



Historical cadastral maps as a tool for identifying key biotopes in the cultural landscape

S. T. Domaas, L. N. Hamre & I. Austad

Faculty of Science, Sogn og Fjordane University College, Norway

Abstract

GIS was used to refine information from a cadastral map of a Western Norwegian farm and a supplementary written protocol, both from 1874, and to identify areas of meadow presumed to be species-rich. To do this, information on hay meadows of low production capacity and meadows with stony soil was extracted from the cadastral map. The cadastral map was transformed onto a modern coordinate system and linked with a vegetation survey carried out in 2002. This enabled us to investigate how far areas identified from the 1874 map coincided with the meadow types existing today. The results reveal that 85% of the biologically most interesting hay meadows found in the area today coincide with areas identified as presumably interesting from the 1874 cadastral map. Information from the cadastral map and the protocol also make it possible to construct specific historical profiles for the different hay meadow types. These seem to be a good tool for differentiating between meadow types and explaining some of the vegetation variation found today.

1 Introduction

Semi-natural vegetation types rich in plant species are threatened by habitat loss and landscape change in the European landscape today [1,2]. Research shows that species diversity is particularly high in hay meadows with a long continuity of use [3,4]. The proportion of light-demanding grasses and herbs, and also of vulnerable species, may be high in such meadows [5,6]. Nowadays, meadows of this kind are often found on steep slopes where productivity is low and on shallow and/or stony soils, that is on areas that have not been tilled and farmed

more intensively. They are therefore likely to have a long history of continuous use.

For the management of valuable cultural landscapes, it is important to identify meadows of this kind. Since there are often large areas, perhaps several hundred hectares, to be investigated, we need labour-saving methods that can be used for rapid identification of potentially interesting meadows in the landscape today.

Historical cadastral maps and protocols from the mid 19th century contain valuable information about land use, ownership, production capacity and how stony the soil was at the time of land consolidation. Historical cadastral maps have been used in several ecological and geographical studies [7–9] because they can provide information on areas with a long continuity of land use and management. For example, Cousins and Eriksson [10] used information from cadastral maps to investigate the links between selected meadow species and the history of the landscape.

With the help of GIS, we can make use of information from the old cadastral maps to reveal whether current forms of land use are related to historical land use. In addition, we can look at whether there are any patterns linking the distribution of species-rich hay meadows in the area today and land-use history. If we can find such patterns, they may be a useful tool for identifying areas where there is interesting vegetation today, thus considerably limiting the area that needs to be investigated in the field. GIS can also be used to “construct” historical profiles for different meadow types. Easily recognizable historical profiles that can be related to different types of meadows will be useful tools for understanding the vegetation found today.

The questions we asked were:

- 1) Can information from cadastral maps and protocols from the mid 19th century help us to identify areas where there are likely to be species-rich meadows today? And if so, to what extent?
- 2) Is it possible to identify specific historical profiles for the different meadow types?

2 Material and methods

2.1 The area investigated

The farm under investigation, Grinde, has a long history of human activity and settlement, traced back to BC 2505–2415 (collection of twigs and foliage) and BC 1875–1680 (farming) [11]. The farm is located on the northern side of the Sognefjorden in Leikanger municipality, Western Norway (61°32'N, 10°04'E), and is situated on a terrace 100–125 metres above sea level. The soil consists mostly of minerogenous material, such as moraine and glacio-fluvial deposits. The mean annual precipitation is 1750 mm, and the mean temperature is + 16°C in July and - 4°C in January. The snow cover is stable during the coldest period. The farm is a typical fjord-hill farm with a small-scale structure.

2.2 The 1874 cadastral map

In 1857, a new Land Consolidation Act was passed in Norway, and brought about extensive reorganization and redistribution of agricultural areas. Before this, strip-farming had been practised on many farms, especially in Western Norway, where it was a long-standing tradition. The 1857 Land Consolidation Act required land surveys and the production of maps and written protocols. The cadastral maps that resulted provide information on land use. In this investigation we used a cadastral map from 1874. The map describes the distribution of tilled fields, meadows and impediments in addition to man-made elements such as buildings, stone structures and fences. The written protocol gives information about ownership, land use, the amount of stone in the soil (in different classes of stoniness) and production capacity, and for this farm 1450 small parcels of land are described in detail. The cadastral map covers an area of 630 da (63 ha).

