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The Value of Ecosystem Services from Swedish Cattle Production

Master's thesis in Sustainable Energy Systems

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Department of Space, Earth and Environment
CHALMERS UNIVERSITY OF TECHNOLOGY
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Cover: Ecosystem services provided by the agricultural landscape (Jordbruksverket & Naturvårdsverket, n.d.)

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Abstract

Ecosystem services (ES) are the goods and services the nature provides to society. The quantification and valuation of ES are a necessary step to fully understand the importance of different ecosystems.

The Swedish cattle production stands for 40 % of the agricultural land use and provides Sweden with around 2.9 *million ton* milk and 0.1 *million ton* beef each year. This thesis examines the effects of land uses associated to the Swedish cattle production on ecosystem services. As a result, the monetary value of the total cattle production in Sweden are 27 - 37 *billion SEK/year* where physical and experiental interactions have the largest value (29 - 32 %) closely followed by milk (26 - 36 %). The provisioning services contributes to a share of the total maximum value of 39 - 53 %, the regulating and maintenance services have a share of 1 - 10 % and the cultural services have a share of 46 - 51 %.

The total value of the non-market services; regulating and maintenance- and cultural services, for land uses associated to the cattle production are 13 - 22 *billion SEK/year*. The non-market value for the alternative land uses cropland and forest are 1 - 4 *billion SEK/year* and 2 - 21 *billion SEK/year* respectively. These values could be used as guidelines for policies and compensation programs to prevent a decrease of cattle associated land use areas.

Keywords: *Ecosystem Services, Cattle, Land use, Sweden, Quantification, Monetary valuation, Indicators*

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Sabina Söderstjerna Jörgensson, Göteborg, June 2017

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List of Abbreviations

CICES	Common International Classification of Ecosystem Services
EEA	European Environment Agency
ES	Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
MA	Millennium Ecosystem Assessment
MAES	Mapping and Assessment of Ecosystems and their Services
SCB	Statistics Sweden (*Statistiska centralbyrån*)
WoS	Web of Science

Swedish authorities mentioned in the report

Naturvårdsverket	Swedish Environmental Protection Agency
Jordbruksverket	Swedish Board of Agriculture

1 | Introduction

Nature and its ecosystem provides both goods and services to society, for example food, energy, water, fertile soils, pollinated crops as well as beautiful scenery. The ecosystems cooperate in various complex feedback systems. The services are affected and compromised by different land use and maintenance practices, for instance heavy machinery and intensive agriculture. The effects on the individual ES, how they work together and the value for society have been examined since the late 1960s and 1970s (Helliwell, 1969; P. Ehrlich, Ehrlich, & Holdren, 1977).

It was not until 1981 (P. R. Ehrlich & Ehrlich, 1981) the term "ecosystem service" was introduced. In 1997 Costanza et al. presented a value of the global natural capital. In 2001 the Millennium Ecosystem Assessment (MA) began to identify and evaluate the impacts on human well-being from ecosystem changes. In line with the work done by the MA the European Union presented a report on Mapping and Assessment of Ecosystems and their Services (MAES, 2014) with indicators and data availability status.

One of the first reports in the subject of valuating ES in Sweden is Björklund et al. (1999) where the intensification of agriculture was examined. Today Sweden has environmental objectives that contain for example a varied agricultural landscape, a rich diversity of plant and animal life as well as reduced climate impact (Naturvårdsverket, 2016). For Sweden to be able to reach these goals assessments and quantifications of ES are needed. In 2015, the Swedish Environmental Protection Agency (Naturvårdsverket) published a guideline on how to assess ES as a result from a government assignment (SOU 2013:68, 2013). The environmental protection agency is continuing their work regarding the value of ES and their importance to society.

Swedish agriculture stands for around 8 % of the land area (SCB, 2017) and 15 % of Sweden's greenhouse gas emissions (23 % if Land Use and Land Use Changes are included) (Jordbruksverket, 2017). A sustainable agriculture is of importance both to maintain the ES and lower the greenhouse gas emissions. Cattle production stands for around 40 % of the agricultural land area and only the methane from the cattle digestion process stands for around 20 % of agriculture's greenhouse gas emissions (IPCC, 2006; Jordbruksverket & Statistiska Centralbyrån (SCB), 2016). This leads to heated discussions regarding our meat consumption and questions the importance of cattle.

If cattle farming decreases large amount of pasture areas would change to forest or, in the more soil fertile areas, cropland. These transformations leads to changes for the ecosystem services. The environmental objective, a varied agricultural landscape specifies for instance an open landscape with for example natural pasture (Naturvårdsverket, 2016) which implies that cattle is present in Swedish agriculture and landscapes. A large analysis and monetary valuation of the ES associated with cattle land use is not present today.

In this thesis, the ES provided and effected by land use associated to cattle production land will be examined further. A literature study to identify connections between ES and cattle production will be followed by a quantification and monetary valuation of selected ES.

1.1 | Aim and Objectives

The aim of this study is to present a monetary value of land uses associated with Swedish cattle production. To this aim the following objectives apply:

1. Identify connections between ES and land uses associated with Swedish cattle production, based on a review of the scientific literature
2. Quantify selected ES using biophysical indicators
3. Estimate the economic value of the services quantified in objective 2

2 | Methods

2.1 | Definitions

In Sweden cattle land usage consists of three different land management principles; grassland, cropland and natural pasture. The grasslands are both used as pasture and harvested for feed, silage. In Table 2.1 different terminology is presented for each land use.

To be able to do a comparison of the effects on ecosystem services from cattle related land uses two alternative land uses are introduced. The alternative land uses used are forest and cropland with annual crops, mostly cereals. These are chosen as they are the "natural" alternative to cattle land use. For example if cattle are not present on the natural pastures it will eventually grow into a forest. On the more fertile soils in the south of Sweden the land uses will transform into croplands and for the remaining parts of Sweden it will transform into forest. For the alternative land use cropland only cereals, not used for cattle production, are harvested.

Table 2.1: Cattle associated land use in Sweden their definition and associated names found in the scientific literature.

Cattle land use		Definition	Different terminology
Grassland	**Ley**	Grassland cultivated on cropland	Meadow[1], hay-fields, grassland, permanent grassland[2], temporary grassland
	Pasture	Grassland used as pasture	Pasture, grazing grassland[3], rangeland[4]
Natural pasture		Non-arable land used for pasture	Semi-natural pasture[3], wood-pasture[5]
Cropland		Annual crops for forage and grain	low intensity cropland, arable land[2]
Other		Patches between and in cropland, grassland and natural pasture	edge zone[6], fence, microhabitats[7], stone wall, non-productive area, waste area, islands

[1](Battaglini et al., 2014) [2](van Eekeren et al., 2008) [3](Andersson et al., 2015) [4](Lal, 2013) [5](Garrido et al., 2017) [6](Milestad et al., 2011) [7](Westphal et al., 2010)

2.1.1 | Classification of ecosystem services

The ecosystem service classification chosen for this thesis is the Common International Classification of Ecosystem Services, CICES (2013) developed by the EEA. The ecosystem services in this classification are divided into three sections; provisioning services, regulating and maintenance services and cultural services. These are further divided into divisions, groups and classes to avoid double counting.

Provisioning services are the different services where the environment provides us with goods such as food, fiber and energy. The regulating and maintenance services are services provided by nature to uphold and regulate different processes as for example soil health, mediation of toxics and climate regulation. The cultural ecosystem services for example heritage values, symbolic values and usage of nature.

2.2 | Overview of ecosystem services associated with cattle related land use

To be able to get an overview of the connections between ecosystem services and land uses associated with cattle production a literature overview was performed. To be able to identify effects on ecosystem services land uses were compared to the alternative land uses, cropland and forest.

The overview started with different keyword searches on various search engines. Further on new searches and findings in reference lists led to new articles and reports. From the literature descriptions of impacts on ecosystem services from land uses and land maintenance was identified. This together with comparisons between land uses was interpreted as positive, negative or positive-/negative effects on the ecosystem services. The results are presented in Table 3.1 and 3.2 showing the effects from cattle land use comparing to the alternative land uses.

2.3 | Systematic review of effects from cattle related land use of selected ecosystem services

As a result of the overview eleven ES from all sections were chosen to be investigated further. The services chosen is further presented in section 2.4. For the provisioning services, nutrition, as crops and animal outputs, and biomass-based energy were chosen because the large differences as well as the discussions regarding food vs. energy. For the regulating and maintenance services the chosen services are connected to Sweden's environmental objectives (Naturvårdsverket, 2016) as well as to soil health. Discussions regarding the usage of fertilizers and pesticides effect on pollinators and natural enemies (Intagliata, 2017; Rosner, 2013; Biello, 2013). This together with unexpected effects from grassland areas led to the inclusion of lifecycle maintenance and pest and disease control easy. With the lack of scientific research and valuation along with the importance of cultural heritage all cultural ES with observed effect was chosen.

A systematic review was performed to confirm and further strengthen the connections found in the overview. The review was performed for eight of the selected ecosystem services within the regulating and maintenance and cultural sections. Literature searches for the chosen ecosystem services was performed in Web of Science (WoS) during March 2017. The keywords for each ecosystem services are shown in Table 2.2. In total the WoS search resulted in 3 862 hits, with some duplicates across categories. The hits were then filtered based on title and abstract. This screening process was based on the two questions; "Do the literature evaluate and/or compare effects on ES for the relevant land usages to the alternative land uses?" and "Is it transferable to Swedish conditions?". For the regulating and maintenance ES same or alike climate zones were important. For the cultural ES the cultural upbringing, religion and the approach to nature and recreation are of importance (Fredman et al., 2013). For these reasons only articles from Europe were considered. For the remaining studies full text was obtained when possible. The captured information from each study was;

- ES examined
- Which land uses that were evaluated
- Effects on the studied ES from the land use
- Geographical information
- Methods used in the study (empirical, modelling approach, literature review or survey based)

To count as a modelling approach the main results in the study should have been obtained by a model, the parameters could therefore be based on empirical data without being classified as an empirical type article. To be classed as an empirical type article the collected data are presented as part of the result.

In Table 2.3 the amount of hits and articles that went through the screening process is shown for each ecosystem service and in total. The amount of retrieved full text varies between 7 % and 23 % and in total approximately 9 % of the WoS hits where retrieved in full text. References to the retrieved full text articles can be found in Appendix A.

Table 2.2: Keywords, Web of Science hits and number of obtained full text papers in the systematic review.

Ecosystem service		Keywords	WoS hits	Full text
Regulation and maintenance[1]	**Mediation of waste, toxics and other nuisances**	nutrient* or soil organic matter or nutrient cycling or soil pollution and (storage or filtration or sequestration)	248	29
	Mass stabilisation and control of erosion rates	erosion or erosion rate or soil erosion or mass stabilisation or erosion risk or erosion prevention	333	24
	Lifecycle maintenance, habitat and gene pool protection	pollinat* or bee or bees	126	29
	Pest and disease control	natural enemies or beneficial arthropods or pest control or disease control	181	30
	Global climate regulation by reduction of greenhouse gas concentrations	carbon sequester* or carbon or organic carbon or sequester carbon or carbon storage	1 495	108
Cultural[2]	**Physical and experiental interactions**	tourism or recreation* or trail* or tourist* or sport*	329	46
	Heritage, culture	heritage or cultural value or historic	652	60
	Other cultural outputs	enjoyment or willing* or preference*	238	25
		national park* or protected area*	260	9

General keywords:
[1](grassland* or cropland* or arable or forest* or livestock or pasture*) AND (ecosystem service* or ecosystem* or agro-ecosystem*) AND agriculture or forestry
[2](outdoor* or landscape* or nature) AND (ecosystem service* or ecosystem* or agro-ecosystem*) AND (cultural or non-market or contingent or perception*)

Table 2.3: Number of WoS hits and articles in the screening process for all ecosystem services, references in Appendix A.

Ecosystem service		WoS hits	After Question 1	After Question 2	Retrieved full text	Percentage
Regulation and maintenance	**Mediation of waste, toxics and other nuisances**	248	63	31	29	12 %
	Mass stabilisation and control of erosion rates	333	71	24	24	7 %
	Lifecycle maintenance, habitat and gene pool protection	126	50	29	29	23 %
	Pest and disease control	181	53	31	30	17 %
	Global climate regulation	1 495	193	113	108	7 %
Cultural	**Physical and experiental interactions**	329	67	47	46	14 %
	Heritage, culture	652	85	61	60	9 %
	Other cultural outputs	498	43	37	34	7%
	Total	**3 862**	**625**	**373**	**360**	**9 %**

The result from the systematic review was investigated using two indicators for each land use and ES. The size of the knowledge base within the scientific literature, and its consistency, regarding effects on ES from cattle related land uses in relation to the alternative land uses. The effects considered were, positive, negative, positive and/or negative, and no effect. The size of the knowledge base describes the share of articles with a described effect, see Equation 2.1. The indicator helps describe how large the scientific research base is, with regards to the keywords. The consistency indicator describes the share of articles with the same described effect, see Equation 2.2. This helps to identify the concurrence within the retrieved articles. In Equations 2.1 and 2.2 i and j describes the different land uses and ecosystem service respectively. Together the indicators can identify the connections degree of certainty for each ES and land use.

$$size\ of\ knowledge\ base = \frac{(Total\ number\ of\ articles\ with\ a\ described\ effect)_{ij}}{(Number\ of\ retrieved\ full\ text\ articles)_{j}} \tag{2.1}$$

$$consistency = \frac{Max(number\ of\ articles\ for\ each\ effect)_{ij}}{(Total\ number\ of\ articles\ with\ shown\ effect)_{ij}} \tag{2.2}$$

2.4 Quantification of selected ecosystem services associated with cattle land use

To be able to quantify the chosen ecosystem services different indicators from MAES (2014) together with an interpretation of the CICES (2013) explanations and linkages presented by Pérez Soba et al. (2017) were used. The ES, indicators and units are shown in Table 2.4-2.6.

