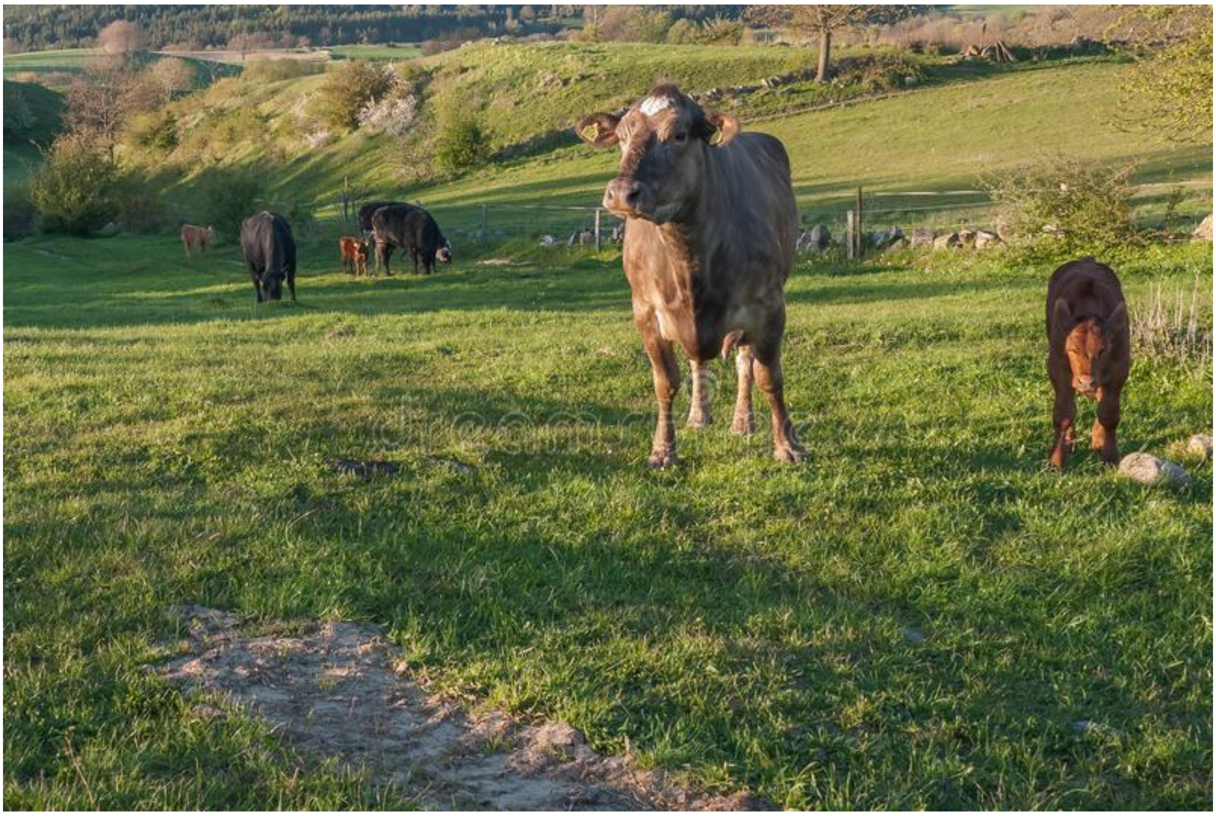
On the historical extent and spread of grazing land in Sweden



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Summary

There has been much land use change over the past centuries; this has had several effects on the natural environment. Land use affects the carbon cycle, other nutrient cycles, the hydrological cycle and the albedo effect; these things have impact not only on the global climate but also on other things such as biodiversity and water availability. Land use change is important for climate change as it accounts for 24% of global greenhouse gas emissions. Furthermore, knowledge about historical land use is important to understand future land use.

The worldwide historical land use is categorized in HYDE; this database is quite extensive but much of the data of the deep past that it contains is based on educated guessing and is therefore subject to uncertainty. The aim of this thesis is to add on more exact data to the HYDE database. In order to do this the case study of Sweden will be examined. The research question for this thesis is: what was the extent and spatial distribution of grazing land in Sweden from the 17th century until the present?

