land

MDPI

Article

Coping with Risk. A Deep-Time Perspective on Societal Responses to Ecological Uncertainty in the River Dalälven Catchment Area in Sweden

Kailin Hatlestad [1,*], Joakim Wehlin [1,2] and Karl-Johan Lindholm [1]

[1] Department of Archaeology and Ancient History, Uppsala University, P.O. Box 626, 751 26 Uppsala, Sweden; joakim.wehlin@arkeologi.uu.se (J.W.); karl-johan.lindholm@arkeologi.uu.se (K.-J.L.)
[2] Dalarnas Museum, P.O. Box 22, 791 21 Falun, Sweden
* Correspondence: kailin.hatlestad@arkeologi.uu.se

Abstract: In addressing the current climate crisis, research into how past societies have coped with risk and ecological uncertainty can provide old solutions to new problems. Here, we examine how human niche construction can be seen as risk management in the face of uncertainty by exploring the spatial patterning of land-use activities over time. Dalarna county, an agriculturally marginal boreal forest environment, provides the opportunity for addressing change in terms of agricultural responses and other activities. C14 archaeological records complied by Dalarna Museum were the base of this analysis. The spatial and temporal components of these Boreal Forest records were analyzed in the open-source software QGIS, guided by a historical ecology framework. Human niches diversified and intensified during specific periods in the Boreal forest environment; our focus has been on how humans managed resource risk related to the ecological uncertainty within this forest environment characterized by long winters and short growing seasons. We conclude that constructed niches shaped the Boreal Forest, spanning its environmentally unique upland and lowland regions, into a more predictable environment. Tracking the diversity, multi-functionality, and intensity of these past land-use activities can provide insights for best practices in land management, not only for the Boreal Forest area, but also for elsewhere. These insights will assist in policy-making decisions, as the methodology is adaptable and replicable for various landscapes.

Keywords: risk management; land use; human niche construction; radiocarbon dating; spatio-temporal analysis; GIS

Citation: Hatlestad, K.; Wehlin, J.; Lindholm, K.-J. Coping with Risk. A Deep-Time Perspective on Societal Responses to Ecological Uncertainty in the River Dalälven Catchment Area in Sweden. *Land* **2021**, *10*, 883. https://doi.org/10.3390/land10080883

Academic Editors: Nik Petek-Sargeant, Federica Sulas and Paul Lane

Received: 11 May 2021
Accepted: 20 August 2021
Published: 23 August 2021

1. Introduction

Environmental change has always been difficult to predict and prepare for. The current unprecedented effects of global warming mean looming changes will still be more challenging to prepare for. We are now aware that the evolution of our land use has contributed to our current climatic situation. We must seek solutions in our uses of land to help mitigate global warming effects. The past can inform our thinking processes about the future and better inform our land use decisions with examples of how ecological uncertainty has been handled over time. Fortunately, archaeological and paleoecological records show 'completed' information or at least the process of information over the long durée [1]. Our work here attempts a meta-analysis of the Dalälven catchment area's experience and practice, as the Dalälven, a river system over 500 km long running through central Sweden, provides a rich spatio-temporal dataset across diverse topography.

This paper undertakes initial steps toward an integrated landscape analysis (ILA) of this study area. ILA is a process that synthesizes multiple lines of scientific inquiry in order to understand and explore environmental and societal interactions and develop new approaches to contemporary issues, in this case, for sustainable land management [2,3]. Our focus here has been to identify general trends in the archaeological material and radiocarbon dates within the river Dalälven catchment area to understand how these local and regional communities responded to risk and ecological uncertainty.

1.1. Understanding Risk and Human Niche Construction

Risk management is crucial for success in any environment, as all settings present some risk; we define risk as a chance for undesirable consequences or "the effect of uncertainty on objectives [4]". As seen in past human activities, archaeological studies of risk management have focused on how groups provided for continued subsistence [5–7]. In that same vein, this paper focuses on how humans managed resource risk related to ecological uncertainty, as it applies to unpredictability of ecological events, in a boreal environment characterized by long winters and short growing seasons. We have aimed to investigate how the archaeological manifestations of human niche construction in this environment worked to mitigate risk and foster resource stability.

Humans have constructed niches throughout time to make landscapes and their ecologies act more predictably or, in other terms, to avoid risk [5,8]. These niche construction activities, specifically land use activities as we are concerned with here, alter landscapes' form or structure and ecological function during the process [8,9]. Ecologist Richard Levins and biologist Richard Lewontin, two initiators of niche construction theory (NCT), describe niche construction in their 1985 book, *The Dialectic Biologist*, as a process in which "an organism influences its own evolution, by being both the object of natural selection and the creator of the conditions of that selection (1985)". Our paper focuses on land use as one aspect of the "creation of the conditions [10]". Niche construction has been argued to include a wide range of human activities, for which it has drawn criticism for being amorphous or a catch-all phrase. However, we see niche construction as helpful in understanding human land use, as land-based activities leave a long-lasting footprint that feeds into how future society can construct niches [11–15]. We argue that niche construction responds to resource risk with land use activities, and these leave a residual mark on the land in the form of both features and spatial organization. The temporal feedback of land use equates it with niche construction as "organisms modify—deliberately or inadvertently—their own and other organisms' selective environment to such a degree that it changes the selection pressures acting on present and future generations of said organism or organisms [12]".

Risk sensitivity theory, a theory explored within a wide range of disciplines from ecology to economics, suggests that organisms move from risk-averse behaviors to risk-prone behaviors in times of need [6,7]. Accepting this theory implies that organisms manage risk by experimenting with new, untried, or unproven behaviors when in need. Typical risk management steps include avoidance, transfer and sharing, mitigation, and then acceptance [5,16–18]. These phases of risk management relate to the concept of resilience; the definition of resilience embeds the concept of risk in that resilience means persistence in the face of loss and uncertainty [19–21]. Thus, both theories advocate for diversification as a mechanism to mitigate risk, protect against uncertainty, and provide for resilience [5,7,22].

As noted above, humans have constructed niches to promote resource availability predictability, which manages risk by default. By engaging in subsistence activities learned from experiences, termed ancestral niche behavior, such as settling near waterways that provide reliable resources and transportation routes or continuing traditional hunting practices, niches work to avoid risk [23]. Niches can also transfer or share risk, most commonly seen in the diversification of niches but directly connected to trade and the niches that support it. Winterhalder et al. argue that risk sensitivity analysis in anthropological settings is qualitative and often assigns risk-averse behavior to outcomes; however, certain factors can influence humans to create or adopt initially risky niches [6,7]. For example, environmental factors, cultural diffusion, population pressure, and the social capital associated with it provide an impetus for a risk to be taken. However, if successful, these risks develop predictable resources that can potentially intensify and further exploitation.

A better understanding of risk management (i.e., the activity of niche construction for predictability) within this boreal forest environment can inform how to create future niche practices that promote sustainable landscape dynamics. Spatial and temporal analysis of radiocarbon records retrieved from archaeological contexts in the Boreal Forest in Dalarna, Sweden provides the basis for the approach. This analysis will explore the following questions:

- Can we see how human niche construction in Dalarna is a response to ecological uncertainty?
- How were niches spatially organized across the landscape to deal with inherent ecological uncertainty?
- How did these niches adjust over time?

Insights to these questions would contribute to a better understanding of the following phenomena over approximately 11,000 years:

- The nature of the use of the outland Boreal forest in the Dalälven catchment and its diversification.
- The appearance of the agriculture niche and its intensification.
- Regional variation in land use.

Our archaeological study of land use and radiocarbon dates aims to address risk and uncertainty from a quantitative point of view. It aims to provide foundations for measuring the consequences of spatial diversification on human-environmental resilience and the effects of niche diversification and intensification on the ecological functioning of the Boreal forest environment. Ultimately, our goal has been to map the development of human niche construction in our study area over time to identify the effectiveness these constructions have for guarding against risk in this particular environment.

The following section discusses the study area environment, focusing on the variable environmental aspects of the Dalälven catchment and the inevitable challenges this presents to human land use. Subsequently, we provide a brief overview of previous research in the study area. Next, we describe the methods used in this analysis, followed by the analysis results and, finally, a discussion of the results.

1.2. Study Area: Dalälven Catchment and the Boreal Forest

It is first necessary to outline the main components of the environment in order to understand human niche construction and ecological functioning in this region. The study area is situated in the catchment area of the river Dalälven (28,927 km^2), which is the southernmost of the big rivers of northern Sweden (Figure 1). Dalälven is formed by a confluence of two rivers, the Österdalälven (East Dalälven) and Västerdalälven (West Dalälven), which originate in the Scandinavian Mountain range and flow over 500 km southeast before discharging into the Baltic Sea. The easternmost part of Dalälven provides a natural southern border to Sweden's Norrland region [24].

