Master Thesis

im Rahmen des
Universitätslehrganges „Geographical Information Science & Systems“
(UNIGIS MSc) am Zentrum für GeoInformatik (Z_GIS)
der Paris Lodron-Universität Salzburg

zum Thema

„Georeferencing Agricultural Survey Statistics“
Developing an Indicator of Farming Intensity

vorgelegt von

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U1407, UNIGIS MSc Jahrgang 2008

Zur Erlangung des Grades
„Master of Science (Geographical Information Science & Systems) – MSc(GIS)“

Gutachter:
Ao. Univ. Prof. Dr. Josef Strobl

Bern, 30. November 2011

"There is nothing in which the birds differ more from man than the way in which they can build and yet leave a landscape as it was before."

Robert Lynd, *The Blue Lion and Other Essays*

Irish essayist and nationalist (1879 - 1949)

Acknowledgements

It has been an interesting opportunity to combine GIS with my work environment and a hobby I am passionate about. To get this far I have been able to rely on numerous colleagues patiently answering my many questions and hope to have provided the Swiss Ornithological Institute with some valuable new inputs.

I am indebted to many friends and colleagues who have helped me to get this far. My sincere thanks go to the following:

- the GELAN Informatik team for their support and understanding at all stages of my UNIGIS studies,
- Simon Birrer and Niklaus Zbinden from the Swiss Ornithological Institute for embracing my ideas and helping to develop a suitable approach to tackle the subject matter and available data,
- fellow UNIGIS students Horst, Jürg, and Tuxa for their motivation, tips, reassurance and many shared laughs,
- Sue Murphy for her friendship, encouragement and assistance throughout,
- and finally, to my fabulous friends for their understanding, invaluable support throughout, endless patience as well as for keeping me sane and ensuring I didn't become a complete hermit. Thanks go especially to Ursi, Rufi, Roberto, Rennski, Claudia, Ingrid, Paul, Soos, Jim, Anabel and Annelies.

Statement of Originality

I hereby certify that the content of this thesis is the result of my own work. This thesis has not been submitted for any degree or other purposes, neither in whole nor in part. To the best of my knowledge and belief, it contains no ideas, techniques, quotations or any other material from the work of other people unless acknowledged in accordance with standard referencing practices.

Berne, 30th November 2011

Mary Brown

Abstract

Georeferencing Agricultural Survey Statistics

Annual agricultural statistical surveys gather a vast amount of information relating to agricultural practice which could potentially be of interest in other fields of study. This thesis explores ways of exploiting the spatial potential inherent within this numerical data. Numerical agricultural survey data are successfully georeferenced, providing spatial access to a decade of data for Canton Berne for the first time.

After detailed examination of the survey content and of the associated Gelan agrarian information system's database, relevant data was identified and a method was developed to georeference farmed land based on linking the numerical land parcels to cadastral geodata. The perimeter of farmed land was then reduced by subtracting ineligible land-use categories. The remaining perimeter was used as a base to georeference crop and livestock data per farm. These data not only give an indication of the agricultural intensity in any given region – e.g. by mapping livestock units per area of fertilized land – but also help to some extent to illustrate the levels of diversity in crop cover. These factors are significant in evaluating the potential for suitable habitat for farmland bird species. Less intensive farming methods have been proven to benefit species diversity and population numbers.

Georeferenced output is successfully adapted and illustrated at varying scales, thereby revealing distinctive regional patterns and providing a new detailed indicator of agricultural intensity. The new spatial data produced in this study was developed with the particular interests of the Swiss Ornithological Institute in mind. The georeferenced agricultural survey statistics can provide them with significant new inputs relevant for population studies and analysis of habitat potential related to aspects of agricultural intensity.

Although the methods developed in this study for georeferencing agricultural survey statistics are based on the situation in Canton Berne, they also provide scope for a general approach using the data collected by the government at a national level.

Keywords: GIS, georeferencing, agricultural survey statistics, agricultural intensity, farmland birds, farmland habitat, livestock density, crop diversity.

Kurzfassung

Georeferenzierung der Agrarerhebungsstatistik

Eine grosse Menge an Information bezüglich landwirtschaftlicher Praxis wird mit den jährlichen Agrarerhebungen gesammelt. Die erhobenen Statistiken könnten potenziell auch in anderen Themenbereichen von Interesse sein. Diese Master Thesis untersucht Wege um das räumliche Potenzial, inhärent in den numerischen Daten, auszunutzen. Numerische Agrarerhebungsdaten werden erfolgreich georeferenziert. Dadurch werden Daten für den Kanton Bern aus einem Jahrzehnt zum ersten Mal räumlich zugänglich gemacht.

Nach detaillierter Untersuchung der Erhebungen selbst sowie der assozierten Daten, welche im Gelan Agrarinformationssystem verwaltet werden, wurde relevanter Inhalt identifiziert und eine Methode entwickelt, um landwirtschaftlich genutztes Land mittels Verknüpfung numerischen mit vektoriellen Parzellen zu georeferenzieren. Der Perimeter des landwirtschaftlich genutzten Landes wird dann durch Abzug ungültigen Bodenbedeckungskategorien reduziert. Die verbleibende Fläche wird als Basis verwendet um Kulturpflanzen- und Tierhaltungsdaten pro landwirtschaftlichen Betrieb zu georeferenzieren. Diese Daten geben nicht nur Hinweise zur landwirtschaftlichen Intensität in einer Region – z.B. durch Darstellung der Anzahl Grossvieheinheiten pro Are düngbares Land – sondern erlauben auch die Darstellung der landwirtschaftlichen Kulturpflanzenvielfalt. Diese Faktoren sind wichtig bei der Evaluierung des Potenzials geeigneter Lebensräume für Kulturlandvögel. Es wurde bereits bewiesen, dass weniger intensive landwirtschaftliche Praxis die Artenvielfalt sowie die Populationsgrösse begünstigen.

Georeferenzierte Ergebnisse wurden erfolgreich aufbereitet um in unterschiedlichen Massstäben darzustellen. Dadurch werden ausgeprägte regionale Unterschiede feststellbar sowie einem neuen detaillierten Indikator für landwirtschaftliche Intensität zugänglich gemacht. Die neuen räumlichen Daten, welche diese Studie zur Verfügung stellt, wurden unter Berücksichtigung der Interessen der Schweizerischen Vogelwarte entwickelt. Die georeferenzierten Agrarerhebungsstatistiken können sie mit neuen Inputs liefern, welche Relevanz für Populationsstudien und Analysen von Lebensraumpotenzial unter Berücksichtigung von Aspekten der landwirtschaftlichen Intensität haben.

Obwohl die Methoden Agrarstatistiken zu georeferenzieren, wie sie in dieser Studie entwickelt wurden, auf die Situation in Kanton Bern basieren, bieten sie auch Möglichkeiten für eine allgemeingültige Vorgehensweise, wie die Daten, die auf Bundesebene gesammelt werden, auch genutzt werden könnten.

Stichworte: GIS, Georeferenzierung, Agrarerhebungen, landwirtschaftliche Intensität, Kulturland Vogelpopulationen, Kulturland Lebensraum, Kulturpflanzen-vielfalt, Tierhaltungsdichte.

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Glossary

Arc	a line defined by a connected series of unique x,y coordinate pairs, often to refer to regular curved line segments
ArcGIS	a suite consisting of a group of GIS software products produced by Esri®
Are	unit of area (a), equal to 100 square metres (10 m × 10 m), used for measuring land area
BE	Canton Berne
CAP	Common Agricultural Policy
CLC	CORINE Land Cover
CORINE	**Co**-**or**dination of **In**formation on the **E**nvironment
DB	Database
DB2	an IBM relational database
DIPANU	**Di**gitale **Pa**rzelle**nnu**mmern (georeferenced land parcel numbers)
DP	Direct Payments (DZ/Direktzahlungen)
DZV	Direktzahlungsverordnung (direct payment regulations)
ECA	Ecological compensation areas (part of agri-environment scheme)
EEA	European Environmental Agency
EEC	European Economic Community
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FME	Feature Manipulation Engine (Safe)
FOAG	Federal Office for Agriculture, Switzerland
FSS	Farm Structure Surveys
FR	Canton Fribourg
GDB	Geodatabase
GELAN	**Ge**samtlösung **E**DV **La**ndwirtschaft & **N**atur
GELAN-IS	Agrarian Information System managed by Gelan Informatik (a department of the Cantonal Office for Agriculture & Nature, Ct. BE)

GEOSTAT	Federal Office of Statistics, Switzerland
GVE	livestock unit (Grossvieheinheit)
ha	hectare (100m x 100m; 100a)
HNV	High Nature Value (Farmland) – low-intensity farmland supporting or associated with a high rate of biodiversity
HQ	Headquarters
IACS	Integrated Administration and Control System: established by the EEC in 1992 to administrate and control agricultural subsidies
LBV	Landwirtschaftliche Begriffsverordnung; SR 910.91
LN	Landwirtschaftliche Nutzfläche
LPIS	Land Parcel Identification System
LU	livestock unit
MS	Microsoft Software Firma
NUAA	Agricultural land outside the UAA (ausserhalb LN)
NUTS	Nomenclature of Statistical Territorial Units – hierarchical system (with 3 levels NUTS1 – NUTS3) for dividing up the economic territory of the EU into administrative units
OAF/ÖAF	agri-environment[1] schemes (Ökologischer Ausgleichsfläche gemäss DZV)
SO	Canton Solothurn
SQL	Structured Query Language
SR	Swiss Law
UAA	utilised agricultural area
Unprod	unproductive land cover categories (not eligible as farmland)
VECTOR25	digital landscape model of Switzerland
XML	Extensible Markup Language

[1] Council Regulation (EC) No 1257/1999
(Chapter IV) defines the concept "agri-environment" as "*support for agricultural production methods designed to protect the environment and to maintain the countryside …* it *shall promote ways of using agricultural land which are compatible with the protection and improvement of the environment, the landscape and its features, natural resources, the soil and genetic diversity.*"

1 Introduction

"Understanding the link between agricultural intensity and farmland biodiversity is of considerable importance, because after millennia of landscape modification, farmland now constitutes the single largest habitat in Europe, comprising around 45% of the total European land area." [Donald et al, 2006]

According to the official Land Use Statistics, a quarter of the land area in Switzerland [BFS, 2009] is given over to agricultural land-use and as such the agricultural landscape has an important influence on the bird population which can be sustained in any given area. The importance of Canton Berne for typical farmland birds is particularly high as it contains 45% of the total area of agricultural land in the country.

Recently released results from the Pan-European Common Bird Monitoring Scheme[2] which studied bird population figures in 25 European countries between 1980 and 2009, show that European farmland bird populations are at their lowest since records began. Overall species numbers are at an all-time low, with farmland bird species the most threatened. In Switzerland, the known difficulties of birds dependent on agricultural habitats are reflected by the negative trend shown by the Swiss Bird Index (SBI®) (Zbinden *et al.*, 2005). A pronounced decline in farmland bird populations associated with increasing agricultural intensification has been the focus of numerous studies. Farming practices and crops grown in any farming landscape influence the food supply and the availability of suitable nesting sites for typical farmland bird species (Geiger *et al.*, 2010). Less intensive farming practices and more diverse landscapes with a tendency for smaller field size (or smaller stands of one crop variety) have been proven to benefit the farmland bird populations (Henderson *et al.*, 2009).

Gelan Informatik is a specialised IT service centre within the Office for Agriculture and Nature of the Canton of Berne. As such, it runs an agrarian information system (GELAN-IS) for three partner cantons (Berne, Fribourg, Solothurn) which contains agricultural survey statistics and payment relevant information for all farmers resident in these cantons and qualifying for the numerous programmes run and their associated direct payments.

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[2] http://www.ebcc.info/index.php?ID=470

1.1 Motivation

There is a vast amount of numerical agricultural data available at both cantonal and national levels offering huge potential for further analysis provided it can be georeferenced. The non-geographical nature of the data has, up until now, limited its use for further analysis. The potential offered by annual comprehensive cantonal agricultural statistical surveys has thus remained largely unexploited. The development of a method of georeferencing this vast amount of numerical data could make it accessible to a wide audience for new forms of analyses with relevance in a variety of fields related to nature conservation. It is hoped that the georeferenced data will provide a new indicator of agricultural intensity based on crop and livestock data gathered in the annual surveys.

The Swiss Ornithological Institute has expressed an interest in exploring the data this process intends to make available. They are keen to have a new base map to use in bird population studies and additional information providing an indicator of agricultural intensity is especially relevant. They currently rely on low resolution data which is often at municipality level or based on national periodical land-use statistics and associate this with field data which is commonly gathered per square kilometre. A new base map of agricultural statistics would allow them to repeat their analyses at an increased level of detail and allow a comparison with previous results.

Biologists involved in wildlife population (e.g. butterfly) surveys are also keen on having a further base to relate their findings to. A new method of agrarian data visualisation could assist in the planning for projects aiming to optimise regional ecological networking.

From a personal point of view, this thesis combines the core topics of my work environment with a private interest in ornithology and nature protection. Finding new ways of spatially adapting standard agricultural statistical data and thus making it accessible to those organisations involved in protecting and securing the environment for local and migrating bird populations was an ideal project for me.

The fact that agrarian data is not widely used for spatial analysis purposes can largely be explained by ignorance of the data available and the potential it offers. This thesis is intended as a first step towards positively changing this situation.

1.2 Objectives

The main objective of this thesis is to explore the potential within the GELAN-IS agrarian information system for spatial implementation of its contents:

- The study aims to establish a method of extracting relevant data from the complex array of agrarian data stored in the combined agrarian database for the cantons Berne, Fribourg and Solothurn.
- An attempt will be made to establish a method of georeferencing the numerical agricultural survey data for Canton Berne in order to make the information available in a suitable spatial form for further analysis.
- It is further aimed to enable the creation of new base map layers as indicators of agricultural intensity which would be applicable on a cantonal (or where feasible a national) level (e.g. of crop coverage or livestock numbers per farm).
- With the methods developed during this study enabling spatial exploration of agrarian statistical data at a high level of detail for the first time, initial steps will be taken towards the development of spatially explicit indicators of agricultural intensity.

1.3 Scope

The study concentrates on the potential of existing agrarian survey statistics for the three Gelan partner cantons – Berne, Fribourg and Solothurn. The practical focus will be on developing methods using data from Canton Berne and results described will apply to Berne unless otherwise stated. While the work will be to some extent specific to the current data structure in the Gelan Agrarian Information System, the methods and concepts presented will remain relevant in examining the potential for a national approach.

Although the agrarian data for each of the three partner cantons is stored in the same conceptual schema, it is managed in individual databases. The methods developed in this thesis are to some extent applicable to all three Gelan partner cantons; however the analysis itself will be based solely on data from Canton Berne. The data held within GELAN-IS and used as input for this study pertain solely to farmers resident in Canton Berne. The spatial aspect applies only to land these farmers have which lies within Canton Berne.

1.4 Approach and Methodology

The approach and methodology which will be applied to achieve the stated objectives is described in the following section.

1.4.1 Theoretical approach

The first step will involve investigating the content and structure of the GELAN-IS database. The way in which this relates to agricultural survey statistics – including the regulations and requirements applicable to agrarian data capture – as well as the associated enforcement of government regulations will be considered. In order to understand the database content, a basic understanding of the Gelan-application itself and how it relates to the bi-annual surveys carried out by the cantonal authorities (on behalf of the Federal Agency) is required.

In order to fulfil the aim of the thesis of georeferencing agricultural survey data, a method is required with which to spatially locate the numerical data in some way. As the survey statistics are for the most part gathered at farm site level, this would appear to be the most important unit to georeference. For each farm site, the Gelan database contains a list of the associated land parcels – if these can be georeferenced, then so can the farm sites themselves.

1.4.2 Methodology and Tools

One of the first steps will be an analysis of the database content in an attempt to establish which data are relevant for the proposed study. This will involve examination of the federal and cantonal guidelines regarding the implementation of subsidy payment regulations. Once an understanding of the internal data structure is acquired, tests on filtering out the relevant data and joining the various tables will be carried out to gain a first impression of the potential within the data as well as the limitations and the complexity of extracting it.

In order to georeference the data, a method of georeferencing the farm area is required. A list of land parcels per farm site is held in the Gelan database and the aim is to link these to the official cadastral data in vector form. Agricultural survey data is held per farm site and in most cases not per land parcel, so if the farmed land parcels can be georeferenced they can be aggregated per farm site. Consequently, the associated numerical data can be approximately spatially located in that its maximum spatial extent can be defined in this way.

A vast amount of detail is contained in the Gelan database, and extracting the relevant information and combining it in a suitable form is one of the challenges faced. In consultation with the Swiss Ornithological Institute, an attempt will be made to simplify things somewhat by aggregating the individual crop types into groups with similar characteristics as regards growth, structure and attractiveness to birds and insects.

Tests will focus solely on Canton Berne and its data, but the principles are generally applicable to other cantons – the main provisos being the existence of compatible vector cadastral data and an association between farms and their farmed land parcels.

Exploratory analysis of the Gelan data will be carried out using a combination of the data model and the data itself. The data is held in two IBM DB2 enterprise relational databases for each canton and can be accessed via the DB2 Control Center (database management system) using SQL[3] commands, with ESRI desktop GIS tools (ArcGIS) and with Safe's Feature Manipulation Engine (FME). A summary of the software which will be employed for process development, analysis and documentation is given in Table 1.

Software/Tool	Purpose
Power Designer	Required to examine the data model
FME 2011 Desktop, FME 2012 Desktop Beta	Used to develop processes for the following purposes: • Query and extraction of data from the Gelan-DBs • Data aggregation und geoprocessing operations
ArcGIS Desktop (versions 9.3.1/10)	Data analysis, processing and visualisation
ArcGIS Spatial Analyst	Raster processing
SQL	Preparatory analysis and querying of Gelan-DBs
IBM DB2-Control Center	Graphical user interface to manage and administer DB2 server system and query data
DB2 Database Views	Virtual DB table (stored SQL query) – used to simplify access to the data
Microsoft Visio	Process illustration / documentation
Microsoft Office 2007	Documentation

Table 1: Software employed

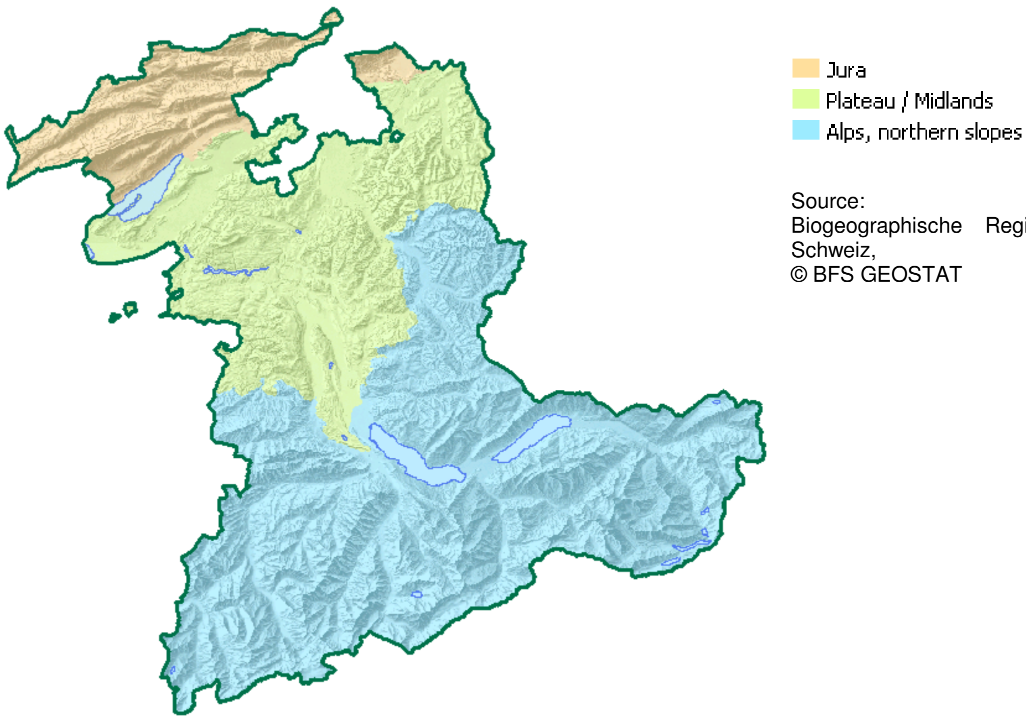
After analysis of the data structure and content, a process to join the numerical data to the vector cadastral data will be developed. The development of a method of aggregating the vast amount of statistical data into a form suitable for georeferencing, further analysis and visualisation will follow.

[3] Structured Query Language

No comparable attempts to extract and georeference information from annual agricultural statistical surveys to such a level of spatial resolution were found. This fact, along with the nature and quantity of the data itself influenced the choice of approach used in this study to examine the assumed potential of the data for fields of interest other than agriculture and in particular in the field of ornithology.

1.4.3 Pilot Regions

Due to the complexity and quantity of data involved, it was decided that the first phase of the analysis involving feasibility assessment and tests should concentrate on smaller pilot regions. The heterogeneous nature of the topography in Canton Berne means it is impossible to adequately represent the typical conditions in the canton within one pilot region. The varying topography and altitude are associated with differing climatic conditions and hence support different species of flora and fauna. The topographic variation of Canton Berne and its associated biogeographic regions are illustrated in the map below.



Source:
Biogeographische Regionen der Schweiz,
© BFS GEOSTAT

Figure 1: Topography and biogeographic regions, Canton Berne

In the specific case of birds and agricultural land, there are also associated differences in farming practices, whilst the terrain and altitude also define which crops are grown. Consequently, the Swiss Ornithological Institute was interested in pilot regions in differing topographical areas and thus relevant for different bird populations. The pilot regions used in the development are shown in Figure 2.

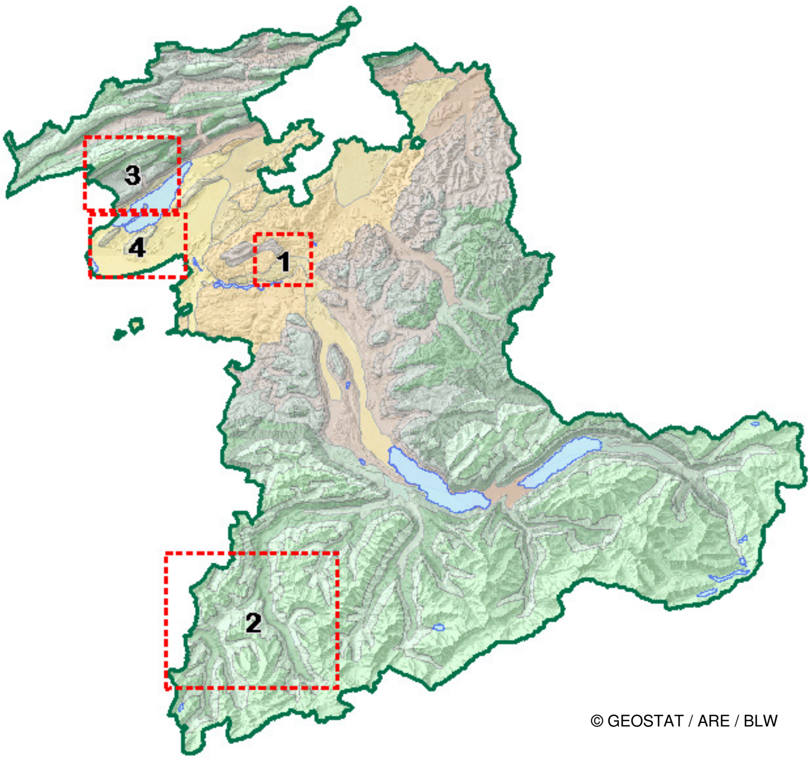


Figure 2: Pilot regions in differing zones of climatic suitability for agriculture[4]

1.4.3.1 Region 1 – Kirchlindach

Two surveys carried out by the Swiss Ornithological Institute in 1998-99 and 2002-03 at 23 study sites in the Swiss Midlands (Birrer *et al.*, 2007) investigated the breeding numbers of 37 farmland bird species. The predominant land-use in the Kirchlindach study area was defined as being of the category 'mixed farming' and was one of 4 sites in Canton Berne. It was chosen as a suitable pilot region due to the possibility of gaining a first impression of potential through direct comparison with existing data and through integrating the results of this study with those from the field surveys.

1.4.3.2 Region 2 – Bernese Oberland

An interest was also expressed in having a pilot region in the more mountainous Bernese Oberland. The terrain, altitude, climate and vegetation as well as the type and intensity of farming practised differ considerably from those encountered in Region 1. The agriculture in the region is dominated by dairy farming and cattle breeding.

[4] Discussed in more detail in chapter 4.1.2.1

1.4.3.3 Region 3 – Jura

The third pilot region is situated in the Swiss Jura Mountains and represents another landscape category with relevance for further bird species' populations. The region of the Diesse Plateau was selected due to its relevance for ongoing research in the Swiss Ornithological Institute. The farming in the region is grassland dominated and typically intensive with some arable farming and particularly at higher altitudes, some dairy farming.

1.4.3.4 Region 4 – "Grosses Moos"

The fourth and final pilot region is in the lowest lying and most intensively farmed part of Canton Berne. This region lies within the country's most important arable farming region and a large proportion of land is dedicated to intensive vegetable farming.

1.5 Expected Results

The work presented intends to provide answers to the following questions:

- Can a method of georeferencing numerical data from agricultural survey statistics stored in the GELAN-IS be established?
- Which data gathered as part of annual agricultural statistical surveys are relevant indicators of agricultural intensity?
- How best can the relevant data be extracted and made available in a form suitable for further analysis?
- An association between less intensively farmed areas and the likelihood of more beneficial conditions for birds to feed, find cover and nest, exists. Can the data extracted from GELAN-IS provide new insight into the distribution of farmland of varying intensity?
- What implications can be identified for similar work on a national scale?

1.6 Excluded Topics

In this section, those aspects which would be of relevance to the topics broached in this thesis but which are beyond its scope are outlined.

- **Nutrient balance:** in any analysis of farming intensity, information on the nutrient balance within the farming environment is of interest. In this case, interest was expressed by the Swiss Ornithological Institute. The relevant data with regard to the amount of fertilizer applied to and manure produced within a farm unit form part of the "Suisse-Bilanz" statistics as defined by the Federal Office for Agriculture (FOAG) and collected by official control organisations (Agridea/FOAG, 2010). Suisse-Bilanz statistics allow farmers to calculate a farm's nutrient balance, the maximum supportable livestock numbers and to make a fertilizer plan per farmed land parcel. The amount of fertilizer being produced and applied to a farm is a significant indicator of agricultural intensity. However, as these data are not an integral part of the federal or cantonal agricultural data surveys, they are not stored in the cantonal agrarian database managed by Gelan Informatik. Consequently, as this study is limited to using the existing data within this database, the additional information on nutrient balance which these statistics could provide, is not considered.