The data collection for this thesis was done by examining, among other sources, historical livestock tax registers. The process of converting the data involved several steps. The first step was to convert the livestock numbers to livestock units that are based on how much an animal grazes. These livestock units were consequently converted to an area of grazing land. Lastly, a land use map was made showing grazing land based on climatological, historical and contemporary data.

It was found that the grazing land use in Sweden fluctuated over the centuries and was generally higher than that HYDE indicated. This is important because this result could be implemented into HYDE to make it more accurate which in turn could make climate change modelling more accurate. Regarding the spatial distribution of grazing land in the 17th century the lowest density of grazing land was to be found in the north of the country and the highest density of grazing land in the south of the country.

Introduction

Historically, land use has changed significantly over the past centuries (Klein Goldewijk et al., 2017b). This has had several effects on the natural environment such as changes in the carbon cycle, changes in other nutrient cycles, changes in hydrology and changes in the albedo effect (Smith et al., 2014; De Oliveira Serrão et al., 2022; Munch et al., 2019). All these aforementioned changes have certain impacts on the global climate and on the change thereof. The effect of land use on the carbon cycle and other nutrient cycles is that land use change can disturb them, for instance by converting forests to pastures, causing more greenhouse gas emissions; the category of 'Agriculture, forestry and other land use', namely, emitted around 24% of global greenhouse gases in 2014 (Smith et al., 2014). The effect of land use on hydrology is that the hydrological cycle of an area can be altered; for example when a forest changes to a pasture this has impacts on water retention (De Oliveira Serrão et al., 2022). This change in the hydrological cycle, in turn, can have an effect on the climate. Furthermore, land change can have an impact on the albedo effect in the way that more or less sunlight will be reflected by the land which also has effect on the climate (Munch et al., 2019). All these factors can lead to climate change and therefore land use and the change in land use is important for society.

In this thesis grazing land use and the historical changes of grazing land will be discussed and examined. It might not be immediately obvious that historical land use is important because oftentimes fossil fuels are the main focus point when talking about climate change tough land use actually is important. From this an objection might be made against the relevance of land use. This objection would be that land use change is often perceived to be contributing little to climate change because the greenhouse gas emissions of it are relatively low compared to emissions by fossil fuels. This does not deny the relevance of land use change, however, as land use change is not only concerned with greenhouse gas emissions but also with problems like biodiversity and water management. Also, though the greenhouse gas emissions are relatively low compared to fossil fuel emissions, they are still significant at 24% and can be vital in finding a solution to the current ecological problems in the world (Smith et al., 2014). One other objection against the relevance of historical land use change is that historical land use concerns the past instead of the present or the future. An answer to this objection is that exactly historical land use is important to help understand future land use change patterns (Bürgi et al., 2007).

The worldwide historical land use is categorized in the History Database of the Global Environment (HYDE); this database is quite extensive but much of the data of the deep past that it contains is based on educated guessing and is therefore subject to uncertainty (Klein Goldewijk & Verburg, 2013). HYDE, namely, calculates the area of grazing land from the population numbers of the time period. The aim of this thesis is to add on more exact data to the HYDE database. In order to do this the case study of Sweden will be examined; Sweden was chosen because it has accurate data on historical livestock numbers and accurate historical maps (Dahlström et al., 2006). Therefore the research question of this thesis is what the extent and spatial distribution of grazing land in Sweden from the 17th century until the present was. There will also be two sub-questions that will be answered which are: how much land was used for grazing; and what is the spatial distribution of the grazing land.

Key concepts

In this thesis several key concepts will be used that are important to be defined and explained. Two of these key concepts are land use change and land cover change; though these concepts are intimately related they do differ from each other. Land use change, which is the main focus of this thesis, is the change in the way the land is used while land cover change is the change in the physical characteristics of the land (Verma et al., 2020). An example of this is that when a natural grassland that was formerly not being exploited by humans is used for grazing livestock the land use changes while the land cover remains the same.

Another key concept that is important to define is grazing land; grazing land, which is quite obviously defined as land used for grazing, can be subdivided into the two categories of pasture and rangelands (Klein Goldewijk et al., 2017b). The difference between pasture and rangeland is that pasture is intensively used for grazing while rangeland is extensively used. A difference can also be made between converted and unconverted grazing land.