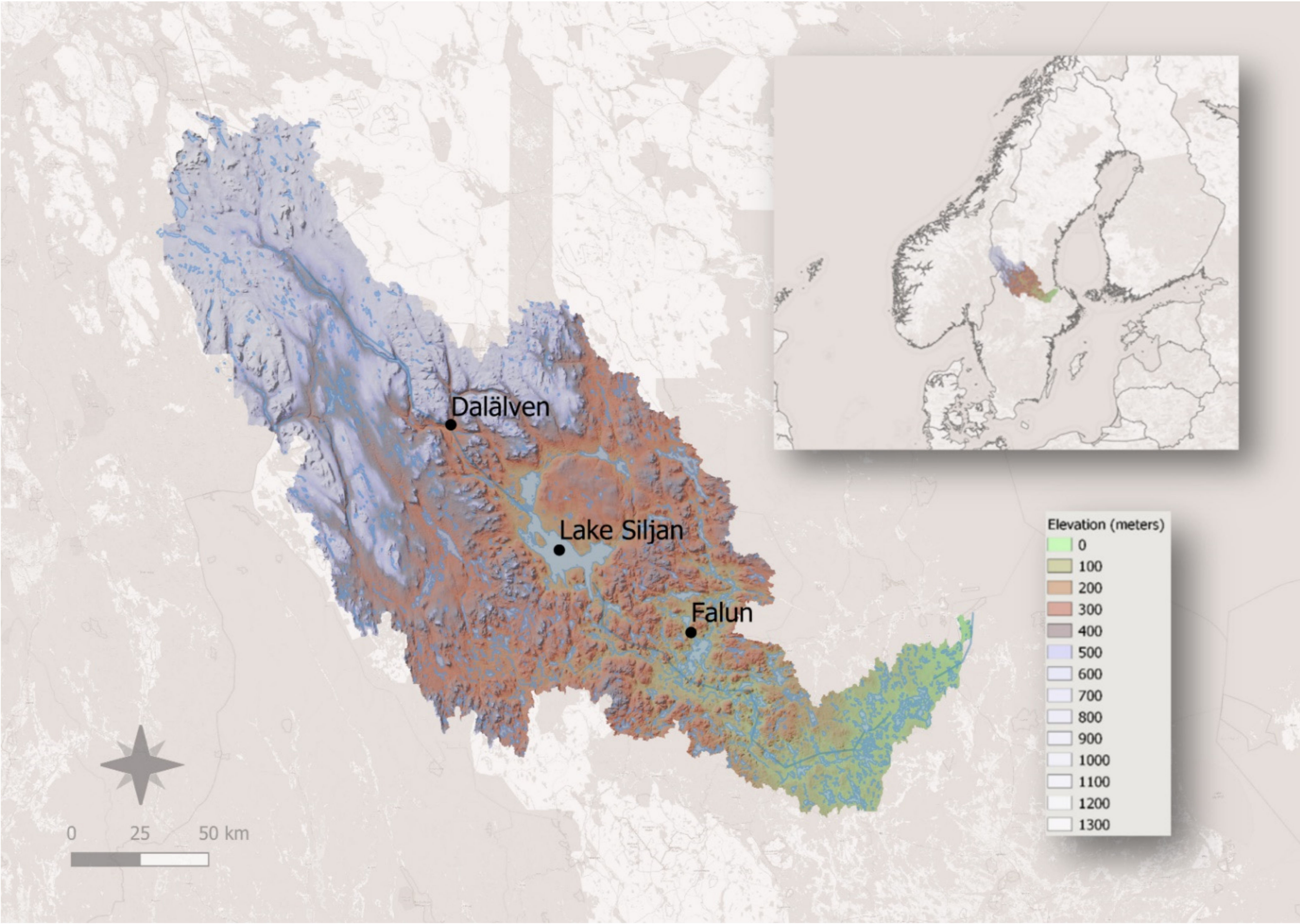


Figure 1. Study area digital elevation map (DEM), Dalälven catchment, Dalarna län; *elevation DTM 50 m© Lantmäteriverket; shoreline data provided by Strandnivåer Rikstäckande at 1800 CE© SGU; rivers and boundaries shapefiles courtesy of the European Environmental Agency (EEA); background map© OpenStreetMap contributors*.

Lake Siljan is situated in the center of the study area and is the largest lake in the entire Dalälven catchment, with a surface area of 292 km^2 [25]. After the confluence of the Österdalälven and Västerdalälven just south of Siljan, the river passes the Tuna plain and soon trends east, changing character. It leaves the deep valley and enters into a flat country, uniquely marked by a series of eskers. The eskers were formed during the retreat of the Weischselian ice sheet ~12,000 years ago [26]. The ice sheet left behind many depressions on the land surface; thus, bogs and numerous lakes are also characteristic of the boreal zone. The last 120 km before emptying into the Baltic, the river alternates between large bays dotted with small islands and rapids. Regular flooding, sometimes over vast areas, also characterizes this section of the Dalälven. After the retreat of the glacial ice sheet this final stretch of Dalälven was below sea level. Over time, along with isostatic uplift, i.e., the process by which land rises out of the sea, the land area has gradually extended eastwards, and the eskers became the best sites for initial human occupation [26–28].

The environment of the study area is predominantly boreal forest, characterized by strong seasonal variation, with long and cold winters and short, moderately warm, and moist summers [29]. Environmentally unique regions, conjoined by the Dalälven, were roughly divided geographically by us: the mountain region, the interior forest region, Lake Siljan, the Tuna plain, and the coastal region. The undulating terrain and dramatic differences in altitude, slope direction, soils, and the drainage system affects vegetation and growing seasons, which are considerably shorter at higher altitudes and in specific localized settings. In boreal environments, rivers and large lakes have temperature-equalizing effects, and local climate tends to be milder in the vicinity of these sizable water bodies [30].

Holm has summarized environmental factors to consider for farming and livestock herding in a boreal environment [30]. The proximity to a large open lake reduces the risk of damage to grain from frost during late summer and autumn nights as the lake will operate as a heat reservoir, warming the overflowing air masses. These temperature-equalizing effects during late summer and autumn are favorable for cultivation. Higher grounds with forest and mire dominated a large portion of our study area, which is a disadvantage in terms of farming conditions, as there is more risk of frost. This risk further increases in depressions and valleys without large water bodies, as heavy cold air sinks. Cultivation favors soils in a crest or slope position (i.e., upon a hillside).

Compared to farming, livestock herding is less sensitive to the climatic conditions of the boreal environment. Livestock production is more mobile and able to exploit a broader range of topographies for fodder, such as mires and meadows [30–32]. A prerequisite for extensive livestock production in the boreal forest was the availability of wetlands on which vegetation could be harvested and used for winter fodder [30]. A shieling is a periodic settlement established in an outfield area where grazing away from arable land occurred during the summer months [32–34]. Such hay-meadows were widespread and generally occurred across northern Sweden in the mid-19th century [33].

1.3. General Archaeological Outlook and Previous Research

The prehistoric period spans over 9000 years in the study area, from when the Weichselian ice sheet retreated until the end of the Viking Age in the 11th century (Figure 2). Archaeology and palaeobotany have discovered that the study area is a diverse but consistent record of archaeological sites along the shores of the lakes, reflecting a penchant to establish settlement in open areas with reliable marine resources. The forested regions also contain archaeological sites, usually reflecting the use of resources, such as game, pastures, wood, rock, and minerals [35,36]. Archaeological research in the study area has primarily focused its studies on specific prominent sites or on establishing general cultural–historical frameworks. From this, it is possible to outline some general characteristics of the record. Stone Age sites are in most cases represented by surface scatters of flaked stone or stray finds near the shores of lakes or rivers; however, some sites, e.g., the Mesolithic site of Limsjön, Leksand, present a more complex archaeological context [27,28,37]. Agricultural activities in Scandinavia's central agricultural regions are usually related to the Neolithic and Bronze Age, except this horizon is obscure, and research suggests that hunting and gathering was the dominant lifeway until agriculture's more regular appearance in the Vendel Period (c. 550–750 CE). Although connections between the exploitation of the forested outlands and the agricultural plains and coastal areas have been archaeologically well established from an early phase, the nature of these dynamic systems is still not fully understood [38–41]. The richest archaeological records formed during the Iron Age (c. 500 BCE–1050 CE) onwards. The first permanent agrarian settlements are generally perceived as belonging to the Viking Age (c. 750–1050 CE) or the Middle Ages (c. 1050–1520 CE), and their presence is explained as a result of population growth and the new technologies that facilitated farming in forested areas. However, a growing body of archaeological data is now challenging this view, supplemented by an increasing number of studies based on modern methods incorporating computational spatio-temporal analysis and absolute dating that highlight variability in the archaeological record [42–45].

Figure 2. Weichselian ice sheet and shorelines in 8800 BC in relation to the Dalälven catchment study area; *shoreline data provided by Strandnivåer Rikstäckande© SGU; boundaries' shapefiles courtesy of the European Environmental Agency (EEA); background map courtesy of Google*.

As mentioned above, Sweden's Iron Age has produced the richest archaeological records, but the information over this large time frame (500 BCE–1050 CE), until recently, has remained a bit flat. However, a new empirical phase is emerging in outland archaeology. A number of ongoing projects, such as Contesting Marginality (UTMA) and Farmers as Hunters, aim to understand the role of Scandinavia's forested inland in the larger historical developments that took place in northern Europe over the last three millennia [46–48]. Recent work by Hennius has also relied on radiocarbon dating to place stricter chronological control on past activities and allow for more accurate comparison with environmental data [24]. However, until now, few studies have taken advantage of the advancing technologies in dating and increasing compilation of radiocarbon dates and then paired them with the detailed work of previous scholars to test and explore data in new ways. The ambition of the present study is to initiate such work with a methodology based on radiocarbon dates linked to a series of specific activities. The next section will outline this methodology.