A literature and statistic review over the indicators were then preformed to be able to quantify the chosen ecosystem services. Statistical values were mainly found from Swedish Environmental Protection Agency (*Naturvårdsverket*), Statistics Sweden (*Statistiska centralbyrån*), Swedish Board of Agriculture (*Jordbruksverket*), Eurostat and IPCC.

For those ecosystem service indicators with various values and sources a mean value for each ecosystem service and land use was found. The mean was found either as an arithmetic mean or as a weighted arithmetic mean, if sample sizes for the different values was available.

Table 2.4: Chosen quantification services, indicators and units for the provisioning ecosystem services.

	Indicators	Unit
Cultivated crops	Yields of food and/or feed crops	$ton\ Dry\ Matter/ha$
	Area	kha
Reared animals and their outputs	Livestock	$cattle/ha$
	Amount of produced milk	$kton/ha$
	Amount of produced beef	ton/ha
Biomass-based energy sources	Forestry products	GWh/ha
	Energy from manure treatment systems	GWh/ha

2.4.1 Provisioning services

The land use in cattle production is distributed as follows: 610 000 ha grassland ley, 78 000 ha pasture, close to 400 000 ha natural pasture, approximately 200 000 ha grain, 10 000 leguminous and 50 000 ha other roughage (e.g. whole crop silage and maize silage) (C. Cederberg, personal communication, 20 April 2017). Co-products from sugare and vegetable oil industry, most important rapeseed cake, soymeal and beetfibres, are used in protein feed production. These areas are not included in the study.

For the provisioning services, statistical values have been collected for the quantification. The amount of cattle and produced milk and beef in Sweden 2015 are collected from Jordbruksverket and Statistiska Centralbyrån (SCB) (2016), the numbers are shown in Table 2.7 and 2.8. The total amount of milk cows also contains recruitment cows, a cow has approximately 0.8 recruitment heifer per cow (C. Cederberg, personal communication, 20 April, 2017).

Table 2.5: Chosen quantification services, indicators and units for the regulation and maintenance ecosystem services.

	Indicators	**Unit**
Mediation of waste, toxics and other nuisances	Soil organic matter, SOM	$ton\ Organic\ Matter/ha$
	Amount of nitrogen in soil	$mg\ N/kg\ dry\ soil$
	Amount of phosphorus in soil	$mg\ P/l\ soil$
	Carbon fraction in soil	$g\ C/g\ Organic\ Matter$
Mass stabilisation and control of erosion rates	Erosion rate	$ton/ha \cdot year$
Lifecycle maintenance, habitat and gene pool protection	Pollination share of harvest	%
	Pollinators species-richness	$Rank\ (1-5)$
	Areal supporting pollination	%
Pest and disease control	Use of pesticides	%
	Areal supporting natural enemies	%
Global climate regulation by reduction of greenhouse gas concentrations	Soil carbon sequestration	$ton\ carbon/ha \cdot year$
	Soil organic carbon, SOC	$ton\ carbon/ha$
	Above-ground carbon	$ton\ carbon/ha$

Table 2.6: Chosen quantification services, indicators and units for the cultural ecosystem services.

	Indicators	**Unit**
Physical and experiential interactions	Willingness to perform recreational activities in the area	$scale\ (1-5)$
Heritage, culture	Protected cultural areas	%
Other cultural outputs	Protected area	%
	Red-listed species	$number/ha$
	Landscape preference	$normalized\ scale\ (0-1)$

Table 2.7: Number of cattle in Sweden 2015 (Jordbruksverket & Statistiska Centralbyrån (SCB), 2016).

Number of cattle	Amount
Milk cows	338 379
Other cattle	184 094
Calves < 1 year	466 017
Heifers, steers and bulls > 1 year	487 035
Total dairy cattle (assuming 0.8 heifer per dairy cow)	*609 082*
Total amount of meat cattle	*866 443*
Total	**1 475 525**

Table 2.8: Milk and beef production in Sweden 2015 (Jordbruksverket & Statistiska Centralbyrån (SCB), 2016).

Milk and beef production	Amount [*ton*]
Milk	2 933 000
Meat from	
Cows	43 380
Calves < 1 year	3 490
Heifers, sticks and bulls > 1 year	86 260
Total	*133 130*

Everitt (2003) recommend an availability of 20 - 30 $kg\ DM/cattle \cdot day$ on the pasture. This amount varies however with the size, age and production level of the cattle (Anett, Johanna, & Sofie, 2012). The recommended number of livestock on grassland pasture and natural pasture used are a mean for grassland and natural pasture respectively. On grassland pasture the recommended mean are five cattle per hectare and for natural pasture the amount are two cattle per hectare (Anett et al., 2012).

For energy from manure treatment systems the biogas potential calculated by Linné et al. (2008) from cattle were used. The factors that are considered are type of cow, manure and its distribution as well as share of dry matter and energy production, see Table 2.9 for the values.

Table 2.9: A selection of values used to calculate the potential for energy from manure treatment systems (Linné et al., 2008).

	Liquid manure	**Solid manure**	**Deep straw bed**
Manure production [$ton/cattle \cdot yr$]			
Milk cows	26.3	10.7	15
Other cattle	12.2	5.9	6
Calves $<$ 1 year	6	2.7	3.4
Heifers, sticks and bulls $>$ 1 year	10.3	5.9	6
Manure distribution [%]			
Milk cows	70	29	1
All remaining cattle	25	57	18
Share of dry matter [%]	9	20	25
Methane production [$Nm^3\ CH_4/ton\ DM$]	150	150	135

The amount of biomass-based energy from forest residues was calculated as a mean from the total amount of produced energy, 50 485 GWh (Energimyndigheten, 2016), divided over the total amount of forest in Sweden, 28 275 000 ha (SCB, 2017).

2.4.2 | Regulating and maintenance services

For the regulating and maintenance service the values are however collected from both literature and statistics. For mediation of waste, toxics and other nuisances four indicators was found.The soil organic matter content in the different soils was calculated from the amount of soil organic carbon collected from various sources and the carbon fractions found in (IPCC, 2006). The carbon fraction for all temperate and boreal forests are 0.47 $g\ C/g\ OM$ and for arable land 0.5 $g\ C/g\ OM$ (IPCC, 2006). The soil organic carbon amounts can be found in Table 2.10. Both the amount of Nitrogen (N) and Phosphorus (P) in the soils are collected from the empirical study described by Creamer et al. (2016). The amount of N in grassland, arable and forest are 435, 169, 540 $mg\ N/kg\ dry\ soil$ respectively (Creamer et al., 2016). For P the amounts are 64, 156, 122 $mg\ P/l\ soil$ for grassland, arable and forest respectively (Creamer et al., 2016).

The erosion rate depends among other things on plant cover, soil structure and buffer zones. For example, a heterogeneous agricultural area, i.e. mosaic landscape, has an erosion rate of 4.21 $ton/ha \cdot year$ while an area with permanent crops has an erosion rate of 9.47 $ton/ha \cdot year$ (eurostat, 2012). A mean for each land use was calculated from two references and the values can be found in Table 2.10 (eurostat, 2012; Cerdan et al., 2010).

The indicators for the service lifecycle maintenance, habitat and gene pool protection are all connected to pollinators. The pollination process contributes to the harvest and are described as the pollination share of harvest. For cropland the share is 5-20 % (12.5 % used) (Pedersen et al., 2009). Since grasslands are not depending on the clover to bloom before harvest or grazing the pollination share of harvest is 0 %. The areal supporting pollinators habitat is depending on species richness in crop as well as suitable habitation. Grasslands, pastures and edge zones often have high plant diversity and are therefore a good habitat for pollinators as well as natural enemies. In Table 2.10 the areal percentages of supporting habitat for pollinators and natural enemies are presented. The species richness has a large variation between the land uses the largest species richness is found in natural pasture it decreases together with the number of flowers for edge zones, blooming crops, grasslands and at last cereals (R.Bommarco, personal communication, 28 April 2017).

For pest and disease control natural enemies are of importance hence two of the indicators are related to them. The areal that supports natural enemies are described above and shown in Table 2.10. The use of pesticides often disturbs the natural pest and disease control hence the use of pesticides is also an indicator. The amount of used pesticides was calculated as a weighted mean from statistics, 87 % of cropland areas and 2 % of grassland ley areas were treated (Statitstiska centralbyrån (SCB), 2011).

The last regulating and maintenance service to quantify is global climate regulation by reduction of greenhouse gas concentrations. The indicators for this service are related to the carbon content and sequestration in soil. The soil organic carbon is, as mentioned above, collected from various sources and an arithmetic mean is calculated, the span is showed in Table 2.10. The variations are large for some land uses depending on climate and soil structure (Eswaran et al., 1993). The soils potential carbon uptake each year is called carbon sequestration. In this study, when quantifying soil carbon sequestration in present land use due to cattle production in Sweden in relation to the alternative land use with cropland with only annual crops, we used data from long term field experiments. These long term soil fertility experiments has investigated changes in soil carbon levels between crop rotations with grassland and annual crops and application with manure ("livestock cropping systems") with annual crops without grass in rotation and no manure application (arable cropping systems) (Kätterer et al., 2012). After a period of around 40 years, C concentrations in top soil in the livestock cropping system are 9% higher than in the arable cropping system. This corresponds to yearly sequestration of 0.13 $ton\ C/ha \cdot yr$. For natural pasture compared to the alternative land use cropland the difference is 0.05 $ton\ C/ha \cdot year$ (Karltun et al., 2010). The alternative land use forest has a soil carbon sequestration rate of 0.1 - 0.2 $ton\ C/ha \cdot year$ (0.15 $ton\ C/ha \cdot year$ used) compared to cropland (B. Berg et al., 2007). The amount of above-ground carbon can also support the regulation of greenhouse gases, values can be seen in Table 2.10.

2.4.3 | Cultural services

For the cultural services bio-physical indicators are harder to identify. For this thesis, the physical and experiental interactions service a survey-based willingness to perform recreational activities scale are used as indicator. The willingness to preform recreational activities in a certain area are collected from an article by Fredman and Hedblom (2015). The results are based on a choice modelling survey and the values are shown in Table 2.11.

For the cultural heritage service only one indicator was found, the amount of protected cultural areas. The indicator is expressed as % of total amount of cultural protected areas in Sweden and are based on statistics on *kulturreservat* (cultural sanctuaries). Croplands have the largest share of the cultural protected areas with 10.6 %, around 2 % of the cultural protected areas are pastures, only 0.3 % are ley grasslands and forests are 0 % of the cultural protected areas (Naturvårdsverket, 2012).

Table 2.10: Quantification values for the regulating and maintenance services.

	Erosion rate[1]		Areal supporting pollination and natural enemies[2]		SOC[3] ~ 30 cm		Above-ground carbon[4]	
Land use	Span [$ton/ha \cdot year$]	Mean [$ton/ha \cdot year$]	Span [%]	Mean [%]	Span [$ton\ C/ha$]	Mean [$ton\ C/ha$]	Span [$ton\ C/ha$]	Mean [$ton\ C/ha$]
Grassland - Ley	0.40 - 2.67	1.54	50-100[5]	75	4.25 - 116	64.55		4.25
Grassland - Pasture	0.40 - 2.02	1.21	100	100	4.25 - 116	64.55	4.04 - 4.85[7]	4.44
Natural pasture	0.07 - 2.02	0.76	100	100	27.87 - 62.4	37.9	14.1 - 18.8[8]	16.45
Cropland	2.67 - 9.47	5.25	30-70	50	5 - 95	50.51		5
Other	0.2 - 2.69	1.45	100	100	30 - 85	68.43	0.75 - 2.25	1.5
Forest	0.07 - 0.2	0.14	0-99	25[6]	4.7 - 179	70.30	70.5 - 94	82.25

[1](eurostat, 2012; Cerdan et al., 2010) [2](Schulp, Lautenbach, & Verburg, 2014) [3](Wiesmeier et al., 2012; UK National Ecosystem Assessment, 2011; IPCC, 2006; Del Galdo, Six, Peressotti, & Francesca Cotrufo, 2003; Eswaran et al., 1993) [4](IPCC, 2006)

[5]Sometimes harvest before blooming [6]Assumed 25 % of the forest are edges (edges 100 %)
[7]Degradation factors (based from Ley); 0.95 and 1.14 [8]Around 20 % of forest above-ground biomass

Other cultural outputs describe the enjoyment of nature and landscapes and the willingness to preserve nature for the future generations. The indicators found to quantify these values are the amount of protected areas, red-listed species and landscape preferences. The amount of protected areas is presented as the share of the total protected land area in Sweden. Other land use is protected within protected biotopes and are only 0.0003 % of the total protected areas, however a large portion of all other land uses are protected (Naturvårdsverket, n.d.). Pastures are 0.14 % of the total protected area while ley areas and cropland have shares of 0.0048 % and 0.066 % respectively (Naturvårdsverket, 2012). For the active production forests the share is 3.9 % (Naturvårdsverket, 2012). The amount of red-listed species on each land use are shown in Table 2.12, for other land use no statistics are available.

Table 2.11: Quantification values for the indicator; the willingness to preform recreational activities (Fredman & Hedblom, 2015).