- **Field survey data:** although the integration of field survey data from the Swiss Ornithological Institute is surely a subject for future consideration, it is not incorporated into this study.
- **Farm Structure Surveys:** no attempt is made to analyse information gathering methods employed for farm structure surveys etc.
- **Ecological compensation areas:** an analysis of the effectiveness of ECAs has been carried out by various authors but is beyond the scope of this study. Future studies of this topic would however benefit from the methods developed and geodata created in this thesis.
- **Data employed:** only agrarian data which is gathered in the annual agricultural censuses and stored in the Gelan database is used in this study. Inputs from other sources which could be important indicators of agricultural intensity are beyond the scope of this thesis. Some agricultural geodata is already freely available for Canton Berne (e.g. geodata of ECAs, vineyards and orchards can be downloaded from the cantonal geoportal) – no further analysis of this data is carried out.
- **Land parcels:** in order to georeference farmed land, suitable vector geodata is necessary. Although coverage of vector cadastral data is not comprehensive, after discussion with the Swiss Ornithological Institute it was deemed sufficient for the purposes of this study. No attempt is made to optimize coverage by integration other data sources.
- **Region:** Processes will be developed using only data from Canton Berne. Although the theoretical aspects are relevant when considering a national

approach, no attempt is made to employ or analyse the data collected at federal level.

- **Crop/livestock distribution:** although some comments are made on the distribution of the different types of crops and livestock, there is no aim to analyse this in detail.
- **Cereal yield data:** no information on cereal yield is collected in the annual agricultural statistical surveys and thus, despite the apparent relevance for a study of this type, this topic can not be considered within the scope of this thesis.
- **Effects of topography:** a high resolution digital terrain model (2m) is available for the study area. It is beyond the scope of this thesis to consider its use to exclude areas unsuitable for farming based on considerations of altitude or gradient.
- **Aims/methods:** although methods of mapping the newly georeferenced agricultural statistical survey data will be developed, the aim is not to develop a conclusive end product. The complex nature of the data and the newness of the type of information this study makes available spatially for the first time, will provide the basis for further spatial analysis by the Swiss Ornithological Institute with the aim of fulfilling their own specific requirements. The development of suitable legend classification[5] schemes to represent the data range of the various data layers produced in an optimal way is outwith the scope of this study. Although some experimentation with further processing of the vector output in raster form is carried out as part of the study, there is no aim to conclusively define a method for this – the intention is simply to indicate some of the potential for further analysis of the new data.

1.7 Target Audience

The target audience addressed with this thesis and the new resource it intends to provide fall into the following groups:

- Swiss Ornithological Institute
- departments within the Cantonal administration
- interested parties working in nature protection or field survey

[5] See Appendix B

A basic to intermediate level of GIS knowledge is required.

- to understand the principles involved a basic understanding of GIS principles would be beneficial
- to apply the methods for further analysis a more in-depth level of GIS knowledge would be required

1.8 Thesis Structure

The thesis structure is summarized in the diagram below – each main block represents a chapter, each small block a section of that chapter.

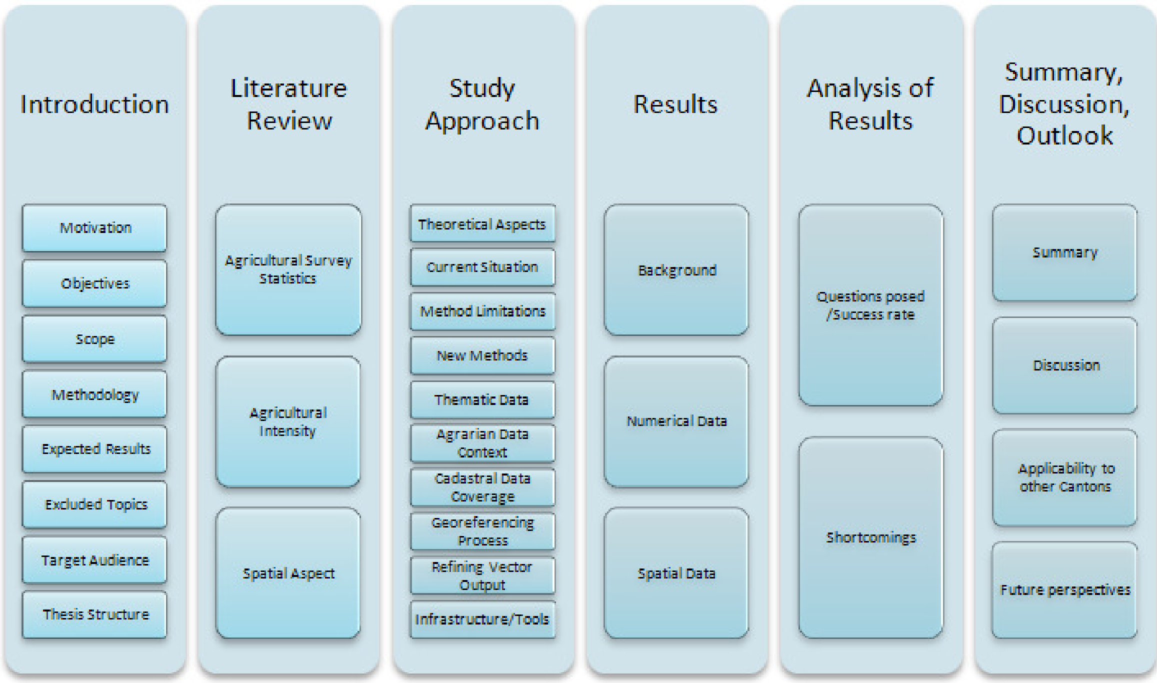


Figure 3: Thesis structure

2 Literature Review

2.1 Agricultural Survey Statistics

Increasing global population and industrial development have led inevitably to increased pressures on agricultural land and natural resources. There is higher demand for building land as housing and infrastructure grows, while at the same time there are increased demands on the existing agricultural land to produce more thus leading to an intensification of farming practices. As a result, there is also increased pressure on valuable wildlife habitat, leading in many cases to habitat loss.

The growing pressure on natural habitat has led to intensified monitoring of developments. The important role which agriculture plays in environmental considerations related to the development of measures to prevent irreversible damage and loss of biodiversity has been recognised. Detailed surveys of flora and fauna are an essential tool in establishing an overview of species present in any given area and thus of monitoring biodiversity. The role of geospatial data has grown in significance in this area and is now a well established instrument in monitoring and administration programmes.

Recent projects related to the recovery and protection of the environment have also led to significant modifications in data collection in the agrarian sector. In standard agricultural survey statistics, precise geographic location of the data is often not a requirement due to the lack of priority of linking the data with the environment (Benedetti *et al.*, 2010). Recent efforts in some European countries show a change in emphasis with the spatial aspect of data survey methods now central in many European Union member states (FAO, 2006). Some countries increasingly gather map-based data (although not all is held in a central digitised form) while remote sensing data has also grown in importance particularly in the EU. Regional analysis is hampered by the restricted access afforded to Integrated Administration and Control System (IACS) data – agricultural data gathered in the EU for the administration of subsidies – and by its heterogeneous nature. In some countries, attempts to spatially locate certain agrarian data are further hindered by confidentiality issues.

The focus of governmental financial support for farmers has changed somewhat in recent years. The early emphasis on supporting market prices by means of subsidy payments has been replaced by funding the development of rural areas and increasing financial incentives for environmentally friendly farming practices (e.g. agri-environment schemes) as well as for not farming environmentally sensitive land (Benedetti *et al.*, 2010). In many countries, agrarian data collection is carried out at a lower frequency and level of detail than is the case in Switzerland where there is an annual survey. The system has had to be adapted in Europe to allow for the increased diversity of content required with the expansion of the European Union (EU). The demand for more spatially detailed data is increasing and Benedetti *et al.* see considerable scope for enhancing multi-purpose spatial surveys with spatial agricultural information.

2.2 Agricultural Intensity

Although studies have shown that land-use intensity appears to be a key determinant of vegetation diversity in agro-ecosystems, these environments as a whole have now been acknowledged for their importance as regards landscape-level biodiversity on a regional and global scale (von Arx *et al.*, 2002). The presence of border or corridor structures is particularly significant for the maintenance of biodiversity in the agricultural environment – aspects which are an integral part of agri-environment schemes and associated extensive farming practices. In a study in Switzerland (von Arx *et al.*, 2002), it was shown that vegetation diversity generally decreased with increasing land-use intensity (with regard to frequency of mowing, grazing or ploughing) – extensive meadow having the highest values followed by permanent pasture, intensive meadows and cereal fields. Any evaluation of the effects of land-use intensity should differentiate between the effects of disturbance and those of fertilisation.

The typical pattern of events in the annual farming cycle interacts with major events in a bird's life such as breeding and migration (Ormerod *et al.*, 2000). The mosaic of agricultural habitats influences nest-site selection, feeding and rates of breeding success. Research has shown evidence of a significant decline in farmland bird[6] populations across Europe over the last 30 years (Donald *et al.*, 2006) – a trend not evident for other habitats, suggesting that factors specific to this habitat as opposed

[6] "farmland birds" is a term commonly used when referring to specialist species that are dependent on farmland and includes species such as skylark and yellowhammer.

to a general population decline are responsible. A significant correlation was found between overall population trends of farmland species and national indices of agricultural intensity. Various aspects are associated with the process of intensification including increased livestock numbers, higher mechanisation and chemical use, crop area changes, different sowing and harvesting times, increasing monoculture, soil moisture changes and loss of complex non-farmed structures such as hedgerows and ponds. The FAO[7] regards the following as indicators of agricultural intensity: cereal yield, fertiliser use, number of tractors per unit of agricultural land and livestock density (as head of cattle per ha of grassland). Interestingly, there was no observed correlation between species population trends and the proportion of land under agri-environment schemes – although this is attributed to the focus and influence of these schemes under the CAP[8]. Where boosting biodiversity has been given precedence, correctly targeted agri-environment schemes have rapidly aided bird populations (Vickery *et al.*, 2004).

A study by the Swiss Ornithological Institute (Birrer *et al.*, 2007) investigated the effects of ecological compensation areas in Switzerland on breeding populations of farmland bird species. Differences in distribution were found between grassland-dominated areas, arable areas and areas of forage crop production. The lack of sufficient "ecological quality" is considered the main reason for only very slight improvements associated with the expansion of ECAs. Also the distribution of the ECAs is unsuitable for many species whilst the most beneficial types for farmland birds are still relatively rare (e.g. those of a high biological quality).

Henderson *et al.* (2009) showed the beneficial effects of farm-scale changes in crop patterns and pesticide application and their associated changes in food and habitat provision on farmland bird species in the UK (particularly effective on species of high conservation concern). They demonstrated the important role played by winter wheat crops – with bird densities on average 2.6 times higher on other field types. The role of pesticides was shown to be complex and difficult to manipulate for arable crops, whereas the management of set-aside (e.g. delayed spraying) was easier to manage, did not affect crop yield and showed direct benefits to bird populations. The extent of uniform crop area is also an important factor, as parent birds have further to travel to forage to feed their young – potentially reducing farmland bird density. A more diverse landscape provides a

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[7] Food and Agriculture Organisation of the United Nations
[8] Common Agricultural Policy

larger variety of food sources and can thus support more bird species/numbers. Different plant and insect groups respond differently to grazing intensity levels and the landscape as a whole should be considered when managing for biodiversity conservation (Sjödin *et al*., 2008). They also demonstrated that farmland bird species respond to farm-scale changes in habitat and food availability.

Bas *et al*. (2009) used agricultural statistics to illustrate that ground nesting birds are particularly sensitive to increased agricultural intensity. Certain – above all granivorous – species are particularly sensitive to arable management and changed timings for cereal sowing which affect the availability of seed-rich winter stubble or increased herbicide use which cause fluctuations in their food supply (Robinson *et al*., 2001). Bird numbers have been shown to increase where arable land is managed to provide areas with spring-sown cereals, over-winter stubble or grass borders. Some studies have shown that the breeding densities of certain species show a direct relation to the diversity of crops at a farm-scale. If arable or pasture land is scarce in a region, increasing it is likely to positively affect species dependent on the habitat.

The role of high nature value farmland (HNV) has been assessed by various authors and Doxa *et al*. (2010) found in a study in France, that low-intensity agriculture positively influences farmland bird abundance. They propose that focussing conservation efforts on HNV farmland over a large geographical area is desirable and maintain that this can be achieved by increasing a minimum of one of the three components that contribute to HNV – i.e. extensive farming practices, crop diversity and landscape elements. Agricultural statistics are one aspect used in defining the HNV farmland indicator. Pointereau *et al*. (2007) employ FSS data to identify HNV farmland in France and to assess how extensive the farming in any particular region is. They conclude that there is potential in the survey data to estimate permanent pastures and to calculate an indicator of crop diversity.

Báldi *et al*. (2005) conclude that there is overwhelming evidence that the decline in farmland species and other wildlife diversity correlates with increasing farming intensity. The same author (2007) also examined the correlation between agricultural intensification (as measured by milk and cereal yields, number of machinery and cattle density) and population decline of the brown hare and grey partridge. In a study in Britain, Newton (2004) identifies 4 aspects of agricultural change as the main causes of declines in farmland bird populations due to reduced food supply, increased disturbance/nest predation and lower survival/reproductive rates: (1) weed-control (herbicide use) affecting seed-eating species; (2) earlier ploughing of stubbles and crop growth associated with the increasing preference for autumn-sown cereals over spring-sown cereals; (3) intensification of grassland management associated with land drainage; and (4) higher stocking densities.

2.3 Spatial Aspect

The gathering of farming statistics per farm holding by means of a regular agricultural census provides data relating to which farming activities are taking place on a particular farm but with no spatial localisation of the data. Early efforts at spatially localising farm holdings were based on georeferencing a single point within the farm area – commonly either the headquarters building or the centroid of associated land parcels (identified by means of point coordinates). Such a system serves the purpose adequately at low spatial resolution or for small-scale farms and has been suitable for animal welfare requirements (Durr *et al.*, 2002), however its inadequacy for use with large farms and the benefits of using actual farm boundaries for georeferencing purposes have been recognised.

Aid became area-based with the 2003 CAP reform and within the EU the Integrated Administration and Control System (IACS) uses the "Land Parcel Identification System" (LPIS) to locate "reference parcels"[9] declared in applications for agricultural aid payments. The spatial potential offered by the IACS scheme is huge, with some 40 systems in use in the EU handling aid applications by around 5 million farmers with some 50 million referenced fields. The quality of the LPIS is dependent on the quality of the reference parcel system employed and there are varying types and methods of creation within Europe (Grandgirard *et al.*, 2008).

Data on land cover is available with varying focus and at differing levels of detail and coverage. On a national scale, land cover data (BFS, 2009) is provided by the Swiss Federal Statistical Office (SFSO). There are two datasets which were developed from the national land-use/land cover statistics: a) an aggregation to conform with the CORINE land cover (CLC) data of Europe – 13 categories are recognised (smallest cell size = 250m^2; minimum mapping unit = 25 ha) – although the differing survey methodology causes some problems for this transfer of

[9] Geographically delimited area with a unique identification code under which it is registered in the Member State's GIS identification system

nomenclature; b) a simplified land cover dataset (100m resolution). The limitation with both is the lack of current data – with the most currently available information from 1997. Landscape diversity and land cover categories which frequently occur in small patches tend to be underestimated by CLC data (Steinnocher *et al*., 2005).

An important input employed in this study is the cadastral survey data of land cover (vector). The detail relating to agricultural land is limited to the differentiation between arable land, intensive cultures, vines, wooded areas and unproductive land categories (e.g. roads, buildings, water bodies, gardens and areas with no vegetation). The only detail regarding what is contained in the category 'arable land' is the data gathered from agricultural surveys – which as previously discussed, is not georeferenced.

The use of CLC data has scale limitations due to its coarse-grained resolution and survey method, with small agricultural structures being below the threshold. As a consequence, relevant land cover classes (and changes) are often not recorded resulting in an underestimation of landscape diversity (Steinnocher *et al.,* 2005). Steinnocher employs spatial disaggregation methods using existing administrative boundaries (NUTS3) and associated statistical data in combination with CLC data to more locally georeference the data, giving a much more accurate representation of areas to which the data applies. As a result of IACS schemes in Europe, detailed spatial information is being gathered – this is potentially relevant to research in various fields. However, data protection issues are likely to prohibit the use of the data at a detailed level of resolution.

There are surprisingly few examples of georeferencing statistical data at anything finer than municipality/district scale for which it is commonly available in aggregated form. The European Environment Agency examines the potential of integrating statistical and administrative data with land cover data (EEA*,* 2001). Prinz *et al.* (2004) and Strobl (2005) explore the possibilities of the flexible aggregation of address-based regional statistical surveys in Austria to raster datasets of varying levels of detail. A smaller raster cell size allows the association of statistical data with fine grained geodata. Wonka (2009) describes associating agricultural survey statistics to a raster grid and discusses the problems of data protection limitations. Although there is reference to representing agricultural statistics, the main emphasis is on purely statistical representation and thus different to aspects relating to agricultural intensity as considered in this thesis. The advantages of having data inputs at high spatial resolution is recognised by Prinz (2007) and the importance of spatially explicit indicators discussed in various contexts (Backhaus *et al.*, 2000)

Wonka (2009) recognises that in order to enable spatial analysis of thematical statistical data, it must first be linked to georeferenced base data. Commonly, administrative units are employed for this purpose which allows the simple mapping of many statistics – for example, population aggregated per municipality. However practical this may appear, it must always be considered that administrative boundaries were defined by criteria other than the statistics in focus.

In order to georeference the statistical data, there must be a means of spatially locating it – e.g. address details – which can then be used to associate or combine it with existing geodata. Most commonly raster data is produced for further analysis due to the advantages it offers for multi-themed analysis and the ease with which it can be further generalised for use at varying scale or as a means of compromise in order to fulfil data protection demands. The chosen raster cell resolution can have a major effect on the accuracy of the data representation or the results of spatial analyses.

Numerous projects involving georeferencing statistical data have their emphasis on geocoding address data, thus contributing to the establishment of address-based statistics. There is a huge potential within the increasing number of address- or coordinate-based statistical surveys (Strobl, 2005), although their use can be problematic with regards to data protection issues. Most commonly, the visualisation of regional statistical values is carried out on the basis of administrative or organisational boundaries. Frequently, the available data is in point format (address matching) which is then aggregated on the basis of a regular raster grid.

The role of brown hare abundance as an indicator for agricultural intensification has been analysed in various studies (Lundström-Gilliéron *et al.*, 2003). Agricultural statistics were aggregated on a municipal level as a model input. Such studies which are based to some extent on agricultural survey statistics would benefit from the availability of more geospecifically accurate data – something which this study aims to provide.

3 Study Approach

This study revolves around the georeferencing of agricultural survey statistics as stored in the Gelan agrarian database – a process which is dependent on the availability of suitable vector cadastral data – and of establishing a means of assessing agricultural intensity from the survey data. This chapter provides information on the available numerical data and explains the processes involved in georeferencing those data as a basis for achieving the aims of this study, including establishing a spatial indicator of the intensity of agricultural land-use.

3.1 Theoretical Aspects

The approach to be taken and the preparatory steps required to georeference agricultural survey data are described in this section.

3.1.1 Terminology

Before discussing the chosen approach, the importance of and differentiation between certain terms should be explained to ensure correct understanding of the theory and interpretation of the results (see Table 2).

Cantons: • Ct.: Canton • BE: Canton Berne • FR: Canton Fribourg • SO: Canton Solothurn
Agricultural survey statistics: • The annual surveys are best described as federal surveys with cantonal additions • Data is collected by the cantons and delivered to the federal government at regular intervals • Farm structure and agriculturally relevant data is collected
The data analysed is from GELAN-IS BE: • Residence principle: data refers only to farmers resident in Ct. BE • The term "Bernese famers" is applied to farmers resident in Ct. BE for direct payment purposes
Land cover: • 'UAA' = utilisable agricultural area • 'Land' = Land cover categories which are viewed as potential UAA • UAA definition in Switzerland: arable land; permanent grassland (excl. alpine meadows); litter meadows; permanent crops; protected crops (greenhouse/plastic); hedge/riparian

woodland/field coppices; extensively used stream borders • NUAA[10]: certain agricultural land-use is outside the UAA (not considered significant for mapping the data this study aims to produce)
Land parcels. • Cadastral land parcels are imported into GELAN-IS annually • The cadastral data includes information on land cover categories per land parcel – from which the potential UAA per land parcel is known • Farmers declare the effective UAA on their land (i.e. land farmed) • A register of farm parcels per farm holding is stored in GELAN-IS; farmers declare the land parcels they farm • "Nature management" contracts exist on some land parcels and regulate land-use and stewardship practices on the specified area
Area: • The "are" (a) is the standard unit of measurement for agricultural statistics in Switzerland (1 are = $100m^2$)
Regulation terminology/translations used: • LBV: Ordinance on Agricultural Terminology[11] (referred to as OAT) • LwG: Federal Law on Agriculture[12] (referred to as FLA) • DZV: Ordinance on Direct Payments[13] (referred to as ODP) • TVD: Animal Traffic Database (referred to as ATD) • TSK: Epizootic Fund[14] (referred to as EF) • TSV: Ordinance on Animal Diseases[15] (referred to as OAD)

Table 2: Explanation of key terms

3.1.2 Isolating numerical data

The chosen approach can be split into theoretical and practical aspects. On the theoretical side, a comprehensive literature review serves to isolate potential factors held within the agricultural survey data which could contribute as indicators of agricultural intensity. Parallel to this, the content of the annual agricultural statistical surveys will be examined with regard to identifying the relevant information they contain.

The next stage will involve an analysis of the data within the Gelan database. To begin with, this involves examining the content and structure of numerical agricultural statistical data held within the Gelan agrarian information system in order to understand how the survey statistics are stored in the database. It is necessary to identify the relevant tables and associated attributes as well as their relationships and dependencies within the complex data structure.

[10] Gelan terminology: equivalent of expression "ausserhalb LN" (ALN) in German
[11] Landwirtschaftliche Begriffsverordnung (LBV), SR 910.91
[12] Landwirtschaftsgesetz (LwG), SR 910.1
[13] Direktzahlungsverordnung (DZV), SR 910.13
[14] Tierseuchenkasse (TSK)
[15] Tierseuchenverordnung (TSV), SR 916.401

Once it is possible to isolate the relevant data within the complex system, data samples from the individual tables will be exported (using SQL commands and MS Access) and further testing will be carried out. Based on these tests, database views will then be created in order to make the relevant data and attributes more easily accessible within the database. One important part of the definition of the views is to restrict the data to that pertaining to the year 2010.

3.1.3 Refining the numerical data

Extraction of the applicable data is only a first step on the way to making the data accessible in a form suitable for establishing a spatial indicator of agricultural intensity. The fine-grained level of detail of the raw data means it is largely unsuited to use as a base for spatial analysis in the required context. Therefore, the next stage will involve analysing and aggregating the data into a suitable and more manageable form for the analysis which follows.

3.1.4 Establishing a spatial link

The next step will involve establishing a link between the numerical land parcel data in the Gelan database and the vector cadastral dataset. An FME workbench process will be designed to join the datasets by means of their municipality number, survey district number and parcel number. Once the land parcel numbers in GELAN-IS are linked to the cadastral geodata, the farmland associated with a particular farm holding can be georeferenced based on the extent of its registered land parcels. The numerical data – which includes data on livestock numbers and crop coverage – can then be georeferenced to the maximum extent of a farm's land coverage.

3.1.5 Mapping indicators of agricultural intensity

Once the agricultural statistical data can be georeferenced using the principal described above, tests can be carried out with the data in pre-defined test regions. The results from these tests will allow decisions regarding which data can best be spatially aggregated to map the inherent indicators of agricultural intensity in a way suited to the needs of the Swiss Ornithological Institute. The processes designed for this study will produce vector data output. However, tests will also be carried out using Spatial Analyst[16] to rasterize some of the output as this format offers significant potential for further geoprocessing and/or spatial aggregation.

3.2 Current Situation

This thesis proposes a method of georeferencing numerical data from agricultural survey statistics with the aim of making the data available for further analysis at an as yet unknown geospecific level of detail. Up until now the most detailed level of spatial reference for agrarian statistics held in the Gelan database was that offered by aggregating data on a municipal level and associating it with a geodataset of those boundaries.

The philosophy of data collection defines to some extent the potential for georeferencing the data on any level. One defining element is the address of a farm holding, as much of the data gathered in agricultural surveys are associated with the farm holding as an entity (for further details refer to Figure 13 and Table 15) and are not more specifically localised (e.g. to land parcel level). As a result, up until now, the most spatially detailed visualisation of the numerical data was based on data aggregated at municipality level and mapped using the administrative boundaries. An example of this method is illustrated in Figure 4 for livestock units.

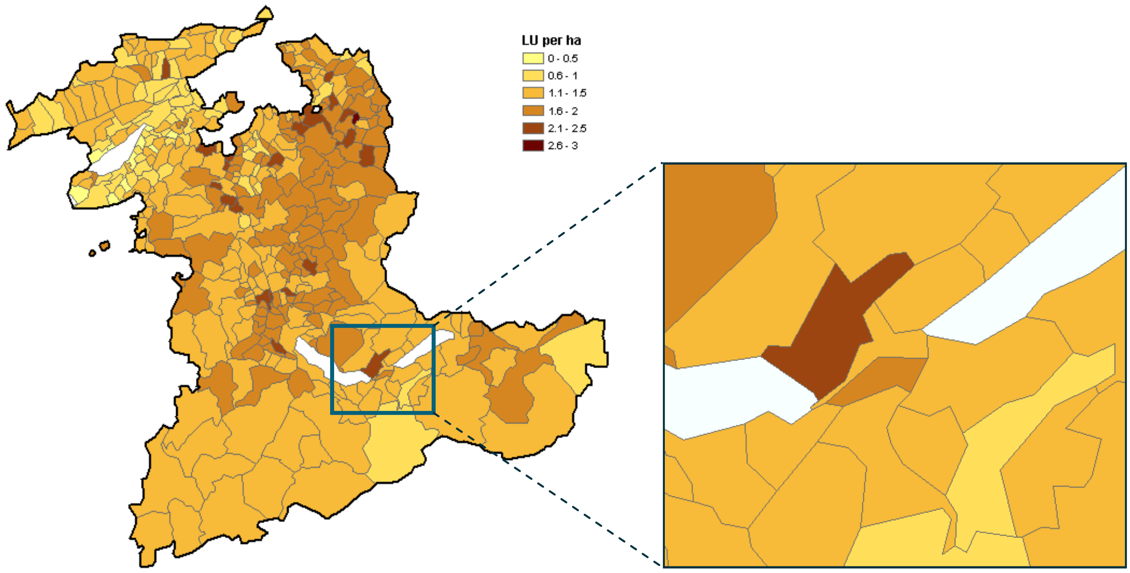


Figure 4: Livestock units per hectare of land, municipalities Canton Berne and detail

[16] An ArcGIS Desktop extension for raster processing

3.3 Method Limitations

The currently available method as described above has several limitations which are described below.

3.3.1 Level of detail

The maximum resolution of the data representation is dependent on the size of the municipalities – which as Figure 4 illustrates, vary greatly in size. No account is taken of where the farmed land in a municipality is situated – for example where built-up areas or extensive woodland take up much of the land area.

3.3.2 Farm holding location

The data collected in annual agricultural surveys is associated with the location of the headquarters of a farm holding. The land belonging to a particular farm need not lie in the same municipality as the headquarters itself. As a result, the aggregation of data per municipality does not (cannot) take account of this fact.

