on hypothesized theoretical relationships, could be with following categories: (1) sour: acidic, soils with a pH below 4.5 that are completely unviable for arable land; (2) somewhat sour: slightly acidic soils with a pH between 4.5 and 5.9 that are only viable for some plants; (3) neutral: soils with a pH between 5.9 and 7.5 that are viable to all agricultural uses (4) somewhat sweet: soils with a pH above 7.6 that are generally unviable for arable land. While pH 7.8 and above is not evident in West Frisia, this final category is created in order to encompass all possible pH values and show viability for application in other ecologies.

These categories are an approximation based upon the relevant knowledge to farmers presented throughout this work; what is discernible with the senses and where boundaries might matter for agricultural fertility. These categories show the structure of categorization possible with further empirical research to determine the actual abilities of farmers' taste differentiation in soils. The presented groupings are broad categories and are a basic estimation of where taste delineation might lie.

The methodology combined modern research and ethnographic studies to propose perceptive categories relevant to all farming craftspeople through the context of MBA West Frisia. Taking that into account, I used MBA arable land composition in West Frisia to understand possible identification processes, considering soil as a material, that farmers skillfully interpreted and manipulated. This proposes one possible way farmers might have used skill to connect known entities in the archaeological record: soil type and land use. This methodology builds upon archaeologists' ability to identify crop choices in relation to soils (Chevalier *et al.* 2014) and works to make headway in our comprehension of prehistoric farmers' relationships with soils using the imposed structure of a farming *chaîne opératoire*. These categories are meant as a tool to categorize how soil might "behave and how this is observable - and thus understood - by craftspeople" (Kuijpers 2014, 78) [in reference to metallurgy]. With this in mind, the utility of my proposed method is to utilize sensory soil identification systems and soil based agricultural science to interpret *how* perception can play a role in MBA farmers' understanding of soil as a workable material and, further, to interpret other archaeological data in light of the decision making process of this craft.

Chapter 6: Conclusion

Introduction

The purpose of this thesis is to present a method of categorizing soil guided by human perception. Pedology on the whole works with perception, through color, texture, and comparative tools, but does not fully explore these characteristics within the context of agriculture. As archaeologists, our minutely detailed knowledge of soil chemistry provides a limited understanding of land use decisions made by farmers without access to modern science. Modern craft theory attempts to approach the actors' perceptions of their craft materials. Therefore, I have presented a craft theory approach to farming and hypothesized perceptive categories for soil typology in an effort to address this fundamental problem.

6.1: Research Questions

Agriculture relies on a skill-based relationship with land, and therefore soil, as a material. This relationship, which facilitates interaction with and manipulation of the land, has the potential to enlighten our understanding of land use actions in the past. The criteria used to choose this land would inform farming-skill related decisions and in order to explore such criteria, this thesis has applied the methodology of 'craft theory' to the archaeological study of farming.

As a case study, I applied this proposal to the Middle Bronze Age in West Frisia, a subsistence agricultural culture that is defined by mixed agricultural techniques and differing land use strategies between adjacent, yet compositionally dissimilar, geographical areas. In West Frisia, land used for agriculture would likely have been chosen from a plethora of environmental conditions. By using arable land composition data compiled and described by van Amerongen (2016), this thesis reconsiders numerical values of compositional soil science and discusses the possibility of soil categorization that can be defined with the senses. Returning to the original research questions, to incorporate perception into agriculturally relevant pedology, I was able to propose an alternative methodology that presents the possibility of translating between sense base identification and scientific categorization. While my proposed categories are not as detailed as they could be with an empirical study of contemporary farmers tasting soil and differentiating between pH, they do represent an application of this concept and can act as a foundation for further research. Overall, this approaches a more relevant understanding of land use strategies through exploring the pertinence of information within the context of farming. In turn, perceptive categories become applicable to soil, and therefore land, differentiation West Frisian Bronze Age. Upon further study, such categories could be used to support explanations of regional differentiation in land use.

6.2: Evaluation of Methodology

My methodology follows craft theory, which seeks a congruence between scientific soil composition data and strategies to define the same compositional factors using senses. Craft theory adds complexities to the *chaîne opératoire* by categorizing steps through the perception of the craftspeople. As farming had not been studied as a craft before, this thesis proposed a *chaîne*. Focussing on soil as the raw material, it then provided a mechanism by which the pH data of modern pedology could be described through the perception of taste of the soil.