Land use	scale (1-5)
Grassland - Ley	2.7
Grassland - Pasture	2.7
Natural pasture	3.45
Cropland	1.95
Forest	3.2

Table 2.12: Quantification values for the indicator; amount of red-listed species (Sandström et al., 2015).

Land use	10^{-4} species/ha
Grassland - Ley	4.18
Grassland - Pasture	24.34
Natural pasture	6.64
Cropland	0.95
Forest	0.65

The landscape preference is the last indicator for other cultural outputs and are obtained from a meta-analysis of European studies by van Zanten et al. (2014). The indicator describes what landscape type and landscape elements people enjoy and prefer based on surveys. The results from the analysis are divided into three categories; agricultural management, land cover composition and landscape element and are expressed as normalized scores (0-1). A mean for each land use was calculated from different values that can be seen in Table 2.13.

Table 2.13: Landscape preferences in a normalized score (0-1) from the meta-analysis by van Zanten et al. (2014).

	Mean
Agricultural management	
Intensive agriculture[14]	0.64
Presence of livestock[23]	0.70
Farm stewardship	0.30
Field margins[5]	0.46
Land cover composition	
Dominance agricultural land cover[14]	0.40
Mosaic landscape[125]	0.75
Dominance forest/natural land cover[36]	0.50
Landscape element	
Green linear elements[5]	0.00
Grey linear elements	0.33
Historic buildings	0.75
Point elements[5]	0.58

[1]Grassland - Ley [2]Grassland - Pasture [3]Natural pasture
[4]Cropland [5]Other land use [6]Forest

2.5 | Monetary valuation of selected ecosystem services associated with cattle land use

An economic valuation for each ecosystem service are performed with basis from the quantification. There are three different approaches of economic valuation that are recommended and used for economic valuation of ecosystem services; market-based, revealed-preference and stated preference (Rodríguez-Ortega et al., 2014). The market-based methods are direct market analysis, production function analysis and replacement or avoided cost which all have the current market price as a basis (Rodríguez-Ortega et al., 2014). The reveled-preference methods are travel cost and hedonic pricing which both are methods that take human behavior into account (Rodríguez-Ortega et al., 2014). The stated preference methods are based on surveys and are called contingent valuation and choice modelling (Rodríguez-Ortega et al., 2014). The methods used for the chosen ecosystem services can be seen in Table 2.14.

Table 2.14: The ecosystem services and the applied economic valuation methods.

Approach	Method	Ecosystem service
Market-based	**Direct market analysis**	Cultivated crops
		Reared animals and their outputs
		Biomass-based energy sources
		Lifecycle maintenance, habitat and gene pool protection
	Replacement or avoided cost	Mediation of waste, toxics and other nuisances
		Mass stabilisation and control of erosion rates
		Lifecycle maintenance, habitat and gene pool protection
		Pest and disease control
		Global climate regulation by reduction of greenhouse gas concentrations
		Heritage, cultural
Revealed-preference	**Travel cost**	Physical and experiental interactions
Stated preference	**Contingent valuation**	Physical and experiental interactions
		Other cultural outputs
	Choice modelling	Other cultural outputs

For the values calculated with a market-based approach a three-year mean value was found. Some of the ecosystem services financial value can be calculated using several methods. For those all methods are presented and maximum and minimum values are found. A discussion around the values found in literature are performed both regarding connections to Sweden but also the completeness of the value for the ecosystem service.

Total values in both $SEK/ha \cdot yr$ and SEK/yr are obtained for all services and alternative land uses divided into milk- and meat cattle and in total. For the alternative land uses an assumption that all other land use is converted into the alternative land use is made. When cropland is presented as the alternative land use an assumption that feed to cattle are not produced resulting in no income from milk, beef or biomass-based energy are obtained.

2.5.1 | Provisioning services

For all three provisioning services market-based direct prices are used. The price of cultivated crops is a mean value for different cereals, the numbers is shown in Table 2.15. The price for milk and beef can be seen in Table 2.16. For the biomass-based energy the electricity price of 256 SEK/MWh was used (Nordpool, 2016).

Table 2.15: Market-based crop prices (Landsbygdsavdelningen, 2016).

Crop prices	$SEK/ton\ DM$
Oats	1 070
Grain	1 150
Wheat	1 210
Triticale	1 140
Rye	1 000
Mean - cereals	*1 114*

Table 2.16: Market-based food prices from the cattle production (LRF Mjölk, 2017; Jordbruksverket & Statistiska Centralbyrån (SCB), 2016).

Animal outputs	SEK/ton
Milk	3 303
Beef - cattle	30 273
Beef - middle-sized calf	28 553
Beef - young calf	34 057

2.5.2 | Regulating and maintenance services

The monetary value of the regulating and maintenance services are found almost exclusively with a market-based approach as a replacement or avoided cost. These are based on previous studies within the area as well as the quantification. For mediation of waste, toxics and other nuisances a replacement cost is calculated with an amendment value of organic matter of 0.023 - 0.039 $SEK/ton\ OM \cdot yr$ (Graves et al., 2015). The amendment value of organic matter is also used to calculate the value of soil organic carbon for the global climate regulation service together with the soil carbon fraction.

The cost of erosion depends only on the cost of the lost harvest associated with a yield loss. The yield loss calculations are based on values such as yield reduction and bulk density from Graves et al. (2015) as well as the erosion rates. The yield losses can be seen in Table 2.17.

Table 2.17: Calculated yield losses associated to erosion based on values from Graves et al. (2015).

Yield loss	$\%/yr$	$ton/ha \cdot yr$
Ley	0.09	0.006
Pasture	0.07	0.003
Natural pasture	0.05	0.0005
Cropland	0.31	0.0164

The lifecycle maintenance, habitat and gene pool protection ecosystem service value is calculated in three different ways. Firstly, if all the pollinators would disappear a yield loss equal to the pollination share of harvest is assumed. For the last two calculations, an avoided cost is calculated based on the areal supporting pollination. The two alternatives used in this study are; to rent honey bee colonies or buy artificial pollinators, also called drone-bees. The cost is for adding honey bee colonies or drone-bees for the areal supporting pollination, the recommended number of colonies are around 3 $colonies/ha$ (Mellblom, 2011). To rent a honey bee colony costs 500 SEK (Friberg & Haldén, 2016) and the cost for an artificial drone-bee would be commercially available for around 11 $SEK/drone-bee$ (Koslow, 2017) with 10 000 - 70 000 working bees in a colony (Nationalencyklopedin, n.d.) the price of a colony is 112 013 - 784 094 $SEK/colony$.

The value of the pest and disease control service is based on the cost of using pesticides on the areal that is supporting the natural enemies. The cost of pesticides as mean value calculated from the total amount of sold pesticides as well as the total economic value for 2012-2014, the values can be found in Table 2.18.

Table 2.18: Total economic value and the sold amount of pesticides 2012-2014 (Jordbruksverket, n.d.; Jordbruksverket & Statistiska Centralbyrån (SCB), 2016).

	2012	2013	2014	Mean
Economic value [$BillionSEK$]	1 833	1 882	2 073	1 929
Sold amount [ton]	4 828	4 466	4 635	4 643
[kg/ha]	1	1	0.9	0.97
Average price [SEK/ha]	380	421	402	401

The value of the global climate regulation is calculated using the soil carbon sequestration indicator and above-ground carbon. The values was obtained using a calculation value for carbon emissions of 1.14 $SEK/kg\ CO_{2equ}$ (Trafikverket, 2016). As 1.14 $SEK/kg\ CO_{2equ}$ is a rather high value for CO_2 emissions a sensitivity analysis is performed. For the indicator above-ground carbon an assumption of a linear growth and removal of biomass when it reaches its maximum is made. With this assumption the amount of above-ground carbon used in the economic calculation is half the average value shown in Table 2.10.

2.5.3 | Cultural services

The monetary value of the cultural services is based on previous studies and surveys as well as from the environmental compensation program in Sweden. For the physical and experiental interactions two studies were examined. In Ezebilo et al. (2013) a survey in Sweden with a willingness to pay open-ended question examined the maximum amount they were willing to pay to be able to visit an area in a recreational purpose. In Ezebilo (2016) another survey in Sweden examined the opportunity cost of travel including travel time as well as food and equipment. The values from both surveys can be found in Table 2.19.

For the heritage and cultural service the values from the environmental compensation program were applied. The compensation program is established to protect nature- and cultural heritage values and are applied for grasslands, natural pasture, edge zones in agricultural areas and forest. For those land areas with three different steps; general nature values, special nature values with and without the conditions for farm support met, a mean was calculated. There is a lot of rules and regulations to follow to be able to get the compensation, in Table 2.20 the maximum values are shown.

Table 2.19: The monetary value of recreation based on two different surveys (Ezebilo et al., 2013; Ezebilo, 2016).

	$SEK/person \cdot year$	$SEK/year$[1]
Stated preference - Contingent valuation		
Forest	5 178	1.3
Pasture	7 389	1.8
Farmland	7 600	1.9
Open/grassland	10 900	2.7
>1 nature type (mosaic)	12 290	3.0
Revealed preference - Travel cost		
Forest	7 205	1.8
Grass[2]	9 561	2.4
Meadow[3]	7 657	1.9

[1]Related to number of tax-payers and the land area share cattle production stands for (SCB, 2015, 2017) calculated with the following equation: $WTP \cdot (tax\ payers) \cdot (cattle\ production\ share\ of\ land\ use)$
[2]Nature area dominated by grasses
[3]Nature area dominated by grasses and other non-woody plants

Table 2.20: Possible compensations from the Swedish environmental subsidees (Jordbruksverket, 2016d, 2016c).

	SEK/ha	*Comments*
Grassland - Ley	500	
Management of pasture	1 000	*General nature values*
	2 800	*Special nature values*
	1 267	*Mean*
Natural pasture, forest	2 500	
Mosaic land areas	1 700	*Complement*

For the last cultural service, other cultural outputs, the values are collected from Nilsson (2004). The values for forest were collected from a survey with both an open- and closed-ended question, contingent valuation method to receive willingness to pay to preserve the forest. For the agricultural areas, a survey with a contingent valuation open-ended question asking the willingness to pay to prevent that half the agricultural landscape turns into forest. The values from both surveys are shown in Table 2.21. In a study by Kumm (2017) the willingness to pay to preserve natural pasture in Västra Götalands regionen, Sweden, was 578 $SEK/person \cdot year$ in increased taxes. With 7 744 031 taxpayers (SCB, 2015) and 442 916 ha pasture (Jordbruksverket, 2016b) the willingness to pay to preserve natural pasture is around 10 000 $SEK/ha \cdot year$.

Table 2.21: The willingness to pay to preserve the landscape based on studies described by Nilsson (2004) in 2017 monetary value.

	$SEK/ha \cdot year$
Forest	
Open-ended	739
Closed-ended	1 596
Agriculture	
Cropland[1]	1 716
Grassland - pasture	3 279
Natural pasture	4 142

[1]Also used for grassland ley

3 | Results

3.1 | Cattle related land uses in Sweden

In this section, the different land use areas for Swedish cattle is thoroughly examined and compared with the alternative land uses in a literature overview. The definition of the different areas and the associated names from articles can be found in Table 2.1. The areal distribution for milk and beef cows are presented in figure 3.1. Grassland is in total 52 % of the total land use where ley stands for 46 % and pasture 6 %. Natural pasture stands for 29 % where beef cows use most of the areal (C. Cederberg, personal communication, 12 March, 2017).

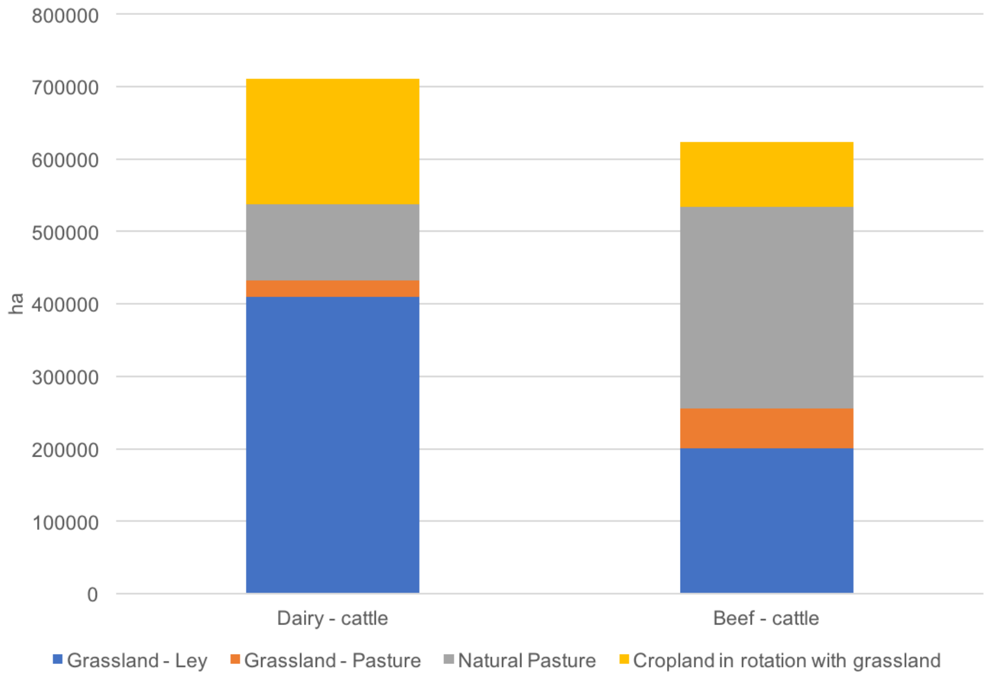


Figure 3.1: Land area distribution for the Swedish cattle industry (C. Cederberg, personal communication, 12 March, 2017)

3.1.1 | Grassland

Grassland is defined as an area covered by different grass and ley species. A grassland could either be used as a grazing area for cattle or as forage. When it is used as forage in Sweden its harvested two-three times per year and the ground is never left bare. In a Swedish grassland, there are a couple of recommended plant-mixtures depending on for example the soil conditions, manuring strategies and if grazing will occur (Jordbruksverket, 2015). The composition and maintenance of a grassland can results in a high bio- and plant diversity depending on the agricultural intensity (e.g., Knudsen et al., 2016; Ihse, 1995). Plant diversity positively affects the number of pollinators and natural enemies present as well as if it is woody or not (Shackelford et al., 2013; Öckinger & Smith, 2007; Cederberg et al., 2016). This leads to that grassland have higher number of pollinators and natural enemies compared to both forest and cropland areas. If manure is added to the area the number of natural enemies also is increasing (Pimentel et al., 1992). This leads to that grazing grassland areas have a higher number of beneficial arthropods than ley grassland. Water irrigation of the grasslands varies from grassland to grassland, in Sweden however the ley grasslands are normally not irrigated. On the grasslands with cattle grazing a small number of water is used as livestock water and the land is not irrigated. If needed manure collected from stables, where cattle is fed by silage, can be used as an energy sources. The potential from Swedish cattle sector is approximately 5.2 $MWh\ energy/cattle$ annually (Linné et al., 2008).