3.3.3 Heterogeneity

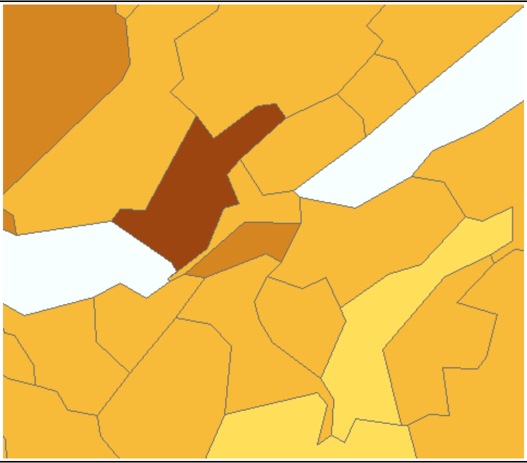
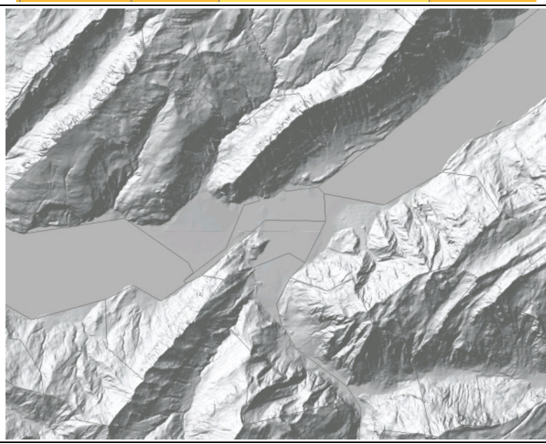
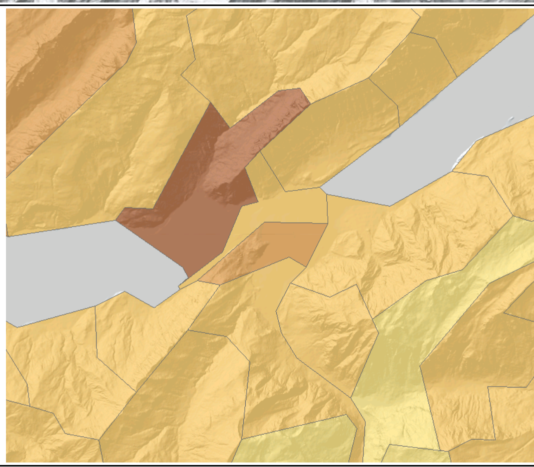
Administrative units vary considerably not only in size and content but also in altitude and topography. As a result, the data which is shown to represent the situation in a given municipal unit is in reality only applicable to those areas which are farmed. This is effectively limited by numerous factors including land-use, altitude, topography, remoteness and climatic factors.

3.3.4 Relevance for bird population studies

From the point of view of gaining input from such an aggregated representation of agricultural statistics for analyses of bird population/distribution, only very generalised hypotheses can be formed. For many purposes the level of detail provided by this method is largely inadequate and the Swiss Ornithological Institute has up until now had to rely largely on data provided by the national land-use and land cover statistics. These statistics from the Federal Statistical Office are based on aerial photo interpretation and are updated infrequently (every 12 years). Land-use/cover data is provided as a raster geodataset at 100m cell resolution (the data gathered is counted as representative for one hectare of land).

3.3.5 Overview

Aspects of the current method of illustrating agricultural statistics on the basis of administrative units are presented in the table below.

a) Livestock unit per unit of fertilized area – data aggregated at municipal level and shown with those boundaries illustrating the maximum resolution permitted by the currently available agricultural statistics.	
b) Digital terrain model of the same region illustrating the heterogeneous nature of the topography.	
c) Combination of the statistical data with the digital terrain indicating the presence of large areas within municipality boundaries which in reality do not qualify as potentially farmed area.	

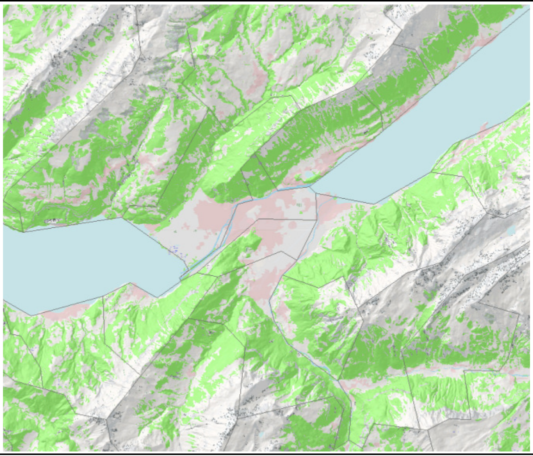
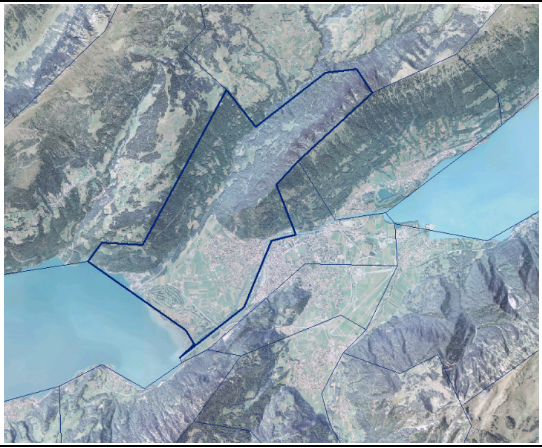
d) Topography is not the only factor limiting farmed area – land cover is a further factor – thus forested (green) and built-up areas (pinkish) are shown here.	
e) The differing terrain and land cover is further illustrated in the orthophoto – large proportions of land within the administrative boundary are obviously not farmed (forested).	
f) Close-up view illustrating the differing terrain and non-farming land-use (settlement, forest)	

Table 3: Drawbacks of illustration of statistics based on administrative units

3.4 New Methods and Optimizing Data Potential

If agricultural survey statistics can be georeferenced, there is considerable potential to improve on the spatial accuracy and usefulness of the mapped data. A means of doing this is presented in the following chapters.

3.4.1 Georeferencing farmland

The first phase in the process of georeferencing farms whose details are stored in the Gelan database, involves identifying their farmed land parcels and joining them to cadastral geodata. Numerical data from the annual cadastral import is stored in the database and is joined to cadastral geodata by means of municipality-ID, survey district ID and parcel number (generally a unique combination). Of the 126,570 land parcels in Canton Berne registered by farmers in 2010, 98.7% (representing 94.1% of the area) can be linked to the available cadastral vector data and thus georeferenced. An example of georeferenced farmland from one farm is shown in Figure 5. There is one additional land parcel not shown below as it is not farmed but instead registered due to having a nature management contract.

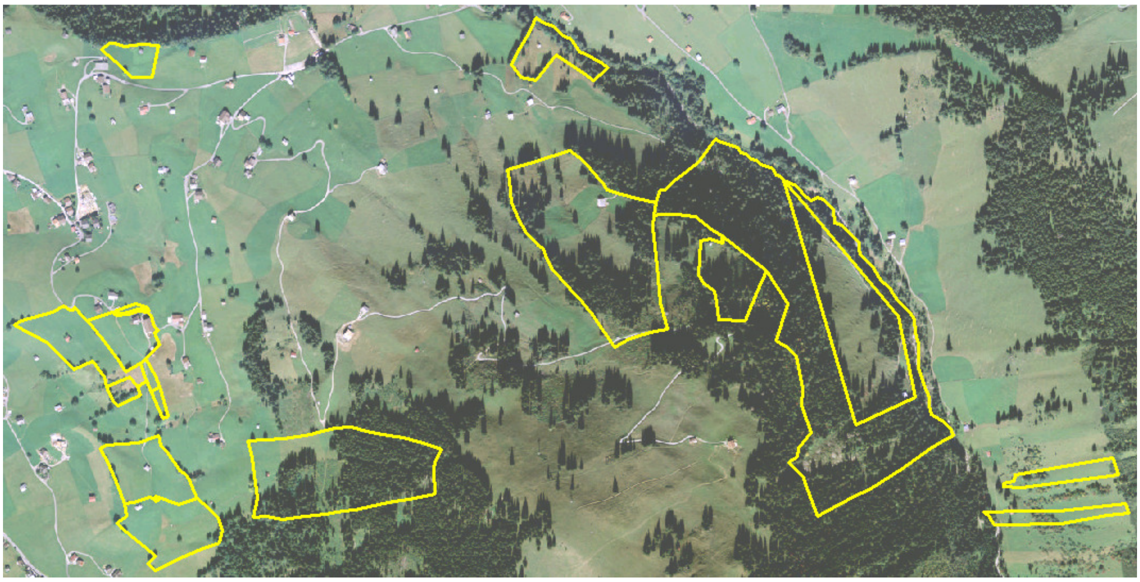


Figure 5: Parcels farmed by one farm in the Bernese Oberland

For the land registered to the above farm, the details per land parcel are listed in Table 4. The column MLN009 contains details given by the farmer on the area of land farmed (in ares) on each individual land parcel. The official cadastral figures on land cover are aggregated under the 3 categories LAND (eligible as farming land), UNPROD (unproductive land) and WALD (forested land) with LAND representing the maximum area which can be declared as farmed land. The percentage covered by these categories is shown in the three "Proz_" columns.

Par_Nr_Orig	MLN009	MAL009	LAND	UNPROD	WALD	TotalAreaBOF	Proz_LAND	Proz_UNPROD	Proz_WALD
261	0	0	29.78	0	5.43	35.21	0.85	0	0.15
510	70.13	0	70.13	0.44	0	70.57	0.99	0.01	0
511	50.26	0	100.52	8.38	39.17	148.07	0.68	0.06	0.26
780	13.71	0	13.71	1.94	0	15.65	0.88	0.12	0
781	603.4	0	603.4	7.99	348.28	959.67	0.63	0.01	0.36
1313	31.91	<Null>	31.91	0	0	31.91	1	0	0
1351	138.45	0	138.45	21.22	0	159.67	0.87	0.13	0
1365	90	0	90.14	0.16	0	90.3	1	0	0
1495	255.62	0	255.62	0.78	0	256.4	1	0	0
1497	211.16	<Null>	211.16	1.01	0	212.17	1	0	0
1500	214.56	0	214.56	2.79	0	217.35	0.99	0.01	0
1653	234.69	0	234.69	22.62	1377.24	1634.55	0.14	0.01	0.84
2197	87.32	<Null>	87.32	0.2	0	87.52	1	0	0
2740	48.59	0	194.38	0.33	529.76	724.47	0.27	0	0.73
6383	61.08	<Null>	61.08	0	134.49	195.57	0.31	0	0.69
6380	434.81	<Null>	434.81	15.26	180	630.07	0.69	0.02	0.29

Table 4: Details of land parcels associated with one farm in the Bernese Oberland

All land parcels in Canton Berne registered to this particular farm could be georeferenced by the described method. Parcel 261 has no land area registered by the farmer as being farmed and refers to the land parcel mentioned above with a nature management contract. The maximum possible area of parcel 510 is farmed (LAND = MLN009), while parcel 511 is shared between two farmers and only half of the eligible land is farmed by this farmer.

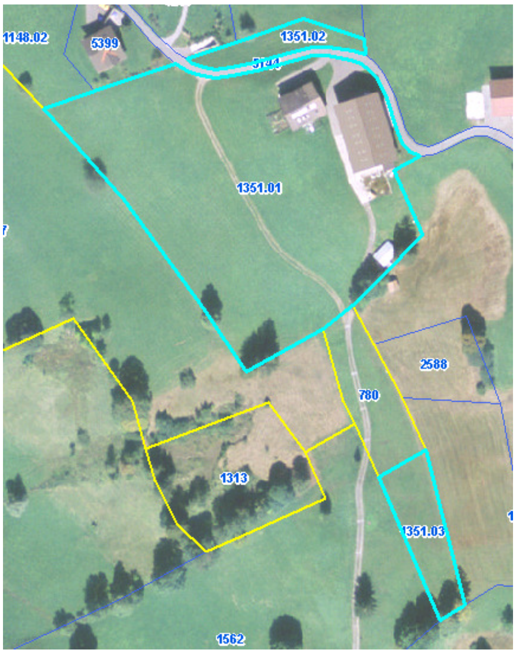


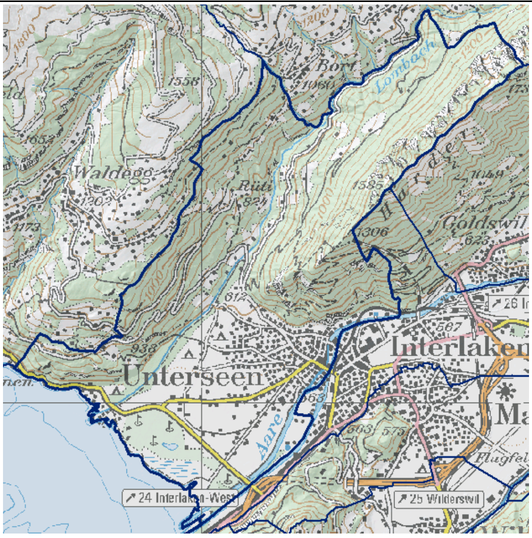
Figure 6: Parcel 1351 (3 parts)

Parcel 1351 presents another facet of the georeferencing challenge as the cadastral data contains three sub-parcels (highlighted blue opposite) under the same main number (split as 1351.01, 1351.02 and 1351.03) whereas such sub-parcels are not stored as such in the Gelan database and the area and land cover data are aggregated on import and in this case stored under one record for 1351.

Identifying farmed land extent

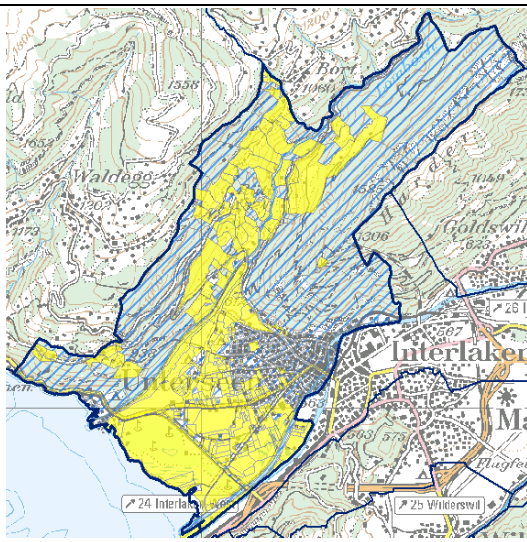
The steps involved in refining the extent of farmed land are described in Table 5 below.

a) Municipality of Unterseen – showing a mix of settlement, flat open land on the valley floor and a steep-sided valley with mostly forested land.



b) Vector cadastral data is available for the whole municipality. Land parcels registered to an active farm are shown in yellow.

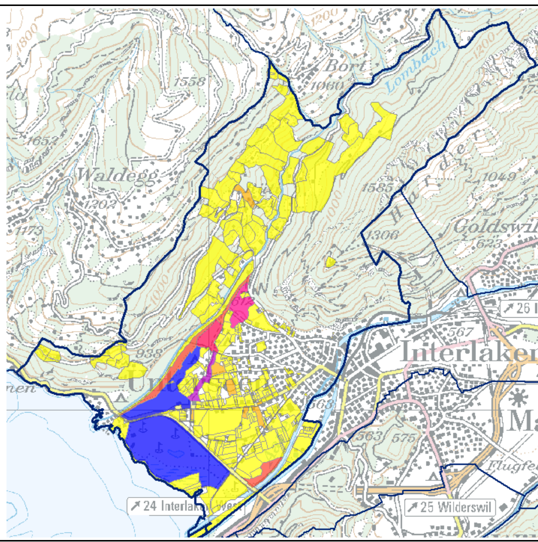
→ the first exclusion level removes forested and urban land.



c) Some land parcels are farmed by more than one farmer.

No. of farmers:

- 1
- 2
- 3
- 4
- 6
- 7
- 9



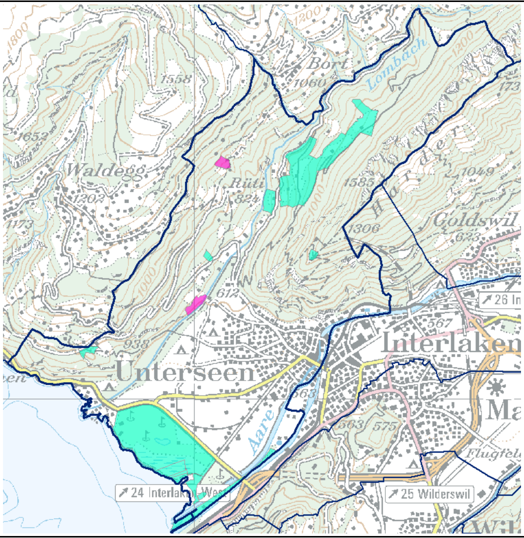
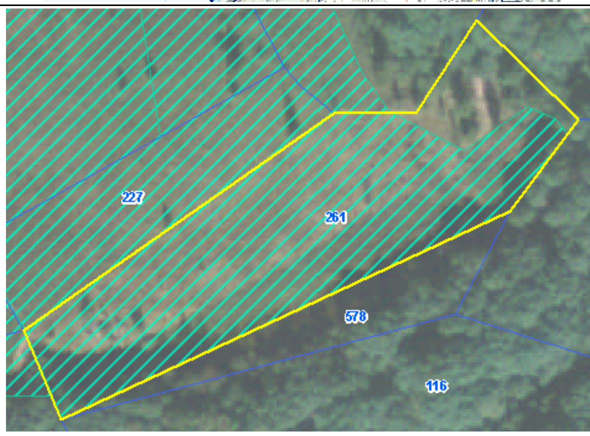
d) Land parcels with nature protection contracts regulating their use or management can also be identified.	
e) Land parcels registered to a farm are not always used for farming purposes. These can be identified and excluded where appropriate. The land parcel opposite is registered to a farm but its non-forested land is entirely within a protected area and under a management contract and hence not farmed.	 → Hatching denotes area within nature inventory

Table 5: Exclusion of non-farmed land from area of municipality

In order to achieve the most accurate results when georeferencing farmed land, the aspects illustrated in Table 5 above need to be taken into consideration thus reducing the maximum area for the mapping of crop or grazing data.

Shared land parcels

From a total of 126,570 farmed land parcels in 2010, 7,070 (5.6%) are farmed by more than one farmer (see Table 6).

No. of farmers	Count	% of total
1	119,500	94.41
2-10	7,011	5.54
11-20	58	0.05
21-30	5	0.004
31-41	2	0.002

Table 6: Number of associated farmers per land parcel 2010

Farmers are required to declare how much land is farmland on each land parcel they register. Where they declare no (or very little) farmland, these land parcels can be excluded when defining the maximum farmed area by means of farmed parcel boundaries.

The example opposite is a parcel with an area of 644.07 ares (cadastral land cover data). The 587.84 ares of eligible farming land is jointly farmed by 4 farmers – the amount of land farmed by each individual is recorded in column MLN009 in the table excerpt below.

MLN009	LAND	UNPROD	WALD	TotalAreaBOF
3.62	587.84	44.4	11.83	644.07
7.1	587.84	44.4	11.83	644.07
460.18	587.84	44.4	11.83	644.07
51.89	587.84	44.4	11.83	644.07

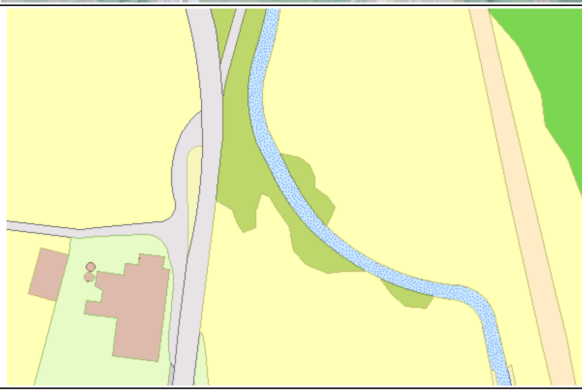
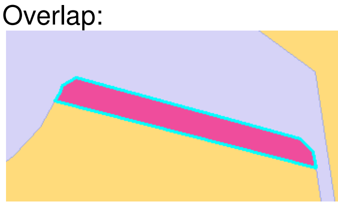
Figure 7: Parcel 78, jointly farmed by 4 farmers

Land parcels under shared use are a complicating factor in the detailed visualisation of agricultural statistics. For the visualisation of livestock units per unit of grazing land, figures are held per farm unit and can only be applied to those land parcels registered to a given farm. As illustrated above, the first means of reducing this area is based on the details given by the farmers in the annual surveys regarding their land-use. Where several farmers share a land parcel, the individual usage cannot be spatially limited to an area smaller than the land parcel boundary. To compensate for this and to allow a representative illustration of the associated numerical data, weighted means are applied where appropriate (e.g. livestock unit per unit of area).

3.4.2 Integrating land cover data

In general, areas with vector cadastral data also have vector land cover data. As a result, this information can be integrated into the process of delimiting farmed land – allowing for example, the exclusion of forested areas or areas with buildings or roads from the potentially farmed perimeter. For the purposes of establishing a new base map layer for spatial data capture of all agricultural land including cropland, grazing land, meadows etc., Gelan has aggregated the official land cover dataset[17] to the categories "land", "unproductive land" and "forested land" [see Table 19], to create a new dataset (called Gelanbof).

The official land cover dataset for Ct. Berne contains in excess of 740,000 features and the nature of survey data capture methods and regulations means this dataset is not topologically correct and contains many mini-polygons, slivers and overlaps, as well as having boundaries constructed as arcs – some examples are illustrated in Table 7. As a result, the official dataset is not suitable for geoprocessing operations and must first be topologically validated.

<table>
<tr><td>Orthophoto showing land-use</td><td></td></tr>
<tr><td>Standard land cover layer (26 categories for Ct. BE)</td><td></td></tr>
<tr><td>Topological errors in standard land cover layer</td><td>Overlap:

Sliver:

Mini-Polygons (m²):
<table>
<tr><th>SHAPE.AREA</th><th>SHAPE.LEN</th></tr>
<tr><td>0.035912</td><td>1.049151</td></tr>
<tr><td>0.03979</td><td>1.298607</td></tr>
<tr><td>0.041623</td><td>1.395599</td></tr>
<tr><td>0.042688</td><td>1.020827</td></tr>
</table></td></tr>
</table>

[17] For each of its partner cantons

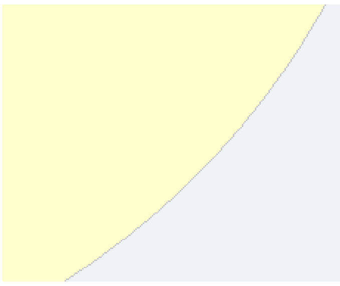
GELANBOF aggregated topological land cover layer LAND UNPROD FOREST	
Arcs removed to aid geoprocessing (illustrated area shown at very large scale)	Original dataset includes arcs:  Arcs are removed in Gelanbof and converted to line segments 

Table 7: Comparison of standard and aggregated land-use layers

The aggregated and topologically sound Gelanbof dataset is suited to complex geoprocessing operations and can be used to exclude parts of land parcels with non-eligible land-cover categories from farming land perimeters. Having reduced the maximum extent of the georeferenced farmed land based on details given on land-use by the farmers in the annual surveys, the land parcels registered to individual farms present the maximum eligible extent of land used for crops or grazing. This extent is illustrated by the hatched symbol in Figure 8.

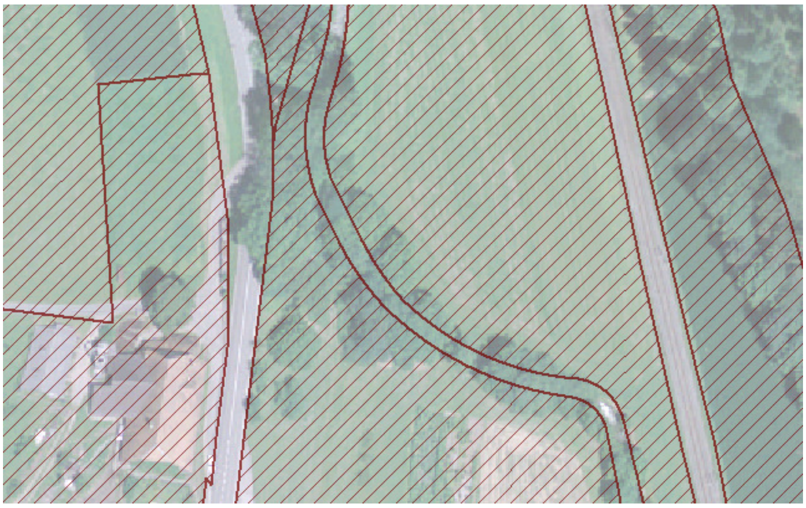


Figure 8: Extent of farmed land based on identified land parcel boundaries

This extent can be reduced by superimposing land cover categories and subtracting the non-eligible (non-yellow shaded below) area by geoprocessing (Erase-Tool in ArcGIS).

Figure 9: The yellow shaded area covers eligible land-cover categories (LAND)

Roads, the railway track and the forest are already excluded as they are not registered as farmed land parcels. The second stage uses the Gelanbof dataset to reduce this area further by excluding the ineligible land cover categories from the registered land parcels. The land area covered with buildings and gardens, as well as parts of the land parcel on the right whose boundary goes into the forested area, are all ineligible as farmland. The areas coloured green, grey and yellow are no longer valid after this latest elimination process – only the orange coloured area in Figure 10 below is eligible as farmland.

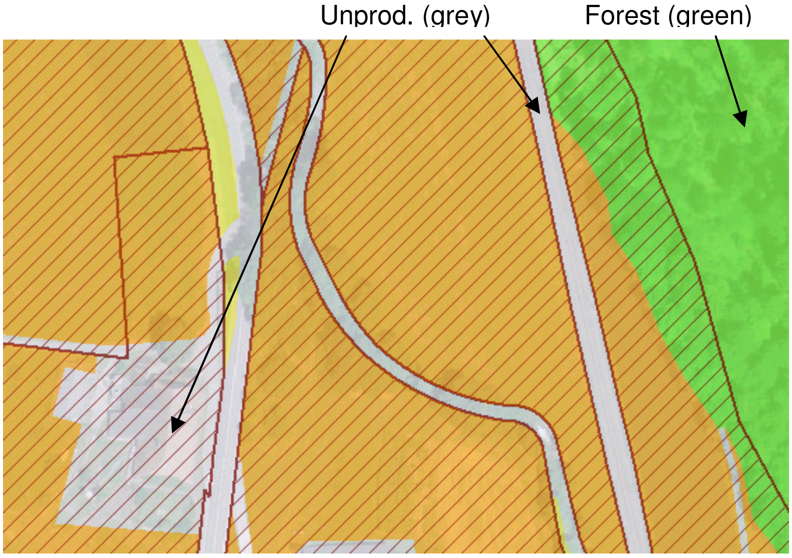


Figure 10: Non-eligible land-cover categories (Unprod, Forest) are erased

By the steps illustrated above, the limits of farmed land can effectively be reduced from the first level of georeferencing based purely on parcel boundaries, to those which are farmed in reality, and then to the land within the limits of those parcels which is of land cover category 'Land'.

