

Flooding in Scania: A Method to Overcome the Deficiency of Nutrients in Agriculture during the Nineteenth Century

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Abstract

This article discusses ecological features during the nineteenth century in the southernmost part of Sweden (Scania). In the beginning of the nineteenth century the old system where hay-producing meadows created natural manure, gradually disappeared as arable land was extended. As artificial fertilizers were not introduced until the end of the century, this created, theoretically, an impossible situation. The paper discusses several ways of overcoming this fertilizer problem, but sees the flooding of meadows as the only technique which had a positive effect on all major elements. The flooding technique is described and its introduction in Scania is mapped. The use of watermeadows increased production fundamentally, but nevertheless, most systems were abandoned at the beginning of our century when artificial fertilizers became available on a large scale. The paper shows that between 1850 and 1890 there was a gap between the need and production of natural manure, and at this time the production of hay on the watermeadows was of utmost importance. The article concludes with a suggestion that watermeadows should be introduced in modern agriculture. This would be of double advantage: it could both act as a sink for phosphorus and nitrogen, and reduce the need for artificial fertilizers.

AGRICULTURE in Europe changed profoundly during the eighteenth and nineteenth centuries. During this time the population increased dramatically. Fallow land diminished, new rotations of crops were introduced, farm implements were improved and enclosure in different forms revolutionized the cultural landscape. Arable land was not only improved, but also expanded in area as land reclamation gathered momentum.¹ David Grigg shows that arable land in England and Wales increased by over 60 per cent between 1696 and 1866.² Omitting the fallow, the area actually under plough more than doubled. Concurrently, pasture and meadows diminished by 15 per cent. Thus, the expansion of arable was at the expense of meadow and pasture. Similar developments occurred

over all of Western Europe but at different times. In Great Britain, the so-called 'Agricultural Revolution' had already begun during the mid-seventeenth century, while it did not reach continental Europe until the mid-eighteenth century, and Sweden in the 1820s.³ In Sweden, the old system where hay-producing meadows (ie areas where hay was cut) created natural manure thus gradually disappeared. In England and France, however, it was the transformation of pasture into arable land that was the most profound change.

In a wider and longer perspective, four main epochs in nutritional economy can be distinguished: hunting-gathering (epoch 1), shifting cultivation (2), permanent manured field cultivation (3), and modern cultivation (4) dependent upon artificial fertilizers

¹ B A Slicher van Bath, *The Agrarian History of Western Europe, AD 500-1850*, 1963, pp 195f.

² D B Grigg, *The Dynamics of Agricultural Change: the Historical Experience*, 1982.

³ P Bairoch, 'Agriculture and the Industrial Revolution, 1700-1914', in C M Cipolla, ed, *The Fontana Economic History of Europe, III, The Industrial Revolution*, Glasgow, 1973, pp 452-506.

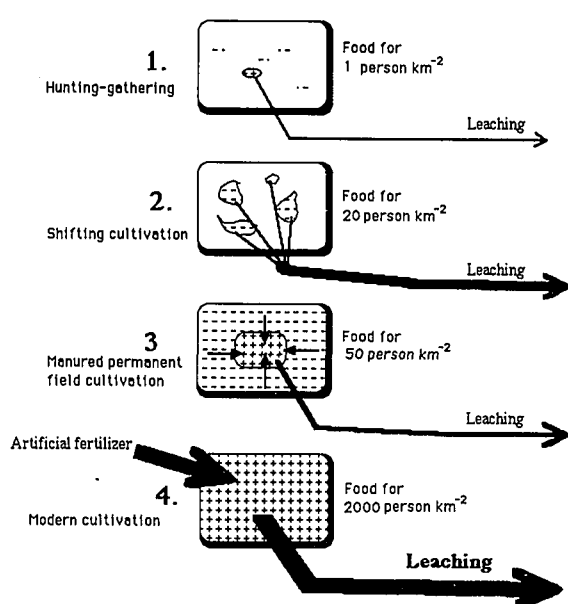


FIGURE 1
Model showing four epochs in nutritional economy.
- areas exporting nutrients
+ areas importing nutrients
Model is based on figures relating to calcareous clay moraine in south-west Scania

(Figure 1). In Sweden, artificial fertilizers were not introduced until the end of the nineteenth century. Manure originating from natural pastures and meadows was essential in early nineteenth-century agriculture, and as it was not directly superseded by artificial fertilizers, there was a time-lag in southern Sweden (Scania) between epochs 3 and 4 of at least eighty years. Artificial fertilizers were not introduced in Scania on a grand scale until the beginning of the present century.⁴ How, then, could farmers in this area eliminate the meadows and therefore the source of natural manure, without having access to artificial fertilizers? This question is the basis of this paper.

The time-lag between practices presented a theoretically impossible situation, which can be described in the form of a vicious

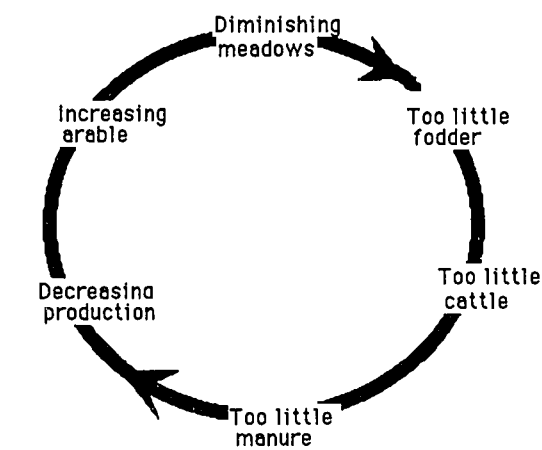


FIGURE 2
Theoretical cycle of nutrient impoverishment due to an imbalance between the proportion of arable land and meadows

circle (see Figure 2). As the farmers in the wake of enclosure gradually created arable land, the once extensive meadows diminished.⁵ This resulted in fodder becoming scarce which, in turn, of course meant that less cattle could be fed. Declining cattle-stocks led to less manure which resulted in decreasing production. To increase production, arable land was extended at the expense of meadows, and so on.

There were several ways of overcoming the fertilizer problem⁶, but the only technique which probably had a positive effect on all of the major elements was the flooding of meadows, i.e. the irrigation of hay meadows. By flooding, the still remaining meadows could produce up to five times as much fodder,⁷ and this was of the utmost importance in Scania in the nineteenth century when natural manure was becoming scarce.

In this paper, our aim is to analyse the shortfall in fertilizers between epochs 3 and 4 above. We suggest that one of the most important methods to overcome this was by flooding of meadows. Concerning nitrogen

⁴ A Zachrisson, *Gödsling och jordförbättring i Skåne från 1800-talets början till nuvarande tid*, Lund, 1914.

⁵ See below, p. 130

⁶ See below, p. 131-5

⁷ See below, p. 142



FIGURE 3

Map showing location of Scania with its two counties, Kristianstad and Malmöhus

alone, however, ley with legumes was probably the most important single factor. Our study area is nineteenth-century Scania (Skåne), the southernmost region of Sweden (Figure 3).

In section I, Scanian agriculture in general is described. The nineteenth century was a decade of transition and the social and economic causes underlying this are analysed. Section II is a presentation of the different methods available to overcome the shortfall in fertilizers. Of these, we are of the opinion that flooding was most significant and, therefore, the method is described in detail, and its distribution is mapped in section III. Its effect on Scanian agriculture is discussed in section IV. Here we present land-use diagrams to enable us to discuss the method in a wider context. Section V, finally, is the conclusion with some suggestions for future research.

I

Scania can be divided into three main regions based on both human and physical features: the forest region (animal and wood products), the intermediate region (mostly animal products), and the plains region (mostly grain products).⁸ Through the years a number of intricate agro-ecosystems developed and this prevailed more or less until the enclosure movement at the beginning of the nineteenth century.

The agricultural area of each village was divided into *inmark* and *utmark*. The former consisted of arable land and meadows, while the latter was mainly used as common grazing land. Different practices existed for the use of the arable land. On the plains the three-field system predominated, while the

⁸ Å Campbell, *Från vildmark till bygd*, Uddevalla, 1948.

two-field system was more common in the forest and intermediate regions.

Some of the meadows were concentrated, while others were intermixed with the arable fields. The meadows were mainly the understoreys of coppice-woodland and provided fodder, timber and firewood. As no artificial fertilizers whatsoever were used, the fodder-producing meadows were of great importance. Up to one half of the land belonging to a village was used as *inmark* in the seventeenth century. Of this, usually only 10 to 15 per cent was cultivated annually. The rest of the *inmark* was either coppice-woodland, wet meadow or fallow land. Gradually, as more land was put under the plough, the *utmark*, ie the natural grazing areas, diminished. The field in fallow was, therefore, used as pasture.

On the southern plains, the *utmark* disappeared totally during the eighteenth century. The three-field system was therefore necessary for pasture. The arable area could extend up to half of the land while different kinds of meadows made up the other half. All coppice-woodland had by then disappeared. Although the system probably was ecologically imbalanced, it produced sufficient corn to sell. This was due to the extremely fertile clay soils.