Production capacity (in Norwegian: bonitet) was used to classify parcels of land according to how much they could produce, to ensure that when a farmer lost a particular area during land consolidation, the land he received in compensation would give an equivalent amount of agricultural production. At Grinde, production capacity was divided into 42 classes on a scale from 1–200. Class 1 was the most valuable, and 2.75 ($2\frac{3}{4}$) or higher corresponded to low production capacity [12]. An area of land in class 2 would produce half as much as an equal-sized area in class 1.

2.3 Vegetation survey

Using aerial photos, economic map sheets and field observations, all open meadow areas in the area investigated were identified and drawn on modern economic map sheets. The classification system of Fremstad [13], was used to identify meadow types. The different types were defined by the presence and frequency of the “characteristic” and “common” species given for each group in this classification system.

2.4 Linking historical information and the vegetation survey using GIS

GIS was used to handle the huge volume of information provided by the cadastral map and the written protocol. The varying geometry and local coordinate systems of historical cadastral maps make it necessary to transform them onto a modern coordinate system. For this investigation, the coordinate system NGO1948 used for Norwegian economic maps was chosen. For the transformation we used a simple GIS-based method, developed by Domaas and Ihse [14]. The results of the vegetation survey were linked to the selected information from the cadastral map and the protocol. Four search criteria using historical information were defined: 1) stony soil, 2) production capacity ≥ 2.75 , 3) stony soil and/or production capacity ≥ 2.75 , and 4) both stony soil and production capacity ≥ 2.75 (overlap). Areas identified using these criteria were

compared with areas identified as biologically interesting by the vegetation survey to see how far they coincided. To find out which search criteria identified the largest proportion of the interesting areas and at the same time minimized the area it was necessary to study in the field, an efficiency coefficient (e) was calculated as follows: $e = [\text{proportion of the area of a particular vegetation type (x) identified using the search criterion} : \text{total area of this type (y)}] : [\text{total area of hay meadows found by this criterion (z)} : \text{total area of hay meadows found in the vegetation survey (t)}]$.

$$e = [(x) : (y)] : [(z) : (t)]$$

Information on land use, stoniness and production capacity was also used to draw up historical profiles for different types of meadow. The historical profiles were constructed using information from all the parcels of land on the 1874 map included within a particular type of meadow today.

3 Results

3.1 Meadow types found in 2002

Five different types of meadows were identified in the study area:

- Type I: *Agrostis capillaries*–*Festuca rubra*–*Anthoxanthum odoratum* grassland
- Type II: *Deschampsia cespitosa* grassland
- Type III: Intermediate, nutrient-rich “old” cultivated meadow
- Type IV: Cultivated meadow older than 10 years
- Type V: Modern cultivated meadow.

Type IV was separated from type III by the presence of seeded grasses, *Trifolium* species and other cultivated species [13]. The most species-rich hay meadow type in this area is type I, a varied group of hay meadows characterized by not being fertilized or only lightly fertilized. A traditional management regime including grazing in spring and autumn and mowing late in the summer is also characteristic. Table 1 and fig. 1a show the proportions and distribution of the five types of meadow in the landscape today. Type I accounted for 39.7 da or 25.5% of the total area of meadow in 2002.

Table 1: Area and percentage of total meadow area for each of the meadow types (I–V) registered in 2002.

veg. type 02	da	%
type I	39.7	25.5%
type II	21.6	13.9%
type III	34.9	22.5%
type IV	22.0	14.1%
type V	37.3	24.0%
total	155.5	



Figure 1: a) Digitized cadastral map from 1874 of the farm Grinde, showing the distribution of meadow types I-V in 2002, b) distribution of meadows, tilled fields, stony soil and areas with production capacity ≥ 2.75 in 1874, c) Overlay map showing the coincidence between open meadows in 2002 and land-use types in 1874, d) Overlay map showing where meadow types I and II in 2002 coincide with areas shown as stony and/or low production capacity on the 1874 cadastral map.

3.2 Linking historical information and meadow types found in 2002

In 1874, areas that met criterion 3, i.e. stony soil and/or production capacity ≥ 2.75 , accounted for a total of 272 da (fig. 1b). In 2002, the total area of open meadow was 155.5 da, or 24.7 % of the area investigated (fig. 1c). Of this, 54.6 % coincided with areas that met criterion 3 in 1874 (table 2).

It was found that 84.7% of the type I meadows and 88.7% of the type II meadows coincided with areas that met criterion 3 (table 3, fig. 1d). Much smaller proportions of the other meadow types found in 2002 coincided with areas that met criterion 3 in 1874: 40.8%, 44% and 22% respectively for type III, IV and V. Meadows belonging to these three types were mainly located outside areas that were described as being of low production capacity and/or stony in 1874 (table 2).