3.4.3 Incorporating Gelan spatial data

Having refined the potentially farmed land surface in the stages described above, the next stage involved the incorporation of existing spatially captured agrarian data held in the Gelan database. Ecological compensation areas in Canton Berne were digitized several years ago, and land given over to these elements (held under contract and subject to farming restrictions in return for additional direct payments) can also be excluded from the generally farmed area as neither crops nor intensive grazing is allowed. The remaining area of eligible land (red shading) which can be used for crops or grazing is illustrated in Figure 11 below.

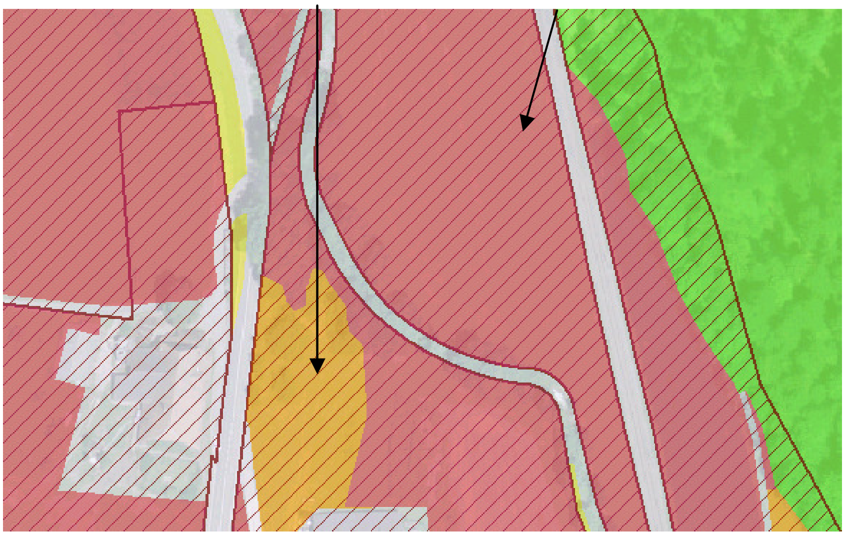


Figure 11: Potentially farmed area remaining after exclusion of ECAs

To summarize, the subtraction process involves the following stages:

a) Hatched area: identify land parcels registered to an active farm

b) Green & grey areas subtracted, yellow remains (land-cover categories forest & unproductive removed, 'land' remains)

c) Orange: ECA → subtract from perimeter

d) Red: maximum extent of land farmed for crops or intensively grazed

3.4.4 Further considerations

3.4.4.1 Nature inventories

The process of reducing the perimeter of potential farming land involves excluding those areas which cannot be used for the purposes of arable farming or grazing land. The section above describes the first phases in this process. However, aspects other than land cover and data on farmed land parcels should also be taken into account. A further topic considered was the potential offered by nature protection inventories – the perimeters of which are in general held as spatial data.

The definition and spatial data quality of the individual inventories vary considerably depending on the date they were established and to some extent on the individuals involved. Which regulations can be enforced within them is dependent on the existence of an overlying nature protection area.

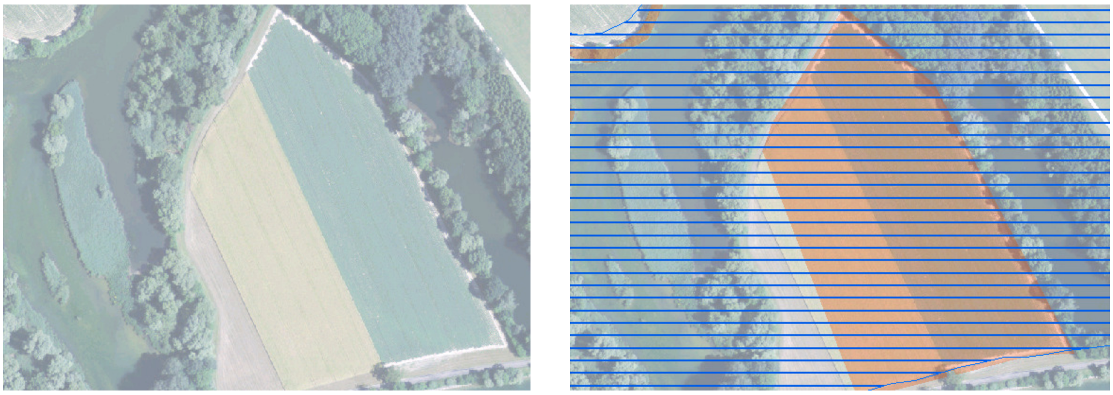


Figure 12: Protected riparian zone (blue line fill) and farmed land within perimeter (brown)

The example above shows registered farmland within a protected riparian zone and illustrates why such inventories cannot be used to exclude land within them from the potentially farmed land area.

3.4.4.2 Areas without cadastral data coverage

The data coverage for cadastral and official land cover data in Canton Berne is not comprehensive. There are gaps for various reasons, including areas where land re-allocation projects are ongoing and areas which have never been surveyed. Most of the unsurveyed area of the canton is typically outwith populated areas and as a result is commonly land which is farmed.

As described in chapter 3.4.1, the georeferencing of farmed land is based on the availability of georeferenced land parcel data. This data is then combined with official land cover data to define the potentially farmed land as accurately as possible. Where appropriate data is not available, the options for identifying land used for agricultural purposes are somewhat limited.

Land parcel data

In regions where no vector cadastral data exists, the only other remaining source of parcel boundaries is in raster form and as thus not suitable for incorporation in this study. One possible input into the parcel georeferencing process is the DIPANU[18] geodataset. Canton Berne georeferences the land parcel numbers from the raster cadastral plan as a point dataset – hence the land parcels can be roughly geolocated (parcel numbers are digitized from labels and lie within the parcel boundary), their boundary is not in vector format and an indication of parcel size comes from an attribute in the point dataset.

[18] Georeferenced land parcel numbers

Land-cover data

In areas with no survey data, land cover information could potentially be taken from the VECTOR25[19] dataset. This is a vector geodataset based on the 1:25,000 scale topographical map of Switzerland and includes data on 28 land cover categories such as built-up area, orchard, scree, quarry, lake, river, dam, swamp, forest, vines and 'other'. There is no category equivalent to arable land or grassland and the data would only be of very limited use in further defining potential farmland. Hence, although used as a reference at various stages of the study, this dataset is not incorporated in the automated processes.

3.5 Incorporating Survey Data

The agrarian data held in the GELAN-IS is collected by means of three annual surveys[20] – the content of which is explained below.

Autumn data survey	• declaration of administrative details • registration for direct payment scheme for following agricultural year • registration for various schemes
Spring data survey	• farm and registered land parcels • workforce details • quota details • livestock details (category, numbers) • ECAs; vines, orchards (spatial data collection) • details of crops grown/pasture (area) • land qualifying for steep slope payments
Alpine pasture survey (qualifying farms)	• farm and registered land parcels • number of animals and duration of their grazing on summer alpine pastures

Table 8: Annual agricultural survey content

As a first exploratory step in the analyses using the georeferenced land parcels, the results of the various monofactorial[21] representations of the data will be compared – e.g. for winter crops, summer crops, root crops, livestock units.

[19] National digital thematic map series in vector format
[20] Details regarding survey participation is provided in Appendix A
[21] Used to signify work with individual crop groups or livestock data as opposed to any combination of groups or themes

3.5.1 Arable Farming Data

Data on a wide range of crops and grassland is collected in the annual agricultural statistical surveys and held in the Gelan database. These can be grouped into the three major categories of permanent grassland, permanent crops and arable land.

Crops

The particular crops recognised by the ordinance on direct payments (DZV) can change marginally from year to year. The differences between the individual crop types can be quite small and from the point of view of their attractiveness to bird populations they can be grouped based on various characteristics such as height, structure, density, land-covering or season (sowing/growing).

The definition of the different groups and which crops belong to them was carried out together with the Swiss Ornithological Institute and the list of 221[22] individual crop's codes was split into 16 groups depending on their characteristics (e.g. height, density) from the point of view of providing habitat for bird populations (see Table 9).

Code[23]	Crop Group	Examples[24]
S	Spring planted cereals	Spring barley/wheat; oats
W	Winter planted cereals	Winter barley/wheat; triticale; rye; spelt; feed grain/wheat
M	Maize	Seed maize; green maize; silage maize
R	Rapeseed (& similar)	Rape; soya; beans; peas
NH	Root crops	Sugar beet; fodder beet; potatoes
H	Tall-growth crops	Sunflowers; hemp; flax; millet; fibre plants
N	renewable resources (biomass)	Miscanthus
G	Vegetables etc. (unprotected)	Vegetables; perennial herbs/medicinal plants rhubarb; annual flowers
P	Vegetables/crops under glass/plastic	Vegetables; mushrooms; raspberries; strawberries
O	Fruit (trees/bushes)	Orchards; berries (various)
V	Vines	
D	Permanent grassland	Permanent meadows/pastures; forage legumes/ grasses; artificial leys;
GOAF	Grassland ECAs	Extensively used/less intensively used meadows; wooded meadow
OAF	Non-grassland ECAs	Wildflower strips; rotational fallow; hedges; litter meadows; ruderal areas; ponds; native trees
F	Forest (& similar)	Forest; tree nurseries; bushes/shrubs
Div	Miscellaneous	Summer (alpine) pastures; gardens

Table 9: Grouping of crops by growth characteristics

22 Number of registered crops for Canton Bern since 2000 (GELAN-IS)
23 Some of codes come from original German names
24 List of examples included is non-exhaustive, a detailed list is available in Appendix C

The above-defined grouping of the wide range of eligible crops in Canton Berne (including pasture) provides a method of gaining a simplified overview of a large amount of data and forms the basis for mapping the numerical crop data held in GELAN-IS for the very first time.

3.5.2 Livestock Data

The annual spring agricultural survey collects detailed information on which livestock is held on each registered farm. The relevance of these details for the assessment of agricultural intensity relate to the density of grazing in any given area. Ecological farming regulations require that nutrient budget be optimized and that livestock numbers are adjusted to suit the circumstances on each individual farm holding with the aim of achieving a neutral balance. The calculation of the allowance for a particular farm is dependent on the requirements of the crops grown and the area of grassland, and is carried out with specialised software. The data on nutrient budget are not part of the data surveys stored in GELAN-IS and thus not available for further analysis in this study.

As this thesis is limited to using the data from agricultural surveys held in the Gelan database, perhaps the best indicator of agricultural intensity on a given farm is its stocking density (the proportion of LUs to the area of fertilizable land available).

3.5.2.1 Livestock Units

There is a standardised method for translating livestock numbers for a wide range of recognised livestock categories into so-called livestock units (LUs). The factor used depends on the particular animal species, whether it is milked or not and its age, and ranges from 1.0 (e.g. for dairy cows or suckling horses), to 0.004 (e.g. for chickens). The livestock unit figure is relevant for the calculation of various aspects of the direct payment data requirements and the permitted stocking density varies depending on the agricultural zone[25] in which the land lies.

[25] Agricultural zones are defined by FOAG and delimit zones of farming difficulty relevant in application of the LwG.

3.5.2.2 Fertilizable Land

The crops which are classified as fertilizable land and as such contribute to defining the maximum allowed LUs includes the categories of farmland as summarized in the table below (brackets denote that the category applies to certain crops in the group).

Category	Code
Fertilizable area	D, S, W, M, R, NH, H, N, G, V, (O, Div, GOAF, OAF)
Non-fertilizable area	F (O, Div, GOAF, OAF)
UAA	D, S, W, M, R, H, NH, G, P, N, O, V, F (non-forest), GOAF (OAF, Div)
NUAA	F (forest), (OAF, Div)

Table 10: Crop group allocation to fertilized area/UAA

As the table above illustrates, fertilizer can be spread on all land planted with arable crops and the majority of permanent crops (including pasture). Land outwith the utilized agricultural area (UAA) and all but a small minority of ECAs do not contribute to the eligible area as the spreading of fertilizer is prohibited in all but a very few cases.

3.5.3 Mapping Thematic Data

The crop groups and the data on livestock units and fertilizable area can be mapped to the georeferenced land parcels associated with each farm. The first stage of mapping the agricultural survey data stored in the GELAN-IS is at a monofactorial level – each group will be considered separately (e.g. root crops, cereals, maize, permanent grassland, etc.). Depending on the outcome and future analysis requirements, the first level of output from this study can be further refined or combined in new, as yet undefined, processes. Before decisions can be made as to what is required as regards combining factors, a better understanding of the information offered by the first layer of aggregation (combining similar individual crops into groups) is required. The Swiss Ornithological Institute wishes to further analyse the monofactorial data with respect to their own specific requirements for an indicator of agricultural intensity before coming to any conclusions on combining the data at a more complex or integrated level. It may be necessary to include further inputs from the analysis of relevant pre-existing geodata which are not explored in this study (e.g. area of ECAs per km^2).

3.6 Agrarian Data Context

The regular agricultural surveys collect data on numerous aspects of agriculture as a basis for regulating, calculating and distributing subsidies to those farms which qualify. Data is collected for all farms in the three Gelan cantons annually[26] – thus providing an optimal base for analyses. This situation is not reflected in other European countries where Farm Structure Surveys (FSS) are carried out periodically on agricultural holdings of at least one hectare (or where market production exceeds certain thresholds).

GELAN-IS has numerous modules and the database contains data relating to crops, animals, agri-environment schemes, environmental stewardship schemes, manure management, erosion and numerous other aspects relevant to agrarian data administration and financial incentives.

After an analysis of the data contained in the Gelan system, it was decided that for the purposes of this study, the data referring to crop coverage and numbers of animals per farm would be the most appropriate to use as a basis to establish an indicator of agricultural intensity. The data is stored in an annual context and the basic content for the three partner cantons extends back as far as the year 2000[27] – theoretically allowing analysis of a decade of agricultural survey statistics – although the system and the data it stores has evolved and expanded over time.

Within GELAN-IS the following data are recorded for each farm site and year (see Figure 13):

- farm holdings with their associated land parcels (list)
- land cover data for the land parcels (aggregated into three categories: "land", "unproductive", "forest")
- numerical data of crops grown on those land parcels – the maximum area covered is based on the land cover data
- agri-environment schemes, orchards and vineyards as geodata
- ecological compensation areas (ECAs) with biological quality (Q)
- ecological compensation areas classed as interlinked (V)
- number and type of animals held on the farm site
- conversion of livestock numbers to livestock units (LU value)

[26] Gelan Wegleitung: http://www.gelan.ch/de/index.php?page=407
[27] Certain data are available for the year 1999

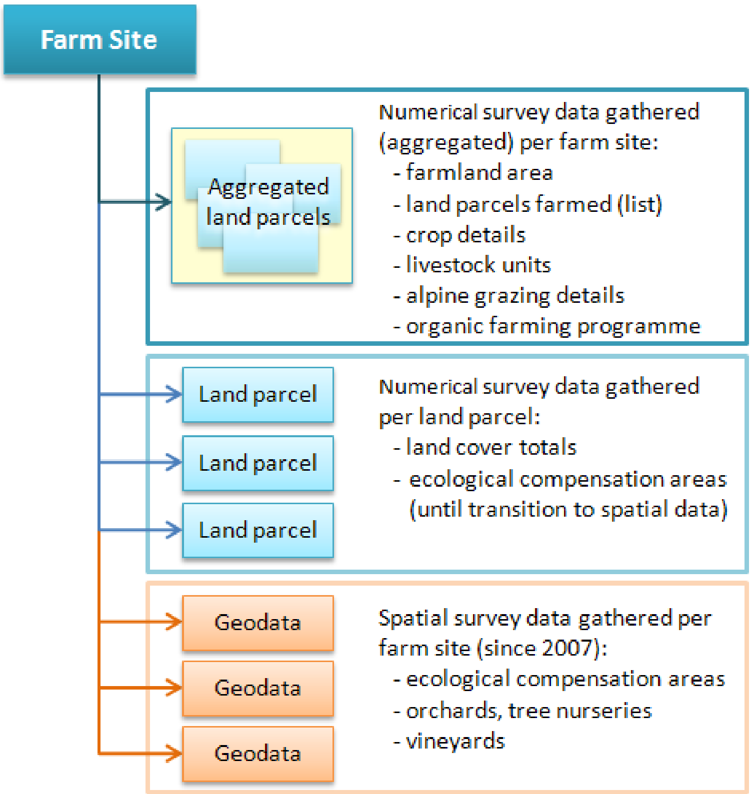


Figure 13: Schematic representation of farm site data capture

The concept of annual datasets is central to the philosophy behind the GELAN-IS and means that there is a complete dataset of the agricultural survey statistics for each calendar year.

3.6.1 Statistical overview

GELAN-IS manages agricultural survey statistics from its three partner cantons, presently approximately 15,600 farmers (see Table 11). The data from annual surveys is the basis for direct payments in excess of 800 million Swiss Francs annually.

	CT	2006	2007	2008	2009	2010
Number of farmers	BE	12,316	12,088	11,909	11,638	11,400
Number of farmers	FR	3,133	3,074	3,015	2,957	2,888
Number of farmers	SO	1,396	1,372	1,359	1,343	1,325
Total		**16,845**	**16,534**	**16,283**	**15,938**	**15,613**

Table 11: Number of farmers entitled to direct payments 2006-2010

The number of farmers eligible for these supplementary payments has been decreasing from year to year – dropping by 7.3% since 2006. The statistics referring to area farmed in Table 12 show only a slight reduction (~1%) in farmed area during the same period. Open arable land decreased by 6.3% while grass cover increased marginally and ECA grew by an average of 5%.

Category	Unit	2006	2007	2008	2009	2010
Total farming land	ha	190,546	189,509	189,390	188,811	188,629
Eligible farming land	ha	190,488	189,450	189,324	188,734	188,560
Fertilizable area	ha	181,256	180,140	179,619	178,788	178,019
Open arable land	ha	50,831	49,383	49,025	48,194	47,631
Grassy area (excl. hay meadow)	ha	137,821	138,215	138,441	138,704	139,061
Ecological compensation area	ha	23,278	23,244	23,827	24,009	24,458

Table 12: Summary of area data 2006-2010, Canton Berne

The livestock statistics show more change within the individual categories (see Table 13). The main category is cattle and shows a 1.5% increase, while pigs are the second most important group with a 5% decrease. Overall there has been virtually no change (0.7% increase) in total livestock unit numbers.

Livestock category	2006	2007	2008	2009	2010
Cattle	190,557	191,136	196,171	194,336	193,359
Horses	7,182	7,207	7,313	7,237	7,176
Sheep	5,107	5,222	5,335	5,267	5,189
Goats	1,658	1,655	1,731	1,699	1,711
Other RLU*	274	286	316	332	354
Pigs	37,078	36,294	35,452	35,279	35,238
Poultry	7,062	6,874	7,259	7,475	7,459
Other livestock	146	167	165	188	256
Total	249,064	248,841	253,742	251,813	250,742

* *RLU roughage consuming LU*

Table 13: Summary of livestock data 2006-2010, Canton Berne

3.6.2 Data employed

3.6.2.1 Numerical data

Numerical data from several tables storing agricultural survey statistics in the Gelan database are a central part of the processes in this study. The concept of data storage within GELAN-IS employs a central farm register for all modules. An annual import of official cadastral and land cover data forms the basis for the annual surveys and is central to data consistency within the system.

As well as data capture pertaining to the individual modules of GELAN-IS, (with data on erosion, water quality assurance, fruit/vine, central register of personal/address data for farmers and system users, inspection results, nature management contracts, etc.), interfaces to other systems are an integral part of the system (importing tax information, exporting data to the federal agency, transfer of direct payment monies or exporting data for mass printing jobs). Quality assurance of the agricultural survey statistics is provided by field checks, data consistence checks and specific control obligations associated with certain contracts eligible for direct payments.

Current statistical analysis of the data relies on aggregation at municipality level. The accuracy is dependent on the underlying data structure and recording strategy. For instance, the details for agricultural holdings are recorded at the farm site level – where a farm crosses municipal boundaries, these data cannot always be split into the individual administrative units – resulting in a certain amount of inherent data inaccuracy.

3.6.2.2 Geodata

A variety of geodatasets are required for this study. These are listed in the table below. Central to the georeferencing process is the official land parcel vector dataset and the geodataset of the administrative boundaries. Land-use/land cover datasets are also used to optimize output while digital height/terrain models are employed for illustration purposes.

Name	Source	Description / Purpose
ASNOAS04	GeoDB	National land-use/cover statistics (hectare grid)
AVR_LIE	GeoDB	Vector cadastral data
AVR_BOF	GeoDB	Vector land cover data
BIOGREG	GeoDB	Biogeographic regions
DHM25	GeoDB	Digital height model (1:25,000)
DIPANU	GeoDB	Digital land parcel numbers
DTM-AV (2m/5m)	GeoDB	Digital terrain models (high precision below 2000m a.s.l.)
FC_OAF_POLY	Gelan-GDB	Ecological compensation areas (polygon features)
FC_OAF_POINT	Gelan-GDB	Ecological compensation areas (point features)
GELANBOF	Gelan-GDB	Aggregated land cover dataset
GRENZ5	GeoDB	Vector administrative boundaries
KL	GeoDB	Climatic suitability for agriculture
LZ	GeoDB	Agricultural production zones
PK25, PK50, PK100, PK200	GeoDB	Topographic maps at various scales used as base maps (raster)
SWISS_I	GeoDB	Orthophotos
Various conservation inventories	GeoDB	Vector datasets of inventories (e.g. wetlands, raised bogs, nature reserves, alluvial plains, amphibian spawning areas)
VECTOR25	GeoDB	Landscape model (vector), 1:25,000

Table 14: Existing geodata employed

3.6.3 Spatial applicability

At present, only a very small percentage of agrarian data is stored directly as geodata and as such comprehensive data analyses are only possible on a purely numerical basis. The only method available until now to form any spatial impression of the statistical data has been at municipality level. The numerical data can be aggregated per municipality and geodata exists for these boundaries – allowing a much generalised spatial representation of the data. The survey data is gathered using the address of the farm holdings and as a result, not all data can be associated with the municipality in which it physically lies. The size of the administrative units and their topography varies considerably – aspects which make any meaningful spatial analysis on this form of georeferenced agricultural statistics virtually impossible.

Land parcel data is stored as core data for several of its sub-systems. This purely numerical data is imported annually from the cantonal cadastral database and held in the Gelan database per calendar year. It serves as the basis for direct payments to the farmers registered by means of the annual farm structure surveys as actively farming those land parcels. In order to successfully georeference those farmed land parcels, a suitable vector dataset of cadastral boundaries must exist.

3.6.4 Data structure

The imported numerical cadastral data is stored in a dedicated table (see T8 in Figure 14) which is linked via another table of production parcels (T9) to the farm register (T6). In identifying the land parcels per farm, these three tables form the basis for the first stage of the process of georeferencing the agrarian data. Tables holding data on crops grown (T18) and animals held (T19) per farm can be linked to these core tables and thus their contents made available to the georeferencing process. A link to the individual farming the land is also possible (via table T1).

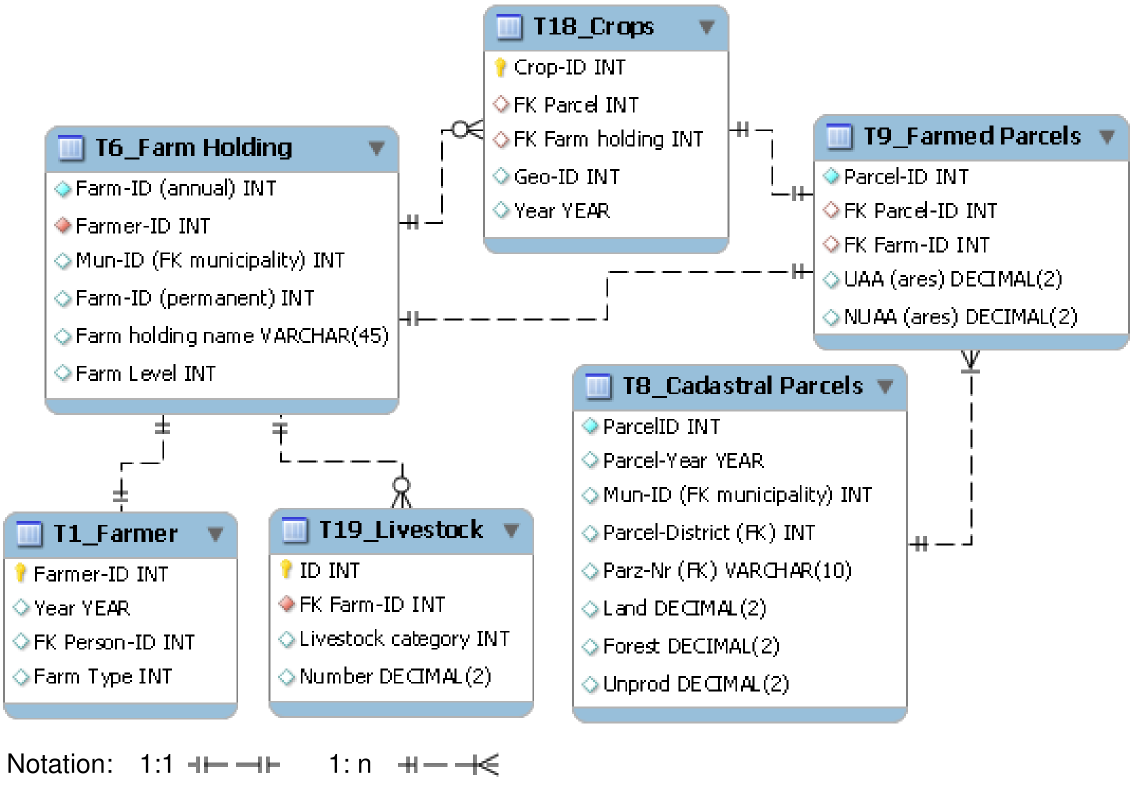


Figure 14: GELAN-IS data model (schematic representation of significant attributes)

To simplify access to the necessary database content for the processes to spatially reference the data, the required content from the individual tables was prepared in specific database views[28].

Having identified and isolated the relevant data within the Gelan database, the possibilities for referencing the data spatially were analysed. The official cadastral data imported annually into GELAN-IS is purely numerical data containing information on land parcels and their associated land cover. The land parcels are identified by means of the following attributes:

- Municipality number (ID)
- Survey district number
- Land parcel number
- Year

Cadastral data in spatial form also contain these same attributes but data capture and transfer methods mean that there can be discrepancies between the two closely related datasets.

[28] Result set of a stored SQL query accessed by means of a virtual database table

3.6.5 Level of Detail

The level of detail stored within the Gelan database reflects that captured in the regular agricultural statistical surveys. Certain information is gathered at farm level; other information is collected at land parcel level or is captured spatially (see Table 15). The type of data captured spatially varies from canton to canton.

Parcel-based data	List of all farmed land parcels per farm
	Agri-environment scheme elements*
	Area qualifying for direct payments for farming in steep terrain
	Vineyards**
	Orchards, tree nurseries***
Farm-based data	Area of all crop types grown
	Area of arable field margin
	Numbers all livestock categories kept
	Registration for extensive cereal growing programmes
	Registration for organic/integrated farming programmes

* in general via spatial data capture in Canton Berne, partial spatial data capture in Canton Solothurn
** in general via spatial data capture in Canton Berne, partial spatial data capture in Canton Fribourg
*** in general via spatial data capture in Canton Berne

Table 15: Agricultural survey data collected (list not comprehensive)

The differing levels of data capture also provide varying levels of detail as regards the potential for georeferencing those data. The most significant parcel-based information for this study – after the linking of the parcels to individual farms – is the data on agri-environment schemes. The method of data capture for these elements has evolved over the years from originally purely numerical parcel-based data to spatial data capture in some regions (full coverage for Canton Berne, partial coverage for Canton Solothurn).