In 1803 the *enskifte*, a radical form of enclosure, was authorized for Scania. The Act aimed at rationalizing the number of plots per farmer. In order to achieve the aim of 'one farmer – one plot', many holders had to leave the village community and move out to their new plots. Thus, a considerable number of villages and hamlets became totally dispersed, while in other cases only two or three holders had to move out. Between 1803 and 1830 over 60 per cent of the Scanian villages had passed enclosure, particularly those situated on the plains.⁹ Enclosure also generated a totally new infrastructure with new road-systems

linking the new farmsteads with the old village site. The *enskifte* can be said to be the starting point of the Agricultural Revolution in Scania.¹⁰

The enlargement and improvement of the arable land followed in the wake of enclosure. Not all farmers received first-class arable land when the villages were enclosed; poorer quality land was compensated by larger acreage. This meant that arable land had to be reclaimed from the meadows. In some villages the tilled land area grew by several hundred per cent.¹¹

The three-field system was superseded by various new rotation systems, ranging from the four-course Norfolk system with clover, wheat, turnips and barley, to a seven-year rotation with both root-crops and ley and little fallow. Zachrisson points out that enclosure and new rotation systems often meant that manuring diminished.¹² As manuring took place only on the fallow, manuring occurred every third year before enclosure but only every sixth or seventh year after enclosure.

Drainage with tiles was introduced in the middle of the century, first on the large estates,¹³ and then during the second half of the century, many lakes were lowered or totally reclaimed. This, of course, contributed further to the expansion of the arable land.

In 1846, England abolished her Corn Laws and, consequently, the Swedish export market grew considerably.¹⁴ Large amounts of grain were transported to the ports for shipping to England. In Scania the main port was Malmö, and its development was helped by a growing railway network from the middle of the 1850s onwards.

¹⁰ S Helmfrid, 'The storskifte, enskifte and läge skifte in Sweden – General Features', *Geografiska Annaler*, 43, 1961, 114–29.

¹¹ U Emanuelsson, 'Skånes vegetationshistoria', *Svensk Geografisk årsbok*, 63, 1987, 70–93.

¹² Zachrisson, *Gödsling och jordförbättring*.

¹³ J Möller, *Godsen och den agrara revolutionen. Arbetsorganisation, domänstruktur och kulturlandskap på skånska gods under 1800-talet*, Lund, 1989.

¹⁴ G Fridlitzius, *Swedish Corn Export in the Free Trade Era. Patterns in the Oats Trade, 1850–1880*, Lund, 1957.

⁹ S Dahl, 'Storskiftets och enskiftets genomförande i Skåne', *Scandia*, 14, 1941.

The large landed estates, which dominate large parts of Scania, took a strong interest in the development of agriculture. It was often they who undertook the new initiatives to change, eg land drainage, marling and the introduction of new machines such as seed drills and mowers.¹⁵

The estates began producing grain for export and the interest in new machines, techniques and also in new transport facilities such as the railway was therefore natural. The flooding of meadows, as shall be seen, was also a technique introduced and developed by the estates. Such undertakings demanded both capital and land. During the last quarter of the nineteenth century the estates gradually moved towards animal production. This partially resulted from the competition from the USA and Russia, who were able to produce cheap grain. Another reason was that domestic grain prices rose in relation to the international level. From the 1880s butter became the main export product. Sugar-beet, which fitted in well in the crop-rotation, was introduced at this time, and fallow land gradually disappeared. Although butter production was introduced for economic reasons, it also had ecological advantages as it stimulated hay production and, therefore, the use of manure.

II

Several innovations were tried in Scanian agriculture during the nineteenth century. Many of these lasted for just a short time while others were developed and are still in use in some form. Many of these innovations were connected in some ways to the problem of annually removing large quantities of nutrients and in some way compensating for this. We will here systematically discuss what we believe were the most important new ways of compensating the soil for the increasing removal of nutrients.

Mobilization of nutrients by ploughing meadows and grazing areas

The intensive enclosure-movement in Scania in the early nineteenth century led to an enormous increase of the arable area of land. At first there were two types of land that were brought under the plough. The first was the meadows in the *inmark* close to the settlement; the second was the grazed common lands which were now distributed between private owners. On both these types of land, there was a grass-sward which had been stable for a long time. In the soil under the grass-sward there was probably a fairly large immobilized nitrogen pool. The available nitrogen pool for the plants was certainly much smaller. Jansson presents general data concerning the nitrogen pools.¹⁶

When a grass-covered piece of land is ploughed the microbiological activity is increased, which, in many cases results in an increase in the pool of available nitrogen for several years. This phenomenon of activating the immobilized nitrogen pool by ploughing probably played an important role in fertilizing much of the new arable land that was brought under the plough, especially during the period of 1810 to 1840. Ploughing the grass-covered land can also have been important for the short-term supply of potassium and phosphorus to the new arable land. However, there is a general difference between the nutrients concerning the size of the pools and the time-spans for which they can be used as sources of nutrients for growing crops.

The nitrogen pool in grassland is mostly in an immobilized form and is concentrated in the uppermost layers of the soil horizon. It is generally possible to mobilize much of this pool by frequent shallow ploughing. All of the immobilized nitrogen pool cannot be mobilized in just one or two years so the pool probably remains useful for up to a decade. On the other hand, much of the

¹⁵ Möller, *Godsen och den agrara revolutionen*.

¹⁶ S L Jansson, 'Utkast till kvävebudget för det svenska jordbruket', in T Roswall, ed, *Processer i kvävet kretslopp*, Statens Naturvårdsverk PM 1213, 1980, 33-9.

phosphorus that will become available after ploughing will be available more or less immediately. However, there was probably quite a large pool of phosphorus below the depth of the old furrows. This pool was not tapped until deeper ploughing came into practice. In the early part of the nineteenth century the ploughing of grass-land probably just released enough phosphorus for the cultivation of crops for only a few years, certainly for a shorter period than that over which the nitrogen pool could be used.

Potassium is present in most soils in quite large quantities. However, most potassium is totally unavailable for the plants, and its mobilization through weathering is a slow process.¹⁷ But by ploughing of the natural grass-sward, potassium from the organic part of the system can be made available for plant production. Therefore, acceptable yields could be obtained from the new arable land with additional manuring with potassium.

It can be assumed that nearly all of the new arable land that was created by ploughing of meadows and the *utmark* grazing areas, had enough nutrients for several years, and was consequently not manured initially. The important question is, however, for how long did those new fields give good yields without the addition of nitrogen, potassium and phosphorus? There is little information about this from the actual sites, but a picture can be reconstructed on the basis of modern data.

Modern crops require 30–100 kg K/ha/y.¹⁸ Clay soils in particular can store around 1000 kg K/ha/y plant available potassium amounts. The early nineteenth century gave yields which were often around a third of modern yields.¹⁹ 30 kg K/ha/y seems therefore to be an acceptable estimate of the rate of withdrawal of

potassium from the new arable lands of the early nineteenth century. It seems possible therefore, that potassium may have been available in sufficient quantities on clay soils for a decade after cultivating a new arable field. Perhaps this is an over-estimate, not taking into account the easy loss by leaching that is characteristic of potassium. It is also worth noting that the earliest expansion of arable fields in Scania in the nineteenth century took place in areas with fertile clay soils, but in the later part of the century most of the new arable fields were cultivated on poor moraine soils and on organogenic soils. Such soils have a small capacity to store K-ions.²⁰ We can therefore assume an earlier deficit of K in the organic soils following ploughing compared to the clay soils. It is not surprising therefore to find that Zachrisson points out that the use of artificial K-fertilizers came into general use when peat-soils were drained and farmed at the end of the nineteenth century.²¹

'Paring and burning'

In the early decades of the nineteenth century the so-called 'paring and burning' method was introduced in Scania. Using this method, the grass-sward was pared loose from the lower soil. Thereafter it was dried, and finally burnt. The ash was then spread over the bare soil. The method was often used on infertile grassland and leys from which the production had fallen due to over-cultivation without adequate fertilizing. The method was used frequently from 1820 to 1870, especially in north-western and south-eastern Scania.²² It is difficult to estimate the extent of this practice. One can assume, however, that as the tools for this practice are found in the majority of state inventories from the middle of the nineteenth century in south-eastern and north-western Scania,

¹⁷ T Troedsson and N Nykvist, *Marklära och markvård*, Stockholm, 1973.

¹⁸ *Ibid.*

¹⁹ S Dahl, *Torna och Bara. Studier i Skånes bebyggelse- och näringsgeografi före 1860*, Lund, 1942.

²⁰ Troedsson and Nykvist, *op cit.*

²¹ Zachrisson, *Gödsling och jordförbättring*.