Another concept that is used in this thesis is the livestock unit. A livestock unit is a universal unit used for measuring how much an animal grazes; the livestock units in this thesis will be expressed in ‘cow values’ which means that the amount that a cow grazes is taken as a standard grazing unit (Linde & Palm, 2014). This would then mean that a full grown cow would be counted as one livestock unit, a horse would be counted as more than one livestock unit, a sheep as less than one livestock unit and so on.

A last term that will be used in this thesis and needs explanation is HYDE. As was stated in the introduction HYDE is the History Database of the Global Environment. This database contains population estimates and allocation algorithms over time (Klein Goldewijk et al., 2017b). HYDE is used, among other things, for quantifying past land use and making maps. This data on past land use can also be used to better understand future land use (Bürgi et al., 2007).

Methods

Data collection

In this thesis several methods have been used; the method that was used for data collection is a literature review in which the historical data for the livestock numbers within the modern borders of Sweden were examined. These livestock numbers have been found in several sources; one of these sources is the historical tax registers that have been made in Sweden since the end of the 16th century (Palm, 2013). These historical tax records contained the livestock numbers of each individual parish and village and were written in an old Swedish handwriting (Riksarkivet, n.d.). Therefore, a set of reports from the University of Gothenburg was used in which the data from all of these tax registers was combined and integrated (Palm, 2012a; 2012b; 2013; Linde, 2012; Linde & Palm, 2014). These reports were available for the years 1570, 1630, 1690, 1750 and 1810 which were all chosen to be included in the analysis of this thesis.

For determining the historic livestock numbers in the time period more recent than 1810 another data source was used, namely Mitchell (1998). The data from Mitchell (1998) stretches continuously from 1888 to 1969 with data on livestock numbers for every year. However, for some of the years there is a lack of data for one or more of the livestock categories; this was the case for the category poultry for the year 1969 which is why for this thesis the years 1888 and 1968 were chosen to be included in the analysis as 1888 is the first year with available data and 1968 the last.

Finally, in order to determine the contemporary livestock numbers the agricultural statistics from SCB (2020) were used. This data source contains, with some intervals, livestock data from 1980 to 2019. Out of this data the year 2010 was chosen to be used for analysis in this thesis because it aligns well with the grazing land data from HYDE against which the acquired livestock data will be compared later on.

Because the time period of this thesis is rather long, spanning around 4 centuries, data samples have been taken; this is because the time available does not allow for examining the data of every year and neither is there continuous data on livestock numbers throughout the centuries (Dahlström et al., 2006). Therefore, it was attempted to take samples of the livestock numbers around once every fifty years; this has been done as far as was feasible when working with the different data sources. This data that has been collected in the samples is quantitative data on the number of livestock that was kept in the whole of Sweden.

Data processing

In this thesis the data processing has been done in several steps. First, the livestock numbers that were collected were translated into livestock units in order to make them more easily comparable over time. Then the calculated livestock units were converted to an amount of grazing land. Lastly, the grazing land density for a specific time period was put into a land use map.

The livestock numbers that have been found were subdivided into several categories like cattle, sheep and pigs. In order to make the numbers of each time period comparable to each other these numbers were translated into livestock units. This was done following the method that Linde & Palm (2014) used in the reports that they made. According to their method, all the different kinds of livestock were standardized into 'cow values'. This means that a horse would count as 1.5 cows, a pig as 0.25 cows, a sheep as 0.1 cows and a goat as 0.083 cows; for the young offspring of the livestock half of the number of the full grown livestock was taken except for calves which are counted as 0.25 cows. There was one deficiency to the method of Linde & Palm (2014) however which was that it did not include a 'cow value' for poultry. Because of this, a conversion factor for poultry was taken from the EU at 0.014 cows (Eurostat, 2023b).

With the aforementioned livestock units the total amount of grazing land was calculated in order for it to be compared to the HYDE data. This was done by determining how much grazing land is needed per animal and multiplying this number with the number of livestock units. Because the years that HYDE has data on do not exactly match the years that there was livestock data available for, different years were selected for the analysis of the grassland area; these years were: 1600, 1700, 1750, 1810, 1890, 1970 and 2010. Of these years the years 1750, 1810 and 2010 do match the years that livestock data was available for; the years 1700, 1890 and 1970 were chosen because the livestock data years were very close to them (1690, 1888 and 1968) so that the data for these years was expected to be around the same. For calculating the grazing land area for the year 1600, the livestock data from 1570 and 1630 was averaged.