3.6.6 Evolving data coverage

Agricultural survey statistics have been gathered approximately in their current form since 1999 and are based on the agrarian reform policy of 2002. The Gelan agrarian database contains the data for its three partner cantons gathered in the period from 2000 to the present. Over time, the content and in some cases the format of the data held has grown in complexity and continually evolved. The following table illustrates the development as regards ecological compensation areas for Canton Berne.

Year	Leading Format (% GIS)	Area (ha) / Tree numbers (% GIS)
2005	Numerical (0%)	3,031 / 76,564 (0%)
2006	Numerical (0%)	2,875 / 71,896 (0%)
2007	Numerical / spatial (40.4%)	2,792 / 70,036 (26.7%)
2008	Spatial (95.5%)	2,921 / 68,527 (99.1%)
2009	Spatial (96.3%)	2,980 / 65,588 (99%)
2010	Spatial (97.8%)	2,981 / 65,951 (99.1%)

Table 16: Agricultural survey data for ECAs held in GELAN-IS (Ct. BE)

As a result of the introduction and establishment of spatial data as an integral part of agrarian data collection – although as yet for only a small percentage of the overall data – a new level of geospecific detail is gradually being made available for further analysis.

3.7 Cadastral Data Coverage

The availability of georeferenced cadastral data with suitable attributes to enable a link to the numerically stored data is central to the requirements of georeferencing agricultural survey statistics. Most Swiss Cantons have a geodataset of their cadastral data; although coverage is by no means comprehensive as illustrated by the map in Figure 15.

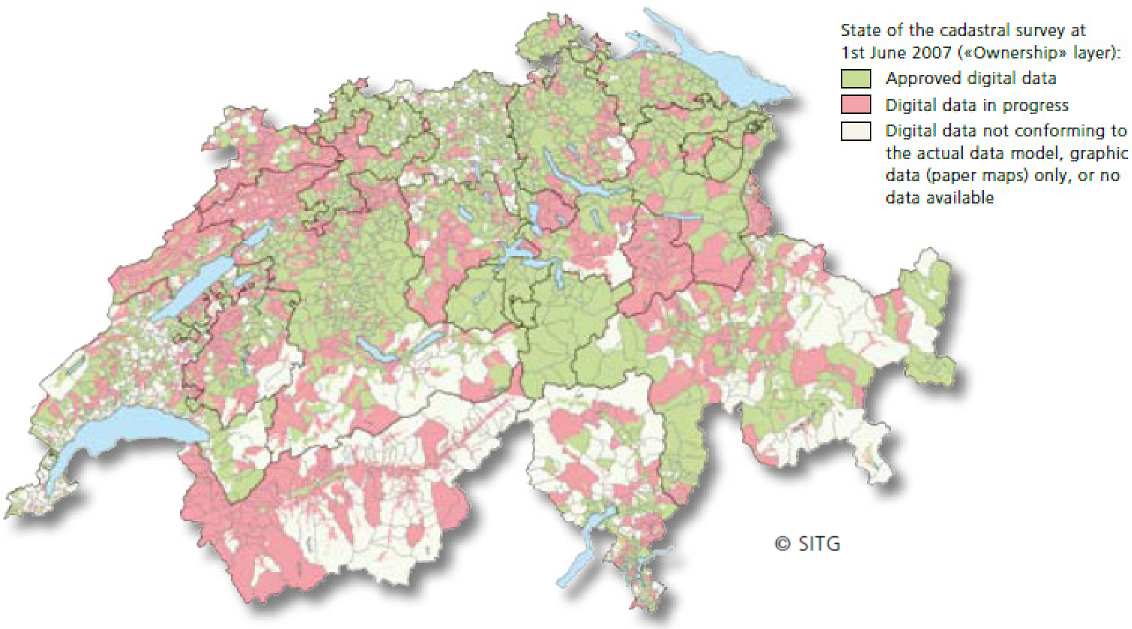


Figure 15: Cadastral survey data in Switzerland, state of coverage as of June 2007[29]

While existing gaps in coverage are constantly being filled and data quality continues to improve, comprehensive coverage of all regions where land is farmed is still some way off. The autonomy of the individual Cantons and the variation in

[29] Federal Office of Topography (2008)
http://www.cadastre.ch/internet/cadastre/de/home/docu/publication/P035.parsys.84414.downloadList.73501.DownloadFile.tmp/avbroschuereen.pdf

terrain within them explains some of the regional differences. As far as Canton Berne is concerned, the regions without vector cadastral data are mostly in sparsely populated areas (generally upland areas). Altitude withstanding, these areas tend to contain a considerable amount of agriculturally used land, and as a consequence a certain amount of data from the agricultural surveys cannot be georeferenced by this method. The spatial data coverage for Canton Berne is substantial and the typically most intensively farmed areas are lowland areas and in general within the cadastral geodata coverage. The current extent of cadastral geodata coverage in the three Gelan-Cantons is illustrated in the map in Figure 16.

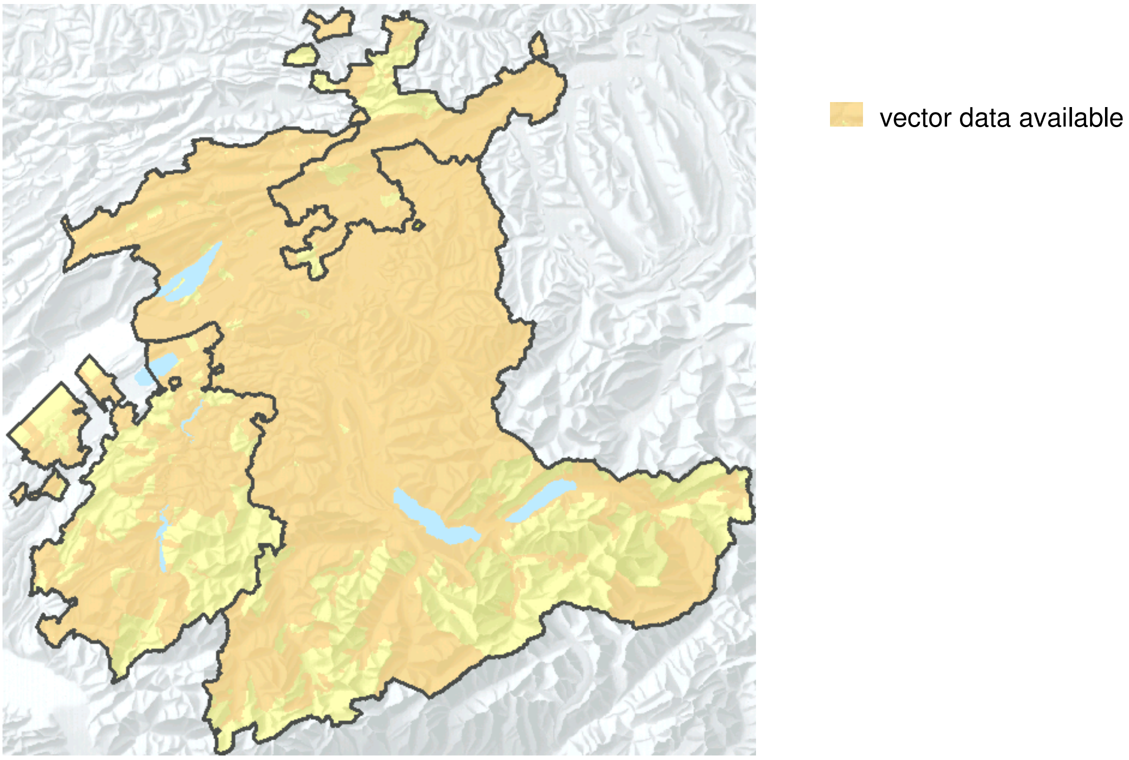


Figure 16: Vector cadastral data coverage for Gelan-Cantons (as of Nov. 2010)

3.8 Methodological Aspects

This section describes the methods employed throughout this study – from the beginnings with exploratory data analysis, to data extraction methods, then georeferencing processes and finally mapping of the results.

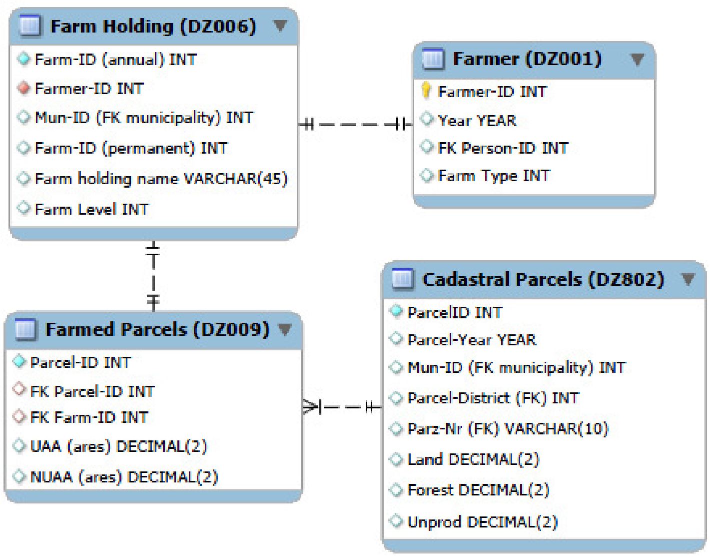
After analysis of the content of annual agricultural surveys, the storage of the data within GELAN-IS was then examined. In order to make the numerical data available for georeferencing processes the relevant data from numerous physical database tables needed to be accessed in a consistent and efficient way. Three methods of accessing the data were available – the pros and cons of using each method are summarized in Table 17.

Access method	Pros and cons
Direct access to original tables using ArcGIS	+ Tables exist, immediate access possible – Multiple tables need to be accessed and joined to vector base – No join to tables possible where no single field join available
Direct access to original tables using FME	+ Tables exist, immediate access possible – Join using multiple fields possible (Joiner transformer) – Multiple tables need to be accessed
ArcGIS/FME access to preprepared DB views	+ Once tables created, effectively allows single table access + Data structure can be optimized + Data from several tables made available in one virtual table + Data can be aggregated during view creation + Data can be filtered – e.g. data per annum + Assists consistent data access + Simplifies joining (e.g. for multiple field joins) + Views can be easily adapted (drop, change SQL) – Views need to be created in database

Table 17: Comparison of numerical data access methods

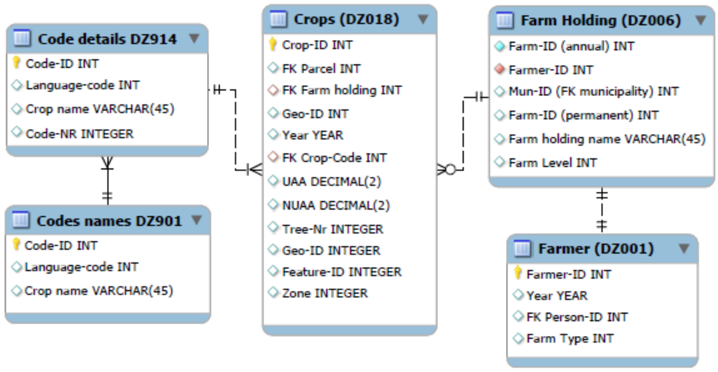
On the basis of the factors listed in the above table and after numerous tests using those methods, it was decided to use the approach of creating database views to most conveniently and consistently access the agricultural survey statistics within the Gelan database. Database views are virtual database tables and are effectively the stored output of an SQL query. They have the advantage of allowing the combination of output (fields) from several tables in one virtual table and thus simplifying access to complex data structure and/or large data volumes. After identifying which tables contain the relevant data and how they are related to each other in the database, SQL queries were designed and tested to create the necessary database views (see Table 18 below).

1. Farm-parcels-year	Data source: 4 tables in GELAN-IS: • DZ001: Farmer-ID, Year, • DZ006: Farm-ID, Mun-ID, • DZ009: UAA, NUAA • DZ802: Parcel-ID, Parcel-Nr., Parcel-District, Land, Forest, Unprod



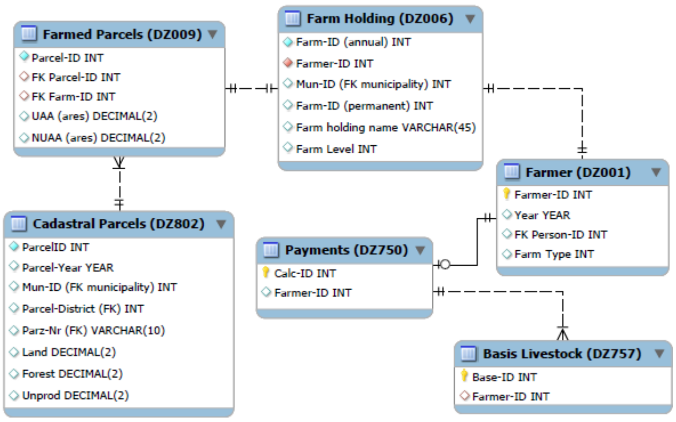
<table>
<tr>
<td>2. Farm-crops-year</td>
<td>
Data source: 5 tables in GELAN-IS:

- DZ001: Farmer-ID, Year,
- DZ006: Farm-ID, Mun-ID,
- DZ018: Mun-ID, UAA, NUAA, Tree-Nr., Geo-ID, Feature-ID, Zone
- DZ914: Code-Nr., Crop name



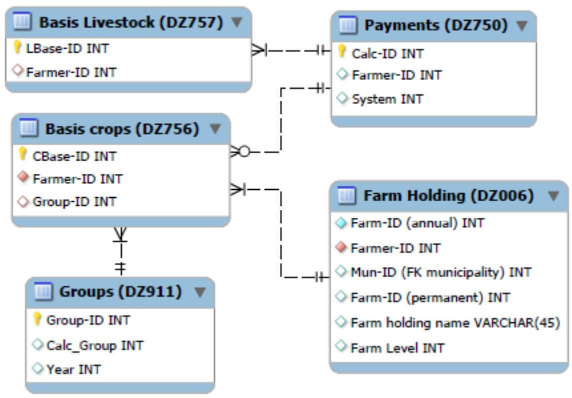
</td>
</tr>
<tr>
<td>3. Farm-livestock-year</td>
<td>
Data source: 6 tables in GELAN-IS:

- DZ001: Farmer-ID, Year,
- DZ006: Farm-ID, Mun-ID,
- DZ009: UAA, NUAA
- DZ802: Parcel-ID, Parcel-Nr., Parcel-District, Land, Forest, Unprod
- DZ757: LU
- (DZ750: used as link)



</td>
</tr>
<tr>
<td>4. Farm-fertilizable area-year</td>
<td>
Data source: 5 tables in GELAN-IS

- DZ006: Farm-ID, Mun-ID,
- DZ750: System
- DZ756: Group-ID
- DZ757: LU
- DZ911: Year, Calc_Group



</td>
</tr>
</table>

Table 18: Database view content with ERD approximation

These database views enable efficient and simplified access to numerical data in GELAN-IS and are central to the development of processes for the georeferencing of agricultural statistics.

3.9 Georeferencing Process

As previously established, the basis for georeferencing the numerical data in GELAN-IS is linking it by means of land parcel numbers to cadastral geodata.

3.9.1 Phase I – Link to Cadastral Geodata

This basic process of geolocating farmed land parcels is illustrated in Figure 17. In the preliminary phase, the data in the Gelan database is filtered and stored as a database view which is then joined to cadastral land parcel data. This serves as the foundation for the follow-on steps relating specifically to crop and livestock data per farm. The output from this preliminary phase provides coarse georeferencing for the data held per farm – i.e. the maximum extent* over which the crop and livestock data are distributed (* providing all land parcels of a particular farm could be spatially located).

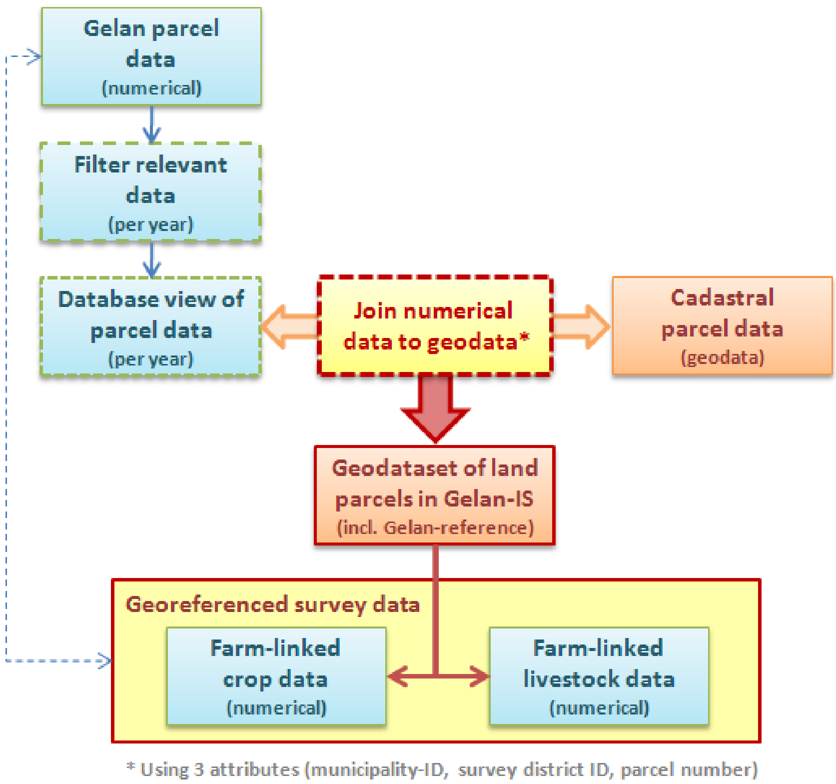


Figure 17: Georeferencing Gelan numerical data via cadastral data

This first level of detail is already sufficient to give a more accurate impression of where each crop type is grown and where the highest livestock ratios are found than has up to now been possible.

3.9.2 Phase II – Incorporating Land Cover Data

The next phase is to reduce the gross surface area of farmed land parcels generated from the first phase, to that area of land within those parcels which can potentially be farmed. This is done by integrating the land cover data into the process in order to exclude categories such as forest, buildings, roads and the like. There are two options to integrate the land cover information into the process. Where geodata is available, it can be directly integrated into the process to eliminate all but potentially farmed categories of land cover. The existing categories in the geodataset for Canton Berne and those excluded as non-farmed land are listed below (Table 19). The coverage of official land cover data for Canton Berne corresponds largely with the availability of vector cadastral data.

Nr.	Description	Category	Farmed Land
0	Building	Building	No
1	Road, track	Paved surface	No
2	Footpath	Paved surface	No
3	Traffic island	Paved surface	No
4	Railway line	Paved surface	No
5	Airfield	Paved surface	No
6	Water rank	Paved surface	No
7	Other hard surface	Paved surface	No
8	Arable land, meadow, grazing land	Vegetated area	Yes
9	Vines	Vegetated area	Yes
10	Other intensive culture	Vegetated area	Yes
11	Garden	Vegetated area	No
12	Moorland	Vegetated area	Yes
13	Other vegetated area	Vegetated area	Yes
14	Standing water	Surface water	No
15	Flowing water	Surface water	No
16	Reed belt	Surface water	No
17	Dense woodland	Wooded land	No
18	Wooded pasture (dense)	Wooded land	Yes
19	Wooded pasture (sparse)	Wooded land	Yes
20	Other wooded area	Wooded land	Yes
21	Rock	Non-vegetated area	No
22	Glacier, firn	Non-vegetated area	No
23	Scree, sand	Non-vegetated area	No
24	Quarrying, disposal site	Non-vegetated area	No
25	Other non-vegetated area	Non-vegetated area	No

Table 19: Land cover categories and potential as farming land (Canton Berne)

For those regions without spatial land cover data, the numerical cadastral data which is imported annually into the Gelan database contains land cover data per land parcel, and could potentially be employed to reduce the number of eligible land parcels. The data included in the cadastral data import supplies details of total surface area per land parcel plus area covered by the category groups 'land', 'unproductive' and 'forest'. This basic information would be sufficient to exclude land parcels which can have no crops or livestock on them – e.g. 100% forest. The adjusted basic georeferencing process incorporating land cover information (as compared to that represented in Figure 17) is shown in Figure 18.

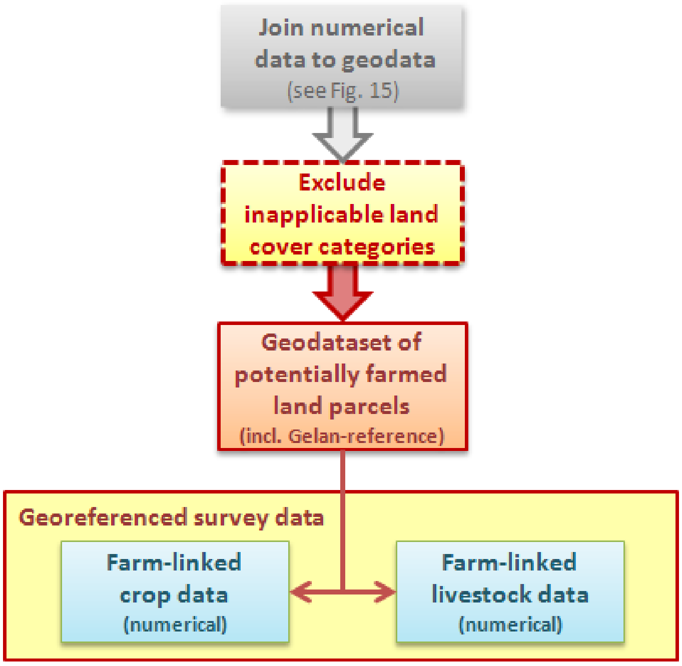


Figure 18: Exclusion of land cover categories in georeferenced survey data

A small proportion of farmed land can legitimately be on land classified as 'unproductive', but the vast majority of data applies to those parts of land parcels which can be attributed to the group category 'land'. Hence, there is significant potential in the data – both spatial and numerical – to reduce the gross farmed area further to a more realistic extent.

3.9.3 Phase III – Incorporating ECA data

The next phase involves reducing the gross farmed area even further. The regulations applying to ecological compensation areas means that they should also be removed from the area of land on which to distribute data on crops grown and livestock kept on any given farm. The result defines the maximum area of land on which crops can be grown, fertilizer spread or livestock grazed for more than a very limited period.

3.9.4 Further considerations

Further geodata which might be relevant for the exclusion of land which cannot potentially be used for crop growing and livestock grazing require consideration.

3.9.4.1 Nature inventories

There are numerous nature inventories protected by a range of regulations at national and cantonal levels (e.g. amphibian spawning grounds; dry grassland areas; wetlands; raised bog; alluvial zone) and their potential for use in this study was assessed. Land management contracts are arranged on an individual basis with those farmers with land within an area of interest as regards nature conservation or species protection, and who are willing to cooperate with the nature conservancy agency to fulfil the criteria required in order to be eligible for management payments. The arrangements vary considerably and can include defining periods where mowing is allowed, leaving unmown patches to a later date, no fertilization and many other individual aspects. The details are often specific only to the contract and need not apply to all land within the boundary of a nature inventory.

After discussion with the cantonal authority responsible for implementing and enforcing the regulations applying to nature protection areas and registered farmland within nature protection inventories, it became clear that the management of farmed land and enforcement of the associated regulations within these perimeters varies considerably. The lack of consensus makes it virtually impossible to define rules for the general exclusion of registered farm land parcels within their perimeters from the overall farmed land surface. At best, proximity to any of these nature inventories could be used as an indicator of reduced farming intensity. The varying quality of the geographical data and the lack of any appropriate attributes in the spatial data which would allow differentiated integration based on selection criteria, led to the decision to disregard the available spatial data in the basic process of reducing the farmed land perimeter.

3.9.4.2 Topography

An aspect which would theoretically allow further refinement of the farmed area, but which is beyond the scope of this study, is the relevance of topographical factors (such as altitude or gradient). The zones of agricultural production– a federal geodataset differentiating zones of varying conditions for farming/habitation of relevance for the application of the Federal Law on Agriculture – might also provide relevant information.

3.10 Refining Vector Output

The method of mapping agricultural statistics onto georeferenced farmland based on the extent of all associated land parcels provides many advantages compared to the methods previously available. There are however also some drawbacks with the new level of detail.

First of all, a higher accuracy is implied than is in fact possible, because although the data is mapped at land parcel level, the statistical data collected is not as detailed as the spatial base it is associated with. While the statistical data is collected at farm holding level, the georeferenced farm extent generally includes numerous individual land parcels and there is no way of knowing which crops or livestock data apply to the individual parcels. As a result, all crop data and livestock data can only be mapped to the entire extent of a farm's eligible land, meaning land parcels can be shown as having a particular crop group on them, while in actual fact the data will apply only to part of a farm's land. As the land parcels associated with any particular farm can be widely distributed, a way of generalizing the data and mapping an averaged value would be appropriate.

In order to correctly average the values on any given land parcel, account must also be taken of overlapping farm extents. Where land parcels are jointly farmed – a quite common practice – there is at present no way of knowing spatially which part is farmed by whom. This means that the spatial extent of one or more farms will overlap on these parcels. In order to prevent distortion of the statistics for these parcels, overlapping farm extents are identified and the values averaged for the overlapping area. The adjusted vector output is then suitable for conversion to raster format.

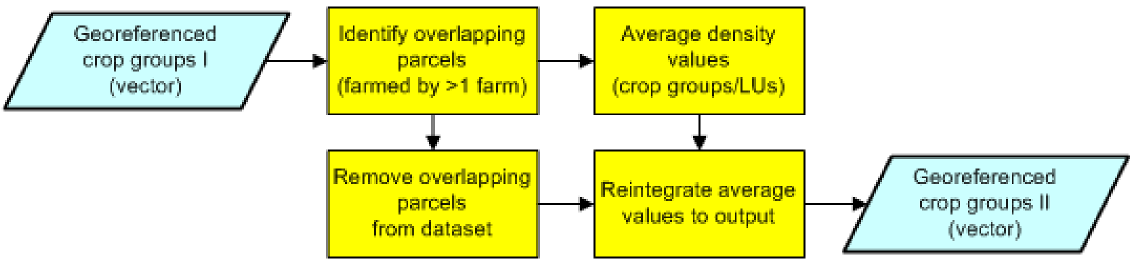


Figure 19: Compensation for overlapping farm extents

A further problem lies in the actual mapping of vector data at small scales. A fine patchwork of land parcels loses legibility as the scale is reduced. A method of generalizing the data for visualisation at small scales (as commonly required by the Swiss Ornithological Institute) is necessary. At the same time, an effort should be made to preserve individual characteristics of the crop group layers as the Swiss Ornithological Institute plans to experiment with the monofactorial output and examine ways of combining the data to suit their own needs.

On the basis of these requirements, it was decided to rasterize the vector output. Rasterizing the data, not only generalizes the output based on the chosen cell size, but also forms a base which can be more easily visualised at small scales, or where necessary generalized further by increasing the raster cell size. Figure 20 below illustrates the first phase of the rasterizing process (Phase I) and how it can be further generalized to larger cell sizes (Phase II).