²² N-A Bringéus, *Brännmodling. En Historisk/etnologisk undersökning*, Lund, 1963.

most farmers practised the method there.²³ Using information from Bringéus, one can assume that about 20 per cent of the farmers in Scania used the method.²⁴ Between a half and one third of the land of these farmers was subjected to this method. About 10 per cent of the arable land in the late nineteenth century is a rough estimate of the area which at some time, was subjected to 'paring and burning'. One can assume that after twenty years of this practice, the area had to be abandoned. Under good conditions, this method could have enabled five to eight acceptable harvests to be obtained without additional fertilizers. However, this must have resulted in a great reduction of the nitrogen content of the soils in particular. Such soils must, therefore, later have been very demanding of fertilizers and difficult to cultivate.

Slash-and-burn agriculture

Slash-and-burn agriculture was widely used during the early part of the nineteenth century, particularly in the forested north-eastern part of Scania. From the middle of this century onwards however, the forest became commercially valuable and the slash-and-burn practice was gradually abandoned. It is obvious from the studies undertaken by Weimarck that nearly all forested land in some villages of north-eastern Scania was used at some time during the nineteenth century for slash-and-burn agriculture.²⁵ In southern Scania, the practice was not so important because of the lack of large forest areas. The burned and farmed forest areas were also important areas for grazing and winter fodder collection which meant that these areas became new sources of nutrients for the enlarged permanent fields.²⁶ It is, therefore, possible that

we can to a large extent regard the slash-and-burn practice as a main factor for supplying the enlarged arable field areas of the northernmost parts of Scania with sufficient nutrients for much of the nineteenth century. However, these areas were of minor agricultural interest for the whole of Scania, and it is not possible to use the slash-and-burn practice as a main explanation of the solution to the shortfall in nutrients.

Ley with N-fixating plants

Gradually, the natural fodder areas diminished through the nineteenth century as the arable land grew. The meadows were, to some extent, replaced by leys. In northern continental Europe (Germany, Belgium, The Netherlands and northern France) one-fifth of the arable land was under leguminous crops in 1880.²⁷ The seven-year rotation including ley, began in some Scanian villages in the 1820s and 1830s.

In the eighteenth century legumes were already being used for fodder plants, and a number of experiments were carried out and documented in various ways.²⁸ At this stage, and also at the beginning of the nineteenth century, it is sometimes difficult to distinguish between ley and meadow, as the meadows were partially improved by sowing some leguminous species (*Trifolium* spp, *Medicago* spp).

According to Lågnert, leys with legumes were regularly in use at the beginning of the 1840s – at least in the areas with more fertile soils.²⁹ It can, therefore, be assumed that the nitrogen requirements of grain crops and potatoes were already met to a substantial degree at this stage. In less fertile

²³ *Ibid.*

²⁴ *Ibid.*

²⁵ G Weimarck, *Ulfshult: investigations concerning the use of soil and forest in Ulfshult, parish of Örkened during the last 250 years*, Lund, 1968.

²⁶ C Bergendorff and U Emanuelsson, 'Vegetation and management in wooded meadows and coppices in Scania', in preparation.

²⁷ G P H Chorley, 'The Agricultural Revolution in Northern Europe, 1750–1880: Nitrogen, Legumes, and Crop Productivity', *Econ Hist Rev*, 2nd ser, XXXIV, 1981, 71–93.

²⁸ H Osvald, *Vallodling och växtföljder. Uppkomst och utveckling i Sverige*, Uppsala, 1962.

²⁹ F Lågnert, *Syd-och mellensvenska växtföljder, del I) De äldre brukningssystemens upplösning under 1800-talet*, Lund, 1955.

areas, it seems that legumes were used some decades later.

Marling

Marling also began in Scania in the 1840s. The method spread quickly with the aid of farmers from Denmark and Schleswig-Holstein. The use of marling on a large scale in Scania was restricted in time to the years 1860–1885. Marling is the practice in which the deep-lying calcareous clay is dug up and spread over the topsoil. In Scania, less calcareous soil types were also dug up and spread over the fields. Marl cannot be said to be a real fertilizer as the fertilizing effect is rather indirect. On clay soils, the calcium ions from the marl will be exchanged for potassium ions located on the clay particles. The potassium ions will therefore be available to the plants. Marling can be regarded as a method which will give short-term advantages to the farmer by 'forcing' out some of the nutrients in the soil. In the long term, the increase in pH can be regarded as a positive effect for the farmer. The calcareous clays increased fertility for a short period; after ten to fifteen years, however, the result was the reverse and marling was therefore said 'to give rich parents but poor children'. Today, the landscape still contains plenty of old marl pits.

In the light of events, marling can be regarded as an emergency action to increase the fertility of infertile soils. Under these circumstances it is very striking to see the sudden decrease in marling around 1885 when artificial fertilizers were becoming commonly used.

Better handling of natural manure

The practice of using natural manure was fundamental to agriculture in the beginning of the nineteenth century, but the technique was still not fully efficient. Still in the 1850s the handling of the natural manure was inefficient according to a number of notes

collected by Zachrisson.³⁰ The dung was collected in places where much of it easily was lost in streams during rainfall. Furthermore, nothing was done to collect urine at this time. In the 1860s some larger farms (for example Säbyholm) developed a good technique to conserve the nutrients in the manure. Slowly, such techniques spread in Scania towards the end of the century.

Early artificial fertilizers

Artificial fertilizers were very little used in Scania until 1840. Ground bones from cattle and horses were already being used in England at the end of the eighteenth century, but even as late as 1825, 13,000 tons of bones were exported annually from Scania to areas where they were used in agriculture.³¹ Another fertilizer of the period – although not so widespread – was ashes derived from burning peat. This was mainly used on the meadows. In the 1850s many larger farms began to use different types of artificial fertilizers, but the average farmer was still not using it regularly in the 1870s. However, more or less all Scanian farmers were regularly using artificial fertilizers by about 1900.³²

The importation of artificial fertilizers began in 1844 when guano was shipped to Sweden.³³ Guano, which contains phosphoric acid and nitrogen, was common during the 1860s and 1870s. Later, towards the end of the century, a change towards superphosphate and Chile saltpetre (sodium nitrate) can be detected.

During the 1860s and 1870s the available nutrients which could be used to fertilize the arable doubled probably because of the development of better manuring practices.³⁴ Between 1870 and 1920 the use of potassium

³⁰ Zachrisson, *Gödsling och jordförbättring*.

³¹ H Juhlin-Dannfelt, *Kungliga Landbruksakademien 1813–1912, samt svenska landthushållningen under nittonde århundradet*, Stockholm, 1913.

³² Zachrisson, *Gödsling och jordförbättring*.

³³ *Ibid.*

³⁴ *Ibid.*

and phosphorus as artificial fertilizers grew rapidly and probably became more important than manure. The relative importance of nitrogen fertilizers came much later in Scania. The arable land in Scania was 589,281 ha in 1912 according to Zachrisson. To this area 71,893 tons of artificial fertilizers were applied. This means that 122 kg/ha of fertilizer was used on average each year in Scania in about 1912. During the late nineteenth century and beginning of the twentieth century importation of oil-cakes as fodder into Scania probably was of some marginal importance for the balance of nutrients. References to this are however scarce.

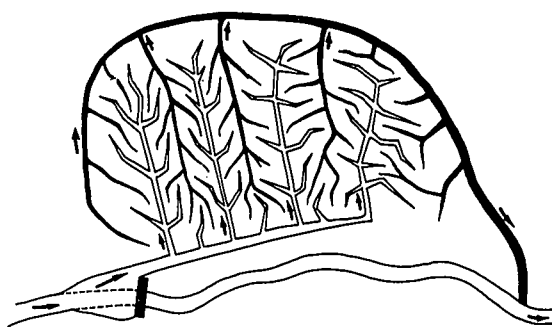


FIGURE 4

Principle of flooding using dammed irrigation. The stream is dammed and the water led into small canals (unfilled) and the supply regulated to the meadow. Surplus water is caught in the other canals (filled) and led back to the stream. After Emanuelsson *et al*, *Det Skånska Kulturlandskapet* (1985)

The flooding of meadows

Flooding of meadows, in its primitive form, was probably already in use in Scania at the beginning of the nineteenth century. More advanced systems were built from 1850 onwards. We assume that these meadows were of great importance for the nutrient balance in nineteenth century Scanian agriculture. They enabled a large production of hay, and associated manure to be obtained. This method will be discussed in more detail in the next section.