The grazing land conversion number that was mentioned before is based on the contemporary livestock density of Sweden calibrated with the FAO data that was used as input for HYDE (Klein Goldewijk et al., 2017). The contemporary livestock density of Sweden is 0.5 livestock unit per hectare which translates to 2 hectares per livestock unit (Eurostat, 2023a). When calibrating the amount of grazing land found in this thesis with the HYDE grazing land data a livestock density of around 2.9 hectares per livestock unit was found for 2010 and around 2.5 for 1970. The density of 2.5 was used for all the years before 1970 that were selected for analysis in this thesis as well because it was assumed that grazing density in the past was around the same as in 1970. This assumption was made because climatic factors are expected to be roughly the same for historical Sweden (Hawkins, 2020).

With the grazing land that was calculated a sketch of a land use map was made. This land use map was made to indicate where the highest and lowest grazing land densities were in Sweden in the 17th century in order to get a better idea of Sweden's past land use. The map that was used is a map of Sweden with its modern borders divided into Sweden's 21 administrative regions (Vemaps, 2019). These regions were then colour coded into three categories of grazing land density: low, medium and high. The density of grazing land was determined by considering several factors; these factors include: climatic factors, a historic source and contemporary land use. The climatic factors were determined by considering the Köppen climate zones which indicate that the climate in the south of the country is more favourable for livestock grazing (Weather and Climate, n.d.); an assumption is made that this is true for Sweden in the past as well. The historic source that was found for the land use map is Dahlström (2008) in which historic grazing dynamics are discussed; from there it is reasoned that Södermanland and Östergötland had higher grazing densities than Jönköping in the 17th century. Several contemporary sources are used as well because little historical data could be found on the distribution of grazing land. These contemporary sources include Swedish livestock density and Swedish land cover data (Tattari et al., 2012; European Environment Agency, 2011)

Justification

These methods were chosen in order to be able to more accurately map the historical land use in Sweden. In the previous studies, namely, population numbers were used to estimate the grazing land use (Klein Goldewijk et al., 2017a). A per capita approach was used in the way that a certain amount of grazing land was estimated to be used per capita without investigating the actual number of livestock present. In this thesis the number of livestock has been taken into account which is expected to be more accurate for estimating grazing land. Though the methods used in this thesis are expected to be more accurate, still there could be given much critiques on this method. Though these critiques might be fair this field of research is still in a pioneering stage so while these methods might be imperfect they are still expected to be able to be more accurate than previous research.

Results

In this section, the results that were found will be presented. First, the historical development of the number of livestock units will be examined. Secondly, the historical development of grazing land will be examined and lastly the spatial allocation of grazing land will be described.

Livestock units

When looking at the historical development in livestock units from past to present an upward trend can be noticed until after 1888 when the trend goes downwards, as can be seen in figure 1. At the first year that was selected for analysis, the year 1570, the number of livestock units in Sweden was at around 1.46 million (Palm, 2013). This number increased over the centuries that followed until it reached a peak of around 3.36 million in 1888 (Mitchell, 1988). After this peak, a decrease set in until there were only 1.52 million livestock units in 2010, the last year that was selected for analysis (SCB, 2020).