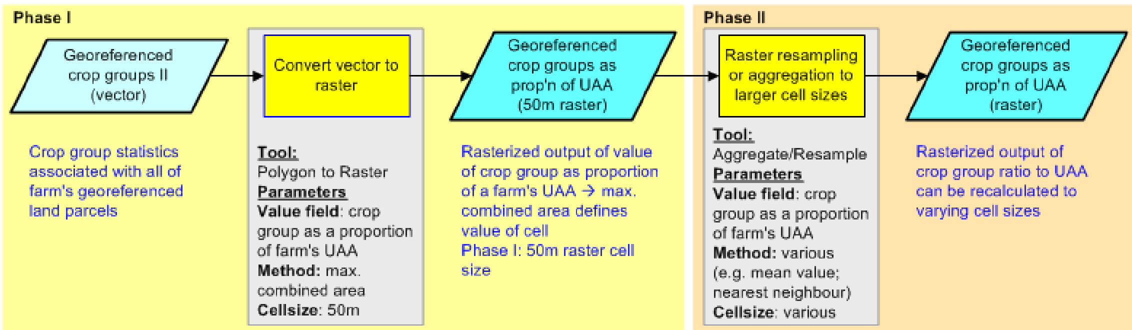


Figure 20: Rasterizing vector output from geoprocessing process

Another advantage of rasterizing the output in this way, is that it makes it easier to combine the output with other layers – for instance by using map algebra techniques. In this way, the monofactorial output from the individual crop groups could be easily combined with each other or with other data in further geoprocessing steps towards refining a spatial indicator of agricultural intensity. A further factor to consider is the processing speed, which tends to be faster using raster analysis to overlay data rather than working with the complex forms of the original vector output.

3.11 Technical Infrastructure and Tools Employed

Hardware and Operating Systems:

- Laptop
  - Intel® dual core T7200, 2.00 GHz, 2 GB RAM
  - Windows XP Professional, SP3
- Workstation I
  - Intel® dual core E8400, 2.99 GHz, 3 GB RAM
  - Windows XP Professional, SP2
- Workstation II
  - Intel® Xeon® E5530, 2.40 GHz, 2GB RAM
  - Windows 7

Software:

- Microsoft Office 2007: Word, Excel, Access, PowerPoint
- Microsoft Office Visio Professional 2002 & 2003
- ESRI® ArcMap™ 9.3.1 & 10: ArcInfo, Spatial Analyst, Model Builder
- FME® Desktop ESRI Edition 2011, 2012 Beta
- IBM® DB2® UDB Database v9.1

4 Results

The results described in this chapter apply to data from Canton Berne from the year 2010. Results from the numerical data analysis and those achieved by georeferencing the agricultural survey statistics for the first time are described.

4.1 Numerical Data

The results described in the following sections refer to data from the year 2010 and – true to the "residence" principal of GELAN-IS – to farmers registered as resident in Canton Berne. This does not mean that all the land parcels they farm are also in Canton Berne and is simply part of how the direct payments system operates. Only the land these farmers farm within the cantonal boundary is considered in this study. Land within Canton Berne but farmed by farmers not resident in the canton is excluded from the analysis.

4.1.1 Farms and farmed land parcels

The first analysis of the data was in regard to numbers of farms and farmed land parcels in Canton Berne. The principal of residence is significant in understanding how the direct payment system operates and in explaining why certain things are as they are in GELAN-IS. Only data from farmers resident in Canton Berne is managed in the Bernese module of GELAN-IS. From this data, only that applying to land within Canton Berne is subject to analysis in this study.

Any analysis of the data on farm holdings should take the various categories of farm holdings recorded in GELAN-IS into consideration. Some categories are as defined by the Ordinance on Agricultural Terminology, others are specific to GELAN-IS modules. The categories relevant for this study and the number of associated farms which exist for the 2010 data are described in Table 20 below.

Farm category[30]	Description
11,932 (OAT with DP)	Farm as defined by FLA, eligible for direct payments
5,159 (non OAT)	Hobby farms, outwith OAT definitions with no eligibility for DP
1,927 (OAT, non-DP)	Farms with land but no DP (e.g. with nature management contract)

Table 20: Numbers of relevant farm categories (2010)

A summary of the basic statistics on farmers, farms and their farmed land parcels as held in GELAN-IS is provided in Table 21.

[30] For explanation of terms refer to Table 2.

Farmers: • 12,468 farmers are registered as resident in Ct. BE
Farms: • 12,577 farm holdings with registered land parcels are registered to BE resident farmers • 12,536 of those have land in Ct. BE
Land Parcels: • 137,539 land parcels are registered to farmers resident in Ct. BE • 2,050 of those are outwith the cantonal boundary, 135,489 are in Ct. BE • 131,355 of the land parcels have land cover eligible for farming (324,737 ha) • 129,342 have declared farmland (UAA) (186,808 ha) (NUAA = 9,411 ha) • 114,755 land parcels were georeferenced (84.7% of farmed land parcels) • Georeferenced land parcels have 160,610 ha UAA (86% of total UAA in BE) • 5,155 parcels have a nature management contract registered, 3,813 were georeferenced

Table 21: Summary of data on farmers, farms and farmed land parcels (BE)

The above statistics set the scene for further analysis of the data and a more detailed overview including illustration of the principle of Bernese resident farmers, and differentiation of the data on that basis is provided in Figure 22. To assist with the interpretation of the statistical data a map of municipality population data is provided in Figure 21. The municipalities with the largest towns and to some extent those with a larger area are evident. Much of the higher population size in communities in the Alps can be explained by the extensive tourism infrastructure in the region.

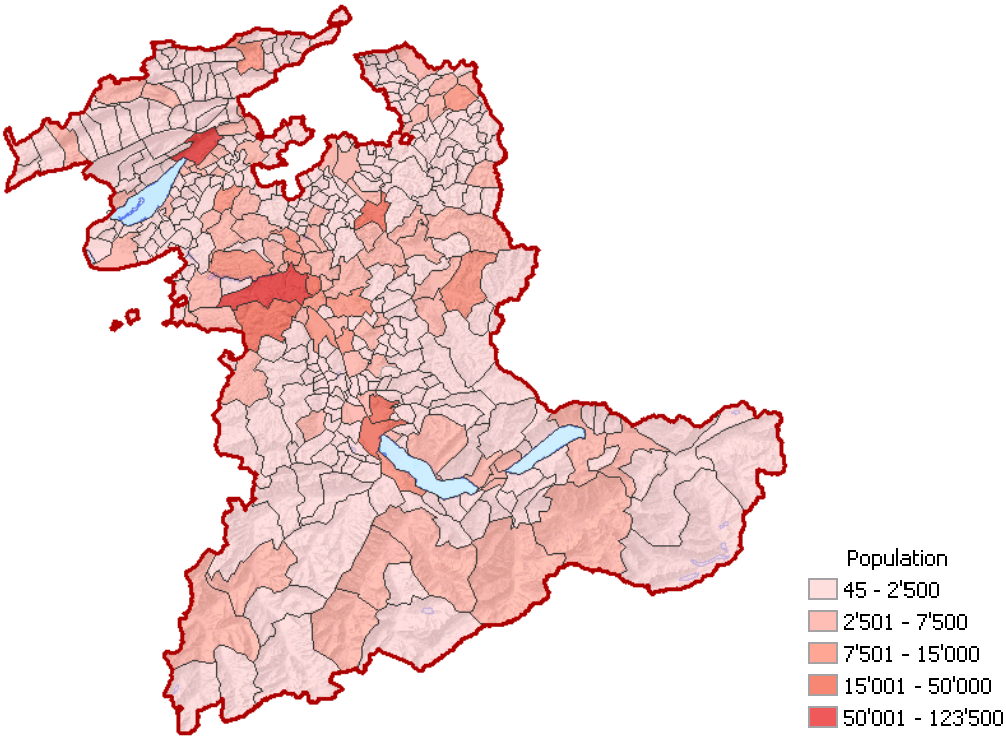


Figure 21: Municipality population statistics (2009)[31]

[31] Source: Finanzdirektion des Kantons Bern

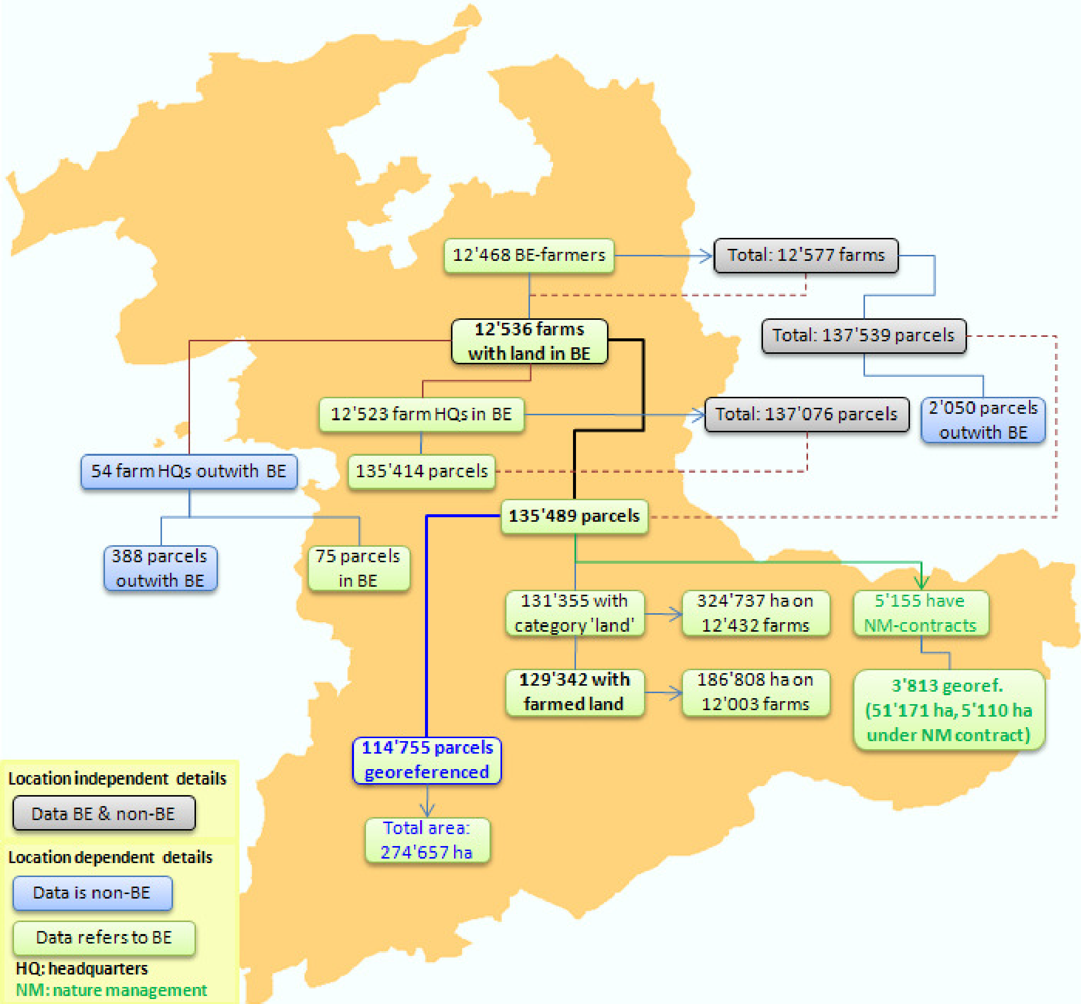
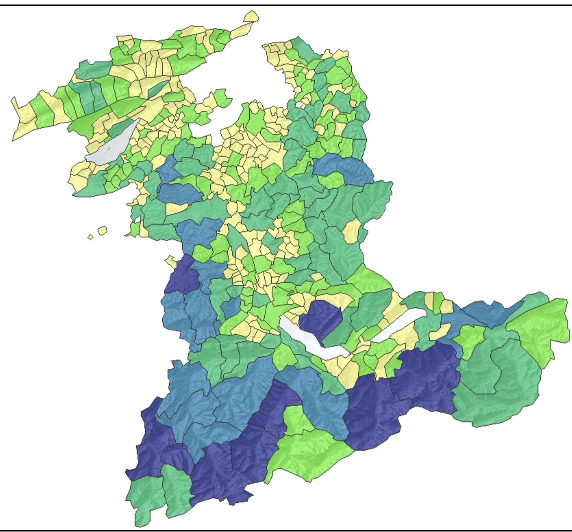


Figure 22: Summary of farms and farmed land parcels

Up until now, the only means of presenting agrarian statistics from Canton Berne was by means of numerical aggregation at municipality level. Some examples of mapping such data are shown in Table 22. There is no consideration of the effects of topography and the resulting heterogeneity in the distribution of farmland.

Number of farm holdings per municipality. No. of farm holdings 2 - 250 251 - 500 501 - 1000 1001 - 1500 1501 - 2300 Comments: • Variation to some extent explained by size of municipalities	

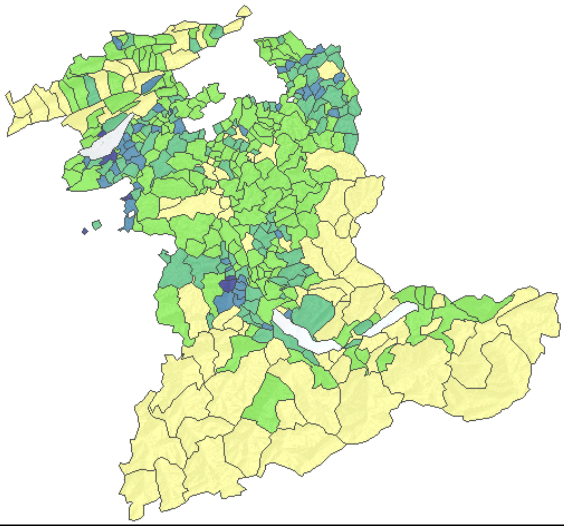
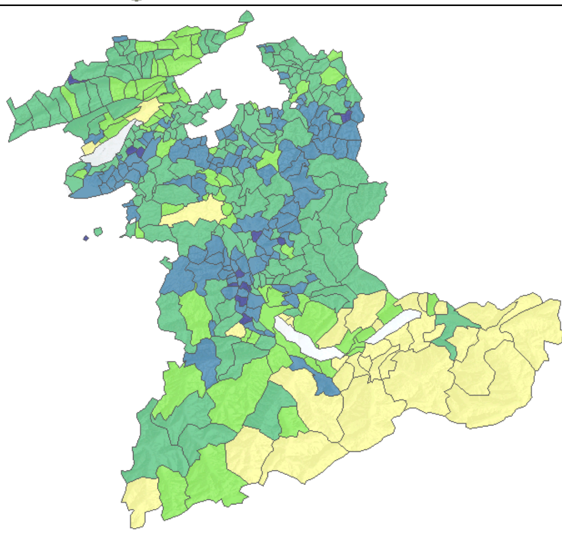
Density of farm holdings per municipality No. of farms per ha municipailty area 0.01 - 0.20 0.21 - 0.40 0.41 - 0.60 0.61 - 1.00 1.01 - 2.22 Comments: • Variation appears related to topography/climatic suitability	
Proportion of area of land cover category 'land' per municipality (in ares) 'LAND'/Mun. area (ares) 0.02 - 0.20 0.21 - 0.40 0.41 - 0.60 0.61 - 0.80 0.81 - 1 Comments: • Variation to some extent explained by municipality size but also by topography and ruralness	

Table 22: Numerical data – spatial presentation pre-georeferencing

The maps in Table 22 illustrate various statistics based on their aggregation at municipality level – the only method available until now. Using this method, no account can be taken of the differences in topography and land cover to provide a more detailed picture of reality – a weakness particularly relevant for the varied geography of Canton Berne. The spatial accuracy is also limited by the fact that some statistics are aggregated to the municipality where a farm holding's headquarters is located, although the associated farmland is often distributed over a larger area and may lie outwith that one administrative unit.

4.1.2 Crop Data

In the same way in which basic agrarian statistics were mapped by means of aggregation at municipality level in the previous section, crop data can also be visualised. To begin with, the basic statistical content can be summarized (see table below).

Crop data: • 181,989 records of crop data overall declared by farmers resident in Ct. Berne • 109,585 elements with crops within the UAA 19,058,132a • 21,734 elements with crops outside the UAA 4,295,879a • 50,675 tree elements, with a total of 467,604 individual trees registered • 142,140 crop elements with biological quality: 42,473 a • 142,136 crop elements classed as interlinked: 1,290,282a • Number of different crops registered: 137

Table 23: Summary of crop statistics 2010

The map in Figure 23 illustrates in which municipalities outwith Canton Berne Bernese resident farmers have registered crops. The majority are close to the cantonal boundary but by no means all.

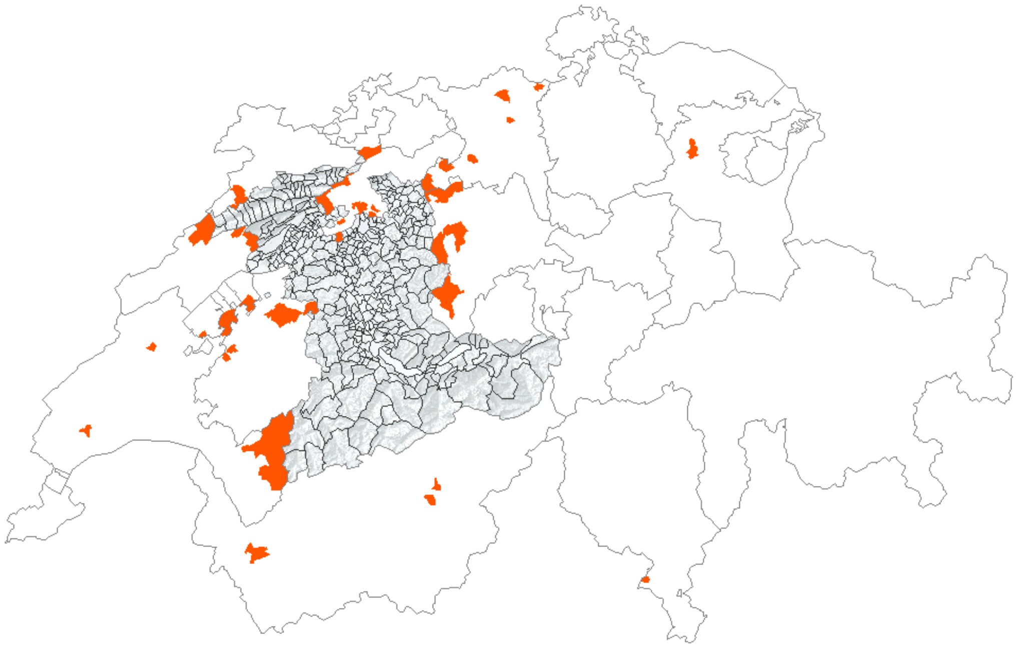


Figure 23: Numerical data – municipalities outwith Ct. BE with crops (BE farmers)

4.1.2.1 Crop Grouping

Due to the high number of individual crops declared by Bernese resident farmers in 2010, any analysis based on individual crops would be very difficult. From the point of view of the relevance of crop cover to bird populations and after discussion with the Swiss Ornithological Institute, it was decided to aggregate the individual crops into groups with similar growth and structural characteristics. The decision as to which groups were required and which crops should be attributed to them was made on the basis of recommendations by the Swiss Ornithological Institute (see Table 9).

The distribution between the groups is illustrated in the graph below (Figure 24)

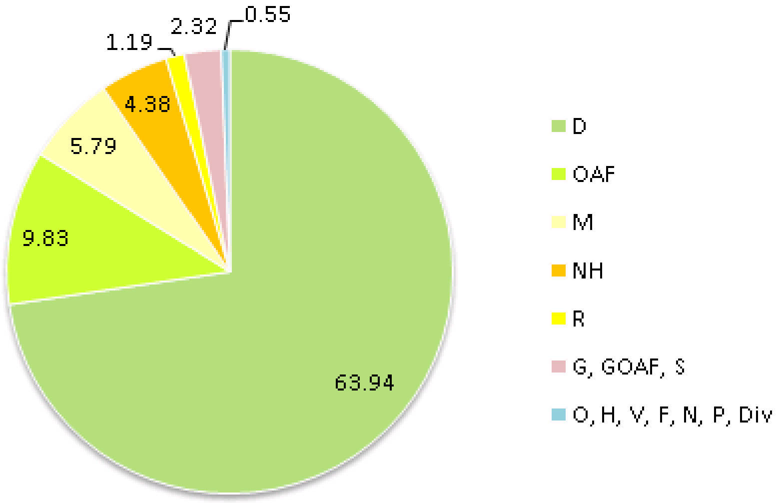
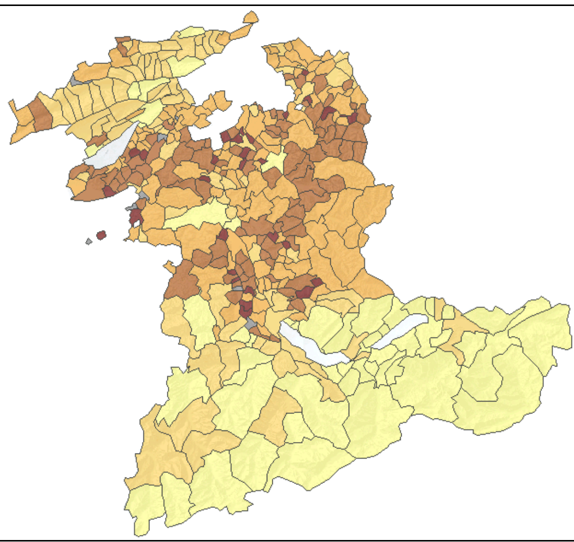
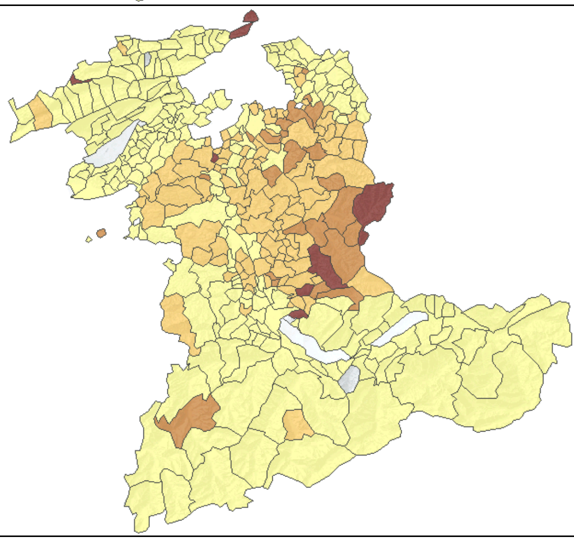


Figure 24: Numerical crop data – crop group percentage of total cropped area

Examples of mapping crop data by the simple method of aggregation at municipality level are shown in Table 24 below.

Total declared cropped area on UAA (ares) Proportion UAA to Mun. area 0.0007 - 0.20 0.21 - 0.39 0.40 - 0.59 0.60 - 0.79 0.80 - 0.98 > 1 Comments: • Urban areas, topography, biogeographic regions and land cover are reflected in the map • Values >1 reflect the spatial limitations of statistical aggregation	
Total declared cropped area on NUAA (ares) Proportion NUAA to Mun. area 0.0006 - 0.10 0.11 - 0.20 0.21 - 0.30 0.31 - 0.39 (some municipalities have no declared NUAA)	

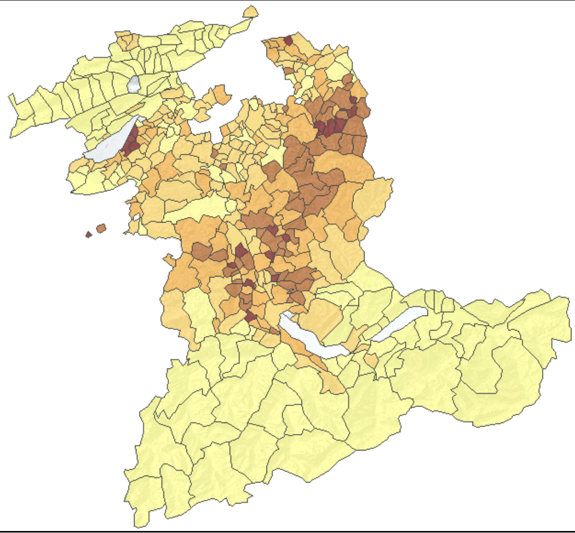
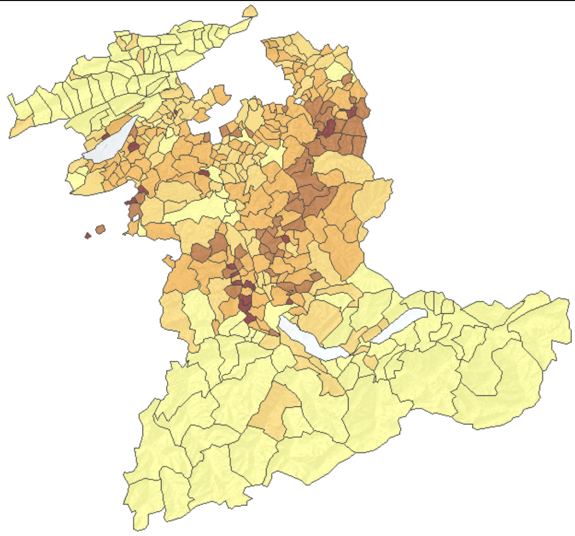
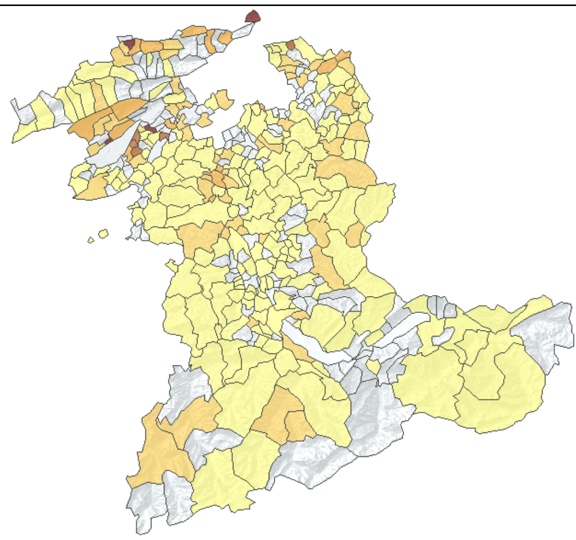
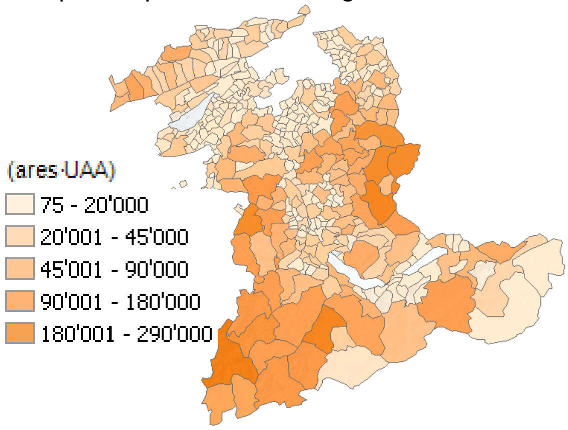
Density of trees declared per hectare (fruit and native trees) No of trees per ha Mun. area 0.001 - 6.50 6.51 - 14.00 14.01 - 23.50 23.51 - 35.50 35.51 - 73.74	
Density of crop elements declared per hectare No of crop elements per ha Mun. area 0.07 - 2.50 2.51 - 5.00 5.01 - 7.50 7.51 - 10.00 10.01 - 21.02	
Density of crops qualifying for ecological quality payments per unit UAA (ares) Density declared with biol. quality 0.0001 - 0.003 0.004 - 0.009 0.010 - 0.017 0.018 - 0.034 0.035 - 0.082	

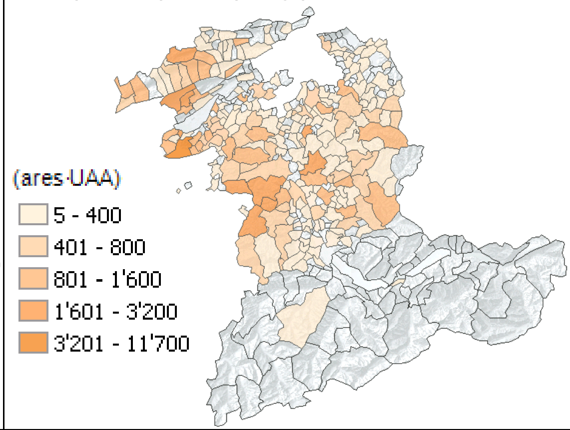
Table 24: Numerical data – spatial representation pre-georeferencing

The level of detail available using the customary method of aggregating crops (total or individual types) at municipality level is quite limited. The large number of eligible crop types in the crop catalogue is too detailed for any form of relevant impression of crop composition – other than by superimposing layers of individual crop types. However, by employing the newly defined crop groups at municipality level, a new level of information is exposed – maps of the crop groups are shown in Table 25. Due to the very low proportions of municipality area or of UAA these crops often cover, it was decided not to represent density but total area for this map series as this gives a good impression of their distribution.