2. Materials and Methods

2.1. Framework

This present work aims to refine the historical ecology of the region and provide a framework and methodology for looking at radiocarbon data. We move toward integrated landscape analysis (ILA) when associating these spatially and temporally explicit archaeological records with environmental information [49]. Historical ecology, a framework incorporating social and natural records to unravel correlations and consequences of social actions, heavily informs ILA [2,19]. Furthermore, radiocarbon C14 dating provides better chronological control versus typology, calibration errors aside, which allows for a more nuanced observation of change over time to compare with the well-dated ecological data component of integrated landscape analysis. Below, we highlight some of these recent developments in the statistical analysis of radiocarbon dating.

2.2. Data and Methods

The data underpinning the analysis reported in this paper were compiled from radiocarbon samples taken within Dalarna county (Swedish: län), Sweden. An Excel database of 1039 radiocarbon dates, spanning approximately 10,700 years of Dalarna's history, contained the Swedish National Heritage Board's Historic Environment Record (HER) RAÄ number, site type, feature type, the layer of excavation, sample material, uncalibrated BP dates and error, c13, and references (available at DOI 10.5281/zenodo.5206121). In order to assist with spatial and temporal analysis, additional information further associated with the database samples included coordinate information, calibrated radiocarbon dates, and an assignment of land-use activity based on site and feature types. Thus, from these 1039 radiocarbon dates, we only used 969, as all samples did not meet the criteria for our seven land-use categories described below or either were missing needed information for calibration or had too recent a date.

Investigations of past human–environmental interactions require categorization of how humans utilized the environment. Thus, we built into the database a common element to explain how these temporal and spatial records connect to human landscape use, by creating a land-use activity category or a niche construction category, based on both site and feature types, as mentioned above. We associated land use with human niche construction, as land use describes the activities of how humans modify their ecological niche or their use of resources [2,10,12]. We developed these categorizations as purposefully general or high-level descriptors of niche construction activities across our 11,000-year time scale of interest, as activities are not homogenous over time or space; however, we were interested in general trends and patterns. Those trends and patterns are better seen with inclusive categories [50]. Defining land use allows for exploration of human niche constructions and their role in risk management in response to ecological uncertainty. The general land use categorizations we present were informed by empirical evidence in the form of artifacts and features and previous archaeological synthesis of site types associated with radiocarbon-dated contexts, and we elaborate on our decision rules for these categories below.

Our analysis focuses on seven main categories of land use:

- ***Settlement***: defined by site and feature types that, in combination, indicate long-term occupation;
    - Post holes, hearths, cooking pits, foundations, cellar pits, pit houses, long-houses, floor layers, remnant fields, urban plots, and ovens are examples of the features that were, when found in combination, interpreted as settlements in study area archaeological site reports;
- ***Activity area***: defined by site and feature types that indicate ephemeral past human presence;
    - We interpreted ground disturbance, uncertain cultural layers, isolated finds, or isolated features as ephemeral cultural presence;
- ***Agriculture***: defined by site and feature types that, in combination, indicate activities associated with either floral or faunal domestication;
    - We interpreted cultivation terraces, clearance cairns, fences, enclosures, irrigation ditches, and flax processing sites as agriculture features;
- ***Hunting:*** defined by site and feature types that indicate pitfall traps (Swedish: *fångstgrop*);
- ***Metal production***: defined by site and feature types that indicate iron or copper production;

    - Bloomeries, slag, roasting features, forging pits, casting pits, and cold rust (Swedish: *kallrost*), a rust colored remnant of copper production visible in soil profiles;
- ***Fuel Production***: defined by site and feature types that indicate charcoal production.
    - Charcoal pits, stockpiles, and charcoal layers found in significant amounts and as interpreted in Dalarna Muesen site reports;
- ***Land Claim***: defined by site and feature types that indicate burials and graves (see below for an extended discussion of this category).

We see these categories grounded in the empirical evidence of the archaeological material record as an effective way of assigning order to a large database and exploring new interpretations of the data. However, while most of the designated land uses were relatively straightforward in our theoretical model, our assessment of burials and graves as a category of land claim requires a more explanatory discussion.

The dated burials that are part of the database fall mainly within the Iron Age onwards, and they can be divided into two general classes. The first class, outland or hunting ground burials, is a distinctive burial tradition of the forested region of interior Scandinavia [51–53]. These burials comprise low, round, stone settings are comparable to contemporary Iron Age graves located in the central agrarian areas of Scandinavia during the first millennium CE in terms of morphological traits and the materials used. As their name suggests, outland burials differ in location, and rather than being located near a farmstead or village, they are located deep within forests or on mountains. Additionally, these burials are generally situated along conjoined water routes, where they would have been visible, suggesting their function as landmarks within communication networks and exchange in the late Iron Age. Outland burials, in turn, are contemporary, with indications of increased exploitation of the boreal forests [24,54,55]. An additional argument for this interpretation is that later medieval pilgrimage and communication routes match the distribution of the outland burials [53,55]. The second class, Iron Age burial mounds, may present a more apparent indication of a land claim or even property in land. In the Scandinavian Iron Age society, visible graves and runestones (boulders, bedrock, or raised stones with Runic inscriptions) associated with cultivated fields have been considered tangible indications of claims to property in agricultural land [30,31,56,57]. This relates to the concept of ‘odal’, which refers to inherited landed property of a family line. In Sweden and Norway, the odal has been known from the early Middle Ages, but it has been suggested that the concept's origins may be earlier [31].

The main aim of the proposed categories was to explore the best methods for categorizing land use in relation to radiocarbon samples and their contexts based on site records and thereby modeling risk management and predictability. The land-use categories have direct relationships to niche construction and, in extension, risk management strategies for constructing predictability in a boreal environment; as an example, most agricultural activities occurred in landscapes or microclimates that provide the longest growing seasons.

We relied on two types of open-source software to analyze trends and patterns of intensity and diversity in Dalarna’s radiocarbon dates (analysis results available at DOI 10.5281/zenodo.5206121). OxCal IntCal20 provided radiocarbon calibration and kernel density estimation for chronological synthesis and visualization [45,58–62]. QGIS 3.16 Hannover provided spatial kernel density estimation in general and across time when assisted by the calibration input of OxCal IntCal20. The default kernel and bandwidth of OxCal’s KDE_Plot function was used.

The use of kernel density estimation (KDE) to identify patterns in radiocarbon data, especially in datasets that span large temporal periods, is increasing. KDE is a non-parametric way to estimate probability density functions (in our radiocarbon case, a temporal density) that inherently calculate the likelihood of an occurrence, based on random or incomplete information [59,62,63]. Compared with the more commonplace summed probability distributions, kernel density estimation offers a less ‘noisy’ visualization of calibrated radiocarbon samples; however, both methods can suffer from calibration and sampling errors [64]. Given our dataset's 10,000-year time span that results in multimodality and stochasticity, smoothing the calibrated data allows better identification of significant signals in the data [59,62]. These recent developments in statistical analysis for radiocarbon dates show promising results in estimating change in intensity, as shown in recent work in both regional and national ranges [44,45].

The analysis of radiocarbon dates, beyond seeing them as a chronological control, involves many source-critical issues such as sample reliability related to 'old-wood effect', marine reservoir effect, taphonomic processes, and the relationship between the sample and the context; acknowledgment of these biases when analyzing radiocarbon dates is necessary [63]. Our dataset used all archaeological ^{14}C-analyzes carried out in the case study area up to the year 2020. We are aware that the standard deviation of some of the older conventional ^{14}C-analyses are high, but we do not consider this to be a problem for the aim of this specific study, considering our sample size and our aims to see general trends. That said, the ^{14}C-analyses have been collected from archaeological reports, and we have not included dates that lack a reliable archaeological record. The database, therefore, contains information regarding archaeological contexts. From the reports, we have also retrieved information about dated material (e.g., wood, charcoal, animal bones, etc.). For wood and charcoal species, analyses have been performed to avoid the issue of potential inbuilt age. Regarding animal bones, species were accounted for when possible. No 13C isotopes gave indications of marine or marine mixed diet for human bones, which needs consideration regarding a possible marine reservoir effect.

3. Results

Spatial and Temporal Configurations of Land Use

Early prehistory of the Daläven catchment demonstrated settlement and activity areas centered around water sources for the period, as they were likely to provide stability in resources. Our radiocarbon evidence shows that the earliest dated activities (~8800 BCE) were focused near present-day Leksand, or the southern edge of Lake Siljan, a water source recently made available by the retreating Weischeilian glacier. As indicated by the available radiocarbon samples, land use during the Mesolithic period reflected a blend of sustenance and settlement activities. This primary trend of land use, i.e., hunting activities and settlement, continued through the poorly studied Neolithic period in the Dalälven catchment area. We must be aware of biases in excavation and sampling agendas; however, the radiocarbon dates indicated an increase in exploration and movement as early as 8000 BCE. While part of this migration was directed north, it mainly trended towards the southeast, as receding shorelines and isostatic rebound revealed more terrestrial territory or waterways reduced to a less daunting and more navigable size.

These first indications of expansion or exploration away from the reliable Leksand site occurred in 7900–7800 BCE, with some occupation shown in the southwest near present-day Järna. Shortly after, in 7400–7300 BCE, human settlement appeared in Älvdalen to the northwest and Stora Tuna to the southeast. Land use following the northwest/southeast meander of the Dalälven continued until around 7000 BCE, when records indicated more exploration away from this main artery of transport and stability; yet, remains were centered around the Siljan area (Figure 3).