The provision of regulating and maintenance services depends on soil health. Soil nutrients, pH-value and organic matter is some of the indicators to a healthy soil (Cardoso et al., 2013). The soil organic matter in soil used for grassland is generally higher than for cropland (van Eekeren et al., 2008) and have lower levels than for a forest (Holubík et al., 2014). The cation exchange capacity is connected to the soils pH-levels and the retention of important nutrients in the soil (Cardoso et al., 2013). In grassland, the cation exchange capacity is slightly higher than for a forest and generally the same as for cropland (Holubík et al., 2014). The pH-levels however, is broadly lower than in cropland and the same as for a forest (Holubík et al., 2014). The amount of soil organic carbon is directly linked to the soil organic matter levels on the contrary, the amount of carbon sequestered differ. A transformation from grassland to forest does not affect the amount of sequestered carbon at the same time a change from grassland to cropland reduces the amount quite a bit (Ostle et al., 2009).

Other utilities affecting the regulating and maintenance services can be indicated by erosion rate, water infiltration and run-off capacity. These indicators are affected by if the ground is covered or uncovered and the amount of tillage used (Wolkowski & Lowery, 2008). All the indicators are positively affected by coverage and no-tillage maintenance. This leads to lower erosion rates and higher water infiltration and run-off capacities for grassland compared to cropland and at the same time small varying differences compared to forest depending on tillage and cattle appearances (Cerdan et al., 2010; GWP, 2015; Wagner et al., 2009; Wolkowski & Lowery, 2008). The buffering and attenuation capacity is measured by the amount of grass-covered areas leading to higher values compared to cropland and lower values compared to forests. The land areas capacity to handle air flows, connected to the ecosystem service; mediation of flows, is increasing with the number of trees present leading to lower values compared to forest areas (MAES, 2014).

The enjoyment grassland areas provide in cultural services varies in Sweden. The amount of bird and red-listed species as well as heritage and protected areas is loosely connected to the lands plant- and biodiversity. A higher biodiversity can lead to a larger amount of bird and red-listed species as well as a higher chance to be protected. However, the willingness to perform a recreational activity in a landscape as well as the enjoyment of its existence is a personal preference that is connected to for example childhood and values (Fredman et al., 2013). The amount of bird and red-listed species is depending on the surrounding areas leading to that grasslands could both have larger and smaller amount of species comparing to a forest (Å. Berg, 2002; Sandström et al., 2015). Comparing to a cropland however, grassland will generally have a larger amount of present species (Å. Berg, 2002; Sandström et al., 2015). The size of protected forest areas is much greater than protected grassland areas in Sweden (SCB, n.d.). However, Hasund, Kataria, and Lagerkvist (2011) states that grassland areas, together with natural pasture, are the most valuable land areas regarding heritage and culture.

Personal preferences are harder to give a value, Fredman and Hedblom (2015) did a national survey about Swedish people's recreational habits. They observed that the will to perform recreational habits in grassland areas are around the same as for a forest and higher compared to cropland. On the contrary, the number of visitors in grassland areas are much lower than for a forest and only slightly higher than for cropland areas (Fredman et al., 2013). In a meta-analysis by van Zanten et al. (2014) they compared European studies about landscape preferences. The result showed that grassland was preferred over both cropland and forest.

3.1.2 | Natural pasture

Natural pasture is often areas that is non-arable or in such a shape or condition that it is non-profitable to grow crops or ley. This results in less overgrown land areas and a maximum usage of resources. Natural pasture areas are an area with similarities to both grazing grassland and forest and consequently the connections to ecosystem services will be alike.

At a natural pasture, a high plant-and biodiversity is present as well as it is a preferable natural habitat for beneficial arthropods and pollinators (Foley et al., 2005; Shackelford et al., 2013; Öckinger & Smith, 2007). The amount of soil organic matter, soil nutrients, the soil pH and the climate regulation in a natural pasture is interpreted as less than for a forest with respect to the negative effects from grazing cattle and less trees (Fromm et al., 1993). This leads to that natural pasture have higher values of soil organic matter, soil nutrients levels (P,N,C,Mg) and climate regulation than cropland (Holubík et al., 2014; Ross et al., 1999; Anderson-Teixeira

& DeLucia, 2011). The amount of sequestered carbon decreases with a change from natural pasture to cropland (Ostle et al., 2009). However, the cation exchange capacity and pH-levels are lower for natural pasture than cropland (Holubík et al., 2014).

The surface of a natural pasture is always covered, provided no-overgrazing occurs, leading to a higher buffering capacity than cropland. Since some of the regulating and maintenance services is affected by if the surface is covered. This leads to lower erosion rates for natural pastures comparing to cropland and higher water infiltration and run-off capacities (Cerdan et al., 2010; GWP, 2015; Wolkowski & Lowery, 2008; Wagner et al., 2009). Comparing to forest instead, varying effects for erosion rates occur (Cerdan et al., 2010). For the remaining regulating and maintenance services mentioned only small negative differences occur depending on cattle appearance (Wolkowski & Lowery, 2008). For the mediation of air flows the amount of biomass, i.e. trees, have a positive effect (MAES, 2014) which leads to that natural pasture have higher values than cropland and the same as for a forest.

As stated earlier in section 3.1.1 natural pasture have a high heritage and cultural value (Hasund et al., 2011). For bird and red-listed species as well as protected areas natural pasture are understood as a forest. They are equivalent because a natural pasture contains the same diversity as a forest and often contain heritages valuable monuments. However, the amount of red-listed species decreases if the pasture overgrows leading to more species in a natural pasture area (Sandström et al., 2015). Comparing to cropland natural pasture both have a larger amount of protected areas as well as present bird and red-listed species (SCB, n.d.; Å. Berg, 2002; Sandström et al., 2015). In the personal preference surveys, natural pasture is interpreted as a forest with cattle present. The will to perform recreational activities, according to Fredman and Hedblom (2015), is increasing with cattle present and are higher for natural pasture compared to cropland. The effect cattle have on the number of visitors are harder to predict. A natural pasture has a higher number of visitors compared to cropland, since both forests and grazing grasslands have higher numbers of visitors (Fredman et al., 2013). At last, from the meta-analysis by van Zanten et al. (2008) the presences of livestock have a positive effect of the enjoyment of the landscape. Furthermore, a dominance of forest and natural vegetation scores higher than dominating cropland areas.

3.1.3 | Cropland

On the cropland, mostly cereals but also more protein rich crops such as field beans, peas, canola and soybean are cultivated. The crops are often in a rotation schedule which is important to maintain the soil in good health, especially for ecological farms where fertilizers are sparsely used (Jordbruksverket, 2016a). Croplands in Sweden are often sparsely irrigated but it varies from cropland to cropland and year to year. If needed, as mentioned for grassland ley, manure produced from cattle in stables fed by cereals can be used as an energy source.

A cropland has low plant- and biodiversity in favor of the cultivated crops. This lead to low amounts of pollinators as well as natural enemies compared to forests (Shackelford et al., 2013). In Sweden, a cropland is bare 8-9 months per year (Aug/Sept to May) if sown with spring cereals. This leads to higher erosion rates and lower buffering capacity, water infiltration and run-off capacities than for a forest (Cerdan et al., 2010; GWP, 2015; Wagner et al., 2009). As said before storm protection depends on the amount of tree present (Maes et al., 2016) leading to low protection comparing to forest areas. Depending on the level of maintenance the soil health differs (Cardoso et al., 2013). Overall cropland have lower amounts of soil organic matter, soil nutrients (P,N,C,Mg) and climate regulation than for a forest (Holubík et al., 2014; Ross et al., 1999; Anderson-Teixeira & DeLucia, 2011). On the contrary, the pH-levels and cation exchange capacity is higher for cropland than forest (Holubík et al., 2014). The amount of sequestered carbon increases with the change from cropland to forest (Ostle et al., 2009).

For the cultural services cropland have the lowest scores in the survey the willingness to perform recreational activities and achieves the lowest number of visitors (Fredman & Hedblom, 2015; Fredman et al., 2013). In the survey about the enjoyment provided by the landscape Cropland scores higher than both other land uses as well as forest (van Zanten et al., 2014). Cropland do not often contain heritage valued monuments or rare species which leads to a low amount of protected cropland areas compared to forests (SCB, n.d.). The bird and red-listed species that occur in croplands are depending on surrounding areas and for example the number of trees present (Å. Berg, 2002; Sandström et al., 2015). This leads to lower amount of present species compared to forest areas.

3.1.4 | Other land uses

This land area symbolizes the patches and islands between or in croplands, grasslands and natural pastures. It could be zones with flowers, trees, water, a fence, ditches etc. These "other" areas are often natural habitats for different natural enemies (Bianchi et al., 2006), pollination animals and/or flowers which often makes them a source of high bio- and plant diversity (Shackelford et al., 2013). They could also contain heritage in the form of for instance stonewalls. These areas also create a mosaic landscape with smaller and more diversified fields which also positively affect the biodiversity (Tscharntke et al., 2005).

The soil health of the edge zones depends on the composition and varies from case to case (Wood et al., 2000, p. 50). Overall a higher amount of soil organic matter and nutrients are found in edge zones compared to cropland. Compared to forest however, these values vary between higher values for edge zones with trees and high flower diversity (Cardoso et al., 2013). For edge zones with ditches and/or stonewalls the values are lower than for a forest. Water infiltration capacity as well as storm protection also depends on the composition (GWP, 2015; Maes et al., 2016). This leads to varying values of storm protection compared to both cropland and forest. For the water infiltration capacity, however overall positive values compared to cropland is found as lower tillage is performed (Wolkowski & Lowery, 2008).

As stated before with other land areas a more mosaic landscape is formed. This has a positive effect on both the amount of birds and red-listed species present (Å. Berg, 2002; Sandström et al., 2015). To keep the amount of present red-listed species high some maintenance of the edge zone is needed as overgrowth has a negative effect (Sandström et al., 2015). A large amount of heritage monuments is placed in other land areas which is confirmed as the amount of non-productive areas that are protected in Sweden are an extensive amount (SCB, n.d.). It is generally the same amount as protected forests and a larger area compared to cropland. From the meta-analysis by van Zanten et al. (2014) it is shown that a mosaic landscape is the most preferable landscape form. In the same article, historic buildings followed by green linear landscapes was the most preferred landscape elements (van Zanten et al., 2014). This leads to that other land areas provides a higher enjoyment than both forest and cropland areas. The willingness to perform recreational activities increases for a mosaic landscape, which these patches and islands create and support.

3.1.5 | Alternative land use - Forest

In the alternative land use forest the residues from forestry are used for energy production and other biomass fibers in the forest is used as timber. This is leading to negative effects for the services connected to energy production and biomass fiber for cattle land use areas. In a Swedish forest a large variety of wild edible plants, berries and mushrooms are present. This can also be true for edge zones depending on its composition, see section 3.1.4. The presence of wild animals, for hunting purposes, are high in Swedish forests they are often also present in nearby crop- and grassland areas. If cattle are present the amount of wild animals present is slightly less.

3.1.6 | Connections between cattle land use and ecosystem services

The connections between cattle land use and ES are presented with an 8-point scale, see figure 3.2, interpreted from the overview presented in section 3.1.1 - 3.1.5.

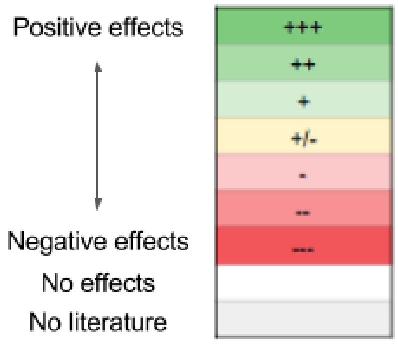


Figure 3.2: The 8-point scale used to describe the effects between cattle land use and ecosystem services.