III

By the term 'flooding of meadows' we refer to the irrigation of hay-producing meadows, or in some cases irrigation of pastures (Figure 4). In this paper we will not discuss the natural flooding of areas around lakes and rivers, although this has been of great value to fodder production in earlier periods. The practice of flooding has been widely used throughout the temperate parts of Europe. In northern Scandinavia and Finland, vast areas were flooded in order

to increase the production of hay during the nineteenth century.³⁵

In Denmark, there is evidence of flooding practices in Jutland as early as in the year 1600.³⁶ The method spread during the 1770s and 1780s, but was discontinued during the Prussian War, and the practice ceased in the last quarter of the nineteenth century. According to Rasmussen, the practice of flooding was restricted almost entirely to Jutland. This is surprising as the islands of Denmark are in many respects (agricultural and biological) similar to Scania. A few of the Danish systems can still be seen in the landscape today.³⁷ The method is currently still in regular use in some countries of Europe, eg in parts of Poland, Yugoslavia, Portugal and Spain. Zimmermann gives

³⁵ E Bylund, *Koloniseringen av Pite lappmark till och med 1867*, Uppsala, 1956; Campbell, *Från vildmark*; J Elveland, *Norrlandska våtmarker*. Bevarande av ett gammalt kulturlandskap, Statens naturvårdsverk, PM 1737, 1983; J Frödin, *Skogar och myrar i norra Sverige i deras egenskap av betesmark och slätter*, Institutet for sammenlignende kulturforskning, ser B, XLVI, Oslo, 1952; Y Vasari and K Väänänen, 'Stratigraphical indications of the former use of wetlands', in K-E Behre, ed, *Anthropogenic Indicators in Pollen Diagram*, Rotterdam, 1986, pp 65-71.

³⁶ S Rasmussen, 'Studier over engvandingen i Danmark specielt vedrørende Store Skjernå Kanal', *Geografisk Tidsskrift*, 63, 1964, 146-90.

³⁷ R M Buttenschön, 'Engvanding', in *Plejebogen - en håndbog i pleje af naturområder og kulturlandskaber*, Fredningsstyrelsen, København, 1984.

detailed descriptions of systems in north-western Spain.³⁸ In southern France, remains of canals and dams can be seen in the landscape. In some cases, the canals are occasionally used for irrigating grazing areas, eg in the Pyrenees and the Cevennes.

There is a difference in the reasons for flooding meadows between areas with mild winter climate – as in England – and areas with more continental climate. In the former the objective of flooding was to expand the grazing period, while in the latter hay production was more important. In England, at the end of the Middle Ages, vast areas of arable land were converted to sheep-grazing areas for the expanding wool industry. The bottleneck of this system was the production of pastures during late winter and early spring. Frost hampered the growth of pasture plants. With the aid of running water, the ground temperature could be increased and this increased the plant production. Systems were constructed already by the end of the sixteenth century,³⁹ and there were still some watermeadows in use in southern England in the inter-war period.⁴⁰

Watermeadows were also constructed to produce as much hay as possible on which to feed sheep during winter months. In this case the sheep were not primarily bred for wool or mutton. Instead, their ability to transport plant nutrients from the commons to the arable fields was the most important feature. After grazing on the commons during the day, the sheep were taken to the arable fields where they were night folded and where the dung was dropped. Thus they were bred to drop only at night when folded on the arable fields. The prime purpose of the watermeadows in this case was therefore the ability to keep as many

sheep as possible over winter so that the transportation of nutrients from commons to arable land could be effective.⁴¹

1 *Its Introduction to Sweden*

It was not until the nineteenth century that the flooding of meadows was introduced in Scania on a large scale. The Swedish landowners and agricultural reformers were influenced by colleagues from abroad, especially those from Germany and England. Many Swedish engineers and agronomists made field trips to north Germany to learn about the method. In an overview, Magnét describes the evolution of the method in Sweden.⁴² He points out, too, the relatively short period in which systems were built.

Many of the Swedish agronomists who introduced the method in Sweden had probably visited the special school for flooding in Herrnsdorff, Ober-Lausitz, Germany. This school must have led to the construction of many systems in Germany. Today, however, all of these systems are probably abandoned. In Sweden as early as in 1814, a national competition led to the establishment of systems at Gårdsby and Böksholm in the county of Kronoberg, and in Söderfors and Valsta north-west of Stockholm.⁴³

Guides on the subject were published in Sweden in the 1840s. Stephens noticed the difference between running and stagnant water.⁴⁴ In contrast to other scientists of the time, he advocated flooding throughout the year, with the exception of the most severe winter days when an ice-crust could be formed. The advantage of this would be the

³⁸ G Zimmermann, *Die bäuerliche Kulturlandschaft in Südgallien. Ein Beitrag zur Geographie eines Übergangsgebietes auf den Iberischen Halbinsel*, Heidelberg Geographische Arbeiten, 23, 1969.

³⁹ C Taylor, *Fields in the English Landscape*, 1975.

⁴⁰ H P Moon and F H W Green, 'Water Meadows in Southern England', in L Dudley Stamp, ed, *The Land of Britain*, 89, Hampshire, 1940, pp 373–90.

⁴¹ E Kerridge, 'The Sheepfold in Wiltshire and the Floating of the Watermeadows', *Econ Hist Rev*, 2nd ser, VI, 1954, 282–9.

⁴² J H Magnét, 'Hvilken erfaring har man hittills vunnit i vårt land med afseende å översilning eller i allmänhet bevattning af odlade marker eller ängsmarker?', *Kongl Landtbruks-Akademiens Handlingar och Tidskrift*, 29, 1890, 243–51.

⁴³ A Eskeröd, *Jordbruk under femtusen år. Redskapen och maskinerna*, Stockholm, 1973.

⁴⁴ G Stephens, *Afhandling om ängsbevattning, dikning och vallars anläggning*, Stockholm, 1841.

earlier greening of the meadows. Another guide was published a few years later by Patzig.⁴⁵ He examined and explained the different kinds of systems. There were two main kinds of meadow-irrigation systems: catchwork irrigation for inclined meadows; and dammed irrigation for flat land. He also describes how to build the systems and which tools to use. Another thorough introduction to the method was given by Arrhenius.⁴⁶ He describes in detail the different types and suggests when to use them. He also lists the disadvantages of transforming meadows into arable land, stressing that the meadow was an essential component of well-cultivated farms. Arrhenius gave this warning at a time when many farmers in Scania created arable land from hay meadows.

2 *The flooding of meadows in Scania*

The advanced form of the technique was used in Scania during a rather short period. The first systems were introduced in the 1840s, and many followed during the 1860s and 1870s.⁴⁷ Some of the earlier systems may have replaced older, more primitive ones.

Primitive systems have probably been in use in Scania since medieval times. One simple form of watermeadow was constructed by damming a stream and letting the water from the dam run into small channels dug at the side of a shallow valley. This simple type of watermeadow has been found at a few sites in Scania, for example at Tolånga in the south-eastern part of the province. At several other sites there are ditches which could be traces of old primitive watermeadow-systems, but the ages of these systems are not known, as we have not yet found any documents specifically relating to this type of watermeadow; all

known examples have been found during field excursions or by contact with farmers.

It can be assumed that this old type of watermeadow has a long history in Scania. Similarities can be found with the British systems of this type. These types were also constructed in northern Sweden and Finland, many before the second half of the nineteenth century.⁴⁸ Sjöbeck is very speculative when he proposes that medieval Cistercian monks constructed watermeadows as early as in the thirteenth century in Scania.⁴⁹ Almost no investigations have yet been undertaken to prove if the watermeadows were constructed in Scania before the nineteenth century.

A variety of the simple type of watermeadow discussed above has been found on some bogs east of Båstad in north-western Scania. Here the water of some rivulets has been directed out onto the ombrotrophic sphagnum-dominated bog. The water has been used for transforming the very unproductive bog to a somewhat more productive carex-dominated fen. This method of transforming bog vegetation into fen vegetation is known from northern Sweden⁵⁰ and from northern Wales.⁵¹ Also Linnaeus describes dams at Lärkesholm in north-western Scania that are used for creating fertile meadows out of infertile bogs. He does not, however, describe any ditches associated with these dams, nor does he include any more information about watermeadows in his texts.⁵²

Another type of watermeadow which is also probably old and has not been satisfactorily described in the literature from Scania was *dammäng*. It is, however, adequately described from northern Sweden.⁵³ In England, the technique was

⁴⁸ Vasaari and Väänänen, *op cit.*

⁴⁹ M Sjöbeck, *Skåne, Färdvägar och vandringsstigar utgående från statsbanorna*, Stockholm, 1936.

⁵⁰ Elveland, *op cit.*

⁵¹ Personal communication, Prof Tony Bradshaw.

⁵² C Linnaeus, *Skånska resa förrättad 1749*, Stockholm, 1751, repr 1963.

⁵³ Elveland, *op cit.*

⁴⁵ G C Patzig, *Enkel och lättfattlig anvisning till ängsvattning*, Stockholm, 1845.

⁴⁶ J Arrhenius, *Hanbok i svenska jordbruket*, Stockholm, 1874.

⁴⁷ See below, pp 138–9.

called 'drowning' or 'floating upwards' according to Taylor.⁵⁴ In Scania such a *dammäng* was often combined with a water-mill. On several sites, for example at Baldringe in south-eastern Scania, there have been several such *dammängar* according to local tradition.

It is almost impossible to give a true and thorough account of when and where the modern technique of flooding meadows was introduced into Scania. Published statistics are not available until the mid-1860s. Prior to this period, one is dependent upon records from the different estates and farms. These, of course, vary in availability and condition. A source of great importance is the series of annual reports from the government's agricultural engineer. His reports give accounts of all the undertakings supervised by him. Unfortunately, some of the reports are missing, while many estates evidently constructed large systems without calling on the engineer's assistance. Zachrisson gave an account of the evolution of the technique, but this is, however, brief.⁵⁵ Our account is a combination of the different sources above.