I acknowledge that craft theory and its application here face challenges and limitations. These are discussed in 4.3 of Chapter 4. The challenge of proposing the perception of others, especially historical actors, is felt deeply, as is the generalization of perception across times and places. Additionally, without conducting an empirical study of my proposed categorization it is unrealistic to definitively determine soil pH perception. Therefore, the the perceptive categorization I have lauded throughout this work has not been explicitly laid out. For now, this limitation is acceptable because of how basic this thesis is as an initial proposition of a methodology, and because I am only attempting to conceptualize how perception and skill might be understood in MBA farming, but these limitations are important to keep in mind if further research is undertaken using this methodology.

6.3: Possible Applications and Further Research

At this point I will return to the quote that began this thesis, “The closer soils are defined, it seems, the less likely we are to know them” (Mollison 1988). This mentality is the foundation of my methodology, and has informed the reconsideration of archaeological data that is presented in my results. I have attempted to describe sense-based comprehension of soil composition in a way that is more *relevant* to the skills that MBA West Frisian farmers might have used to practice agriculture.

A skilled reading of soil composition would allow MBA farmers to asses land and its potential for agricultural use. With the potential for volatile pH, West Frisian soil presents a problem for farmers looking for consistent agricultural yields, and while archaeologists are aware of what soil composition characteristics are necessary for agricultural viability, these are based on agricultural science, experimental work, and ethnographic studies as they relate to agricultural science. Thus, I have suggested the possibility of reorganizing arable land composition data into what I consider to be a more skill-relevant set of criteria to describe what farmers can perceive. The applications of a soil re-categorization based on perception has numerous ramifications for how archaeologists understand farmers’ cognition of the farmscape.

I have attempted to create a tool with which to reconsider the organization of farmscape, and have laid the foundation for further application of perceptive categories as they relate to land use decisions. Therefore, questions asked about how and why Bronze Age settlements were organized (Arnoldussen 2010) are closer to being answered through an understanding of how Bronze Age farmers might have skillfully organized the environment as it related to their craft. Understanding farmers perception, rather than using archaeological data to predict that perception, can perhaps begin to address the oft problematic “mismatch between archaeological expectation and archaeological reality” (van Zijverden 2017, 130).

Figures

Tables

Abstract

This thesis works to address the following proposed obstacle to researchers: potential nuances of small-scale farming in prehistory are likely lost to archaeologists who are personally inexperienced with subsistence living. Without a breadth of agricultural knowledge, it is challenging to understand the extensive possibilities for and reasons behind regional differentiation in food production, farmyard organization, animal husbandry, and local ecological constraints. My aim is to propose an interdisciplinary approach to *why* regional differentiation occurred and *how* farmers dealt with the necessity of small-scale adaptation to their immediate environment.

This thesis assumes that farming skill relies on an intelligent interaction with the environment and an ability to respond to constant fluctuations in material composition and behavior. I approach the question, 'how can one formulate a scientific approach to subjective experience?', by asking 'Why is perception, defined as any sensory input, relevant to agricultural soil identification as used in archaeology, and can perception be incorporated into soil typologies within the context of the ecological and archaeological record of the Middle Bronze Age of West Frisia, Netherlands?'

To answer these questions, this thesis reinterprets agriculture in Middle Bronze Age West Frisia within the framework of craft theory. Craft theory is used as a methodological framework to propose perceptive categories that work explore the agricultural relevance of soil composition and identification strategies. These categories, contextualized within the format of a farming *chaîne opératoire*, work to show the *how* of skilled soil identification as relevant to agricultural craft. By ethnographic examples of agriculturally relevant perceptive land categorization, a chemical understanding of taste, and empirical findings into the relationship between a subject's taste experience and a soil's chemical pH, the feasibility of perceptive categorization is presented.

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Appendix

Appendix A: All compiled pit samples from Bovenkarspel het Valkje and Enkhuizen Kadijken with max and min pH, nitrogen, and salinity values for each collected botanical remain (from van Amerongen 2016).