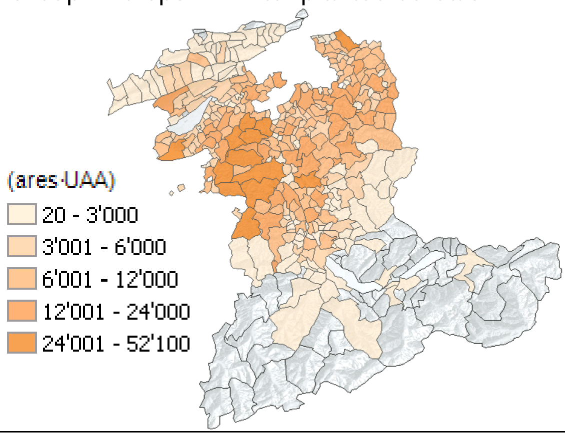
Group D crops – Permanent grassland



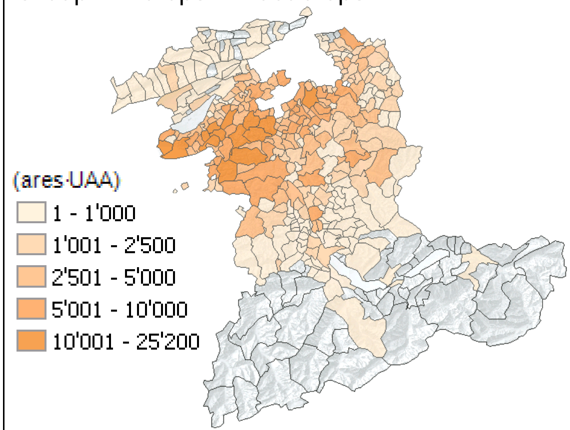
Group S crops – Spring planted cereals



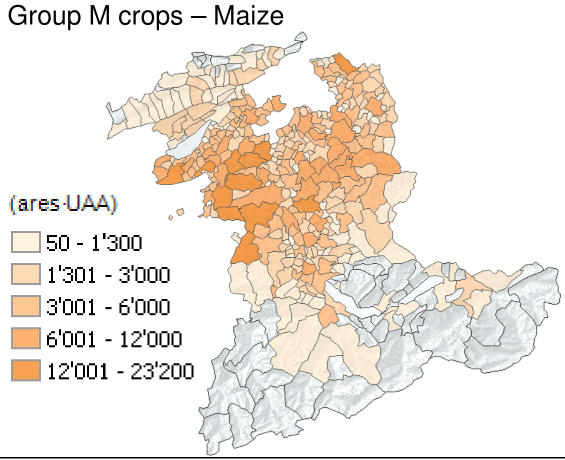
Group W crops – Winter planted cereals



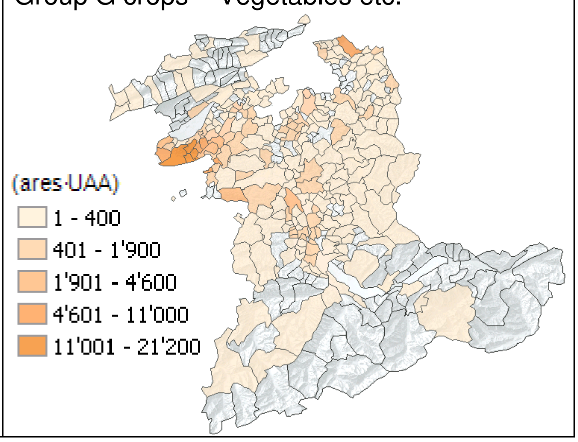
Group NH crops – Root crops



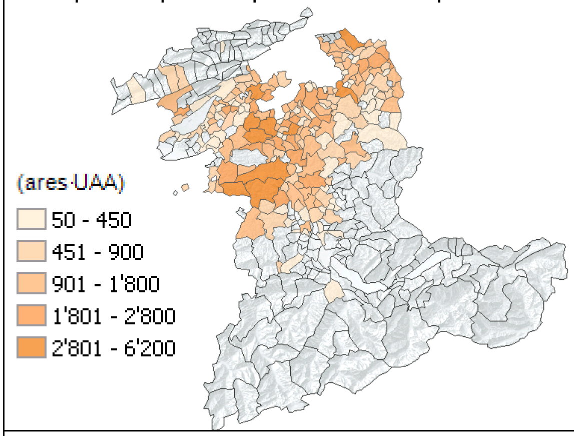
Group M crops – Maize



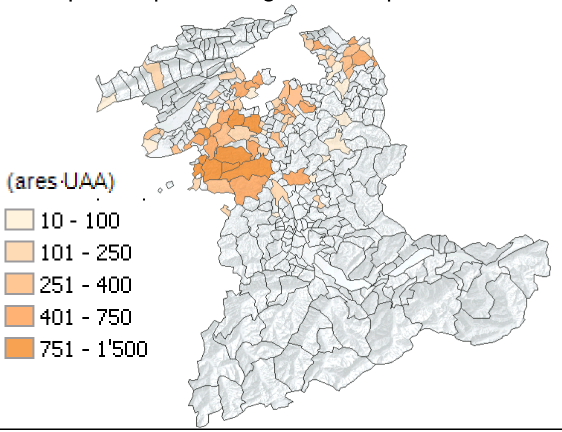
Group G crops – Vegetables etc.



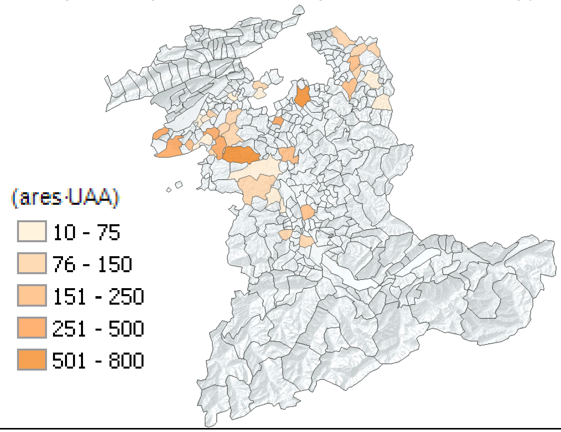
Group R crops – Rape & similar crops



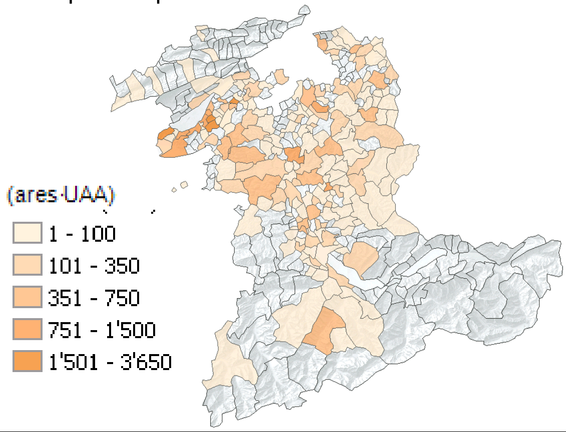
Group H crops – Tall growth crops



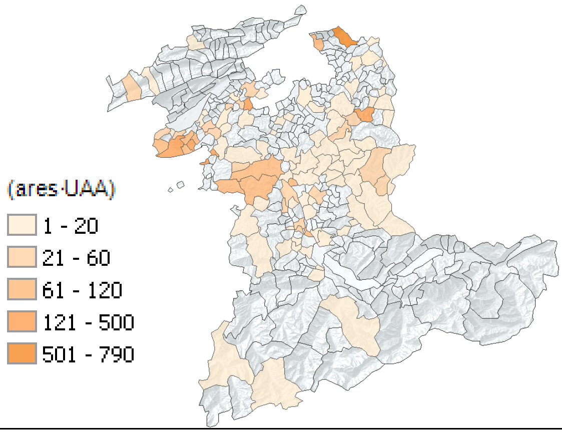
Group N crops – Biomass production (energy)



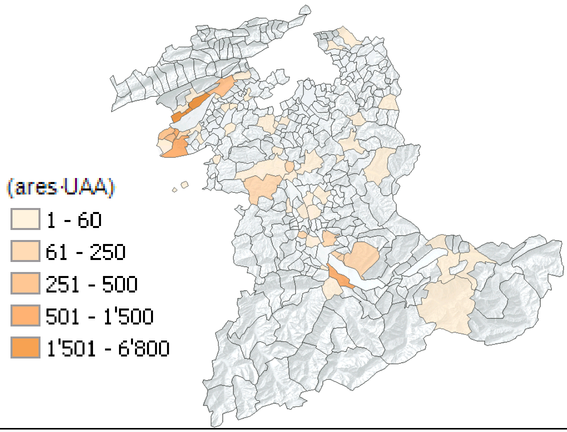
Group O crops – Fruit



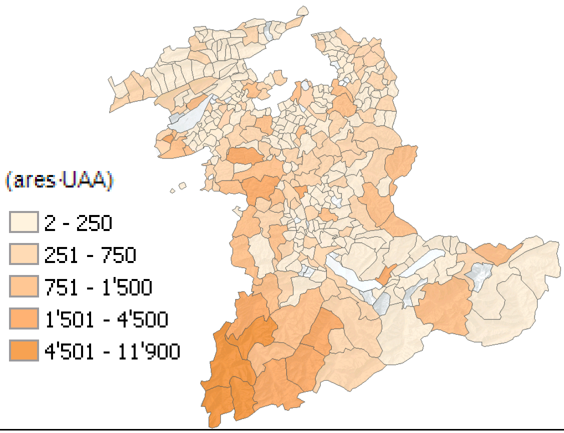
Group P crop – Covered vegetables/crops



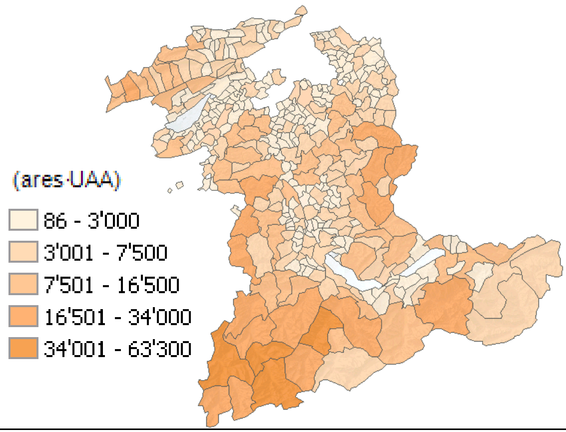
Group V crops – Vines



Group GOAF crops – Grassland ECAs



Group OAF crops – Non-grassland ECAs



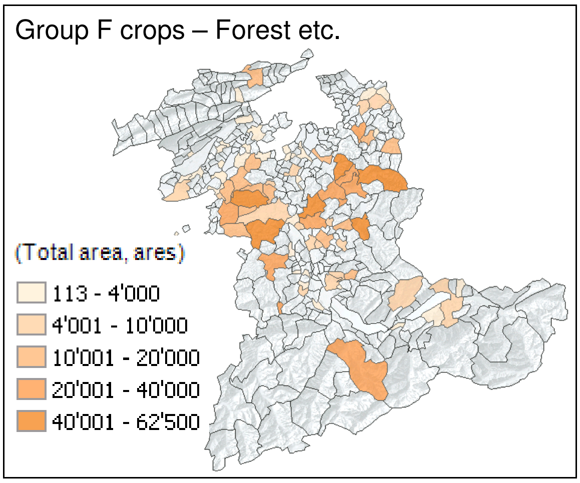


Table 25: Numerical data – crop groups per municipality

The conditions required for the various crop types to flourish vary considerably and this is reflected in the differences between their distributions as illustrated in the table above. The frequency of the various groups is explained to a large extent by the map of climatic suitability for agriculture in Figure 25.

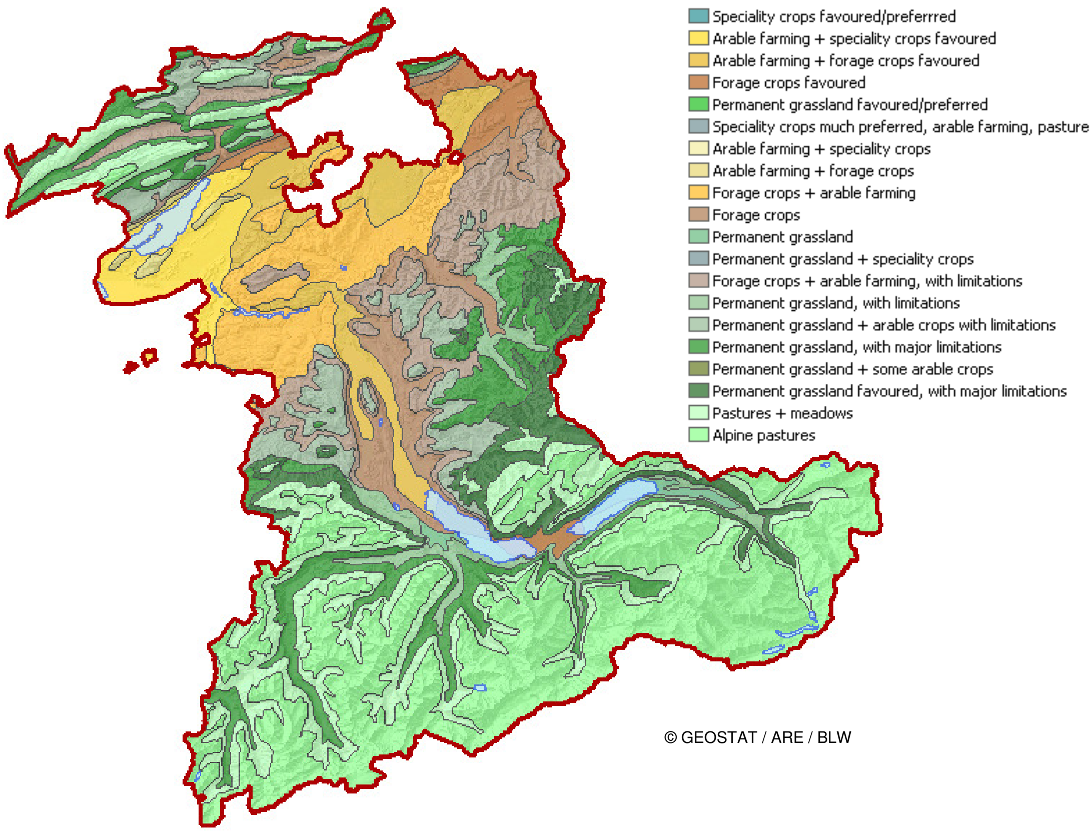


Figure 25: Climatic suitability for agriculture

The definition of biogeographic regions and categories of climatic suitability for agriculture (as shown in Figure 1 and Figure 25 respectively) is clearly reflected in the general distribution of crop groups in Canton Berne as illustrated in Table 25. The level of detail in the agricultural statistics mapped at municipality level, does not take into account the terrain and the associated variation in topography and land cover.

4.1.3 Livestock Data

Different types of livestock are converted to so-called "livestock units" (LU, a cattle equivalent) by a predefined scale. This allows easy comparison of LU values per farm or region where in reality many different individual categories of livestock are kept, each having differing demands on their environment. The phosphorous and nitrogen balance of a farm should be within +10% of the requirements of crops on that farm[32]. This is regulated by defining the LU limits a certain amount of farmland can support while maintaining a neutral nutrient balance. These limits are based on the area of fertilizable land on each farm. Fertilizable land is the area of farmland excluding extensively farmed meadows and pastures as well as ecological compensation areas or areas under nature conservation contracts.

The livestock statistics for 2010 are presented in Table 26 below.

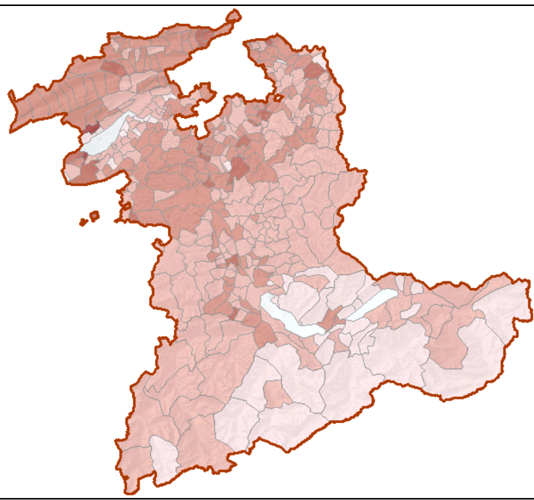
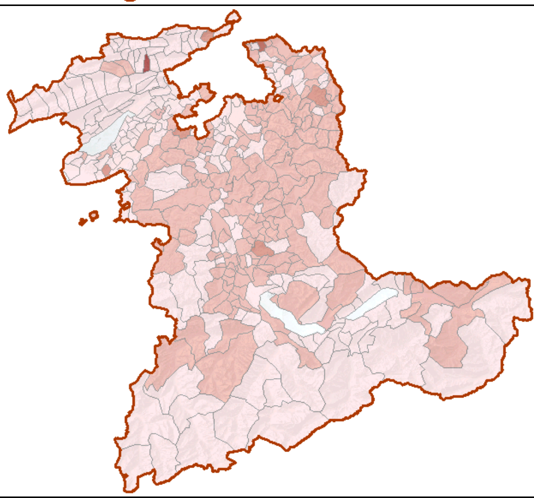
Average LU per municipality Livestock Units 3 - 15 16 - 25 26 - 40 41 - 80 81 - 169	
Average LU per ha fertilizable land LU per ha fertilizable land 0.5 - 1.5 1.6 - 3.0 3.1 - 6.0 6.1 - 9.0 9.1 - 26.1	

Table 26: Numerical data – livestock data per municipality

32 FOAG: http://www.blw.admin.ch/themen/00006/00049/01163/index.html?lang=de

The pattern of average livestock units aggregated to municipality level (above) reflects the differences in regional farming practice and to some extent the topography. Lower numbers of livestock are evident in the alpine regions. Within the individual municipalities, this method of statistical representation makes no allowance for the differences within the administrative boundaries – where for example topography or land cover mean large areas are sparsely farmed.

4.2 Spatial Data

As the georeferencing of farmed land parcels is central to this whole thesis, the success achieved in the basic georeferencing process was a significant factor.

4.2.1 Georeferencing farmland

4.2.1.1 Basic georeferencing process

Using the method illustrated in Figure 26, the Gelan farmed land parcels for 2010 were georeferenced using cadastral geodata.

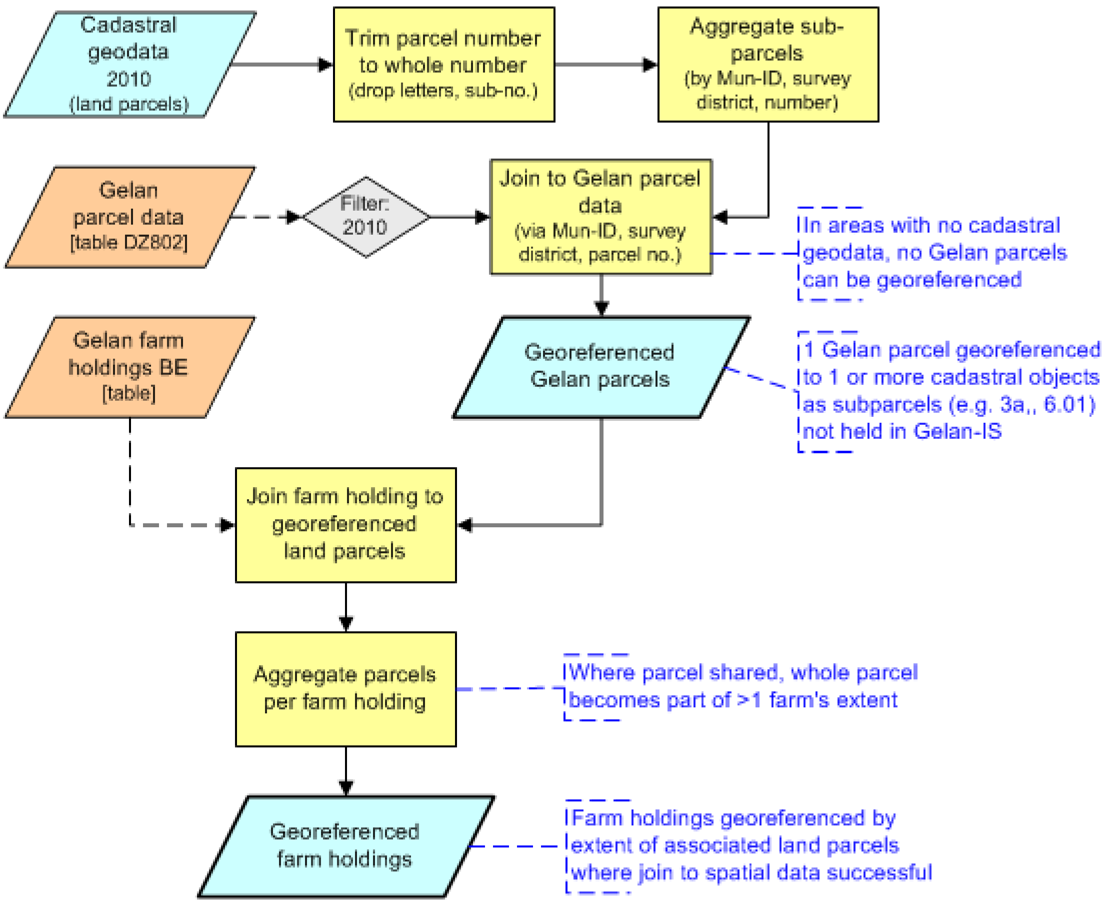


Figure 26: Georeferencing farmed land parcels

Of 427,420 vector land parcels available for Canton Berne, 118,477 were georeferenced as farmland from the data in GELAN-IS. Of the 126,113 land parcels within the cantonal boundary which are registered to an active farm, 118,477 (93.9%) of those, covering an area of over 2,900 km^2, were successfully georeferenced by the methods described in chapter 3.4.1. The extent of the georeferenced land parcels is illustrated in Figure 27 and is based on parcel boundaries, with effective UAA covering a smaller area.

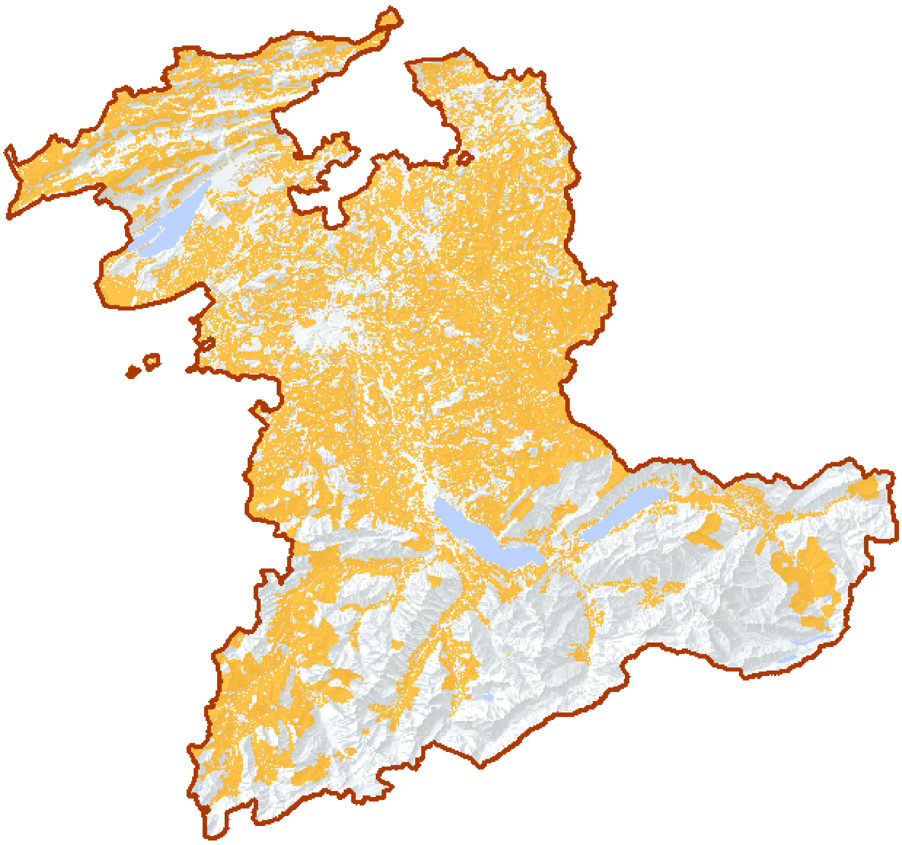


Figure 27: Extent of georeferenced farmed land parcels for 2010 (Canton BE)

The lack of georeferenced farmland in the southern part of the canton can be attributed to two main factors. On the one hand, farming is limited by the topography and associated climate in this alpine region, while on the other hand, much of the land is unsurveyed and thus no vector cadastral data are available.

In order to georeference the data captured per farm holding in the annual agricultural statistics survey, individual farms need to be georeferenced. Each active farm is registered with a list of its associated land parcels. The success of the basic georeferencing process developed in this study is illustrated in Table 27 (figures obtained by summarising numerical and spatial output).