Before 1850, flooding was in its earliest stages. We know that some smaller systems had been constructed in the 1840s at the estates of Marsvinsholm, Klågerup and Krapperup. In 1851, the engineer Åkerman constructed a system on *flat* land and claimed that this was the first such undertaking in the country. In the 1850s, the method spread considerably and vast areas were flooded, eg meadows belonging to the manors of Börringekloster, Skarhult, Osbyholm, Dybeck, Hjularöd and Övedskloster.

Figure 5 shows those places where at least fifty hectares have been permanently flooded. Of the twenty-six locations in the province, four estates had systems of at least 150 hectares, viz Vomb (owned by Övedskloster, by far the most extensive

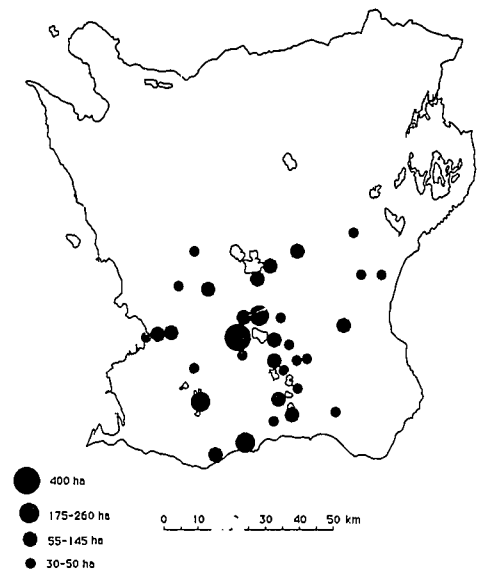


FIGURE 5
Flooding in Scania. Places where at least 50 hectares are known to have been flooded during the nineteenth century

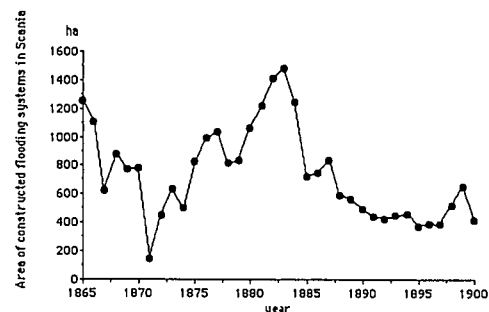


FIGURE 6
Construction of flooding systems in Scania (hectares). Source: Zachrisson, (1922).

system with over 400 hectares), Dybeck, Börringekloster and Hjularöd.

Figure 6 shows the total effect of flooding since 1860, ie, from the start of published statistics. As can be seen, the period 1875-85 was of great importance. The total area of registered flooding in Scania was 33,302 hectares.⁵⁶ This figure is, however, an underestimate as many systems were unregistered. It should be noted that all systems were not functioning simultaneously. The

⁵⁴ Taylor, *op cit.*

⁵⁵ A Zachrisson, *Nyodling, torrläggning och bevattning i Skåne 1800-1914*, Lund, 1922.

⁵⁶ *Ibid.*

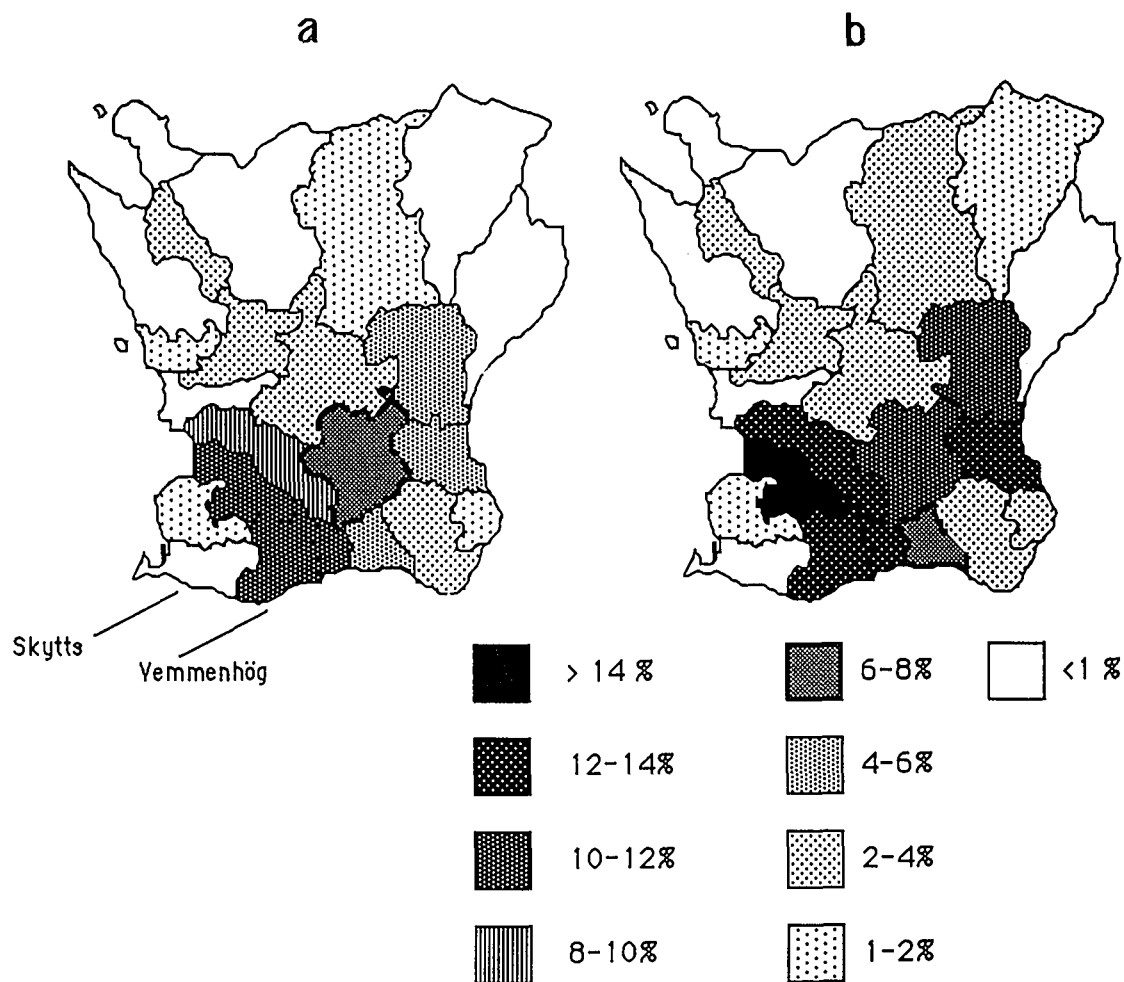


FIGURE 7
Flooding of meadows in Scania 1865-1911 in relation to
(a) total area (b) area of arable land
Source: Bidrag till Sveriges Officiella Statistik, N) Jordbruk och Boskapsskötsel

decrease in the extent of flooded land during the first years of the 1870s can be explained by the lack of capital for the construction of watermeadows due to several bad harvests at the end of the 1860s.⁵⁷

Flooding in relation to area is presented in Figure 7 where it can be seen that it was

concentrated in the middle and southern parts of the region. These areas were dominated by large landed estates, and this has probably contributed to the high figures. Note, for example, the difference between Skytts and Vemmenhög (arrows), which are physically similar but have a different social structure. In the peasant-dominated Skytts, there was almost no flooding as the

⁵⁷ E Sommarin, *Ur det skånska jordbrukets historia från 1800-talets början till 1914*, Lund, 1938.

construction of irrigation systems required both capital and labour. Ecological features also need to be taken into consideration. Especially striking is the lack of systems in the forested northern parts of Scania. Here the fodder-producing areas were much more difficult to transform into arable land, and therefore the great imbalance seen in the plains never occurred here. However, there is proof that several systems existed but as they were either old, small or primitive they were never entered in the statistics. Note the difference between the two maps. Flooding in eastern Scania was of great importance although the absolute area was not so extensive.

Few systems were constructed after the turn of the century, and old systems were allowed to decay. According to Zachrisson, no more than fifteen systems were working in the 1920s. The last systems were abandoned in the late 1940s. In many cases it was the flooding during late autumn which made the practice inefficient as the water was too cold and the nutrient poor.

The watermeadows which were constructed during the nineteenth century were mostly located on relatively flat ground. The largest systems were placed in the most fertile agricultural areas. Quite advanced technical solutions were found at a number of places to improve the practice. At Öved, in southern-central Scania an aqueduct was built to carry water over the river Björkaån (Figure 8). The aqueduct can still be seen even if most of the watermeadows have gone (Figure 9). At Torreberga and some other places, there were pumps to carry the water up to the meadows. Watermeadow-systems were often constructed in association with sugar-beet and other factories which produced a lot of waste water. One example is at Torreberga.