The efficiency coefficient for criterion 3 was 1.55, while it was 1.78 for criterion 4 (areas with both stony soil and production capacity ≥ 2.75). In other words, we can identify the largest area of interesting meadow for least effort in the field by using criterion 4.

Table 2: Area of each meadow type that coincides with areas identified from the 1874 map using various search criteria and GIS.

da	prod. cap. ≥ 2.75	stony	p.c. and/or st.	p.c. and st.
type I	32.1	29.6	33.7	28.1
type II	19.0	16.3	19.1	16.1
type III	13.6	8.8	14.2	8.2
type IV	8.0	7.7	9.7	6.0
type V	7.9	4.0	8.2	3.8
total	80.6	66.4	84.9	62.1
% of total	51.9 %	42.7 %	54.6 %	39.9 %

Table 3: Percentage of the area of meadow types I-V that coincides with areas identified from the 1874 map using various search criteria and GIS.

% of type area	prod. cap. ≥ 2.75	stony	p.c. and/or st.	p.c. and st.
type I	80.8 %	74.6 %	84.7 %	70.7 %
type II	88.1 %	75.3 %	88.7 %	74.7 %
type III	39.0 %	25.2 %	40.8 %	23.4 %
type IV	36.3 %	35.0 %	44.1 %	27.3 %
type V	21.3 %	10.8 %	22.0 %	10.1 %

3.3 Historical profiles

Using GIS, it was possible to combine historical information for all the small parcels of land identified on the cadastral map belonging to each of the five meadow types found today. Thus we constructed five different historical profiles for a) land use, b) the amount of stone in the soil and c) production capacity.

Most of the area identified as type I or II today was used as hay meadow in 1874 (83%, fig. 2a). These areas also included a substantial proportion of scree. A relatively large proportion of the area identified as type III, IV or V was used as tilled fields in 1874: 33%, 26% and 63%, respectively. Type V is clearly different from the rest, since most of the current meadow area was tilled fields in 1874.

The amount of stone in the soil in 1874 can be used to divide the five meadow types into two groups: types I and II include ca. 75% stony soil and types III, IV and V only 12 to 35% stony soil. This shows that most of the ground in these meadow types already had already been cleared in 1874 (fig 2b).

The total area of each meadow type is made up of many small parcels of land that were of varying production capacity in 1874. Figures 3a-e show, for each of the meadow types, the percentage belonging to each production capacity class. A large proportion of the areas now identified as type I (fig. 3a) and type II (fig. 3b) belonged to the middle to poorer production capacity classes, whereas most of the areas identified as types III and IV belonged to the best production capacity classes (fig. 3c,d). Most of the area identified as type V meadow belonged to production capacity class 1 or close to 1, although it did also include areas of lower production capacity (fig. 3e). The average production capacity value for meadow types I and II was low, 4.38 (type I) and 4.56 (type II), respectively (fig. 4), while the average values for the other three types indicated better production capacity: 2.27, 2.01 and 1.46 respectively for types III, IV and V.

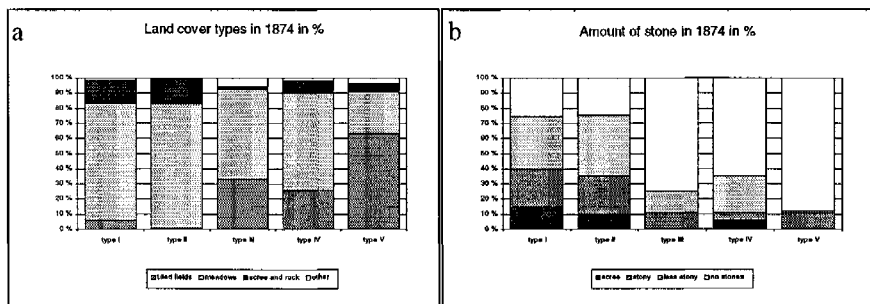


Figure 2: a) Land use in 1874 and b) amount of stone in the soil in 1874 in areas identified as meadow types I-V in 2002. Percentage distribution based on information from the cadastral map and protocol.