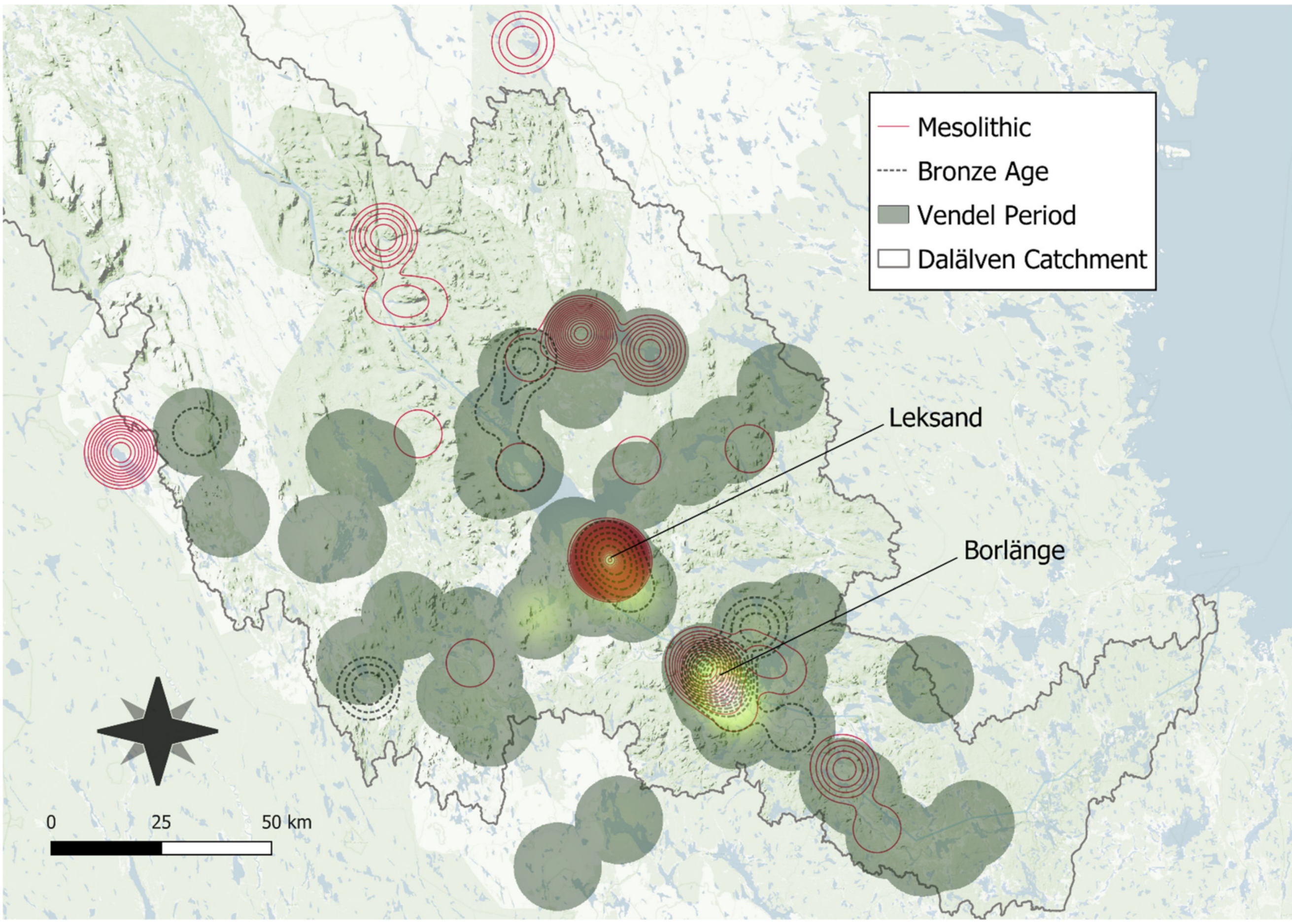
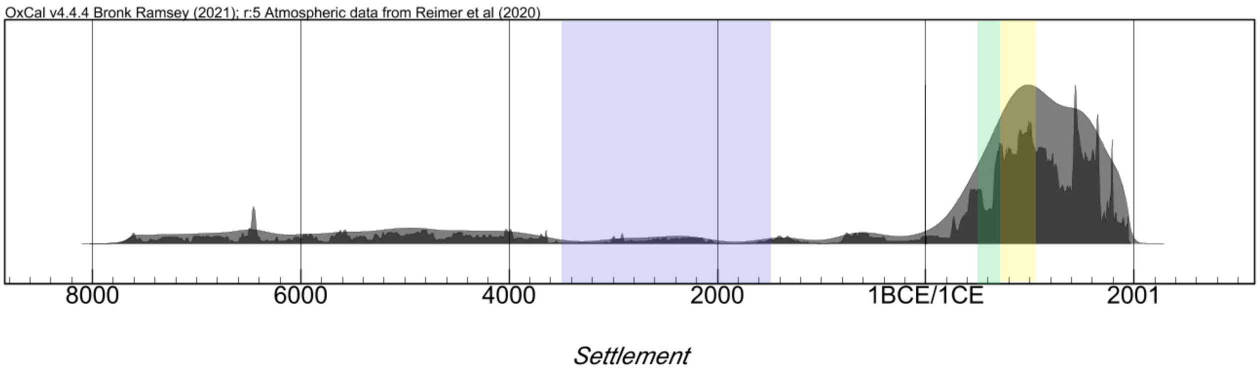
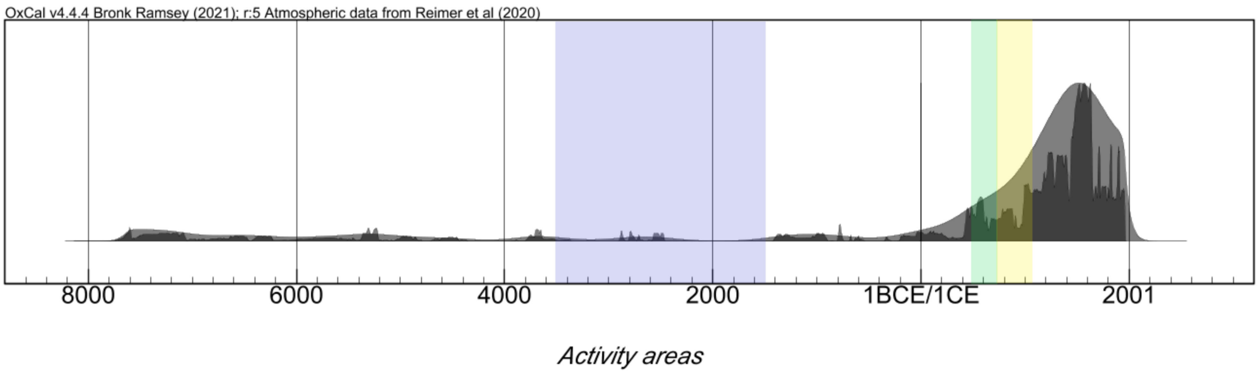


Figure 3. Detail of Dalälven catchcment study area displaying spatial intensity of land use at different time periods as indicated in the legend; *background map© OpenStreetMap contributors; shapefile of catchment area courtesy of the European Environment Agency (EEA).*

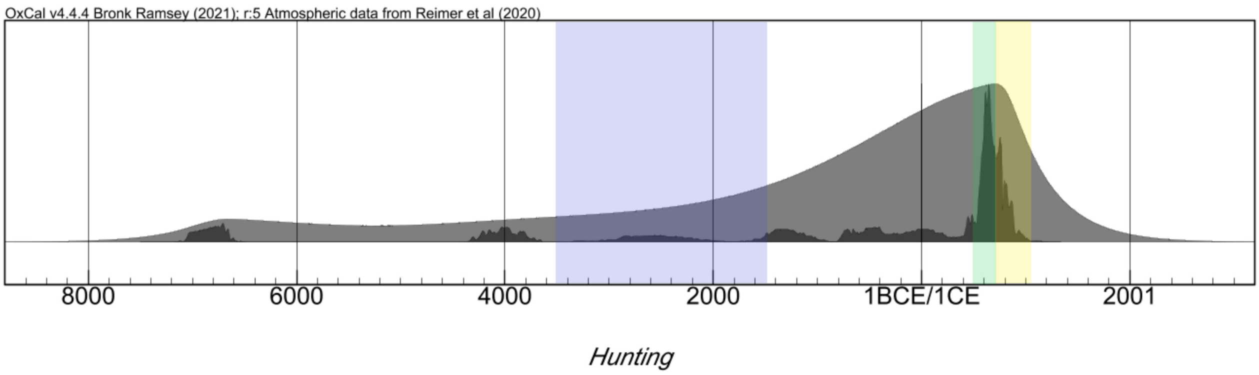
As seen from our GIS analysis, this expansion closely followed waterways and did not suggest established occupations in outland or forested areas, though continued use for subsistence was likely. Radiocarbon-dated samples from the Meso- and Neolithic periods were located approximately 2 km from a water source. This Stone Age spatial configuration, concentrated around permanent water sources and following waterways, could be interpreted as an avoidance of risk; experience in the environment was still limited, and ancestral approaches to generating resource predictability were likely relied on [53]. While KDEs indicated a slight increase in sites over this long temporal span (8800 BCE–1800 BCE), they did not display marked spikes in this Stone Age data (Figure 4). However, for the approximate Neolithic to Bronze Age time frame (~3500–1000 BCE), the KDEs and GIS heatmaps did suggest a slight spatial contraction in land use, partnered with a marginal decrease in intensity, as well as an increase in hunting practices. The level of influence from a volatile climate or changes in the cultural economy during this period requires further investigation and was not the current aim of this paper (see Section 4 for further discussion).