Today, channels previously used for flooding of meadows can be seen at at least twenty sites in Scania. At two sites (Beddinge on the south coast and Öved at the eastern shore of Lake Vombsjön), the

abandoned systems are still well preserved. At Vombsängar, west of Lake Vombsjön, a large watermeadow-system was restored in the early 1970s. The restoration was carried out for the preservation of cultural history. Unfortunately, the restorations were subsequently neglected.

3 *Production results*

The advantage of using watermeadows was, of course, the increase of production. The increased production can be of two types: increases during the normal vegetation period; and prolonging of the vegetation period. The latter is especially stressed by authors dealing with British⁵⁸ and Portuguese conditions. In these cases it was mostly pasture that was flooded. In such areas there was or is a need for early spring grazing but because of the mild winters there is not much need of stored winter fodder.

The increased production during the vegetation period was especially important in areas where large quantities of stored winter fodder were needed. The supply of nutrients in the water to flood meadows has been regarded by several authors as a major cause for increased production.

Discussing the amount of nitrogen and phosphorus that could have been available in nineteenth century Scanian watercourses, we can of course not rely on any chemical measurements from this time. Today, a very nutrient-rich river as Höljeån has a content of 2–12 g/m³ of total N and 0.05–1 g/m³ P.⁵⁹ In some smaller riverlets these values can reach figures around 30 g N/m³. In less nutrient-rich rivers around 1 g total N/m³ and 0.1 g P/m³ are normal values. Using the later values and a value of 10–20 litres water per hectare and second as a normal flooding regime, 1 hectare will be exposed to 864–1728 g total N and 86–173

⁵⁸ Taylor, *op cit.*

⁵⁹ N-O Mårtensson, *Höljeån 1988. Samordnad vattendragskontroll*, Staffanstorps, 1989.

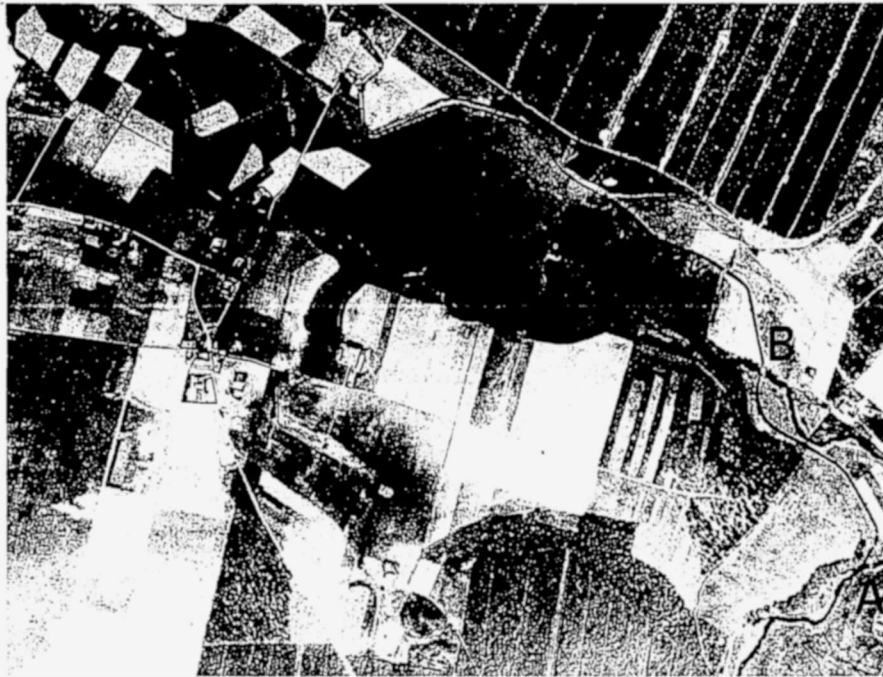


FIGURE 8

The area around the river Björkaån in 1939. Canals and rivers are recognizable as dark lines. The dammed river can be seen at the lower right (A). The canal crosses the river on an aqueduct (B). The flooded meadows lie between the canal and the river in the middle of the photograph (C).



FIGURE 9

The abandoned aqueduct which brought the canal over the river Björkaån.
Photographed in January, 1986

g P during 24 hours. With approximately 100 days of exposure a year, it will theoretically be possible for 1 ha water-meadow to catch well above 100 kg N and 10 kg P per year.

On organic soils, Elveland suggests that oxygen in the floating water causes faster mineralization of litter and this is probably a major reason for increased production.⁶⁰ Also, a direct irrigation effect during dry summers must have been of great importance. Further investigations are required to assess the importance of different factors causing increased production on water-meadows of different types.

Normally, inundation causes anaerobic conditions in the soil. Such conditions are negative in two ways for the production of normally used hay-fodder plants: first, the anaerobic soil will gravely hamper the root-function of the plants; and secondly it will favour the process of denitrification, especially if the water is acid.⁶¹ Thereby much nitrogen will be lost from the meadows. To cope with these negative phenomena drainage was used as an important part of the treatment of the flooded meadows. The water was only left standing in the meadows for a couple of days. Thereafter the meadow was carefully drained. In some cases water was brought on to the meadow at the same time as drainage occurred. The water had to move over the meadow constantly. By using this method anaerobic conditions never occurred. On the other hand, anaerobic conditions would reduce ferric ions to ferrous ions and this would release phosphorus to improve plant nutrition.⁶²

The production of a large watermeadow at Öved on the eastern shore of Lake Vombsjön of approximately 11 ha was 21 lass hö (wagons of hay) according to Harry

Persson, Sjöbo (former farmer of the site). When the practice of flooding had stopped, the yield dropped to 9 lass hö. He also mentioned that the harvest at one meadow was reduced from 46 lass hö to 14 when the irrigation stopped.

There was an annual requirement of 2–300 kg NPK/ha to maintain the production at Vombs ängar after 1949 when the flooding of meadows had stopped. Later the additional amount of NPK/ha per year was as much as 4–500 kg.⁶³

Arrhenius cites several sources as he discusses the results of flooding.⁶⁴ The best results gave increases in production of ten times after flooding had been introduced. This, however, seems to be an exception. Typical increases in production due to flooding were between three and five times.

IV

During the nineteenth century there were a number of ways which compensated for the loss of meadows which produced manure in earlier times. It is important to compare the different fertilizing systems that were used in Scania in the nineteenth century in order to evaluate how the compensation took place. Paring and burning, and different types of slash-and-burn agriculture were probably locally important in the northernmost part of Scania as methods of maintaining the productivity in villages in forested areas.⁶⁵ These methods must have been marginal for Scanian agriculture as a whole. As marling was used for only a short period this was also of marginal importance.

The other methods to overcome the shortfall in fertilizers which have been identified in this paper are: 1, new fields manured by nutrients available when the grass-sward is turned by the plough; 2, use

⁶⁰ Elveland, *op cit.*

⁶¹ C A Black, *Soil-plant Relationships*, 2nd edn, New York, 1968.

⁶² N K Savant and R Ellis Jr, 'Changes in redox potential and phosphorus availability in submerged soil', *Soil Science*, 98, 1964, 388–94.

⁶³ S Bengtsson, H Larsson, and S Petersson, *Vombs ängar. Vegetation, fågelliv, markanvändning samt synpunkter på resaurering och skötsel*, Länsstyrelsen i Malmöhus län, Malmö, mimeograph, 1973.

⁶⁴ Arrhenius, *op cit.*

⁶⁵ Weimarck, *op cit.*

of legumes in crop rotations and in leys; 3, better handling of natural manure; and 4, increasing the amount of natural manure from livestock by using watermeadows which produced more hay per hectare than other meadows. In order to analyse the relative importance of these methods, it is useful to divide the materials into the two administrative regions of Scania; Malmöhus county and Kristianstad county (Figure 3). The first region is dominated by large plains which are mostly used for grain production today. Kristianstads län is a much more forested region where agriculture has always played a lesser role.

The first step in an analysis of the nutrient balance during the nineteenth century is to reconstruct the development of land-use for the two Scanian counties during this period. Such reconstructions are presented in Figures 10 and 11. The figures are largely based upon official statistics from 1858 onwards which seem to be fairly reliable. During the first half of the nineteenth century however, there are only data for 1805 and 1833. The details of the statistics used are described and discussed in the appendix.

It is evident that there were two types of agricultural land; land from which nutrients were exported and land with imports of nutrients. Land from which nutrients were lost were more or less all pastures and meadows in the early nineteenth century. Nutrients were taken from the meadows continually in the form of hay. However, nutrients were also exported from the pastures as much of the livestock was taken home to the farms at night-time and left there a large part of its dung.

The types of land receiving nutrients were those fields that were manured. There were also land-use types that were independent in terms of nutrient transport across the landscape, eg forests and peat bogs. Also those forests which were grazed are regarded as having an independent nutrient circulation.