In Table 3.1 the effects on ES of a transformation from the alternative land use forest to each cattle related land use is presented. The results indicate that cropland has overall negative impact compared to forest, except for cultivated crops, biomass from reared animals, and biogas production from manure. For both grassland and natural pasture the impacts vary for each ES. However, a connection between these land usages can be found. For edge zones and islands positive and positive- and/or negative effects are shown. The positive- and/or negative effects on ES are depending on the composition of the other land area. A lack of scientific research is manifested for the cultural ES.

In Table 3.2 the effects on ES of a transformation from the alternative land use cropland to each cattle related land use is presented. The results imply an overall positive effect for all land usages on the ES. The negative effects can be seen in the provisioning ES with cultivated crops as the largest contribution. The result implies a lack of scientific research for the cultural ES.

Table 3.1: The effects on ecosystem services of a transformation from the alternative land use forest to each cattle related land use.

Ecosystem services			Land use in Swedish cattle production	Grassland		Natural pasture	Cropland	Other
				Ley	Grazing/Pasture			
Provisioning services	Nutrition	Biomass	Cultivated crops	+	+		+++	
			Reared animals and thier outputs	+	++	++	+	
			Wild plants, algea and their outputs	-	--	+/-	-	+/-
			Wild animals and their outputs	+/-	-	+/-	+/-	
		Water	Surface water for drinking					
			Ground water for drinking					
	Materials	Biomass	Fibres and other materials from plants, algae and animals for direct use or processing	-	+/-	+/-	--	
			Materials from plants, algea and animals for agricultural use	+	+	+	+	
			Genetic materials from all biota	++	+++	++	--	
		Water	Surface water for non-drinking	--	-	-	---	
			Ground water for non-drinking	--	-	-	---	
	Energy	Biomassbased energy sources	Plant-based resources	---	---	-	---	
			Animal-based resources	+			+	
		Mechanical energy	Animal-based resources					
Regulation and maintenance services	Meditation of waste, toxics and other nuisances	Mediation by biota	Bio-remidation by micro-organisms, algae, plants and animals					
			Filtration/sequestration/storage/accumulation by microorganisms, algae, plants and animals					
		Mediation by ecosystems	Filtration/sequestration/storage/accumulation by ecosystems	-	-	-	---	+/-
			Dilution by atmosphere, freshwater and marine ecosystems					
			Mediation of smell/noise/visual impacts					
	Mediation of flows	Mass flows	Mass stabilisation and control of erosion rates	+/-	+/-	+/-	--	
			Buffering and attenuation of mass flows	--	-		---	
		Liquid flows	Hydrological cycle and water flow maintenance	--	-	-	---	+/-
			Flood protection	-			---	
		Gaseous/air flows	Storm protection	-	-		-	+/-
			Ventilation and transpiration	-	-		-	+/-
	Maintenance of physical, chemical and biological conditions	Lifecycle maintenance, habitat and gene pool protection	Pollination and seed dispersal	++	++	+++	--	+++
			Maintaining nursery populations and habitats	++	++	+++	--	+++
		Pest and disease control	Pest control	-	+	+	---	+
			Disease control	-	+	+	---	+
		Soil formation and composition	Weathering processes	-	-		---	+/-
			Decomposition and fixing processes	-	-		---	+/-
		Water conditions	Chemical condition of freshwaters					
			Chemical condition of salt waters					
		Atmospheric composition and climate regulation	Global climate regulation by reduction of greenhouse gas concentrations	++	++		---	
			Micro and regional climate regulation	-	--		---	
Cultural services	Physical and intellectual interactions with biota, ecosystems, and land-/seascapes	Physical and experiental interactions	Experiental use of plants, animals and land-/seascapes in different environmental settings	+/-	+/-	+	---	+/-
			Physical use of land-/seascapes in different environmental settings	-	-	+	---	+/-
		Intellectual and representative interactions	Scientific					
			Educational					
			Heritage, cultural	+++	+++	+++	---	+++
			Entertainment					
			Aesthetic					
	Spiritual, symbolic and other interactions with biota, ecosystems and land-/seascapes	Spiritual and/or emblematic	Symbolic					
			Sacred and/or religious					
		Other cultural outputs	Existence	-	-	+	--	++
			Bequest	-	-	+	--	+

Table 3.2: The effects on ecosystem services of a transformation from the alternative land use cropland to each cattle related land use.

Ecosystem services			Land use in Swedish cattle production	Grassland		Natural Pasture	Other
				Ley	Grazing/Pasture		
Provisioning services	Nutrition	Biomass	Cultivated crops	--	--		---
			Reared animals and thier outputs		+++	+++	
			Wild plants, algea and their outputs	+/-	-	+	+/-
			Wild animals and their outputs		-		+
		Water	Surface water for drinking				
			Ground water for drinking				
	Materials	Biomass	Fibres and other materials from plants, algae and animals for direct use or processing	+	++	++	+/-
			Materials from plants, algea and animals for agricultural use				---
			Genetic materials from all biota	++	+++	++	++
		Water	Surface water for non-drinking		+	++	+++
			Ground water for non-drinking		+	++	+++
	Energy	Biomassbased energy sources	Plant-based resources				
			Animal-based resources		-	-	-
		Mechanical energy	Animal-based resources				
Regulation and maintenance services	Meditation of waste, toxics and other nuisances	Mediation by biota	Bio-remidation by micro-organisms, algae, plants and animals				
			Filtration/sequestration/storage/accumulation by microorganisms, algae, plants and animals				
		Mediation by ecosystems	Filtration/sequestration/storage/accumulation by ecosystems	++	++	+++	++
			Dilution by atmosphere, freshwater and marine ecosystems				
			Mediation of smell/noise/visual impacts				
	Mediation of flows	Mass flows	Mass stabilisation and control of erosion rates	++	++	+++	
			Buffering and attenuation of mass flows	+	+++	+++	+++
		Liquid flows	Hydrological cycle and water flow maintenance	+	++	+++	+++
			Flood protection	++	+++	+++	+++
		Gaseous/air flows	Storm protection			+++	+/-
			Ventilation and transpiration			++	+/-
	Maintenance of physical, chemical and biological conditions	Lifecycle maintenance, habitat and gene pool protection	Pollination and seed dispersal	++	++	+++	+++
			Maintaining nursery populations and habitats	++	++	+++	+++
		Pest and disease control	Pest control	++	++	+++	+++
			Disease control	++	++	+++	+++
		Soil formation and composition	Weathering processes	++	++	+++	+++
			Decomposition and fixing processes	++	++	+++	+++
		Water conditions	Chemical condition of freshwaters				
			Chemical condition of salt waters				
		Atmospheric composition and climate regulation	Global climate regulation by reduction of greenhouse gas concentrations	+++	++	++	++
			Micro and regional climate regulation	++	+	+++	++
Cultural services	Physical and intellectual interactions with biota, ecosystems, and land-/seascapes	Physical and experiental interactions	Experiental use of plants, animals and land-/seascapes in different environmental settings	+	++	+++	++
			Physical use of land-/seascapes in different environmental settings	++	+++	+++	+++
		Intellectual and representative interactions	Scientific				
			Educational				
			Heritage, cultural	+++	+++	+++	+++
			Entertainment				
			Aesthetic				
	Spiritual, symbolic and other interactions with biota, ecosystems and land-/seascapes	Spiritual and/or emblematic	Symbolic				
			Sacred and/or religious				
		Other cultural outputs	Existence	+	++	++	+++
			Bequest	++	++	+++	+

3.2 Systematic review of effects from cattle related land use of selected ecosystem services

Selected ES were evaluated in a more thorough analysis based on a systematic review of the scientific literature. A total of 3 862 articles was part of the screening process and 360 (9 %) articles was retrieved in full text.

The result from the systematic review are presented in Table 3.4 and Table 3.5 with matrices showing the effects from each land use. The matrices both display the consistency among the articles as well as the size of knowledge base. The color code used is presented in Table 3.3. For the size of knowledge base a darker color (higher percentage) implies a larger amount of articles for the ES and land use.

Table 3.3: Color code for the presentation of the systematic review result for both consistency and the size of knowledge base for land usage.

Consistency	0-25 %	26-50 %	51-75 %	76-100 %
Positive effects				
Positive and/or negative effects				
Negative effects				
No effect				
size of knowledge base				

The matrices with forest as the alternative land use are shown in Table 3.4. The result indicate that the consistency is overall high for cropland and other-land. However, the size of knowledge base is low for other-land. The results are more inconsistent for grassland, both ley and pasture. The size of knowledge base is for grassland, cropland and natural pasture overall in the upper span of 25-50 % with some exceptions. The most reliable results are the negative effect cropland have on erosion rates and pest and disease control taking both consistency and size of knowledge base into consideration.

In Table 3.5 cropland is the alternative land use. The result indicate an overall higher size of knowledge base than with forest as the alternative land use. The consistency is on average in the span of 76-100 %. However, for some of the ecosystem services and land use categories with a larger size of knowledge base the consistency is decreasing. The most trustworthy result is the positive effect from ley grassland on the mediation of toxics.

For the cultural ES a mosaic landscape affects the different services. The number of articles that introduced mosaic landscape to have a positive effect on the ES was 29 % of the retrieved full text cultural ES articles. For physical and experiental interactions, it was 24 % of the articles. For heritage and cultural it was 28 % and for other cultural outputs 35 % of the articles mentioned a positive effect from mosaic landscape.

3.2.1 | Statistics from the systematic review

The number of retrieved full text studies divided into publication year is shown in Figure 3.3. The number of articles increases with the publication year implying that these types of studies around ecosystem services are a rather new research area.

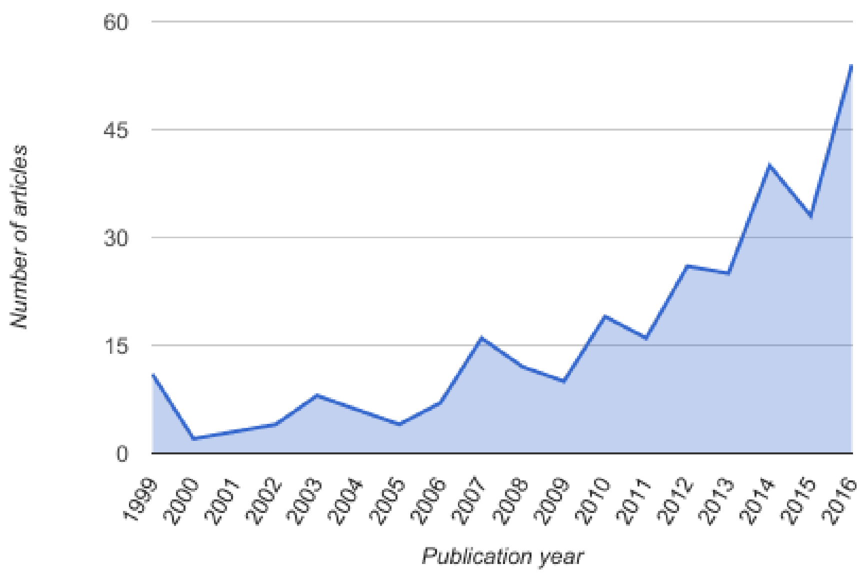


Figure 3.3: Number of retrieved full text studies divided into publication year in the systematic review.

The geographical distribution for the retrieved full text studies varies for cultural and regulating and maintenance services. In Figure 3.4 the statistics are shown. For the cultural services 88 % of the studies are from Europe, 8 % have a global approach, 2 % from North America and for 3 % a geographical place is not applicable. For the regulating and maintenance services 50 % of the studies are from Europe, 23 % from North America, 5 % from Oceania, 3 % have a global approach, 2 % from Asia, 1 % from Africa and 16 % of the studies a geographical place is not applicable.

Table 3.4: Resulting matrices from the systematic review with the alternative land use forest, references in Appendix A.

A: The consistency.

	Swedish cattle land use / Ecosystem service	Ley	Grazing/Pasture	Natural pasture	Cropland	Other
Regulation and maintenance	Mediation of waste, toxics and other nuisances					
	Mass stabilisation and control of erosion rates					
	Lifecycle maintenance, habitat and gene pool protection					
	Pest and disease control					
	Global climate regulation					
Cultural	Physical and experiental interactions					
	Heritage, culture					
	Other cultural outputs					

B: Size of knowledge base.

	Swedish cattle land use / Ecosystem service	Ley	Grazing/Pasture	Natural pasture	Cropland	Other
Regulation and maintenance	Mediation of waste, toxics and other nuisances					
	Mass stabilisation and control of erosion rates					
	Lifecycle maintenance, habitat and gene pool protection					
	Pest and disease control					
	Global climate regulation					
Cultural	Physical and experiental interactions					
	Heritage, culture					
	Other cultural outputs					

Table 3.5: Resulting matrices from the systematic review with the alternative land use cropland, references in Appendix A.

A: The consistency.

	Ecosystem service \ Swedish cattle land use	Ley	Grazing/Pasture	Natural pasture	Other
Regulation and maintenance	Mediation of waste, toxics and other nuisances				
	Mass stabilisation and control of erosion rates				
	Lifecycle maintenance, habitat and gene pool protection				
	Pest and disease control				
	Global climate regulation				
Cultural	Physical and experiental interactions				
	Heritage, culture				
	Other cultural outputs				

B: Size of knowledge base.