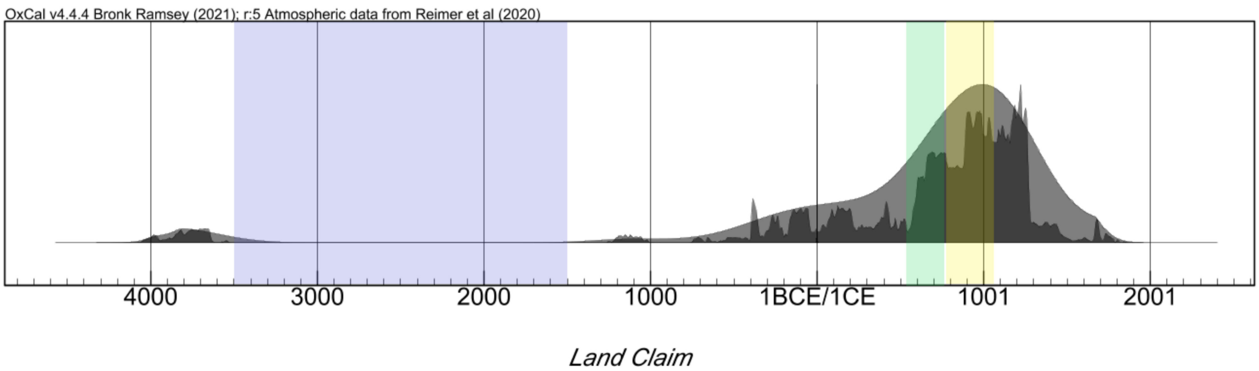
(**a**)



(**b**)

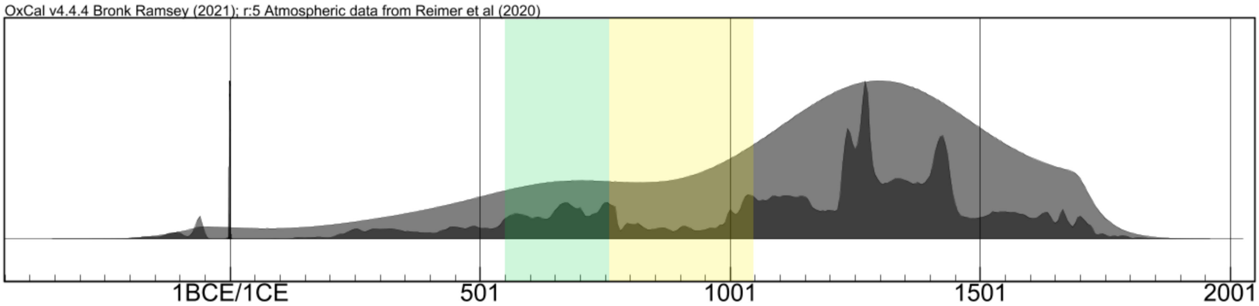


(**c**)



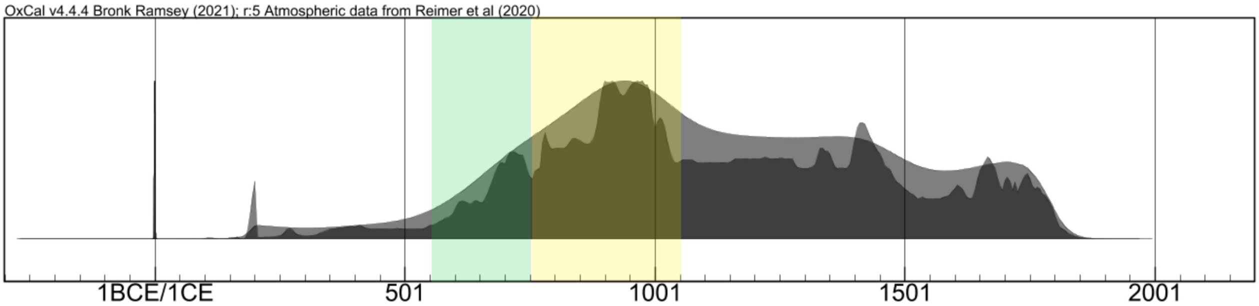
(**d**)

Figure 4. *Cont.*



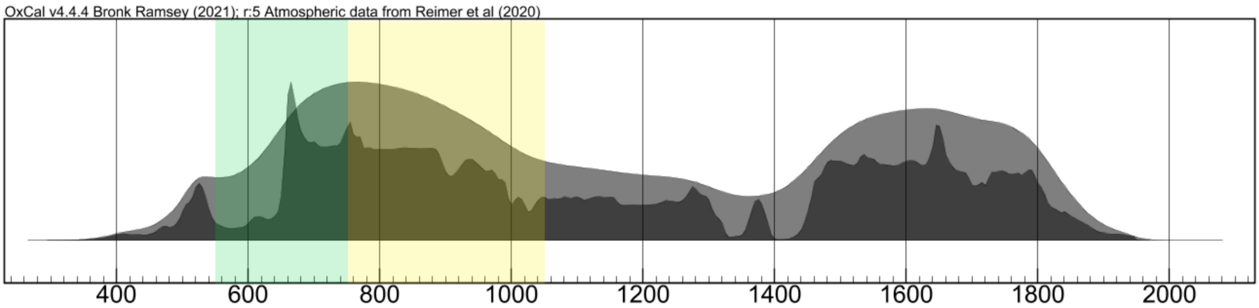
Agriculture

(**e**)



Metal Production

(**f**)



Fuel Production

(**g**)

Figure 4. Kernel density estimation plots for different land uses as described in the text. (**a**) Settlement; (**b**) Activity areas; (**c**) Hunting; (**d**) Land claim; (**e**) Agriculture; (**f**) Metal production; (**g**) Fuel Production. Blue boxes generally denote the Neolithic Period to the Bronze Age; green boxes mark the general Vendel Period; and yellow boxes mark the general Viking Age. Grey curve = KDE_plot; Black = summarized calibration curve; *samples were analyzed using KDE modelling in OxCal 4.4.*

While we observed long continuity in several sites spanning the Mesolithic to the Neolithic period, the samples from sites did not indicate a marked 'neolithisation'; we must note that the purpose of using relative chronological periods is to orient ourselves in a general time frame, rather than define these periods. Dalarna in middle Sweden, through which the Dalälven runs, did not conform to the classic Neolithic period. Neolithisiation began in southern Sweden around 4000 BCE, but agricultural practices occurred much later in our study area. Our radiocarbon-dated samples evidenced this late start; the first dated sample at Falun (C14 identification number Falun 122, 123) calibrated between 350–50 BCE or the Pre-Roman Iron Age. Database evidence for agricultural land use and animal domestication was lacking compared to other land-use activities; however, there was a marked uptick in agriculture beginning in the mid-1st century CE, increasing further in 400–500 CE. These levels were sustained until around 800 CE in the Viking Age, when the intensity of agricultural land use declined, before growing again around 1050 CE or the start of the Middle Ages.

This first evidence for a new type of niche or land-use practice diversification appeared with agriculture, as noted above, and metal production in the Bronze and Pre-Roman Iron Age. A sample from Leksand (Leksand 34:1) evidencing iron production calibrated to 1195–564 BCE. Additionally, we observed an increase in land claims displayed through burials and graves during this time. These visible graves from the Bronze and Pre-Roman Iron Age could be seen as the precursor to the odal and, eventually, the Middle Age provincial laws (Sw: landskapslagarna), which granted rights to settle and farm along rivers and in the forest if one made their presence known through land clearing and building a home [65]. As noted above, odal is often associated with claiming space for agricultural practices; there is debate regarding when this system of establishing property began [30,31,57,58,65,66]. It follows that when KDE analysis of the database indicated a diversification in land-use, in the form of agriculture, we would see a coinciding increase in land claim activities. However, our KDEs did not neatly match this assumption over time. However, there is potential our KDE pattern indicates the concept of property evolved with the idea of inheritance within the agricultural niche.

After the appearance of these new niches, land use became more spatially diversified starting in 300 BCE (Early Pre-Roman Iron Age), which was associated with a rise in hunting and a marginal favoring of activity areas over settlements. Approximately 500 years later, in 200 CE, GIS analysis showed another spatial expansion that took advantage of the Boreal forest and Tuna plains, corresponding with intensified hunting and lowered levels in settlement and activity areas. This dispersed land use continued from 200 CE until 700 CE, when this spatial signal showed a strong pulse prior to re-concentrating around present-day Leksand and Borlänge; this is not to say the 'outlands' areas were abandoned, rather that land use focused itself in these areas. New land-use activities arose, and others become more established during this long period. We observed the appearance of fuel production around 250 CE. Metal production and agrarian practices were more visible in the samples in the mid-3rd century CE, and land claims remained steady from their solid growth that began in 500 BCE. The Vendel Period (~550–750 CE) and the Migration Period (~400–600 CE) fell within these 500 years discussed above, and there were interesting intensity trends in land use around these periods (Figures 4 and 5). While most land uses strengthened, stronger signals were seen in fuel and land claims around 600 CE. Agriculture also exhibited an upward curve throughout the Vendel, before it dipped in the Viking Age.