Site Name	Pit	Structure	Taxa	pH min	pH max	N min	N max	Salt min	Salt max
Bovenkarspel 't Valkje	5	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	5	Huisgreppel	*Chenopodium polyspermum*	99	99	8	8	0	0
Bovenkarspel 't Valkje	5	Huisgreppel	*Lamium purpureum*	7	7	7	7	0	0
Bovenkarspel 't Valkje	5	Huisgreppel	*Polygonum persicaria*	7	7	7	7	0	0
Bovenkarspel 't Valkje	5	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	7	Huisgreppel	*Polygonum persicaria*	7	7	7	7	0	0
Bovenkarspel 't Valkje	7	Huisgreppel	*Solanum nigrum*	7	7	8	8	0	0
Bovenkarspel 't Valkje	7	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	7	Huisgreppel	*Veronica agrestis-type*	7	7	7	7	0	0
Bovenkarspel 't Valkje	15	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	15	Huisgreppel	*Urtica urens*	99	99	8	8	0	0
Bovenkarspel 't Valkje	15	Huisgreppel	*Solanum nigrum*	7	7	8	8	0	0
Bovenkarspel 't Valkje	15	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	15	Huisgreppel	*Veronica agrestis-type*	7	7	7	7	0	0
Bovenkarspel 't Valkje	19	Huisgreppel	*Polygonum persicaria*	7	7	7	7	0	0
Bovenkarspel 't Valkje	19	Huisgreppel	*Solanum nigrum*	7	7	8	8	0	0
Bovenkarspel 't Valkje	19	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	19	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	19	Huisgreppel	*Euphorbia peplus*	99	99	7	7	0	0
Bovenkarspel 't Valkje	19	Huisgreppel	*Solanum nigrum*	7	7	8	8	0	0
Bovenkarspel 't Valkje	19	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	19	Huisgreppel	*Urtica urens*	99	99	8	8	0	0
Bovenkarspel 't Valkje	19	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	19	Huisgreppel	*Echinochloa crus-galli*	99	99	8	8	0	0
Bovenkarspel 't Valkje	32	Huisgreppel	*Polygonum persicaria*	7	7	7	7	0	0
Bovenkarspel 't Valkje	32	Huisgreppel	*Veronica hederifolia*	7	7	7	7	0	0
Bovenkarspel 't Valkje	32	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	32	Huisgreppel	*Veronica persica type*	7	7	7	7	0	0
Bovenkarspel 't Valkje	32	Huisgreppel	*Solanum nigrum*	7	7	8	8	0	0
Bovenkarspel 't Valkje	32	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	32	Huisgreppel	*Solanum nigrum*	7	7	8	8	0	0
Bovenkarspel 't Valkje	32	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	32	Huisgreppel	*Solanum nigrum*	7	7	8	8	0	0
Bovenkarspel 't Valkje	32	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	32	Huisgreppel	*Chenopodium polyspermum*	99	99	8	8	0	0
Bovenkarspel 't Valkje	32	Huisgreppel	*Solanum nigrum*	7	7	8	8	0	0
Bovenkarspel 't Valkje	32	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	32	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	32	Huisgreppel	*Solanum nigrum*	7	7	8	8	0	0
Bovenkarspel 't Valkje	32	Huisgreppel	*Stellaria media*	7	7	8	8	0	0