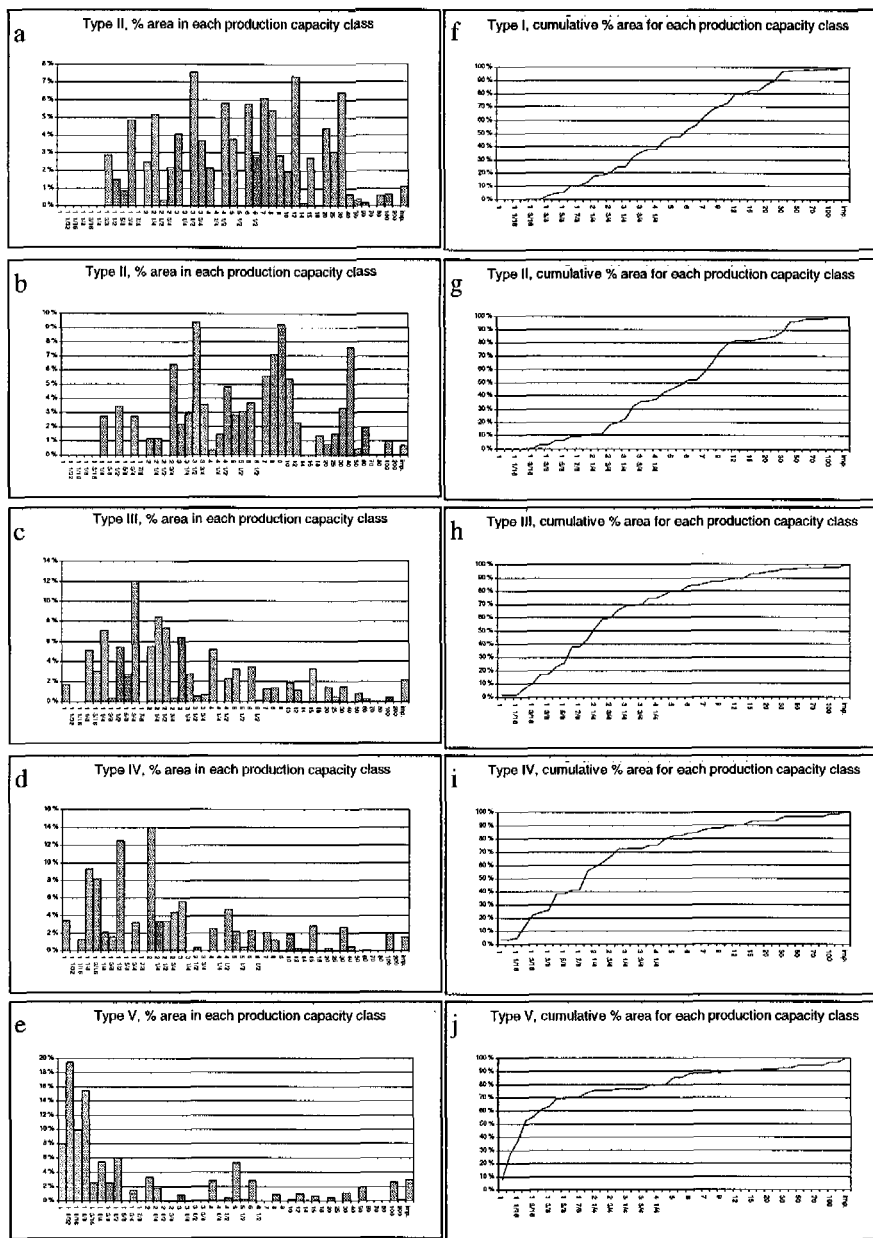


Figure 3: a-e) Production capacity profiles for meadow types I-V showing the percentages of each type belonging to each production capacity class, f-j) Cumulative percentage graphs of production capacity value for meadow types I-V.

Fig. 3f–j shows plots of the cumulative percentage belonging to each production capacity class in 1874 for the five meadow types identified in 2002. We found that 81.8% of the area of type I, 88.1 % of the area of type II, 39% of the area of type III, 36.3% of the area of type IV and 21.3% of the area of type V belonged to production capacity classes ≥ 2.75 (2 $\frac{3}{4}$) (table 3).

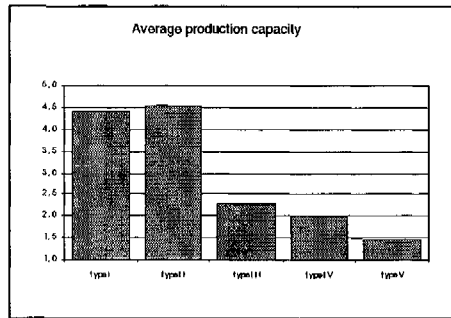


Figure 4: Average production capacity value for meadow types I–V based on information from the 1874 cadastral map and protocol.