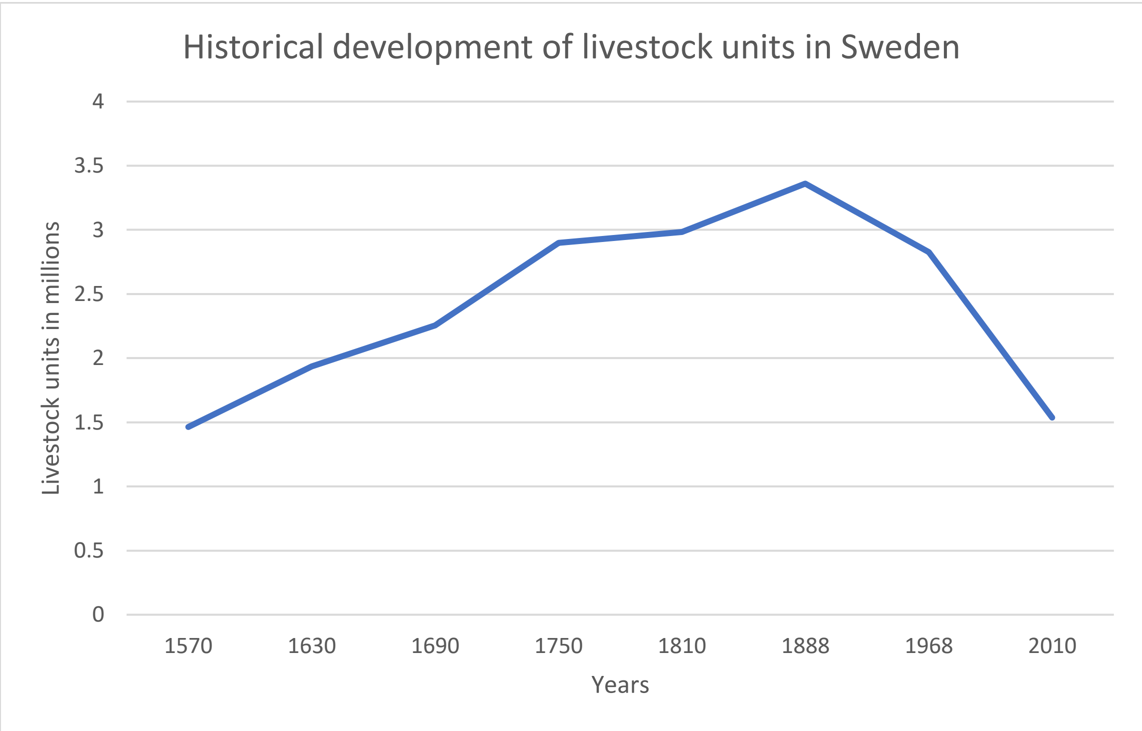

Figure 1: the historical development of livestock units in Sweden.

Grazing land

When considering the extent of the grazing land in Sweden it was found that the area that was calculated according to the method of this thesis was significantly higher than the area of grazing land according to HYDE for the years before 1970, as can be seen in figure 2. In 1600 the amount of grazing land was calculated at 4.21 million ha, which is around 8% of Sweden's total land area (Palm, 2012a; 2013); this is in contrast to the data of HYDE that only gives a number of 1.27 million hectares of grazing land (Klein Goldewijk, 2020). Over the centuries the calculated amount of grazing land increases up to 8.32 million ha in 1890, which is around 16% of Sweden's total land area (Mitchel, 1998); for the year 1890, however, HYDE only indicates 5.46 million hectares of grazing land (Klein Goldewijk, 2020). After this peak the calculated amount of grazing land decreases to 4.51 million ha in 2010 which is around 9% of Sweden's total land area (SCB, 2020); the area that HYDE indicates for the year 2010 is the same because the FAO data from HYDE was used to calibrate the thesis data (Klein Goldewijk, 2020).