	Ecosystem service \ Swedish cattle land use	Ley	Grazing/Pasture	Natural pasture	Other
Regulation and maintenance	Mediation of waste, toxics and other nuisances				
	Mass stabilisation and control of erosion rates				
	Lifecycle maintenance, habitat and gene pool protection				
	Pest and disease control				
	Global climate regulation				
Cultural	Physical and experiental interactions				
	Heritage, culture				
	Other cultural outputs				

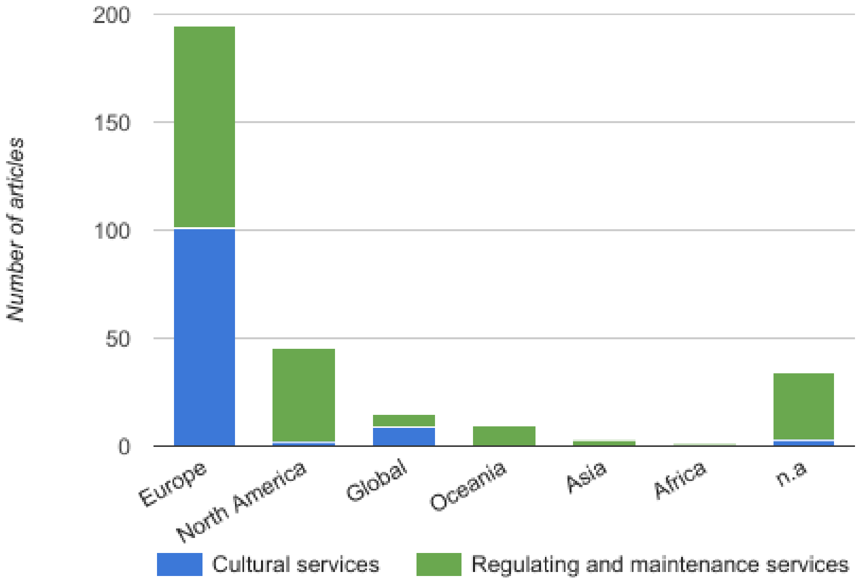


Figure 3.4: Geographical distribution of retrieved full text studies in the systematic review.

Four types of studies were captured from the retrieved full text studies; based on empirical data, a literature review, a modelling approach or survey based. The number of articles observed for each study type are presented in Figure 3.5, some studies were based on two types and are then present in both categories. 45 % of the cultural studies was a literature review, 33 % was based on a survey, 13 % had a modelling approach and 8 % was based on empirical data. The regulating and maintenance service studies were mostly based on empirical data (55 %), 27 % a literature review and 19 % had a modelling approach.

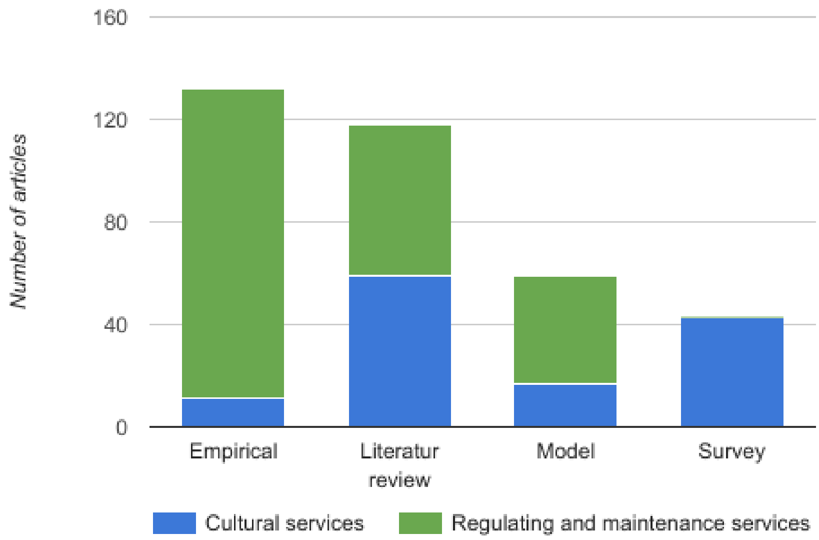


Figure 3.5: Retrieved full text studies divided into type of study in the systematic review.

3.3 | Quantification of selected ecosystem services associated with cattle land use

The result from the quantification is presented in Tables 3.6, 3.7, 3.9 for all cattle related and alternative land uses.

3.3.1 | Provisioning services

The quantities for the provisioning services are mainly statistically measured quantities and have therefore no span, the values can be seen in Table 3.6. For produced milk and beef the cattle related land uses produces in total 4 276 $kg\ milk/ha$ and 222 $kg\ beef/ha$ (Jordbruksverket & Statistiska Centralbyrån (SCB), 2016). Comparing to the alternative land use forest higher numbers are, not surprisingly, shown for all indicators except for energy from forestry products.

Comparing to the alternative land use cropland in Table 3.6 the conventional yields are compared, for ecological ley fields a decrease in yield with 1 $ton\ DM/ha$ happens (C. Cederberg, personal communication (MiBeeInt), 20 April 2017). For cropland, the drop is around 2 $ton\ DM/ha$ (C. Cederberg, personal communication (MiBeeInt), 20 April 2017).

Table 3.6: Quantities for the provisioning services for cattle associated and alternative land uses.

Ecosystem service	Indicator	*Unit*	Ley	Grazing/Pasture	Natural pasture	Cropland	Other	Forest
Cultivated crops	Yields of food and/or feed crops	*ton DM/ha*	6.64	4.2	1.2	5.28	0	0
	Area	*kha*	611	78	383	213	750	-
Reared animals and their outputs	Livestock	*cattle/ha*	0	5	2	0	0	0
Biomass-based energy sources	Forestry products	*MWh/ha*	0	0	0	0	0	1.79
	Energy from manure treatment systems	*MWh/ha*	1.68	0	0	0.59	0	0

3.3.2 | Regulating and maintenance services

The quantities for the regulating and maintenance services are a mix of statistics and study results which leads to a large variation within each indicator. The values presented in Table 3.7 are either an arithmetic mean or a weighted arithmetic mean. For the indicator soil carbon sequestration, global climate regulation, the values can be found in Table 3.8.

The ecosystem service with the most surprising result in the quantification are mediation of waste, toxics and other nuisances. Ley, grassland pasture and other land use were expected to have higher values than forest but overall they have lower values. For both cropland and natural pasture the quantification values are as predicted from the literature overview for this service. Comparing to cropland the values for grassland pasture are unexpected. For the indicators regarding pollination cropland have unexpectedly higher values than forest. For lifecycle maintenance, habitat and gene pool protection and pest and disease services the natural pasture was expected to have the same values as forest, in the quantification natural pasture have higher values for both services. For the other services the result from the quantification is expected and follows the systematic review.

3.3.3 | Cultural services

The quantification values for the cultural services are mainly based on various studies. The quantification results comparing to the alternative land use forest have surprising values in the heritage, cultural service where cropland have a higher percentage of cultural protected areas. In physical and experiental interactions, other land use has a low bird indicator, however as mentioned mosaic landscape makes the landscape more attractive to perform recreational activities which leads to a higher overall quantity for other land use areas. For the comparison to cropland in the cultural heritage service the indicator is surprisingly higher for cropland than for the cattle related land uses. The remaining results are expected seen from the systematic review.

Table 3.7: Quantities for the regulating and maintenance services for cattle associated and alternative land uses.

Ecosystem service	Indicator	*Unit*	*Ley*	*Grazing/Pasture*	*Natural pasture*	*Cropland*	*Other*	*Forest*
Mediation of waste, toxics and other nuisances	Soil organic matter, SOM	*ton OM/ha*	129	75.9	132.8	101	136.9	149.6
	Amount of nitrogen in soil	*mg N/kg dry soil*	435.28	435.28	540.27	168.61	-	540.27
	Amount of phosphorus in soil	*mg P/l soil*	64.21	64.21	121.72	156.12	-	121.72
Mass stabilisation and control of erosion rates	Erosion rate	ton/ha·*year*	1.54	1.21	0.76	5.25	1.45	0.14
Lifecycle maintenance,habitat and gene pool protection	Pollination share of harvest	%	0	0	-	12.5	-	0
	Pollinators species-richness	*Rank*	3	3	1	4	2	5
	Areal supporting pollination	%	75	100	100	50	100	25
Pest and disease control	Use of pesticides	%	2	0	0	87	0	0
	Areal supporting natural enemies	%	75	100	100	50	100	25
Global climate regulation by reduction of greenhouse gas concentrations	Soil organic carbon, SOC	*ton C/ha*	64.5	64.5	37.9	50.5	68.4	70.3
	Above-ground carbon	*ton C/ha*	4.25	4.44	16.45	5	1.5	82.25

Table 3.8: Soil carbon sequestration ($ton\ C/ha \cdot yr$) in cropping systems with and without cattle

	"Cattle" cropping system with grassland (ley) in rotation with annual crops, mostly grain	"Non-cattle" cropping system with annual crops and no rotation with grasslands (ley)
	Yearly soil C sequestration $Ton\ C/ha \cdot yr$	
Grassland ley on cropland	0.13[1]	-
Annual crops (mostly grain) on cropland	0.13[1]	0
Natural pasture	0.050[2]	0

[1](Kätterer et al., 2012) [2](Karltun et al., 2010)

3.4 | Monetary valuation of selected ecosystem services associated with cattle land use

For the monetary valuation maximum and minimum values are obtained when possible for each ecosystem service and cattle associated and alternative land uses. The results are presented in Table 3.10. The cattle production in Sweden have a monetary value of 27.2 - 36.7 $billion\ SEK/year$. If all land area were transformed into the alternative land use forest the monetary value would be 3.1 - 21.8 $billion\ SEK/year$. If all cattle related land areas was converted into cropland the monetary value would be 11.2 - 14.2 $billion\ SEK/year$. The alternative land use cropland has a value of 5 955 $SEK/ha \cdot yr$ for cultivated crops.

The distribution of the average total value for each ecosystem service for cattle related land uses and the alternative land uses are shown in Figure 3.6. For the cattle related land uses physical and experiental interactions, milk, beef and other cultural outputs have the three largest shares of 31 %, 30 %, 14 % and 14 % respectively, see Figure 3.6.A. The ecosystem services with the three largest shares for the alternative land use forest are global climate regulation (68 %), physical and experiental interactions and other cultural outputs (12 %) and biomass-based energy sources (5 %), see Figure 3.6.B. For cropland, as the alternative land use, cultivated crops, other cultural outputs and physical and experiental interactions have the largest shares of 61 %, 18 % and 15 % respectively, see Figure 3.6.C.

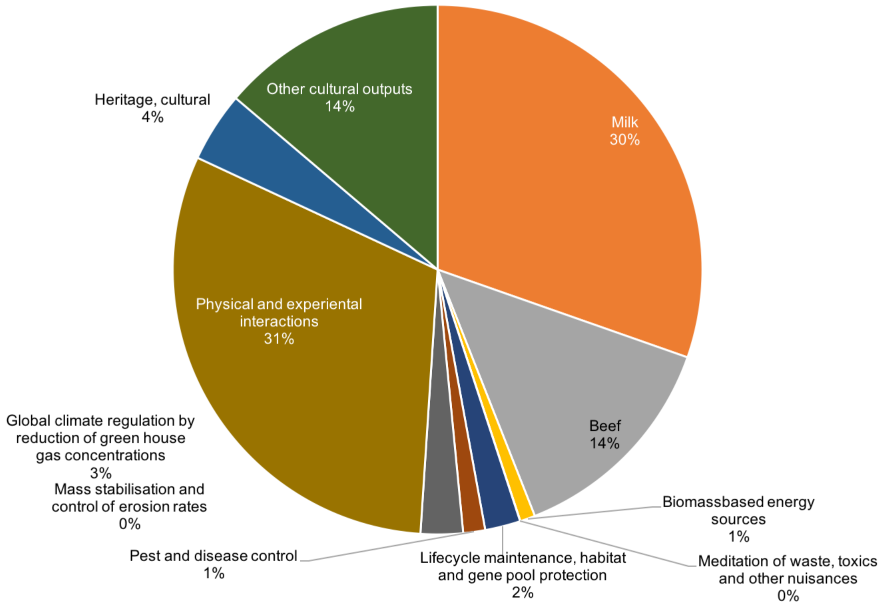
Table 3.9: Quantities for the cultural services for cattle associated and alternative land uses.

Ecosystem service	Indicator	*Unit*	*Ley*	*Grazing/Pasture*	*Natural pasture*	*Cropland*	*Other*	*Forest*
Physical and experiental interactions	Willingness to perform recreational activities in the area	*scale* (1 – 5)	2.7	2.7	3.45	1.95	-	3.2
Heritage, cultural	Protected cultural areas	%	0.28	2.02	2.02	10.55	-	0
Other cultural outputs	Protected area	%	0.0048	0.1403	0.1403	0.0660	0.0003	3.9000
	Red-listed species	10^{-4} *number/ha*	4.18	24.34	6.64	0.95	-	0.65
	Landscape preference	*normalized scale* (0–1)	0.60	0.73	0.60	0.52	0.45	0.50

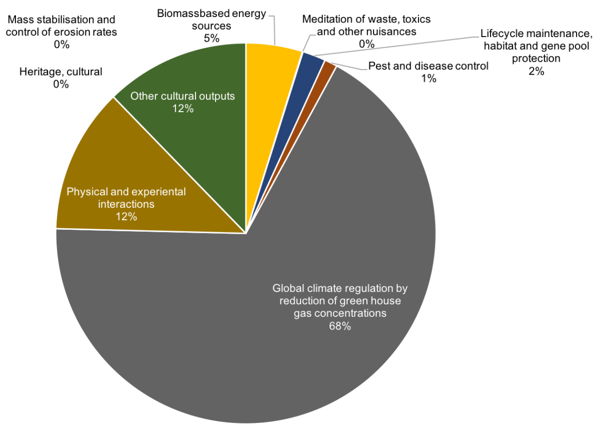
Table 3.10: Minimum and maximum monetary values in $SEK/ha \cdot yr$ for selected ecosystem services associated with cattle land use.