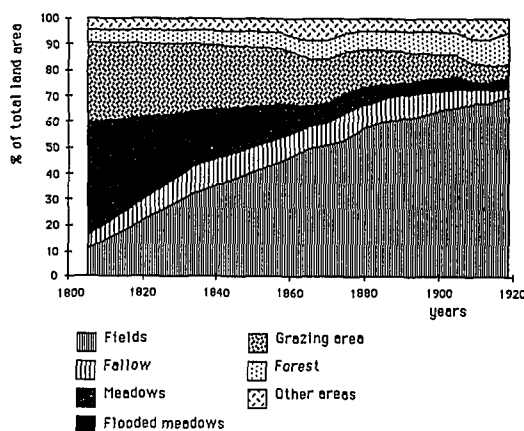


FIGURE 10
Land-use in Malmöhus county, Scania, 1805-1919.
Sources: see appendix

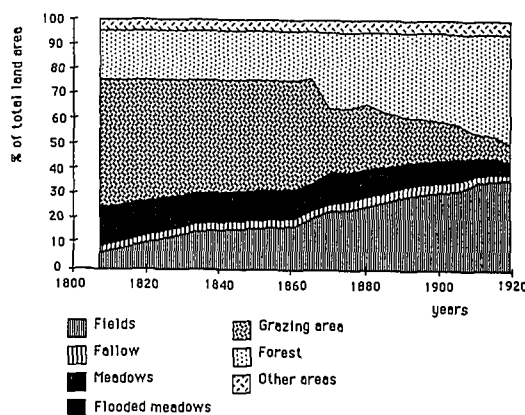


FIGURE 11
Land-use in Kristianstad county, Scania, 1805-1919.
Sources: see appendix

The degree of export of nutrients varies a lot. In order to assess the potential nutrient export at different occasions during the nineteenth century it is necessary to scale the nutrient exporting areas against each

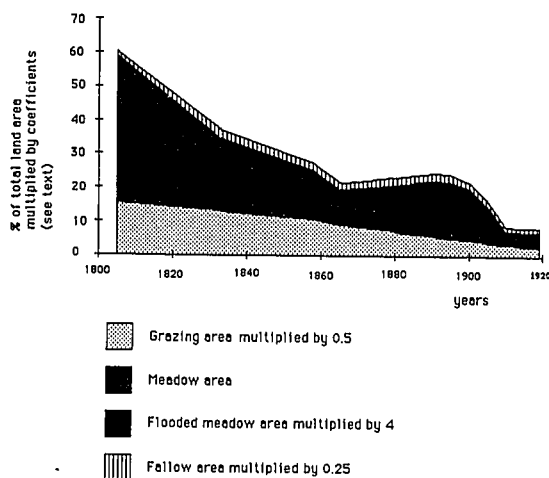


FIGURE 12
Sources of manure in Malmöhus county 1805–1919
Literature sources: see text

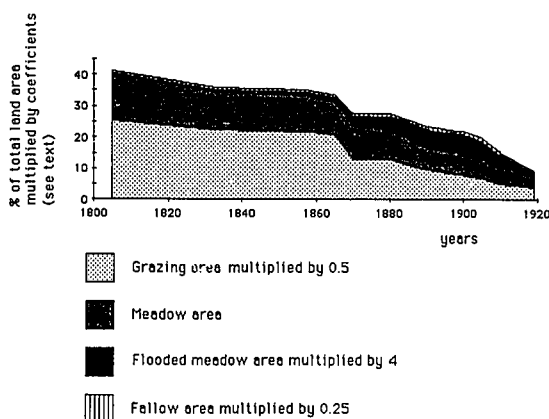


FIGURE 13
Sources of manure in Kristianstad county 1805–1919
Literature sources: see text

other.⁶⁶ This gives a relative potential curve for the export of nutrients from pastures, meadows and fallows during the period 1805 to 1919 (Figures 12 and 13).

The two curves (Figures 12 and 13) show that the manure-producing areas decline

rapidly during the century. In both cases the decline is reduced from the 1860s up to the beginning of the twentieth century. It is evident that this is caused by the introduction of watermeadows on a large scale (black area). Thus, the watermeadows played a significant role in the production of manure in Scania during this half of the century. The decline, and thus the role of the watermeadows, was much greater in Malmöhus county with its large grain producing plains.

The next step is to analyse the need for manure and the sources to supply this need during the period of investigation. The potential use of manure is shown in the two counties of Scania in Figures 14 and 15. The two curves were constructed thus: we started with the curve showing total land under plough. From this we subtracted first 'the self-manuring part' of the fields used for animal fodder production. We use this term because many of the nutrients in the fields are returned as manure. However, this is not a perfectly balanced system, and we suggest that 50 per cent of the nutrients are lost in the circulation between fodder plants, fodder, manure, and nutrients for fodder plants. This means that 50 per cent of the animal fodder producing area can be regarded as 'self-manuring'. We also subtract newly cultivated land which was especially important in the beginning of the nineteenth century. Remaining areas thus need manure from outside the arable system. With minor exceptions (seaweed, heather, peat) the only source of manure at the beginning of the century was animal dung. Artificial fertilizers were not introduced on a large scale until the 1860s. If we subtract the areas which *de facto* received artificial fertilizers, the remaining areas in Figures 14 and 15 are the areas needing natural manure. During the first half of the century the need for natural manure was steadily increasing, reaching a peak during the 1860s and 1870s. The demand was about twice as much in Malmöhus as in Kristianstad county.

⁶⁶ See appendix for the details of the coefficients.

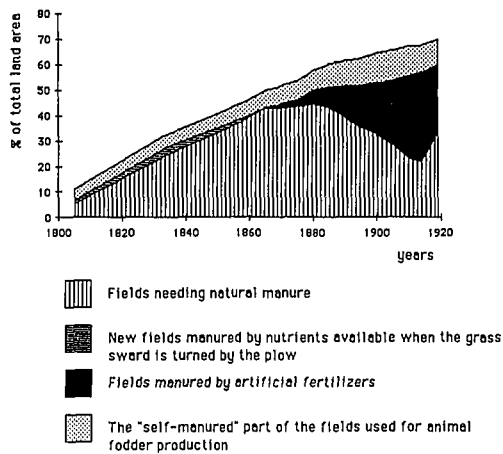


FIGURE 14
Manuring of the fields in Malmöhus county
1805-1919. Sources: see text

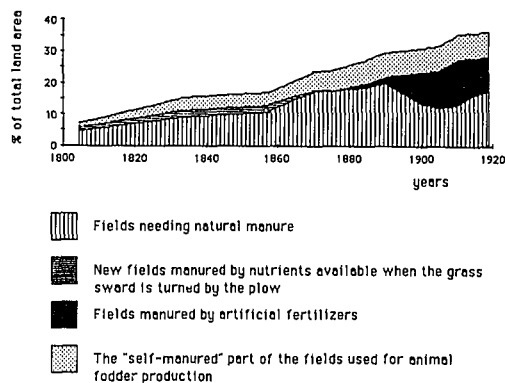


FIGURE 15
Manuring of the fields in Kristianstad county
1805-1919. Sources: see text

It is now relevant to compare the need for manure with the actual production of manure (Figures 16 and 17). The curves showing the areas needing natural manure are taken from Figures 14 and 15. Hypothetical areas for natural manure production are taken from Figures 12 and 13.

There is a theoretical overproduction of manure in Malmöhus county (Figure 16) in

the early nineteenth century, which is transformed into a deficit during the 1840s. Because of the inefficient handling of manure documented by Zachrisson 1922, many of the nutrients were lost and the higher potential harvests could not be achieved. The handling of manure was considerably improved about 1840, and

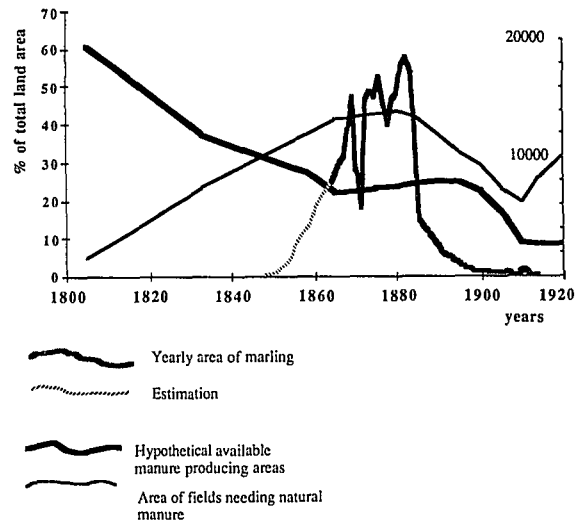


FIGURE 16
Synthesis: need and production of manure in
Malmöhus county 1805-1919. Sources: see text

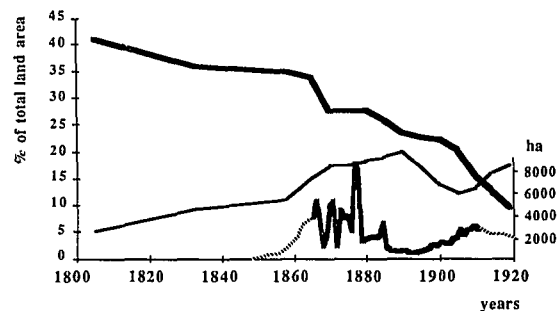


FIGURE 17
Synthesis: need and production of manure in
Kristianstad county 1805-1919. Sources: see text

therefore, the theoretical deficit in natural manure is not shown as a reduction in productivity per hectare.⁶⁷ However, after 1850 the gap between the need and production of natural manure was increased further, and this could not be compensated for by still more efficient handling of manure. Therefore, during a forty-year period marling was used to increase soil fertility. This is also shown in the figure. Marling, however, could only be used during a rather short period, as this method only gives short-term advantages. During the period of marling the production of natural manure was maintained by the introduction and development of watermeadows. In the 1880s, when marling was more or less abandoned, the hay/manure production on the watermeadows came to be of great importance for the fertility of the arable land. Not until the turn of the century did artificial fertilizers become a significant type of manure in Scania agriculture. Concurrently, watermeadows were abandoned probably because of the high costs of maintaining the meadows. In comparison, artificial fertilizers at this time had become both cheap and easily obtainable for the average farmer.