Bovenkarspel 't Valkje	32	Huisgreppel	*Solanum nigrum*	7	7	8	8	0	0

Bovenkarspel 't Valkje	92	Huisgreppel	*Solanum nigrum*	7	7	8	8	0	0
Bovenkarspel 't Valkje	92	Huisgreppel	*Veronica agrestis-type*	7	7	7	7	0	0
Bovenkarspel 't Valkje	92	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	95	Huisgreppel	*Solanum nigrum*	7	7	8	8	0	0
Bovenkarspel 't Valkje	95	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	95	Huisgreppel	*Solanum nigrum*	7	7	8	8	0	0
Bovenkarspel 't Valkje	95	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	100	Huisgreppel	*Solanum nigrum*	7	7	8	8	0	0
Bovenkarspel 't Valkje	100	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	101	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	105	Huisgreppel	*Solanum nigrum*	7	7	8	8	0	0
Bovenkarspel 't Valkje	105	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	117	Huisgreppel	*Sonchus asper*	7	7	7	7	1	1
Bovenkarspel 't Valkje	117	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	121	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	121	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	121	Huisgreppel	*Veronica agrestis-type*	7	7	7	7	0	0
Bovenkarspel 't Valkje	121	Huisgreppel	*Solanum nigrum*	7	7	8	8	0	0
Bovenkarspel 't Valkje	121	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	121	Huisgreppel	*Fumaria officinalis*	6	6	7	7	0	0
Bovenkarspel 't Valkje	121	Huisgreppel	*Polygonum persicaria*	7	7	7	7	0	0
Bovenkarspel 't Valkje	121	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	121	Huisgreppel	*Veronica agrestis-type*	7	7	7	7	0	0
Bovenkarspel 't Valkje	123	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	123	Huisgreppel	*Echinochloa crus-galli*	99	99	8	8	0	0
Bovenkarspel 't Valkje	123	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	123	Huisgreppel	*Fumaria officinalis*	6	6	7	7	0	0
Bovenkarspel 't Valkje	123	Huisgreppel	*Polygonum persicaria*	7	7	7	7	0	0
Bovenkarspel 't Valkje	123	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	123	Huisgreppel	*Fumaria officinalis*	6	6	7	7	0	0
Bovenkarspel 't Valkje	123	Huisgreppel	*Polygonum persicaria*	7	7	7	7	0	0
Bovenkarspel 't Valkje	123	Huisgreppel	*Echinochloa crus-galli*	99	99	8	8	0	0
Bovenkarspel 't Valkje	123	Huisgreppel	*Fumaria officinalis*	6	6	7	7	0	0
Bovenkarspel 't Valkje	123	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	123	Huisgreppel	*Polygonum persicaria*	7	7	7	7	0	0
Bovenkarspel 't Valkje	123	Huisgreppel	*Solanum nigrum*	7	7	8	8	0	0
Bovenkarspel 't Valkje	123	Huisgreppel	*Sonchus asper*	7	7	7	7	1	1
Bovenkarspel 't Valkje	123	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	123	Huisgreppel	*Veronica agrestis-type*	7	7	7	7	0	0
Bovenkarspel 't Valkje	134	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	134	Huisgreppel	*Polygonum persicaria*	7	7	7	7	0	0
Bovenkarspel 't Valkje	134	Huisgreppel	*Solanum nigrum*	7	7	8	8	0	0
Bovenkarspel 't Valkje	134	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	134	Huisgreppel	*Veronica agrestis-type*	7	7	7	7	0	0
Bovenkarspel 't Valkje	134	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	32	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	32	Huisgreppel	*Solanum nigrum*	7	7	8	8	0	0
Bovenkarspel 't Valkje	32	Huisgreppel	*Stellaria media*	7	7	8	8	0	0

Bovenkarspel 't Valkje	32	Huisgreppel	*Solanum nigrum*	7	7	8	8	0	0
Bovenkarspel 't Valkje	32	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	32	Huisgreppel	*Polygonum persicaria*	7	7	7	7	0	0
Bovenkarspel 't Valkje	32	Huisgreppel	*Solanum nigrum*	7	7	8	8	0	0
Bovenkarspel 't Valkje	32	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	34	Huisgreppel	*Polygonum persicaria*	7	7	7	7	0	0
Bovenkarspel 't Valkje	34	Huisgreppel	*Solanum nigrum*	7	7	8	8	0	0
Bovenkarspel 't Valkje	34	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	40	Huisgreppel	*Euphorbia peplus*	99	99	7	7	0	0
Bovenkarspel 't Valkje	40	Huisgreppel	*Fallopia convolvulus*	99	99	6	6	0	0
Bovenkarspel 't Valkje	40	Huisgreppel	*Solanum nigrum*	7	7	8	8	0	0
Bovenkarspel 't Valkje	40	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	40	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	40	Huisgreppel	*Chenopodium polyspermum*	99	99	8	8	0	0
Bovenkarspel 't Valkje	40	Huisgreppel	*Euphorbia peplus*	99	99	7	7	0	0
Bovenkarspel 't Valkje	40	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	40	Huisgreppel	*Solanum nigrum*	7	7	8	8	0	0
Bovenkarspel 't Valkje	40	Huisgreppel	*Solanum nigrum*	7	7	8	8	0	0
Bovenkarspel 't Valkje	40	Huisgreppel	*Echinochloa crus-galli*	99	99	8	8	0	0
Bovenkarspel 't Valkje	40	Huisgreppel	*Echinochloa crus-galli*	99	99	8	8	0	0
Bovenkarspel 't Valkje	40	Huisgreppel	*Chenopodium polyspermum*	99	99	8	8	0	0
Bovenkarspel 't Valkje	40	Huisgreppel	*Polygonum persicaria*	7	7	7	7	0	0
Bovenkarspel 't Valkje	40	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	40	Huisgreppel	*Veronica agrestis-type*	7	7	7	7	0	0
Bovenkarspel 't Valkje	40	Huisgreppel	*Solanum nigrum*	7	7	8	8	0	0
Bovenkarspel 't Valkje	40	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	40	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	40	Huisgreppel	*Euphorbia peplus*	99	99	7	7	0	0
Bovenkarspel 't Valkje	40	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	40	Huisgreppel	*Chenopodium polyspermum*	99	99	8	8	0	0
Bovenkarspel 't Valkje	40	Huisgreppel	*Solanum nigrum*	7	7	8	8	0	0
Bovenkarspel 't Valkje	40	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	40	Huisgreppel	*Echinochloa crus-galli*	99	99	8	8	0	0
Bovenkarspel 't Valkje	46	Huisgreppel	*Chenopodium polyspermum*	99	99	8	8	0	0
Bovenkarspel 't Valkje	46	Huisgreppel	*Polygonum persicaria*	7	7	7	7	0	0
Bovenkarspel 't Valkje	46	Huisgreppel	*Solanum nigrum*	7	7	8	8	0	0
Bovenkarspel 't Valkje	46	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	46	Huisgreppel	*Urtica urens*	99	99	8	8	0	0
Bovenkarspel 't Valkje	46	Huisgreppel	*Euphorbia peplus*	99	99	7	7	0	0
Bovenkarspel 't Valkje	46	Huisgreppel	*Polygonum persicaria*	7	7	7	7	0	0
Bovenkarspel 't Valkje	46	Huisgreppel	*Solanum nigrum*	7	7	8	8	0	0
Bovenkarspel 't Valkje	46	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	46	Huisgreppel	*Veronica agrestis-type*	7	7	7	7	0	0
Bovenkarspel 't Valkje	46	Huisgreppel	*Echinochloa crus-galli*	99	99	8	8	0	0
Bovenkarspel 't Valkje	92	Huisgreppel	*Echinochloa crus-galli*	99	99	8	8	0	0
Bovenkarspel 't Valkje	134	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	136	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	136	Huisgreppel	*Solanum nigrum*	7	7	8	8	0	0
Bovenkarspel 't Valkje	136	Huisgreppel	*Stellaria media*	7	7	8	8	0	0