	Ecosystem service	Comment	Ley		Grazing/Pasture		Natural Pasture		Cropland		Other		Total - cattle land use		Forest	
			Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
Provisioning	**Cultivated crops**		0		0		0		0		0		0		0	
	Reared animals and their outputs	Milk	-		-		-		-		0		14 123		0	
		Meat	-		-		-		-		0		7 263		0	
	Bimassbased energy sources		431		0		0		151[1]		0		582		458	
Regulation and maintenance	**Mediation of waste, toxics and other nuisances**		5.01	3.00	2.94	1.77	5.15	3.09	3.92	.35	5.31	3.18	22.32	13.39	5.80	3.48
	Mass stabilisation and control of erosion rates		-6.64		-1.81		-0.32		- 19		-		-27.49		-	
	Lifecycle maintenance, habitat and gene pool protection		1 125	0	1 500	0	1 500	0	750	-753	1 500	0	6 375	-753	375	0
	Pest and disease control		312		416		416		208		416		1 768		104	
	Global climate regulation		661	40.42	690	40.42	2 557	15.55	777	40.42[1]	233	5.31	4919	142.11	12 786	46.64
Cultural	**Heritage, culture**		500		1 267		2 500		0		1 700		10 852		0	
	Other cultural outputs		1 716		3 279		10 106	4 142	1 716		0		16 816	10 852	1 590	739
	Total	$[SEK/ha \cdot yr]$	15 621	13 874	8 293	6 142	22 617	12 609	7 423	5 181	3 855	2 119	57 808	39 925	15 324	1 350
	Cultural - Physical and experiental interactions	$[billion\ SEK/yr]$	2.7	2.37	2.37	1.83	1.83	1.79	1.9	1.88	3.05	0	11.84	7.87	1.79	1.28
	Total	$[billion\ SEK/yr]$	12.8	11.4	3.7	2.9	11.9	8.0	5.2	4.7	3.1	0.1	36.7	27.2	21.8	3.1

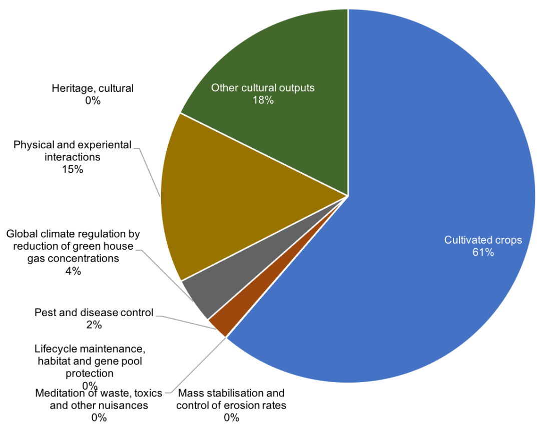
[1] Alternative Land Use Cropland - 0 $SEK/ha \cdot yr$



A: Cattle related land uses



B: Alternative land use, Forest



C: Alternative land use, Cropland

Figure 3.6: Pie charts over the distribution of the average total value in *billion SEK/year* for each land use category and ecosystem service

The provisioning services contributes with the largest, most certain, monetary value of 14.3 *billion SEK/year* (39 - 53 %), for the cattle related land uses. Regulating and maintenance services stands for 0.3 - 3.6 *billion SEK/year* (1 - 10 %) and the cultural services stands for 12.5 - 18.8 *billion SEK/year* (46 - 51 %) of the maximum monetary value. In Figure 3.7 the distribution within the provisioning service are shown with milk and beef as the largest shares of 68 % and 30 % respectively. For the cultural services the largest contributor are physical and experiental interactions with a share of 63 % of the value and other cultural outputs with a share of 30 %.

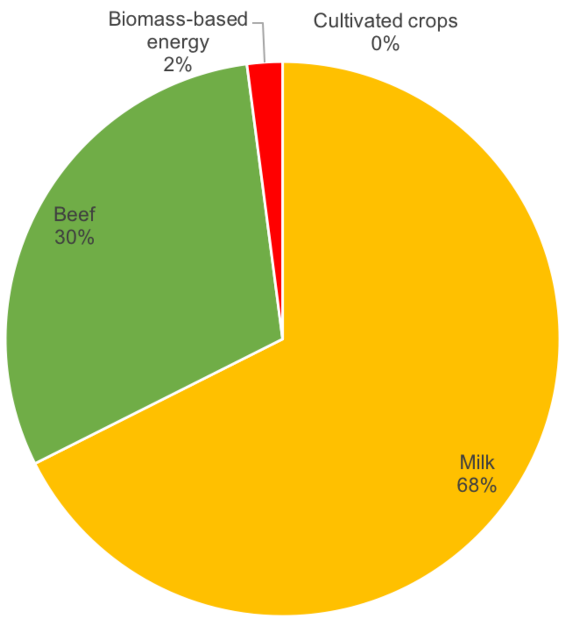


Figure 3.7: Pie chart over the shares within the provisioning services total economic value in *SEK/year*.

As the provisioning services stands for a large share of the total value the non-market values from the regulating and maintenance and cultural services are shown in Figure 3.8. The result implies that the cattle related land uses have a larger monetary value for the non-market values than both the alternative land uses.

The distribution over the specific land uses related to cattle production can be seen in Figure 3.9. Here the production of milk and beef are divided over the land areas using the land area distribution for each service. This leads to that the distribution is connected to the specific land distribution and will most likely change if the land distribution changes. Grassland ley stands for the largest share of 35 - 42 % and natural pasture stands for 29 - 32 % of the monetary value. This is probably connected to the fact that they have the largest amount of produced milk and beef per hectare respectively together with the fact that grassland ley stands for the largest area. For the monetary values measured in $SEK/ha \cdot year$ both grassland ley and natural pasture stands for around 25 - 30 % of the monetary value each which strengthens the theory.

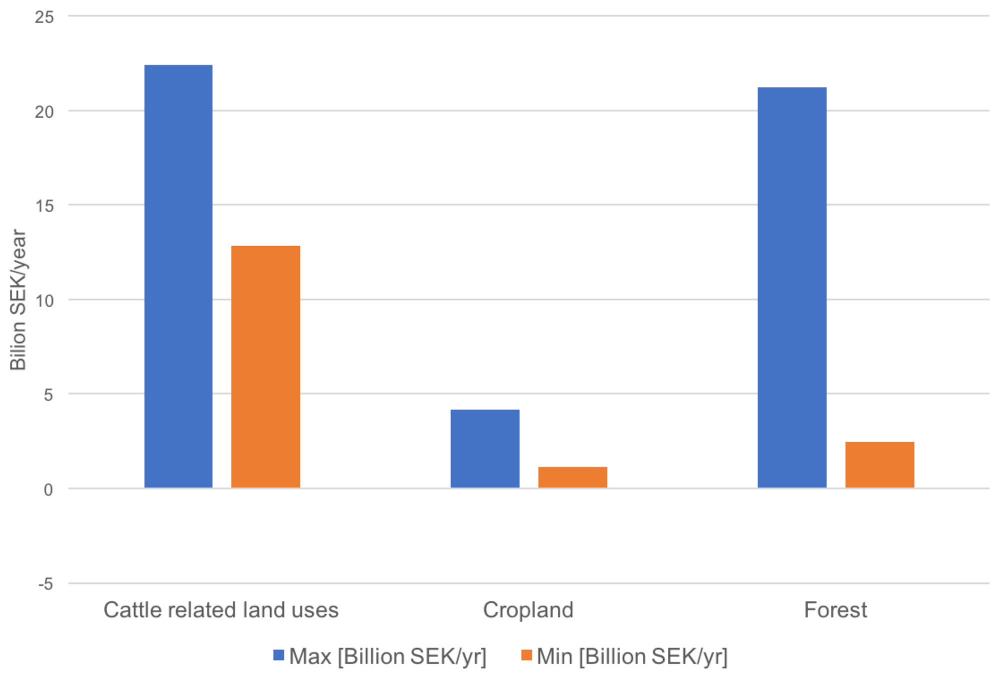


Figure 3.8: The non-market values, regulating and maintenance- and cultural services, for cattle related and the alternative land uses.

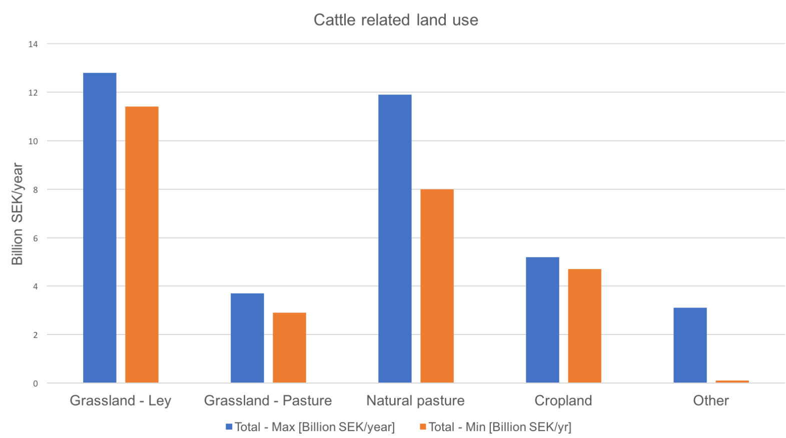


Figure 3.9: The total value distributed for cattle associated land uses.

The monetary value of dairy production is 15.9 - 20.0 $billion\ SEK/year$ and for beef production the value is 11.2 - 16.7 $billion\ SEK/year$. The distribution between the land uses for the maximum values can be seen in Figure 3.10. The values for dairy and beef production are divided over the land areas using the land distribution. This leads to that the results are connected to the land use shares, see Figure 3.1, considered that in 2015 almost 22 times more milk was produced, see Table 2.8. The results and shares will therefor also change together with a change in the land distribution.

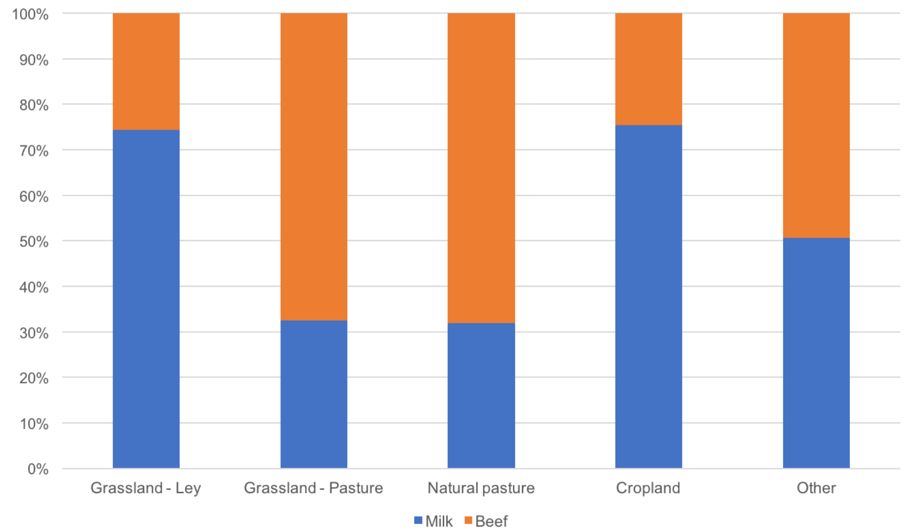


Figure 3.10: Distribution of shares of the total maximum monetary value (in $SEK/year$) for milk and beef cattle for each associated land use in.

4 | Discussion

4.1 | Uncertainties and methodological limitations

The thesis is based on a literature study and are therefore limited to the data available in other studies and assumptions. We have chosen to exclude biodiversity as an ecosystem service as well as abiotic ecosystem outputs that are not included in our classification of ecosystem services. This have most likely affected the thesis to underestimate the value of some land uses both in the quantification as well as in the monetary valuation.

Only the effects on the chosen ecosystem services from the land uses are considered in this thesis. For example, the amount of methane from cattle's digestive system is not considered as well as emissions from machinery.

4.1.1 | The screening process in the systematic review

The result from the systematic review are depending on the screening process and chosen keywords. The general keywords; *ecosystem service* or ecosystem* or agroecosystem**, can be seen in Table 2.2, have potentially sorted out a large number of relevant articles. On the contrary, a total of 3 862 articles was obtained in the first search. A search in WoS without these keywords result in an increase with around 8 times for the regulating and maintenance services and 15 times for the cultural. This is because the concept of ecosystem service and ecosystems are relatively new and has not taken place within especially the cultural services. If this would have affected the result significantly is however, hard to predict.

The title and abstract screening process was divided into two parts with the two questions; "Do the literature evaluate and/or compare effects on ES for the relevant land usages to the alternative land uses?" and "Is it transferable to Swedish conditions?" as a base. During the first question around 85 % of the articles were rejected. Most of the articles that was rejected in the first round did not compare the relevant land uses to one of the alternative land uses or had performed an overview of scientific literature in the area. After question two, 40 % of the remaining articles were further rejected. For the regulating and maintenance services the largest share of the rejected articles was from tropical climate zones. If the climate zones in Sweden had not been considered the result from the systematic review would have been different. For example, the soil organic carbon varies in different soil types for different climate zones which effects both mediation of toxics and the climate regulation service (Eswaran et al., 1993). For the cultural ecosystem services only 25 % of the articles was rejected in the second round. These were scattered throughout the world from Chile, South America to China, Asia. If these would have been included the results would have differ because the perception about cultural ecosystem services varies globally mainly because of cultural differences (Fredman et al., 2013). The perceptions also vary because of different compositions in nature (Fredman et al., 2013). For example, is Sweden covered to 55 % of forest (SCB, 2017) and forest is the dominated land use in Europe (SCB, 2010). In Asia, however grassland is the dominated land use (SCB, 2010). This effect the perception and enjoyment of different nature areas, at what extent and direction is however not clear.