4 Discussion

4.1 Delimitation of biologically valuable areas of meadow

It has previously been assumed that old hay meadows with a long history of continuous use and shallow and stony soils (low production capacity) are likely to have high species diversity and a high content of characteristic hay meadow species, and therefore be biologically interesting today [6]. In this study, a total area of 272 da of the meadows existing in 1874 was evaluated to be potentially interesting, and 84.9 da of this was still open meadow 128 years later (fig.1a–d). The proportion of the meadows from the 2002 vegetation survey that coincided with potentially interesting meadow in 1874 was highest for meadow types I (and II), 84.7% and 88.7%, respectively.

Type I meadows are expected to have the highest species diversity and number of light-demanding meadow species. Type II appears to come in second place, probably because in this area, type II meadows are in an early successional phase of type I [15]. Continued grazing has maintained many of the light-demanding meadow species, but greater accumulation of biomass and the discontinuation of mowing has favoured the growth of *Deschampsia cespitosa*, a grazing-tolerant species that has become dominant on these areas.

Although it is reasonable to assume that there have been major changes in this cultural landscape over the past 128 years, it appears that meadow that was defined as stony and/or not very productive at the end of the 1800s has remained largely “undisturbed” since then. In other words, there has been little clearance, cultivation or fertilization of these areas more recently. This appears to indicate that information on land use, the amount of stone in the soil and production

capacity taken from the 1874 cadastral map can be used to identify semi-natural vegetation types that are likely to be species-rich today. By using this method, it is possible to limit the areas that need to be investigated in the field. The areas selected on the historical map can also be transformed onto modern map sheets, making their identification in the field much easier.

4.2 Efficiency—field work and selection criteria

Although criterion 3, stony soil and/or production capacity ≥ 2.75 , identified the *largest area* of the most interesting hay meadows (84.7% of type I), it also identified a large proportion of other types of meadows, which are considered to be of less interest in this context. By using criterion 4, both stony and production capacity ≥ 2.75 (overlap), we “only” identified 70.7% of the type I hay meadows, but it was possible to limit the area to be investigated even further and thus make the field work more efficient, as shown by the calculated efficiency coefficient.

4.3 Historical profiles for meadow types existing today

Figures 2a and 2b show that there are marked differences between the five types of meadows identified in 2002. Types I and II show clear similarities as regards earlier land use and the amount of stone in the soil, while types III, IV and V form another group easily distinguished from type I/II, and with some common features. Type V differs from the other two in that only a small percentage (5%) was stony in 1874, and 63 % of the areas now belonging to type V were tilled fields 128 years ago. These profiles show that earlier land use (as tilled fields in 1874) appears to have a strong influence on later use: although they are no longer tilled, these areas are still being used for intensive production in 2002 as “modern cultivated meadow” which has been seeded with grasses and heavily fertilized. Intensive use and heavy fertilization results in lower species diversity than is found in uncultivated meadows that have not been fertilized or used as tilled fields.

Type I and type II meadows include no areas belonging to the three best production capacity classes, but otherwise include areas along the whole scale of production capacity classes. The distribution is skewed towards the poorer production capacity classes. For type V we find the opposite: there is a concentration of areas belonging to the very good production capacity classes (fig. 3). Type V does include some areas of low production capacity, but this is probably a result of changes in the way these areas were used after the land consolidation process, including clearance, cultivation and intensive fertilization. The distribution pattern for type II is similar to that for type I, while types III and IV are intermediate between type I/II and type V. Only 15–20% of the area covered by type I (and II) has a better production capacity than 2.75 (23%), while most of the areas of types III and IV belong to better production capacity classes (fig. 3). This is even more marked for type V, where 75% of the total area belongs to production capacity classes that are better than 2.75 (fig. 3). The same

patterns can be seen from the average production capacity value for each meadow type calculated on the basis of the small parcels of land included in each meadow type (fig. 4). The results show clear relationships between production capacity value, the amount of stone in the soil and land use in 1874. This was as we expected. What is more surprising is that the historical information on land use, production capacity and the amount of stone in the soil taken from the 1874 cadastral map appears to explain the meadow types existing today to such a large degree, and can help to confirm classification at this level.

Land consolidation entails major changes on a farm, and the time frame used here is a long one. There must have been changes in land use during this period, which will also have influenced the vegetation in the area. Nevertheless, the results of the investigation suggest that there are important historical influences behind land use patterns and the composition of the vegetation today. A suitable next step would be to test the importance of historical profiles as compared with other ecological factors in explaining the variation in vegetation types and their species composition in this cultural landscape. It would also be of interest to find out whether the results for meadows in this study also apply to other types of vegetation, and whether our findings at Grinde can be extended to other farms.

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