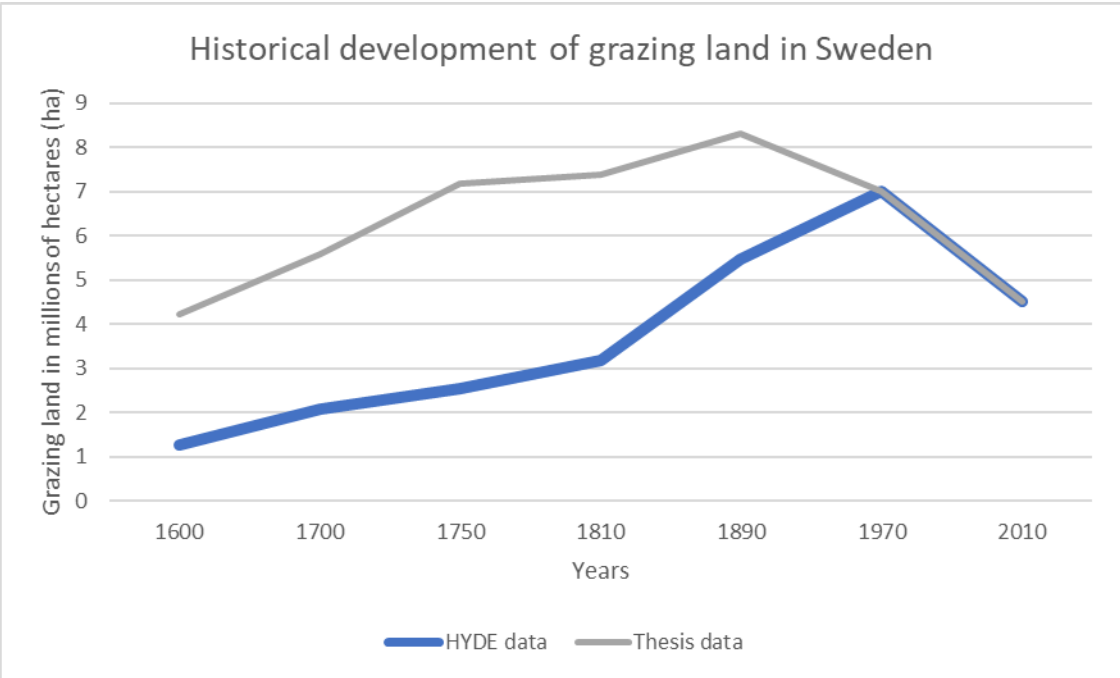

Figure 2: a comparison between the data from this thesis and the data from HYDE on the historical development of grazing land in Sweden.

Allocation of grazing land

When looking at the density of grazing land in 17th century Sweden a general trend can be identified, as can be seen in figure 3. This trend is that the highest density of grazing land was historically to be found in the south of the country and the lowest density in the north of the country due to the different climates in different latitudes (Weather and Climate, n.d.); this trend is backed up by the data on livestock density distribution in contemporary Sweden which shows the same distribution (Tattari et al., 2012). There are some exceptions to this general trend, however, as can be seen in the regions of Skåne, Jönköping and Gotland. In the southernmost region of Skåne and the island region of Gotland a medium density of grazing land is to be found; this is because of the relatively high density of arable land in these regions which leave less space for grazing land (European Environment Agency, 2011). The region of Jönköping, which is located in the middle of southern Sweden, was also found to have a medium density of grazing land This is because the area of Alseda, in Jönköping, has a lower density of grazing land than the areas of Fornåsa, in Östergötland, and Selaön, in Södermanland; which are the two regions directly northeast of Jönköping (Dahlström, 2008).

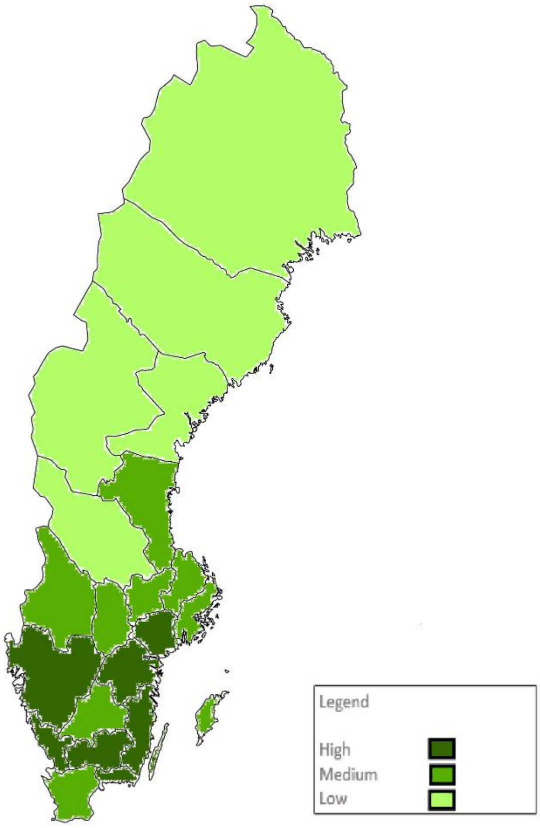

Figure 3: land use map of the Swedish grazing land density in the beginning of the 17th century.