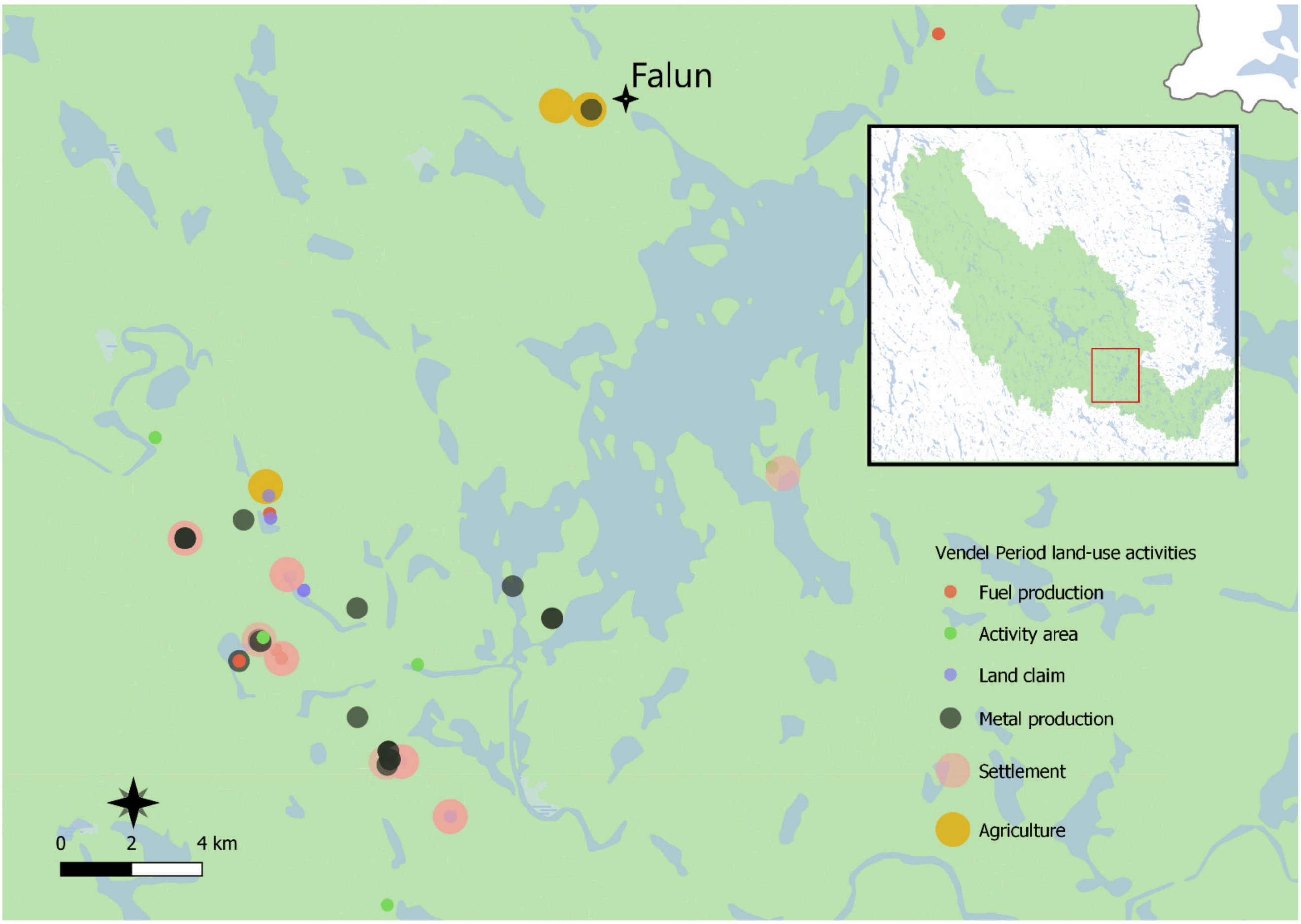


Figure 5. Detail of different land-use activities in the Vendel Period; *shoreline level at 600 BCE© SGU; boundaries shapefiles courtesy of European Environmental Agency (EEA); background map courtesy of CORINE landcover 2018*.

At the beginning of the Viking age (~750–1050 CE), the decline of agriculture paired with a waning peak in hunting and a waxing peak in land claim, decreasing fuel production, and intensification in metal production. These patterns support the increased trade of the time, which helped transfer risk away from agriculture in an environment not naturally suited for that type of land use. Moreover, this could have been a regional trend for the period that subsequent comparative studies could examine. The following historical period of the Middle Ages showed a significant drop in hunting but steady inclines in activity areas, settlements, and agriculture. The paired increases in activity areas and incline in agriculture could indicate greater use of shieling systems and relate to land claims for farming. These specific niches could be easier to create due to years of past use in these areas; niches intensified, as the shaping and opening of landscape in this marginal environment already began with previous metal production and hunting uses.

4. Discussion

Our spatial-temporal analysis, utilizing kernel density estimates, allowed us to see land use development and human niche construction in the Dalälven catchment area in Sweden over the last 11,000 years. This overview of spatial land use and the temporality of niche diversification and intensification showed patterns that support previous theories while challenging others, and it encouraged a closer look at certain time periods' environmental or social aspects. For example, what might have influenced the Neolithic to Bronze Age spatial contraction and increased reliance on the hunting niche? How do the land use activities and intensified niche constructions of the early Vendel period relate to environmental events? Is the Dalarna catchment area an example of a regional difference in the intensity of Viking Age niches and why?

Our analysis here has been the first iteration of a method that aimed to identify patterns and general trends of diversification and intensity in land use of the study area over time. We see this as one component of integrated landscape analysis and recognize that refinements will be needed and our work extended; for example, we wish to explore how our analysis may be enhanced by and compares to other spatial-temporal approaches, such as R-Cran [67]. Future extensions are discussed further at the end of this section. ILA has great potential to provide a biography of human–environmental interaction; however, developing a proper analysis is a multi-step, iterative process, where various social and environmental components are woven together.

We consider human niche diversification and intensification patterns as a risk management approach to ecological uncertainty in this marginal boreal forest environment. Diversification of land use transfers the risk from agriculture, as this marginal boreal environment does not support it well. Still, space for agriculture was opened up by the consequences of other uses, such as deforestation for fuel and iron production, eventually leading to its intensification, which scholars suggest had unintended beneficial implications for biodiversity and positively affected the ecological functioning of the Boreal environments [9,33]. For example, shieling agricultural practices, an outland pasture system, created liminal spaces and produced edge effects and havens for biodiversity.

Subsistence outside the spectrum of agriculture and animal husbandry is necessary when suitable land for cultivation is scarce [30,36,68,69]. In contrast, current research suggests that such resources were the driving force behind the expansion into the inland region in the Early or Middle Iron Age. Therefore, the settlement expansion should be considered a niche construction aimed at exploiting valued trade resources. Hence, the expansion of forest agro-pastoralists seems to have been based on, and also shaped by, more complex social and economic relations, reflecting interrelated rather than separate socio-economic systems, including extraction, production, and consumption.

Moreover, our work relates to and has potential to support recent Scandinavian scholarship. A 2021 paper by Blank et al. explored the increase in and variation of mobility patterns of Late Neolithic populations in southern Sweden [70]. While our analysis was based on a broader range of radiocarbon samples, not strictly human bone and their associated isotopic signals as in the Blank et al. study, the Late Neolithic (2200–1700 BCE) period in our region reflects a downturn in activity. Even though our methods differed from Blank et al., a closer analysis of the results between regions could provide insight into interregional mobility and reveal the social-ecological impetus for particular niche constructions, helping to answer our above postulation: what might have influenced the Neolithic to Bronze Age spatial contraction and increased reliance on the hunting niche?

Another recent Scandinavian study by Hennius utilized the KDE method to refine the chronology of pitfall hunting in Sweden [49]. His results challenged the previous assumption of the importance of hunting and trapping in the Viking Period. Our results support his refined chronology of pitfall hunting while indicating an upturn in metal production and land claims during this period; these results call for a more focused comparison against the period's environmental factors to explain this concentration of niche practices.

Other regional works have explored the effects of the climatic event known as the Fimbulwinter on the social organization of 6th century Scandinavia [57,71–73]. The majority of these works perceived this as a period of abandonment, decline, and social reorganization, possibly in response to the ecological effects of a volcanic eruption. Our analysis for this period preliminarily reflected increases in activities, thus highlighting the need for further attention to this result and integration with fine-resolution climatic data surrounding this event of the Migration period (400–550 CE).

Given the discussion above, we suggest further extensions of this work that test if this same methodology applies to other geographical areas with a comparable record of radiocarbon dates. Moreover, additional work on this boreal forest data will more explicitly connect climatic data to the archaeological record to test the correlations between environmental variability and human niche construction. Thus, future steps in this integrated analysis will include synthesizing fine-grained climate data against our records and results, as it was not currently within the scope of this paper.