The development in Kristianstad county (Figure 17) shows many similarities to that in Malmöhus county. However, the transformation of meadows and pasture into arable land was not at all of the same magnitude as in Malmöhus. This means, of course, that there were not such large deficits of natural manure here. As a consequence, marling was not used to the same extent.

As shown by Olsson,⁶⁸ using seventeenth- and eighteenth-century material from Scania, lighter soils and soils with lower pH need a much larger input of nutrients to achieve the same production as heavy soils

with higher pH. This fact explains to a large extent the comparatively high input of manure used in the agriculture of Kristianstad county, which is a country of generally lower pH soils and lighter soils compared to Malmöhus county.

We have now shown how it was possible to increase the extent of arable land without having artificial fertilizers available; marling and nitrogen fixing legumes were important factors; but methods of conserving the nutrients in the agro-ecosystem were of greater importance. The two main methods were the flooding of meadows, and improved treatment of animal dung. It was in this way possible to drastically change the relationship between arable and meadow by conserving the nutrients. The nineteenth century developments in Jutland in Denmark seem to have been fairly parallel to those in Scania, and Rasmussen stresses the importance of the watermeadows as sources of hay and thus manure for fertilizing the increasing arable lands.⁶⁹

As already mentioned, we can divide patterns of land-use into four main epochs (compare Figure 1). Permanent fields dependent upon large areas of meadows were in use in Scania probably from the eleventh century up to the beginning of the nineteenth century. Then, as has been shown above, the relationship between arable land and meadows was significantly changed. As a result of the good conservation of nutrients in the agro-ecosystems (eg watermeadows), many of the land-use systems of the nineteenth century can therefore not be said to belong to epoch 3 as it persisted during most of the historical time. We therefore suggest that epoch 3 should be divided into two sub-epochs, 3a and 3b (Figure 18).

In the south of Sweden, sub-epoch 3b lasted only for about eighty years, from the 1820s until the beginning of the twentieth century. In England and The Netherlands,

⁶⁷ *Historical Statistics of Sweden*, II, 'Climate, Land Surveying, Agriculture, Forestry, Fisheries - 1955', Stockholm, 1959.

⁶⁸ G Olsson, 'Nutrient Use and Productivity for Different cropping Systems in South Sweden during the 18th Century', in H H Birks, H S B Birks, P E Kaland and D Moe, eds, *The Cultural Landscape. Past, Present, and Future*, Cambridge, 1988.

⁶⁹ Rasmussen, *op cit*.

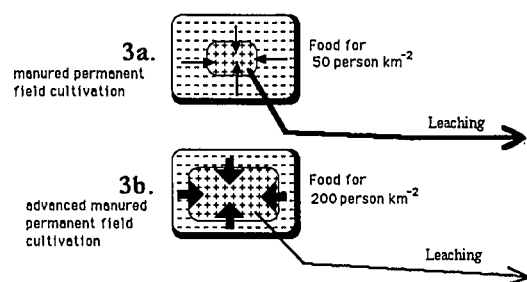


FIGURE 18

Model showing epoch 3a and 3b. Compare Figure 1
 — areas exporting nutrients
 + areas importing nutrients

watermeadows and other nutrient-conserving systems (eg the Norfolk system) were introduced much earlier – in some cases as early as the end of the seventeenth century. Artificial fertilizers, however, were not introduced significantly earlier than in southern Sweden. The extent of sub-epoch 3b was thus much longer in England (c 200 years). The practices spread to northern Germany and Denmark before they came to Scania. As the distance between the innovation centres (England and The Netherlands) and the areas importing innovations increased, the duration of sub-epoch 3b probably decreased. For instance, in remote parts of northern Scandinavia, sub-epoch 3b was never introduced; in parts of Lapland the transition from 3a to 4 was made in the 1940s.

V

Evidently, there was a time-lag in Scania of about eighty years between the major enlargement of the arable fields and the introduction of artificial fertilizers. It is, however, not possible to show a significant reduction in the production per hectare during this period. The theoretical 'vicious circle' did obviously not exist on a regional scale. The shortfall in nutrients was 'filled' by the introduction of a number of methods

to conserve the nutrients in the agro-ecosystem. Of methods fixing nitrogen, the flooding of meadows was of great importance during the second part of the nineteenth century. Such methods may have helped England escape the 'vicious circle' two centuries earlier.⁷⁰ An agricultural system without artificial fertilizers but, with effective conservation of nutrients, must be categorized as a separate system from the earlier systems where small fields were dependent upon large meadows, and the treatment of the manure was inefficient.

The methods of efficient treatment of manure and the flooding of meadows must have been known to the Scanian farmers for a long time, but as the system involved both capital and labour, it was not introduced until it was really needed. It was the large landed estates which introduced it on a grand scale, as they had both capital and labour. This agrees well with Boserup who emphasizes the primary role of population: although an innovation in another region is known it is not introduced until the population size has passed a certain threshold thereby making the available resources limited.⁷¹ When artificial fertilizers were introduced, flooding rapidly decreased in importance.

Looking towards the future, it is interesting to note that the waste water from the sugar-beet factories of Staffanstorp and Jordberga, as well as the waste water from the city of Lund, was used to fertilize water meadows during the beginning of this century. Today, we have problems, especially during spring and parts of autumn, with nitrogen and phosphorus eutrophication of rivers, lakes, and the sea. Nitrogen in particular is to a large extent not removed by the sewerage plants, and there is, at that time of the year, a major loss of nutrients from ploughed fields. A new type of watermeadow using modern

⁷⁰ Kerridge, *op cit.*

⁷¹ E Boserup, *Population and Technology*, Oxford, 1981.

techniques would, therefore, be of double advantage: on the one hand it would act as a sink for phosphorus and nitrogen thereby reducing the risk of eutrophication and on the other hand, the use of artificial fertilizers could be reduced by growing hay and energy-crops (eg *Salix*-spp). Thus a knowledge of past agro-ecosystems can be applied to the needs of modern agriculture and environmental planning.

APPENDIX:

The statistical material

The land-use figures

The early land-use figures from the time before 1865 derive from Zachrisson *Nyodling, torrläggning och bevattning: Skåne 1800-1914*, Lund, 1922, (1805), and from *Tidning för Landthushållning*, nr 1 1858, published by Skånska Hushålls-föreningen (1833 and 1858). From 1865 onwards, the figures are taken from *Bidrag till Sveriges officiella statistik*, N) *Jordbruk och boskapsskötsel*. The flooded meadows are not distinguished in official statistics; they are calculated from *Tidning för Landthushållning* and Zachrisson. Additional material has been gathered from *Malmöhus läns Jordbruk år 1909*, published by Malmöhus läns Hushållningssällskap.

The manure-source figures

During the scaling the relative amount of nutrients exported from the 'meadow'

category was set to 1. The harvest from watermeadows are equal to those from untreated meadows 2-10 times as large (see above). A factor of 4 for the increase in harvests of the watermeadows is estimated here to be an approximate average. The grazing areas have a factor of 0.5 as more than half of the dung is probably dropped on the pastures and not around the farms at night-time. It must also be stressed that the meadow during autumn actually functioned as pasture. Finally, the fallows are assumed to be poor nutrient exporters (0.25) as such areas were often used for pigs and ducks from which little manure was collected. Another reason is the sparse vegetation.

The need of manure figures

Figures for the area where artificial fertilizers and marling were used were calculated from figures given in Zachrisson, *Gödsling och jordförbättring: Skåne från 1800-talets början till nuvarande tid*, Lund, 1914.

Figures of flooding of meadows

Figures are calculated from 1, *Tidning för Landthushållning*; 2, Zachrisson (1922); 3, The annual reports from the government's agricultural engineer, archives of Kungliga Skogs-och Landtbruks-akademien; and 4, *Malmöhus läns Jordbruk år 1909*.

Notes on Contributors

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