Discussion

Interpretations

In this section the results of the thesis will be interpreted, the limitations of these thesis will be assessed and the implications of these results will be discussed. As was seen in the results section, there was a significant number of livestock units in the 17th century; namely, there were more livestock units than in our modern period. This concurs with what Lindström (2018) states about 17th century Sweden which is that it was dominated by mixed farming, meaning that livestock herding was as important or more important than arable farming; this, in turn implies a high number of livestock.

Another research that is, at least partly, in line with the results of this thesis is that of Olsson & Svensson (2010) who state that from the 18th century going into the 19th century livestock became economically less relevant for farms; they also state that livestock became economically less important because of better ploughs which reduces the need for animals to pull the ploughs. On the one hand this seems to contradict the results of this thesis as the number of livestock units keeps rising at least until the end of the 19th century but in fact it explains part of the decrease in livestock units in the 20th century; this is because as livestock became economically less important and arable farming more important it created the possibility for livestock to decrease.

Another observation from the results of this thesis that concurs with the literature is that the number of livestock units decreased after the year 1888; also, the amount of grazing land decreased after the year 1890. This is in line with Dahlström et al. (2006) who state that after 1932 there was a decrease in livestock in Sweden while much of the grazed outland was abandoned.

A result, or rather a part of the methods, that does not seem to make sense immediately is that the number of hectares per livestock units in 2010 is higher than in 1970. This is because it would be expected that in the modern time period less hectares per livestock unit would be needed because of agricultural intensification and fertilisation of pastures. However, the opposite is found to be the case, namely, more hectares per livestock unit are needed. A possible explanation for this is that in order to achieve higher animal productivity, so to produce more milk, meat, etc. per animal, more food is needed per animal and therefore more hectares per livestock unit (Encyclopedia Britannica, 2023).

Limitations

Though this thesis has produced results that are, at least partly, supported by literature, it has several limitations as well. One of these limitations is that the number of hectares per livestock unit in this thesis was come by through general assumptions. This is a limitation because in all likeliness this number, which is vital for the results of this thesis, could have been more accurately calculated by doing field investigations or remote sensing to determine the net primary production of Swedish grazing land as has been done in other studies (Meshesha et al., 2019; Li et al., 2022). This could however not be done for this thesis due to lack of time and resources.

Another limitation to this thesis is that an implicit assumption was made that all the livestock eat the same food and are therefore always competitive with each other for their grazing needs. This is however not always the case for all the different sorts of livestock; cattle, namely, primarily eat grasses while sheep are more inclined to eat herbaceous plants and leaves next to grasses (Gaskamp & Roberts, n.d.). Because of this, the amount of grazing land that was presented in the results might be estimated a bit too high though it is not expected that any drastic changes in the area of grazing land would have occurred if this limitation would have been taken into account.

Implications

The results of this thesis have several implications, both for the academical field of sustainability science as well as for society in general. An implication for the academic field is that the method that HYDE uses to calculate the amount of grazing land, using the population number instead of the amount of livestock, seems to be flawed. This is because the grazing land calculated from the number of livestock units in the results turns out to be quite a bit higher than the grazing land according to HYDE. This can be explained by the fact that different types of societies with different cultures and economies will have different amounts of livestock; therefore, the population number by itself is not always a good indicator of the amount of grazing land in a country.

A societal implication of the results that follows on the aforementioned academic implication of this thesis is that the grazing land use data might indirectly help in the modelling of climate change models. This is because the land use reconstruction in HYDE has been used for climate change modelling (Klein Goldewijk, 2017b). Therefore, because the results of this thesis could be useful for HYDE and could in some way be integrated into HYDE it could have the effect of making the grazing land use reconstruction more accurate. This in turn could have a positive impact on the accuracy of climate change modelling which would give greater certainty on calculating carbon budgets which would help governments make better policies to stay within these carbon budgets (Klein Goldewijk, 2017b).

Following the interpretation, limitations and implications that were made above, it would be recommended that further research be done in the area of this thesis. A first area for further research would be the categorizing of historical livestock in countries other than Sweden; this is because it would help in making more accurate predictions on the amount of grazing land in these countries. Naturally, not every country in the world will have the historical records to execute this research though. A second, related, area in which further research is recommended is the net primary production of grasslands, in Sweden or in other countries; this is because it would help in determining how much hectares of grassland are needed per livestock unit which is crucial information for doing research like this thesis.