In conclusion, we found that spatial-temporal kernel density analysis was a suitable method to establish in diachronic detail the diversification, intensification, and spatiality of human niche construction. Over time, we observed how the construction of niches shaped the Boreal Forest, spanning its environmentally unique upland and lowland regions, into a more predictable environment. Results of the analysis gave insight into general regional trends and provided proof-of-concept for its usefulness as a component of ILA that investigates how humans managed resource risk related to ecological uncertainty.

Author Contributions: Formal analysis, K.H.; investigation, K.H.; data curation, J.W. and K.H.; writing—original draft preparation, K.H. and K.-J.L.; writing—review and editing, K.H., J.W., and K.-J.L. All authors have read and agreed to the published version of the manuscript.

Funding: This research has received funding from the European Union's Horizon 2020 research and innovation program, under grant agreement No 813904. This output reflects the views only of the authors, and the European Union cannot be held responsible for any use which may be made of the information contained therein.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data that support the findings of this study are published at Zenodo and are available here: DOI 10.5281/zenodo.5206121.

Acknowledgments: The authors would like to thank the European Union for the funding of this research. We also would like to thank Daniel Löwenborg of Uppsala University for his excellent support during project implementation and his expert technical advice.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Sinclair, P.; Moen, J.; Crumley, C.L. Historical Ecology and the Longue Durée. In *Issues and Concepts in Historical Ecology: The Past and Future of Landscapes and Regions*; Crumley, C.L., Lennartsson, T., Westin, A., Eds.; Cambridge University Press: Cambridge, UK, 2017; pp. 13–40. [CrossRef]
2. Lindholm, K.J.; Ekblom, A. A framework for exploring and managing biocultural heritage. *Anthropocene* **2019**, *25*, 100195. [CrossRef]
3. Bürgi, M.; Ali, P.; Chowdhury, A.; Heinimann, A.; Hett, C.; Kienast, F.; Mondal, M.K.; Upreti, B.R.; Verburg, P.H. Integrated Landscape Approach: Closing the Gap between Theory and Application. *Sustainability* **2017**, *9*, 1371. [CrossRef]
4. International Organization for Standardization. Risk Management—Vocabulary (ISO/DIS Standard No. 73). 2009. Available online: https://www.iso.org/obp/ui/#iso:std:iso:guide:73:ed-1:v1:en (accessed on 23 January 2021).
5. Marston, J.M. Archaeological markers of agricultural risk management. *J. Anthropol. Archaeol.* **2011**, *30*, 190–205. [CrossRef]
6. Winterhalder, B. Diet Choice, Risk, and Food Sharing in a Stochastic Environment. *J. Anthropol. Archaeol.* **1986**, *5*, 369–392. [CrossRef]
7. Fitzhugh, B. Risk and Invention in Human Technological Evolution. *J. Anthropol. Archaeol.* **2001**, *20*, 125–167. [CrossRef]
8. Eriksson, O.E.; Arnell, M. Niche Construction, Entanglement and Landscape Domestication in Scandinavian Infield Systems. *Landsc. Res.* **2017**, *42*, 78–88. Available online: https://www.tandfonline.com/doi/full/10.1080/01426397.2016.1255316 (accessed on 23 January 2021). [CrossRef]
9. Boivin, N.L.; Zeder, M.A.; Fuller, D.; Crowther, A.; Larson, G.; Erlandson, J.M.; Denham, T.; Petraglia, M.D. Ecological consequences of human niche construction: Examining long-term anthropogenic shaping of global species distributions. *Proc. Natl. Acad. Sci. USA* **2016**, *113*, 6388–6396. [CrossRef]
10. Levins, R.; Lewontin, R. *The Dialectical Biologist*; Harvard University Press: Harvard, MA, USA, 1985.
11. Spengler, R.N. Niche Construction Theory in Archaeology: A Critical Review. *J. Archaeol. Method Theory* **2021**. [CrossRef]
12. Riede, F. Niche construction theory and human biocultural evolution. In *Handbook of Evolutionary Research in Archaeology*; Prentiss, A.M., Ed.; Springer: Cham, Switzerland, 2019; pp. 337–358. [CrossRef]
13. Kendal, J.; Tehrani, J.J.; Odling-Smee, J. Human niche construction in interdisciplinary focus. *Philos. Trans. R. Soc. B Biol. Sci.* **2011**, *366*, 785–792. [CrossRef]

14. Laland, K.N.; O'Brien, M.J. Cultural niche construction: An introduction. *Biol. Theory* **2011**, *6*, 191–202. [CrossRef]
15. Eriksson, O. Human Niche Construction and the Rural Environment. *Rural. Landsc. Soc. Environ. Hist.* **2014**, *1*, 1–4. [CrossRef]
16. Winterhalder, B.; Lu, F.; Tucker, B. Risk-Sensitive Adaptive Tactics: Models and Evidence from Subsistence Studies in Biology and Anthropology. *J. Archaeol. Res.* **1999**, *7*, 301–348. [CrossRef]
17. Hintze, A.; Olson, R.S.; Adami, C.; Hertwig, R. Risk Sensitivity as an Evolutionary Adaptation. *Sci. Rep.* **2015**, *5*, 1–7. [CrossRef]
18. Mitchell, T.; Harris, K. *Resilience: A Risk Management Approach*; ODI Background Note; Overseas Development Institution: London, UK, 2012; pp. 1–7.
19. Crumley, C.L.; Westin, A.; Lennartsson, T. *Issues and Concepts in Historical Ecology: The Past and Future of Landscapes and Regions*; Cambridge University Press: Cambridge, UK, 2017; pp. 1–338.
20. Redman, C.L.; Kinzig, A.P. Resilience of Past Landscapes: Resilience Theory, Society, and the Longue Durée. *Ecol. Soc.* **2003**, *7*, 14. [CrossRef]
21. Kirch, P.V. Archaeology and global change: The Holocene Record. *Annu. Rev. Environ. Resour.* **2005**, *30*, 409–440. [CrossRef]
22. Collard, M.; Buchanan, B.; Ruttle, A.; O'Brien, M.J. Niche Construction and the Toolkits of Hunter–Gatherers and Food Producers. *Biol. Theory* **2011**, *6*, 251–259. [CrossRef]
23. Young, E.S.; Frankenhuis, W.E.; Ellis, B.J. Theory and Measurement of Environmental Unpredictability. *Evol. Hum. Behav.* **2020**, *41*, 550–556. [CrossRef]
24. Hennius, A. Outlanders?: Resource Colonisation, Raw Material Exploitation and Networks in Middle Iron Age Sweden. Doctoral Dissertation, Department of Archaeology and Ancient History, Uppsala University, Uppsala, Sweden, 2021.
25. Paradeisis-Stathis, S. Holocene Lake-Level Changes in the Siljan Lake District—Towards Validation of von Post's Drainage Scenario. In *Dissertations in Geology at Lund University*; Lund University: Lund, Sweden, 2020; 600p.
26. Stroeven, A.P.; Hättestrand, C.; Kleman, J.; Heyman, J.; Fabel, D.; Fredin, O.; Jansson, K.N. Deglaciation of Fennoscandia. *Quat. Sci. Rev.* **2016**, *147*, 91–121. [CrossRef]
27. Ericson, A. Senatlantiska Faunalämningar Från En Boplats Vid Leksand, Dalarna. *Fornvännen* **1994**, *89*, 251–256.
28. Holm, J.; Larsson, L. *The Earliest Occupation of Europe: Scandinavia*; Leiden University Press: Leiden, The Netherlands, 1991.
29. Esseen, P.A.; Ehnström, B.; Ericson, L.; Sjöberget, K. Boreal Forests. *Ecol. Bull.* **1997**, *46*, 16–47.
30. Holm, O. Självägaromrädenas Egenart: Jämtland Och Andra Områden I Skandinavien Med Småskaligt Jordägande 900–1500. Doctoral Dissertation, Stockholm University, Stockholm, Sweden, 2012.
31. Zachrisson, T. The odal and its manifestation in the landscape. *Curr. Swed. Archaeol.* **1994**, *2*, 219–238. [CrossRef]
32. Frödin, J. *Siljansområdets Fäbodbygd*; C.W.K. Gleerups: Lund, Sweden, 1925.
33. Eriksson, O.; Arnell, M.; Lindholm, K.J. Historical Ecology of Scandinavian Infield Systems. *Sustainability* **2021**, *13*, 817. [CrossRef]
34. Nyman, A. Den svenska fäboden—Ålder, uppkomst, utbredning. In *Fäbodar*; Lidman, H., Ed.; SAGA Egmont: Stockholm, Sweden, 1963; pp. 15–39.
35. Magnusson, G.; Segerström, U. Leva i skogsbygd. När blev männniskan bofast i Södra Norrland? In *Bebyggelsehistorisk Tidskrift*; Föreningen Bebyggelsehistorisk Tidskrift: Uppsala, Sweden, 2009; Volume 57, pp. 7–25. Available online: http://urn.kb.se/resolve?urn=urn:nbn:se:uu:diva-436701 (accessed on 23 January 2021).
36. Svensson, E. *Människor i Utmark. [Lund Studies in Medieval Archaeology 21]*; Lund University: Lund, Sweden, 1998.
37. Wehlin, J. *Pionjärerna vid Limsjön. Arkeologisk Undersökning av Boplats Från Äldre Stenålder, RAÄ 405 i Leksands Socken och Kommun, Dalarna*; Arkeologisk Rapport 2014:14; Dalarnas Museum: Falun, Sweden, 2014.
38. Hyenstrand, Å. *Järn Och Bebyggelse: Studier i Dalarnas Äldre Kolonisationshistoria*; Dalarnas Museum: Falun, Sweden, 1974.
39. Zachrisson, I. *NoMöten i Gränsland: Samer Och Germaner i Mellanskandinavien*; Statens Historiska Museum: Stockholm, Sweden, 1997.
40. Serning, I. *Dalarnas Järnålder*; Kungliga Vitterhets Historie och Antikvitets Akademien: Stockholm, Sweden, 1966.
41. Ersgård, L. *Det Starka Landskapet: En Arkeologisk Studie av Leksandsbygden i Dalarna Från Yngre Järnålder Till Nyare Tid*; Riksantikvarieämbetet: Stockholm, Sweden, 1997.
42. Ashby, A. From global to local: Reshoring for sustainability. *Oper. Manag. Res.* **2016**, *9*, 75–88. [CrossRef]
43. Lindholm, K.-J.; Ljungkvist, J. The Bear in the Grave: Exploitation of Top Predator and Herbivore Resources in First Millennium Sweden—First Trends from a Long-Term Research Project. *Eur. J. Archaeol.* **2016**, *19*, 3–27. [CrossRef]
44. Pilø, L.; Finstad, E.; Ramsey, C.B.; Martinsen, J.R.P.; Nesje, A.; Solli, B.; Wangen, V.; Callanan, M.; Barrett, J.H. The chronology of reindeer hunting on Norway's highest ice patches. *R. Soc. Open Sci.* **2018**, *5*, 171738. [CrossRef]
45. Hennius, A. Viking Age tar production and outland exploitation. *Antiquity* **2018**, *92*, 1349–1361. [CrossRef]
46. Ljunge, M.O.; Wehlin, J. Outlining the study of Nordic Bronze Ages. Moving from singularity to diversity. In *Life and Afterlife in the Nordic Bronze Age. Proceedings of the 15th Nordic Bronze Age Symposium, Lund, Sweden, 11–15 June 2019*; Acta Archaeological Lundensia Series altera in 8°; Apel, J., Svensson, A., Tornberg, A., Eds.; Department of Archaeology and Ancient History: Lund, Sweden, 2019; in press.
47. Hunters as Farmers, Farmers as Hunters: Animals, Humans and Landscapes in Inland Scandinavia 1000 BCE-500 CE. Financed by Marcus and Amalia Wallenberg foundation (MAW 2019.0118). Available online: https://www.arkeologi.uu.se/Research/Projects/hunters-en/ (accessed on 23 June 2021).