For the cultural services only articles from Europe was obtained in full text because cultural upbringing, religion and the approach to nature and recreation are of importance. However, parts of United States are more alike Sweden in this sense than southern parts of Europe. Leading to question the plausibility of this limitation. Only parts of US are alike Sweden and with the lack of a complete knowledge base this limitation was relevant. This may however, have favored articles that are irrelevant on the cost of relevant ones. How this has effected the result of the systematic review and to what extent is however unclear.

When the screening process was done, the articles were retrieved in full text. Only 13 articles (3 %) could not be retrieved in full text spread among 6 of 8 ecosystem services. If these articles were retrieved the results would probably not change noticeably. During the process when data was captured some degree of free interpretation of the articles content occurred. The free interpretation could be both in context of effect and land area category as some articles for example used different land use classifications. If only articles with outspoken quantities for the ecosystem service and relevant, correct, land areas were considered free interpretation would have been limited. This is probably the largest source of error in the result as it is colored by previous knowledge. However, overall the results have a low rate of consistency which shows that free interpretation of the articles, and previous knowledge, is not reflected in the results.

4.1.2 | Quantification

The amount of ecosystem services to be reviewed and quantified was limited and chosen based on a semi-quantification with an 8-point scale interpreted from the literature study. The categories were chosen for different reasons connected to both Sweden's environmental objectives (Naturvårdsverket, 2016) and the current discussion topics among researchers and politicians. If different services were chosen the result would most likely look different. The differences between cattle related land use and the alternative land uses would probably not change noticeably. The ecosystem services chosen reflects the overall effects from the land uses which results in good comparing numbers.

The indicators for each ecosystem service covers various amounts of the service. For the provisioning services the indicators covers their service completely but for both regulating and maintenance and cultural service the indicators does not fully cover their service. The mediation of waste, toxics and other nuisances is a service that describes the decomposition, filtration and binding of compounds in the soil. The amount of soil organic matter describes in some way the health status of the soil, another good indicator would for example be the cation-exchange capacity of the soil. The erosion rate indicator for mass stabilization and control of erosion rates only cover part of the service. The other part stands for the control and prevention of erosion with for example vegetation cover. The lifecycle maintenance, habitat and gene pool protection the indicators which are reflecting pollination only covers half the service. The other part of the service is about maintaining habitats for plants and animals, such as edge zones. The indicators for the pest and disease control covers the service well, an indicator covering the total number of natural enemies could be added. The indicators for the global climate regulation by reduction of greenhouse gas concentrations service also covers the service almost completely. The fact that most of the regulating and maintenance services only is half covered by its indicators the quantification is an underestimate of the value of cattle related land uses.

The status for the indicators that cover the cultural services are even worse. For the cultural ES bio-physical indicators are hard to find which leads to a need to quantify perceptions and importance of nature for different persons, subjective valuation. The quantification values are large underestimates for the cultural ES. Where the lack of research in the area as well as the difficulty of subjective valuation are large contributory facts.

The credibility of the indicators can also be questioned based on the large variety of methods used. The indicators obtained by statistical means have the largest credibility while the indicators with only one literature reference have a low credibility. This leads to an uncertainty in the result that is hard to predict and quantify.

Another possibly large factor for an underestimation is the calculation of the other land use area. A simple assumption of large rectangular fields with edge zones of a width of 2 m is a rough underestimation. Fields are overall smaller and contains point islands leading to a larger area of other land areas.

4.1.3 | Monetary valuation

As for the quantification, the indicators that are the basis for the monetary valuation have a large variety of credibility as well as the question about covering the whole service. The provisioning services monetary values are from statistical values and indicators that covers the services completely leading to a high credibility and a trustworthy result. For the other, non-market values, this is not the case. For both categories of services the values are obtained from a few sources and only cover a part of the service which leads to an uncertainty in the result. Since the indicators at most covers part of the services, see section 4.1.2, the result is most likely an underestimation of the monetary value. How large the fault is, is however hard to predict.

For the cultural services the method of using values from the environmental compensation program is most likely a large underestimation as the program is highly debated. The reason for the choice of the values are the lack of other indicators for the cultural and heritage service. Together with the fact that subjective valuation is difficult, the largest underestimation is probably within the cultural services.

To calculate the total value for the alternative land use, an assumption that all other land areas were converted into the alternative land use was made. This is however not completely true, it would always exist at least edge zones around the area. For a change to cropland some of the other land areas would disappear to maximize production but it is not likely that all would disappear. For example, dry stonewalls would not be removed from the landscape. This leads to an overestimation of the value for the provisioning services for both alternative land uses. For cropland, an underestimation for provisioning and maintenance as well as cultural services is made. For forest a slight overestimation for provisioning and maintenance as well as the cultural services are made.

4.2 | The results and their implications

With the literature overview as a base the systematic review showed a couple of surprising effects comparing to forest. For the regulating and maintenance services grassland ley and pasture showed overall a more positive effect in the systematic review than the literature overview except for global climate regulation. Natural pasture has no effect according to the systematic review while both positive and negative effects was observed in the literature overview. For mass stabilization and control of erosion rates grassland ley, pasture and natural pasture had positive- and negative effects from the literature while from the systematic review a negative effect was shown with a consistency rate of 50 - 75 %.

For the cultural services, less surprising results was observed in the systematic review. For other cultural outputs, positive effects with a consistency rate of 40 % from grassland ley and pasture was observed instead of the negative effects noticed in the literature overview. For psychical and experiental interactions, other land use showed a positive effect with a consistency of 100 % (size of knowledge base 17 %) while it had positive-/negative effects observed in the literature overview.

In the results from the systematic review a higher consistency and size of knowledge base overall can be seen when comparing to cropland as the alternative land use. This can probably be explained with the overall higher number of articles comparing the respectively land uses to cropland, see Figure 4.1. An overall low size of knowledge base for other land uses, e.g. edge zones, is most likely a result from the chosen keywords were other land areas are not highlighted, see Table 2.2. Another reason for the low size of knowledge base for other land areas could be as simple as the amount of research in the area is limited.

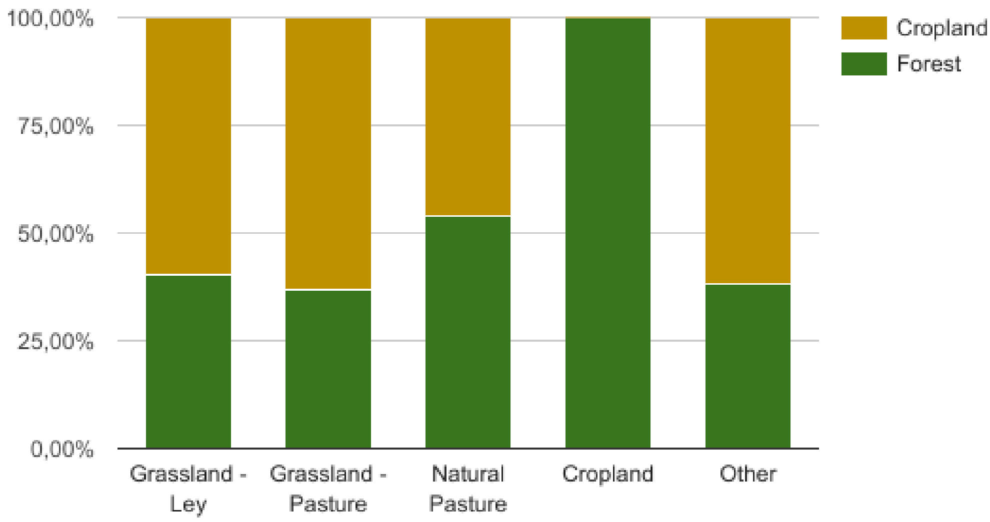


Figure 4.1: Percentage distribution of the total number of articles comparing each cattle associated land use to the alternative land use.

For regulating and maintenance services the overall size of knowledge base is higher than for the cultural services. This is most likely a result from the choice of keywords, for cultural ecosystem services the screening process resulted in an overall higher number of articles. However, the number of articles were an effect could be collected was low. For the cultural services the amount was around 60 % and for the regulating and maintenance the amount was around 90 %. Another reason why the size of knowledge base for cultural services is low could be the fact that the amount of research in the area is lower. These factors together are probably the reasons why the overall size of knowledge base is low for cultural services.

The monetary valuation result for cattle associated land use is moderately depending on the income from biomass-based energy (1 % of total value). The quantification indicator; energy from manure treatment systems is calculated as a total potential of biomass in Swedish cattle production implying that this income may not be present. If the income from biomass-based energy from manure was not present the value of Swedish cattle production land use would be 26.9 - 36.4 $billion\ SEK/year$.

Two economic indicators were excluded from the total valuation, drone-bees and the cost of soil organic carbon. The reason to exclude drone-bees was because the cost of drone-bee communities had a large variation, 112 - 784 $thousand\ SEK/community$.

If these would have been included the maximum value of cattle related land use would increase with 6 564 % while the alternative land use forest would increase with 3 458 % and cropland with 21 195 %. As the indicators, amount of soil carbon sequestration and above-ground carbon, for the ES global climate regulation describes and covers the service the best soil organic carbon is excluded.

As mentioned before, the calculations regarding other land areas could be a source of under- and over estimations. An assumption of a twice as large area for other land use leads to that the total value only increases with 0.2 - 9 % implying a low dependency of other land areas. The other difficulty with other land areas was regarding the transformation into the alternative land use cropland. If we assume that all edge zones, other land areas, was kept intact in the transformation to cropland. The total value of the alternative land use cropland, with other land areas remaining intact, would then be 11.1 - 17.1 *billion SEK/year*, a change with -1 - 21 % of the value.

Both the regulating and maintenance services and cultural services are assumed to be underestimates. If the regulating and maintenance services increases with 100 % the total value increases with 10 %. For the cultural value an increase of 100 % results in an increase of 51 % for the total value. This implies that the results are relative robust for changes within the regulating and maintenance services but not for the cultural services.

As the CO_2 emission cost of 1.14 $SEK/kg\ CO_{2equ}$ is high a sensitivity analysis was performed with half the value, 0.57 $SEK/kg\ CO_{2equ}$. The total value of cattle related land use is decreased by 2 %, the alternative land use cropland by 4 % and forest by 38 %. This is implying relative robust results for changes regarding CO_2 emission cost except for the alternative land use forest. The main reason that the alternative land use forest are more sensitive to changes in CO_2 emission costs are the fact that global climate regulation stands for the largest share of the total value (68 %).

Comparing the value of lifecycle maintenance, habitat and gene pool protection of -160 - 1 539 *million SEK/year* with the study by Pedersen et al. (2009) that estimated the total value of pollination to 189 - 325 *million SEK/year*. This implies both a large under- and overestimation of the pollination service. The study however bases their values on the yield loss related to the pollination share of harvest while the maximum values from the thesis are based on the avoided cost of adding beehives on the areas supporting pollination.

Losey and Vaughan (2006) estimates the total value of natural control from insects to $ 4.5 *billion/year*, 686 *million SEK/year* in today's currency, Swedish cattle production stands for 40 % of the land use resulting in a value of 274 *million SEK/year*. The result from the monetary valuation of pest and disease control are 427 *million SEK/year*, implying an overestimation of the pest and disease service. However, the service is not only containing the natural control from insects implying that the service is in a good range of values.

There were parts of the work that was difficult to preform regarding to the time frame. For example, a sensitivity analysis of the monetary values for, for instance milk- and beef prices would have been interesting. As well as a complete valuation of all ecosystem services to collect the total value of cattle related land use together with a deeper analysis of each service.

4.3 Future recommendations

To expand and improve this thesis result a deeper examination of each ecosystem service and suitable indicators for both quantification and economic valuation is recommended. This will probably make the largest difference for the cultural ecosystem services as they today are the least researched services and the hardest to valuate. Both quantification and monetary valuation indicators and values that completely covers the cultural services are missing.

5 | Conclusion

The monetary value of selected ecosystem services for cattle related land uses are 27 - 37 *Billion SEK/ha*. If all land was converted into the alternative land use forest a decrease of 15 - 24 *Billion SEK/ha* occur and for a change to cropland a decrease of 16 - 23 *Billion SEK/ha* occur.

The values from the valuation are underestimations as only selected ecosystem services are examined as well as the values does not cover the services completely. However how large the underestimation is, is hard to predict.

These results together with only the non-market values implies the importance of cattle in Swedish agriculture for the ecosystem services. If the cattle production would decrease an economic loss from degraded ecosystem services would be a fact.

The results from this thesis can be used as a guideline to predict the economic losses for land use changes within cattle related and both alternative land uses. The monetary values for the ecosystem services can also be used as guidelines for policies, compensation programs etc.

To be able to do a complete monetary valuation of the ecosystem services from cattle related land uses a deeper analysis of all ecosystem services needs to be performed. The cultural services are the category of services with the largest uncertainty as well as it is the least researched area. Which is also why the future recommendations lies mainly in expanding the research of cultural ecosystem services.

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