Conclusions

In this section, the research question and sub-questions of this paper will be answered, the key findings of the research will be summarized and the take home message will be presented. The research question that was used to guide this thesis was what the extent and spatial distribution of grazing land in Sweden from the 17th century until the present was. The two sub-questions that were answered are: how much land was used for grazing; and what is the spatial distribution of the grazing land.

The answer to the first sub-question is that the grazing land use in Sweden fluctuated over the centuries. Sweden started off with 4.21 million ha (around 8% of Sweden's total land area) in 1600 this went up to 8.32 million ha (around 16% of Sweden's total land area) in 1890 and went down again to 4.51 million ha (around 9% of Sweden's total land area) in 2010. The answer to the second sub-question is that, in the 17th century, the lowest density of grazing land was to be found in the north of the country and the highest density of grazing land in the south of the country with the exception of a few southern regions. By answering these two sub-questions the overall research question is answered as well.

The main finding from this thesis is that the amount of grazing land that was calculated according to the thesis' method was higher than the amount of grazing land that was found in HYDE. This is important because it is expected that the method of calculating grazing land that was used in this thesis is more accurate than the population based method that HYDE currently uses. Therefore it would be beneficial if the results of this thesis would be incorporated into HYDE to make its grazing land estimates more accurate. This in turn would have the potential of making climate change modelling more accurate as HYDE is often used for this purpose; this is important for the whole of society because around the world governments are dealing with climate change.

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Appendix A: Livestock table

	1570	1630	1690	1750	1810	1888	1968	2010
Adult horses					280760			
Adult mares		259268	298904	484436	240264	482000	69000	
Young equids		48550	67031	128694	96935			
Oxen		160118	200443	236830	240307			
Steers		241277	267856	206361	146994			
Bulls				70599	52061			
Cows		732051	842184	1012147	1132118	2349000	2065000	1057800
Heifers		319287	322949	330049	300338			
Calves		284835	296897	360645	344614			478900
Sheep		814455	1081378	1577830	1964681	1360000	286000	273100
Lamb		601303	617154	665317	685157			291800
Goats		321664	357878	409593	357818			
Young goats		327800	278141	181363	103964			
Old pigs		291491	368990	507285	373147	610000	2043000	155900
Young pigs		342961	422255	593098	493896			1363900
Fowls and chickens							8452000	7708200
Livestock units	1463711	1936618	2255244	2899513	2982411	3360500	2826178	1536802

In order for this table to be understood properly, some notes need to be made. First is that for the year 1570, for Sweden with its modern borders, no data on the number of livestock was available, only the livestock units. Secondly, for the years 1630 and 1690 the bulls are included among the oxen and steers. Thirdly, for the years 1630, 1690, 1750, 1888 and 1968 the adult horses are included among the adult mares. Lastly, for the years 1888 and 1968 all the young animals are included among the full-grown animals.

Appendix B: schedule

Week number	Meetings and deadlines	Tasks and time used
4 (15-05)	Go/no go for proposal (Tuesday) Meeting with supervisor and peer group (Wednesday 10 AM)	Collection of data
5 (22-05)	Meeting with supervisor and peer group (Wednesday 10 AM) Workshop (Wednesday 11 AM)	Collection of data
6 (29-05)	Meeting with supervisor and peer group (Wednesday 10 AM) Workshop (Wednesday 11 AM) Lecture/workshop (Thursday 9 AM)	Conversion of data
7 (05-06)	Meeting with supervisor and peer group (Wednesday 10 AM)	Making map in GIS
8 (12-06)	Meeting with supervisor and peer group (Wednesday 10 AM) Thesis draft submission (Friday 5 PM)	Making map in GIS
9 (19-06)	Meeting with supervisor and peer group (Wednesday 10 AM)	Writing thesis and making poster
10 (26-06)	Poster submission (Monday 9 AM) Meeting with supervisor and peer group (Wednesday 10 AM) Thesis submission (Thursday 5 AM) Poster session (Friday)	Writing thesis and making poster