48. Contesting Marginality: The Boreal Forest of Inland Scandinavia and the Worlds Outside, AD—1500 AD; Swedish Research Council: Stockholm, Sweden. 2018. Available online: https://www.arkeologi.uu.se/Research/Projects/contesting-marginality/ (accessed on 23 June 2021).
49. Hennius, A. Towards a Refined Chronology of Prehistoric Pitfall Hunting in Sweden. *Eur. J. Archaeol.* **2020**, *23*, 530–546. [CrossRef]
50. Morrison, K.D.; Hammer, E.; Boles, O.; Madella, M.; Whitehouse, N.; Gaillard, M.-J.; Bates, J.; Linden, M.V.; Merlo, S.; Yao, A.; et al. Mapping past human land use using archaeological data: A new classification for global land use synthesis and data harmonization. *PLoS ONE* **2021**, *16*, e0246662. [CrossRef]
51. Stephens, L.; Fuller, D.; Boivin, N.; Rick, T.; Gauthier, N.; Kay, A.; Marwick, B.; Armstrong, C.G.; Barton, C.M.; Denham, T.; et al. Archaeological assessment reveals Earth's early transformation through land use. *Science* **2019**, *365*, 897–902. [CrossRef] [PubMed]
52. Gollwitzer, M. Yngre järnålder i fjälltrakterna. In *Möten i Gränsland: Samer Och Germaner i Mellanskandinavien*; Zachrisson, I., Ed.; Statens Historiska Museum: Stockholm, Sweden, 1997; pp. 27–32.
53. Wehlin, J. Fäbodarnas förhistoria. In *Fäbodlandskap och Vallmusik. Dalarna 2019*; Dalarnas Fornminnes-och Hembygdsförbund i Samarbete Med Dalarnas Museum: Falun, Sweden, 2019; pp. 16–27.
54. Wehlin, J. Fångstmarkens folk. In *Arkeologi i Dalarn*; Carlsson, E., Ed.; Dalarnas Fornminnes-Och Hembygdsförbund i Samarbete med Dalarnas Museum: Falun, Sweden, 2016; pp. 218–249.
55. Sakarias, L. *Mötesplatser i Fångstmarken*; Uppsala University: Uppsala, Sweden, 2019.
56. Lindholm, K.J.; Ersmark, E.; Hennius, A.; Lindgren, S.; Loftsgarden, K.; Svensson, E. *Contesting Marginality: The Boreal Forest of Middle Scandinavia and the Worlds Outside. The Global North: Spaces, Connections, and Networks from the Iron Age to 1650. The Medieval Globe 7.1*; Arc Humanities Press: York, UK, 2021.
57. Löwenborg, D. An Iron Age shock doctrine—Did the AD 536-7 event trigger large-scale social changes in the Mälaren valley area? *J. Archaeol. Anc. Hist.* **2012**, *4*, 3–29.
58. Runer, J. Från Hav Till Land Eller Kristus Och Odalen: En Studie av Sverige under Äldre Medeltid Med Utgångspunkt Från de Romanska Kyrkorna. Doctoral Dissertation, Stockholm University, Stockholm, Sweden, 2006.
59. McLaughlin, T.R. On Applications of Space–Time Modelling with Open-Source 14 C Age Calibration. *J. Archaeol. Method Theory* **2019**, *26*, 479–501. [CrossRef]
60. Reimer, P.; Austin, W.; Bard, E.; Bayliss, A.; Blackwell, P.; Ramsey, C.B.; Butzin, M.; Cheng, H.; Edwards, R.; Friedrich, M.; et al. The IntCal20 Northern Hemisphere radiocarbon age calibration curve (0–55 cal kBP). *Radiocarbon* **2020**, *62*, 725–757. [CrossRef]
61. Ramsey, C.B. Bayesian analysis of radiocarbon dates. *Radiocarbon* **2009**, *51*, 337–360.
62. Ramsey, C.B. Methods for Summarizing Radiocarbon Datasets. *Radiocarbon* **2017**, *59*, 1809–1833. [CrossRef]
63. Carleton, W.C.; Groucutt, H.S. Sum things are not what they seem: Problems with point-wise interpretations and quantitative analyses of proxies based on aggregated radiocarbon dates. *Holocene* **2021**, *31*, 630–643. [CrossRef]
64. Crema, E.R.; Bevan, A. Inference from Large Sets of Radiocarbon Dates: Software and Methods. *Radiocarbon* **2021**, *63*, 23–39. [CrossRef]
65. Brink, S.; Collinson, L. (Eds.) *New Approaches to Early Law in Scandinavia*; Acta Scandinavica 3; Brepols: Turnhout, Belgium, 2014.
66. Lindholm, K.J.; Sandström, E.; Ekman, A.K. The archaeology of the commons. *J. Archaeol. Anc. Hist.* **2013**, *10*. Available online: http://urn.kb.se/resolve?urn=urn:nbn:se:uu:diva-211075 (accessed on 23 January 2021).
67. CRAN R-Project. Spatio-Temporal Kernel Density Estimates. 2021. Available online: https://cran.r-project.org/web/packages/rcarbon/vignettes/rcarbon.html#spatial-analysis (accessed on 27 June 2021).
68. Lindholm, K.J. A new approach to the archaeology of livestock herding in the Kalahari, Southern Africa. *Antiquity* **2009**, *83*, 110–124. [CrossRef]
69. Karlsson, H.; Emanuelsson, M.; Segerström, U. The history of a farm–shieling system in the central Swedish forest region. *Veg. Hist. Archaeobotany* **2010**, *19*, 103–119. [CrossRef]
70. Blank, M.; Sjögren, K.-G.; Knipper, C.; Frei, K.M.; Malmström, H.; Fraser, M.; Svensson, E.M.; Günther, T.; Yngve, H.; Jakobsson, M.; et al. Mobility patterns in inland southwestern Sweden during the Neolithic and Early Bronze Age. *Archaeol. Anthr. Sci.* **2021**, *13*, 64. [CrossRef]
71. Gräslund, B. Comments on Daniel Löwenborg's article 'An Iron Shock Doctrine. The 536–537 AD event as a trigger of large-scale social change in the Mälaren valley area'. *J. Archaeol. Anc. Hist.* **2012**, *4*, 2–4.
72. Gundersen, I. The Fimbulwinter theory and the 6th century crisis in the light of Norwegian archaeology: Towards a human-environmental approach. *Primit. Tider.* **2019**, *21*, 101–119. [CrossRef]
73. Price, N.; Gräslund, B.B. Excavating the Fimbulwinter? Archaeology, geomythology and the climate event(s) of AD 536. In *Past Vulnerability. Volcanic Eruptions and Human Vulnerability in Traditional Societies Past and Present*; Riede, F., Ed.; Aarhus University Press: Aarhus, Denmark, 2015; pp. 109–132.