Bovenkarspel 't Valkje	139	Huisgreppel	*Veronica agrestis-type*	7	7	7	7	0	0
Bovenkarspel 't Valkje	139	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	139	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	177	Huisgreppel	*Fallopia convolvulus*	99	99	6	6	0	0
Bovenkarspel 't Valkje	177	Huisgreppel	*Solanum nigrum*	7	7	8	8	0	0
Bovenkarspel 't Valkje	177	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	181	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	181	Huisgreppel	*Polygonum persicaria*	7	7	7	7	0	0
Bovenkarspel 't Valkje	181	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	181	Huisgreppel	*Echinochloa crus-galli*	99	99	8	8	0	0
Bovenkarspel 't Valkje	181	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	181	Huisgreppel	*Silene gallica*	7	7	6	6	0	0
Bovenkarspel 't Valkje	181	Huisgreppel	*Solanum nigrum*	7	7	8	8	0	0
Bovenkarspel 't Valkje	181	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	181	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Bovenkarspel 't Valkje	181	Huisgreppel	*Echinochloa crus-galli*	99	99	8	8	0	0
Bovenkarspel 't Valkje	181	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Enkhuizen Kadijken 5b	1	Huisgreppel	*Solanum nigrum*	7	7	8	8	0	0
Enkhuizen Kadijken 5b	3	Huisgreppel	*Solanum nigrum*	7	7	8	8	0	0
Enkhuizen Kadijken 5b	3	Huisgreppel	*Fumaria officinalis*	6	6	7	7	0	0
Enkhuizen Kadijken 5b	3	Huisgreppel	*Solanum nigrum*	7	7	8	8	0	0
Enkhuizen Kadijken 5b	3	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Enkhuizen Kadijken 5b	12	Huisgreppel	*Anagallis arvensis*	99	99	6	6	0	0
Enkhuizen Kadijken 5b	12	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Enkhuizen Kadijken 5b	21	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Enkhuizen Kadijken 5b	21	Huisgreppel	*Vicia hirsuta*	99	99	4	4	0	0
Enkhuizen Kadijken 5b	40	Huisgreppel	*Stellaria media*	7	7	8	8	0	0
Enkhuizen Kadijken 5b	44	Huisgreppel	*Stellaria media*	7	7	8	8	0	0