	Numerical data[33]	Spatial data[34] (georeferencing)	Success rate
No of farms	12,577	11,951[35]	95%
Number of land parcels	126,113	118,477	93.9%
Eligible farmland	229,651 ha	214,379 ha	94.7%
Registered farmland (UAA)	172,701 ha	164,860 ha	88.3%
Registered farmland (NUAA)	15,730 ha	13,496 ha	85.8%

Table 27: Comparison of numerical and spatial land parcel data (BE)

A high percentage of the registered farmland (88.3%) was successfully georeferenced by means of geolocating the land parcels of the individual farms.

Although 144 of Berne's 393 municipalities contain farms none of whose land parcels could be georeferenced, only 76 actually have active farms with farmland registered to them (see map below).

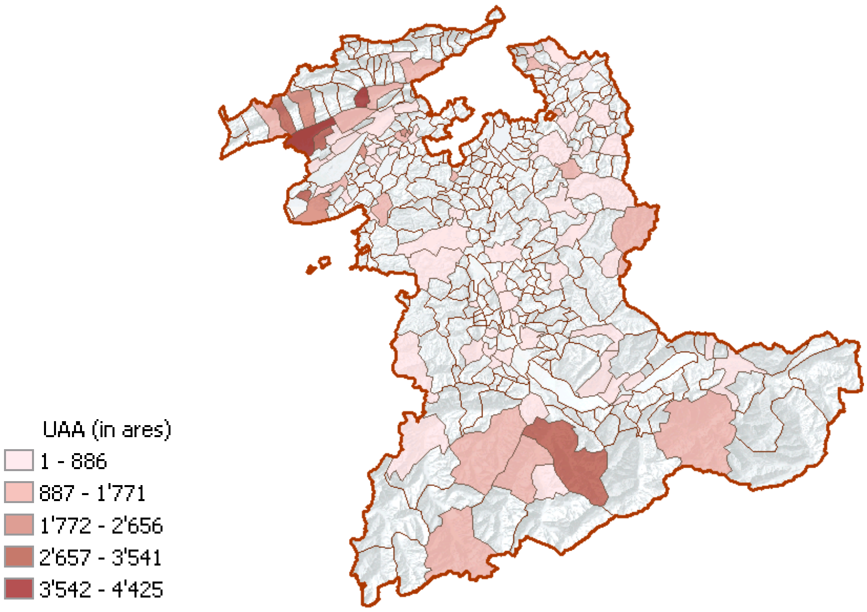


Figure 28: UAA per municipality of farms with no georeferenced land parcels.

4.2.1.2 Defining farmland extent

The maximum extent of georeferenced farmland with UAA is based on the extent of associated parcel boundaries and covers an area of 290,023 ha (see Figure 27). Effective UAA covers a smaller area and ineligible land cover categories are spatially subtracted by overlaying vector land cover data to refine the maximum extent of potential UAA. The process employed is illustrated in Figure 29 (Phase I).

[33] Statistics from GELAN-IS for 2010

[34] Land cover and UAA/NUAA data from GELAN-IS but only that associated with georeferenced land parcels

[35] Includes farms with partial georeferencing of land parcels

Those areas of potential UAA overlying the category forest are first deducted by geoprocessing [Erase Tool[36]]. This reduces the potential UAA area by over 50,000 hectares to 239,845 ha. In the next step 'unproductive' land-use categories (e.g. roads, buildings, railways, rivers, etc.) are erased – 221,454 ha remain as the maximum extent of georeferenced UAA for Canton Berne in 2010.

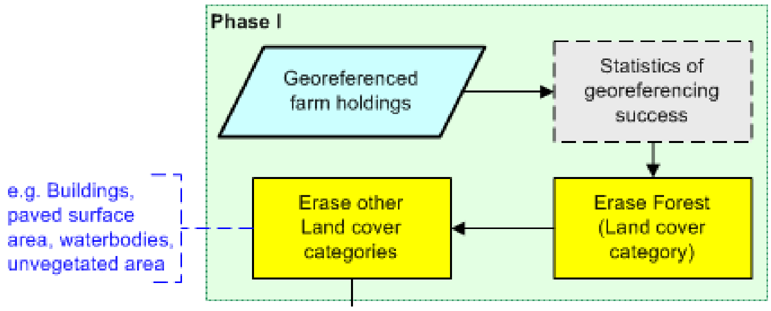
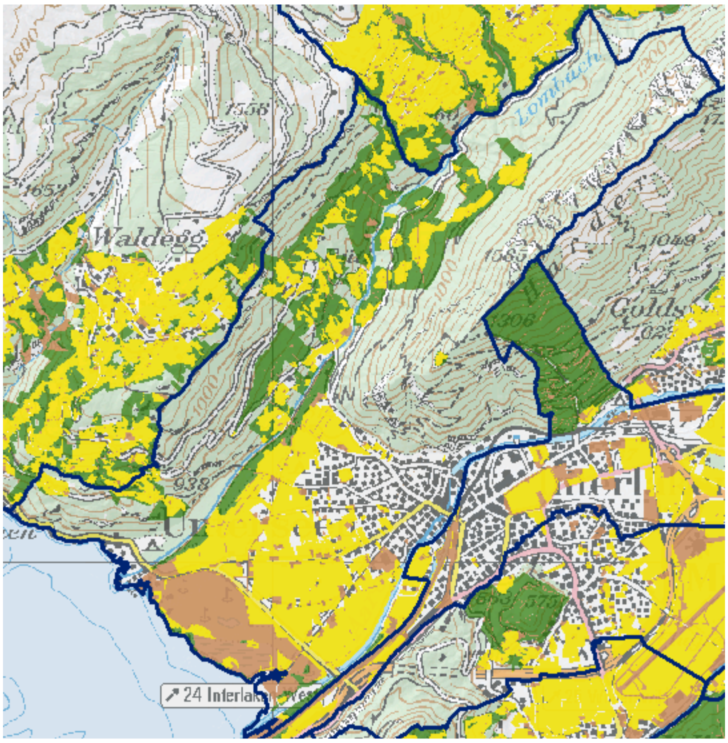


Figure 29: Reducing potential UAA based on georeferenced land parcels

The increased level of detail from a spatial point of view which results from the processes shown above is illustrated in the example below.



Spatial subtraction of land cover categories.

Green: shows areas where forest has been subtracted.

Brown: areas where unproductive land was subtracted.

Yellow: denotes remaining potential UAA extent

Figure 30: Georeferenced farmland – potential UAA extent reduced by forest/unprod.

In Figure 30, the significance of the area within the municipality boundary which has no UAA is exposed. The increased spatial detail provided by this method as compared to the basic information available by statistical aggregation per administrative unit is evident, as is the influence of relief and altitude.

[36] http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#//00080000000m000000.htm

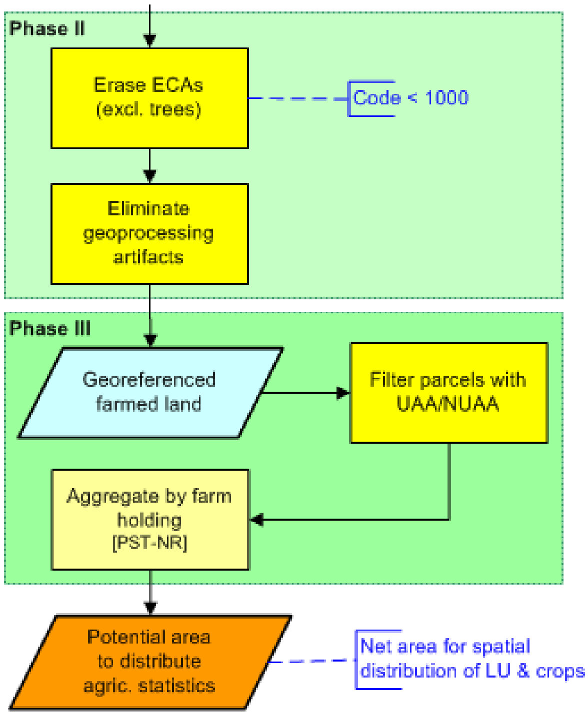


Figure 31: Reducing potential UAA

The next stage in refining the extent of georeferenced farmland is illustrated in Phase II (Figure 31). In this phase, ECAs are subtracted from the area where crops and livestock units can be distributed and finally, any remaining mini polygon remnants were removed from the final net farmland extent. This further reduces the area by 17.8 ha to 203,653 ha – an overall reduction after the various stages of refinement of almost 30% from the original potential extent of farmland.

Apparently coincident features often differ to a minor degree and this disparity becomes evident during geoprocessing, in some cases resulting in numerous features which are not relevant for further processing. Thus, before employing the data in the next stage, prior elimination of various residual boundary artefacts (e.g. sliver and very small polygons) which are generated as a result of the erase procedure is necessary (phase III above). In the end, a combination of feature area, circularity value and neighbourhood analysis were employed to optimize the output.

Analysis of the suitability of nature inventories for further refining the area of farmed land led to such data being excluded from the basic process as the management of farming practices within them varies considerably. Although this data was not integrated into the processes developed in this thesis, the option of using the data in the future as a potential indicator of reduced intensity agriculture remains.

4.2.2 Spatially distributing agricultural statistics

Having obtained a new spatial base geodataset of potentially farmed land, the next stage involved distributing the agricultural survey statistics onto that base. Crop data (grouped as described in chapter 3.5.1) and livestock units per farm holding are associated with the spatial extent of farmland (see Figure 32) and mapped.

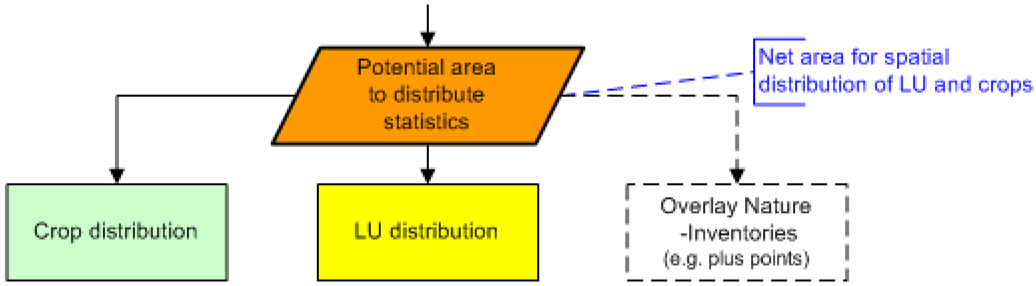


Figure 32: Distributing agricultural statistics on potential UAA

Numerical data is aggregated per farm holding using FME and these data can be joined to the georeferenced farmland associated to each farm and thus represented spatially for the first time.

4.2.2.1 Georeferenced crop data summary

The frequency of the various crop groups georeferenced is illustrated in Figure 33.

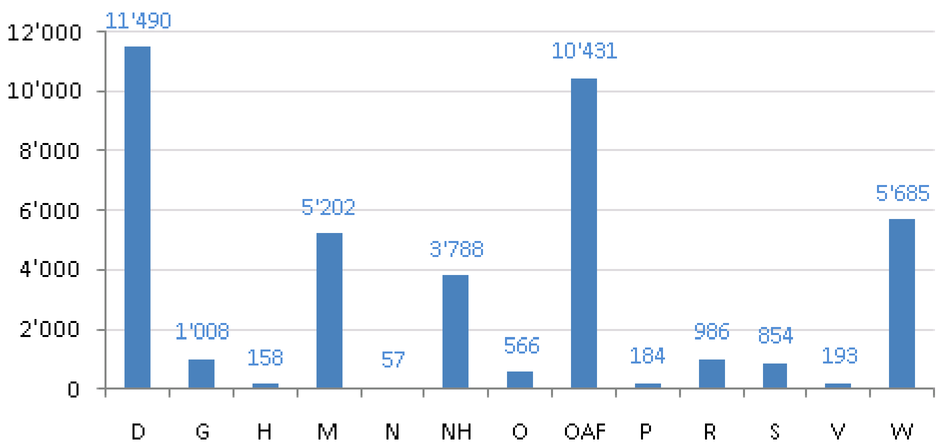
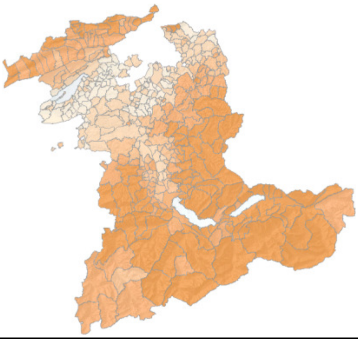
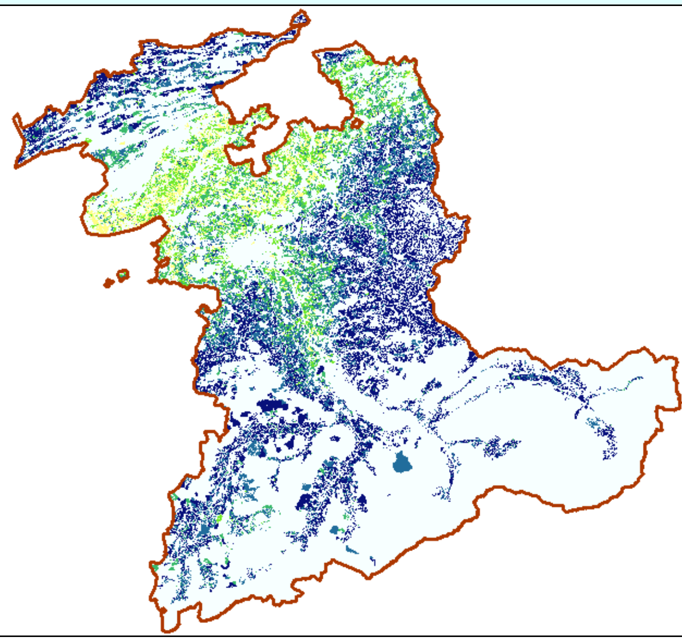
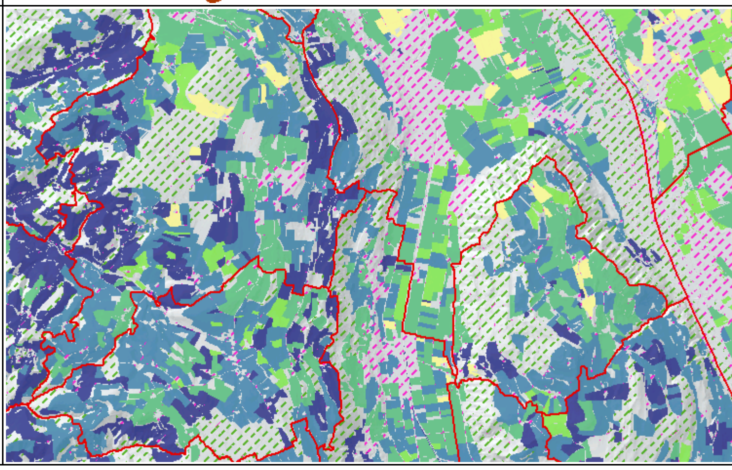


Figure 33: Number of farms and crop group frequency (georeferenced on UAA)

The refined farmed land geodataset was first compared with the numerical data to assess how much of the declared UAA for each farm holding was successfully georeferenced. The UAA associated with the refined georeferenced parcel extent represents over 93% of total UAA registered in Canton Berne. Of the farm holdings which were to some extent georeferenced, 59% of those had over 90% of their UAA identified.

4.2.2.2 Individual crop groups georeferenced

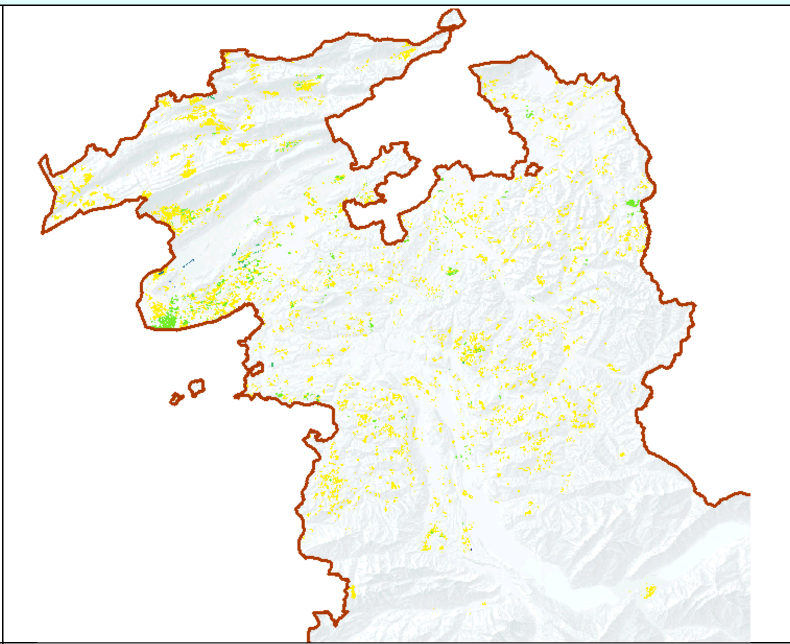
The following section illustrates the results of the georeferenced crop data (based on crop grouping as described in Table 9) and highlights the new level of detail compared to the only previously available method of visualising agricultural statistics. Although it appears that the data are accurate to land parcel level, this is somewhat deceptive. The statistics apply to an entire farm and there is presently no way of knowing which fields have which crops on them and the value is thus associated to all land parcels from a particular farm.

a. Permanent grassland	
Proportion of permanent grassland to UAA per farm > 0 - 0.20 0.21 - 0.40 0.41 - 0.60 0.61 - 0.80 0.81 - 1 Overview density per ha UAA per municipality 	
Comparison of detail  Land cover Unprod. Forest	
Comments: the local and regional variation is easily discernable. The reduced density of data in the south relates to the topography and to some extent a lack of vector cadastral data.	

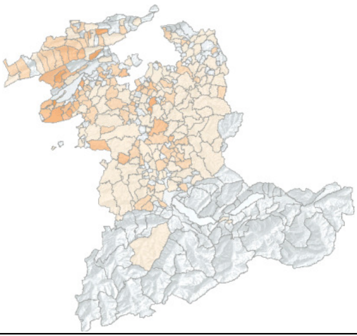
b. Spring planted cereals

Proportion of spring planted cereals to UAA per farm

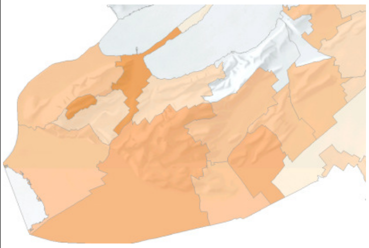
- > 0 - 0.15
- 0.16 - 0.30
- 0.31 - 0.45
- 0.46 - 0.60
- 0.61

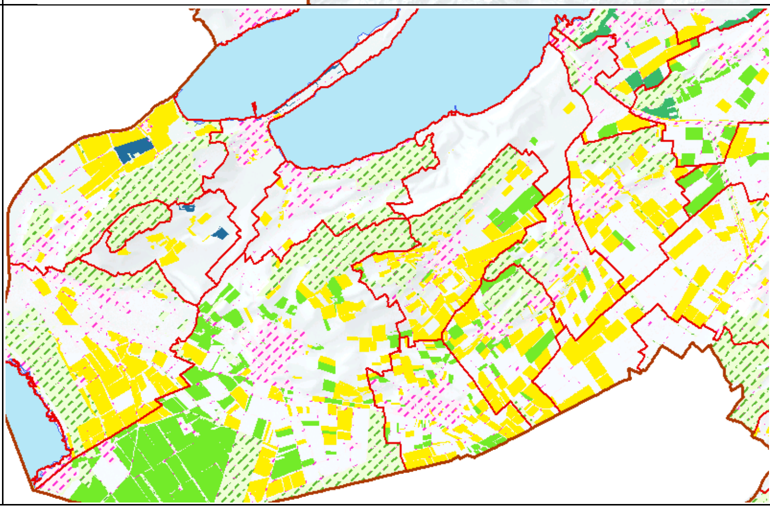


Overview density per ha UAA per municipality



Comparison of detail





Land cover

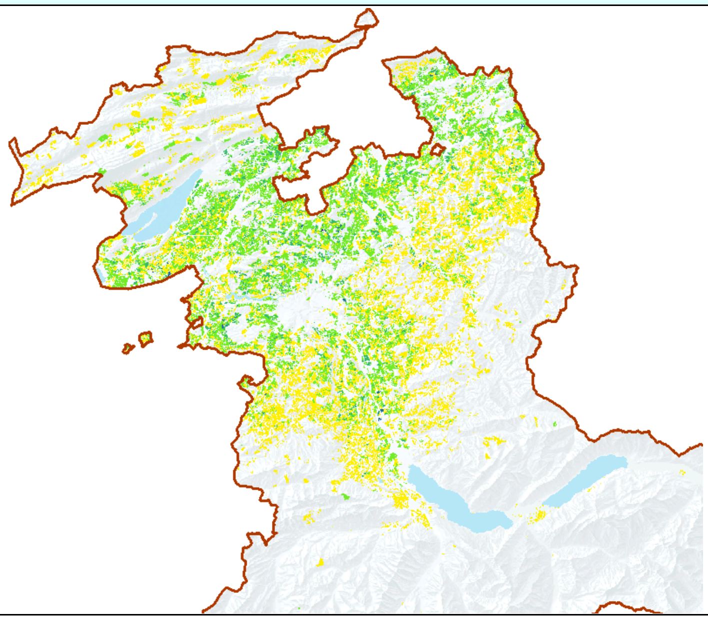
- Unprod.
- Forest

Comments: The concentration in lower lying areas and in particular in the lower lying "Seeland" region is evident in the detailed data representation. Correlation with the climatic suitability zones in Figure 25 is also visible.

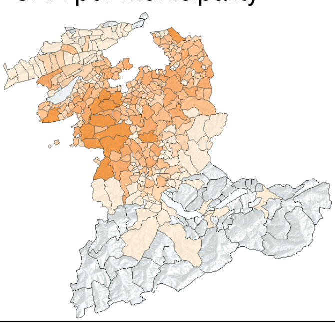
c. Winter planted cereals

Proportion of winter planted cereals to UAA per farm

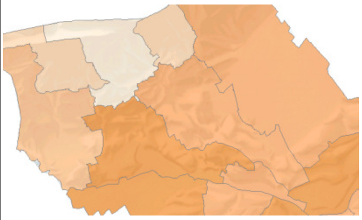
- > 0- 0.20
- 0.21 - 0.40
- 0.41 - 0.60
- 0.61 - 0.80
- 0.81 - 1



Overview density per ha UAA per municipality



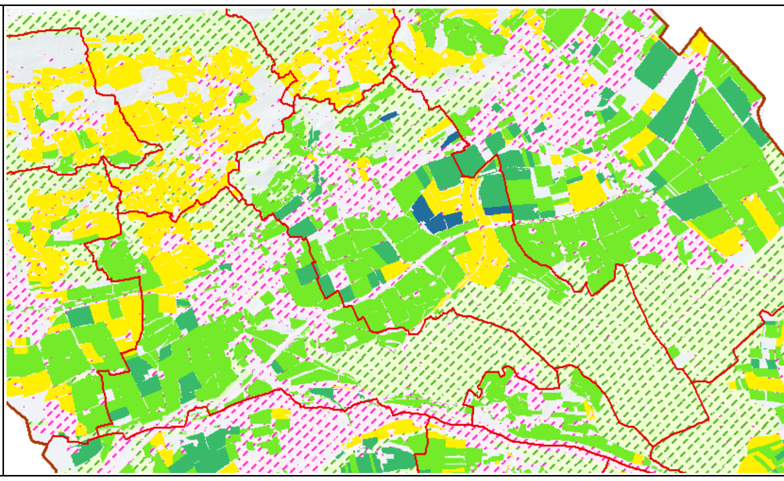
Comparison of detail



Land cover

Unprod.

Forest

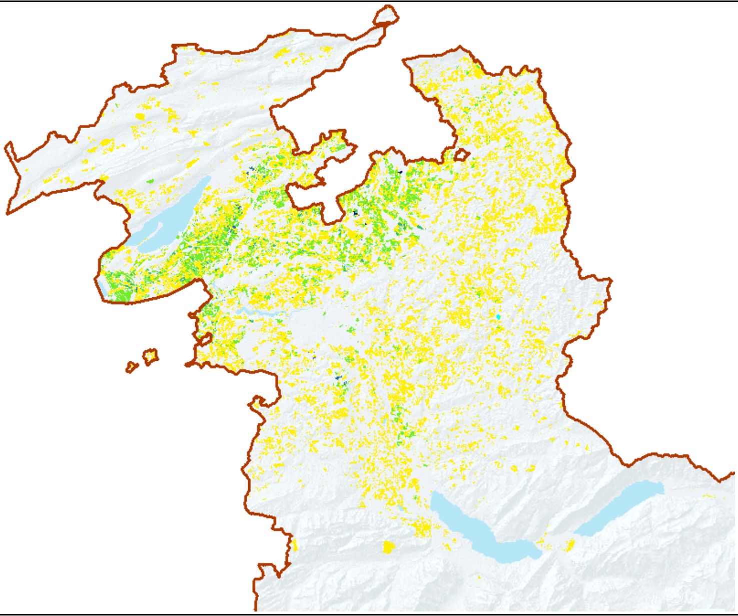


Comments: The concentration in lower lying areas is evident while a clear correlation with the climatic suitability zones in Figure 25 can also be recognized.

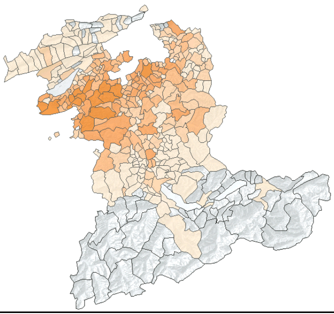
d. Root crops

Proportion of root crops to UAA per farm

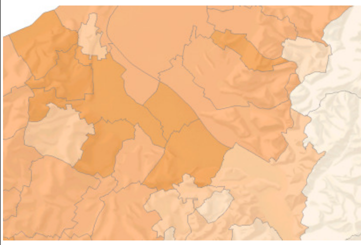
- > 0- 0.20
- 0.21 - 0.40
- 0.41 - 0.60
- 0.61 - 0.80
- 0.81 - 1



Overview density per ha UAA per municipality



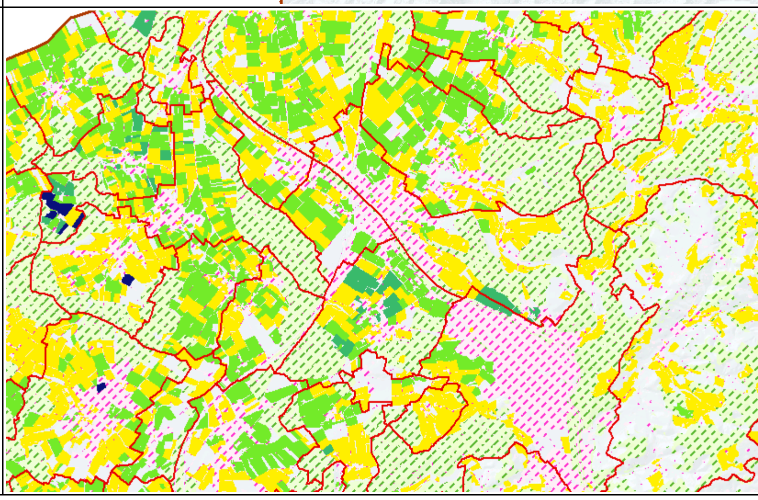
Comparison of detail



Land cover

Unprod.

Forest

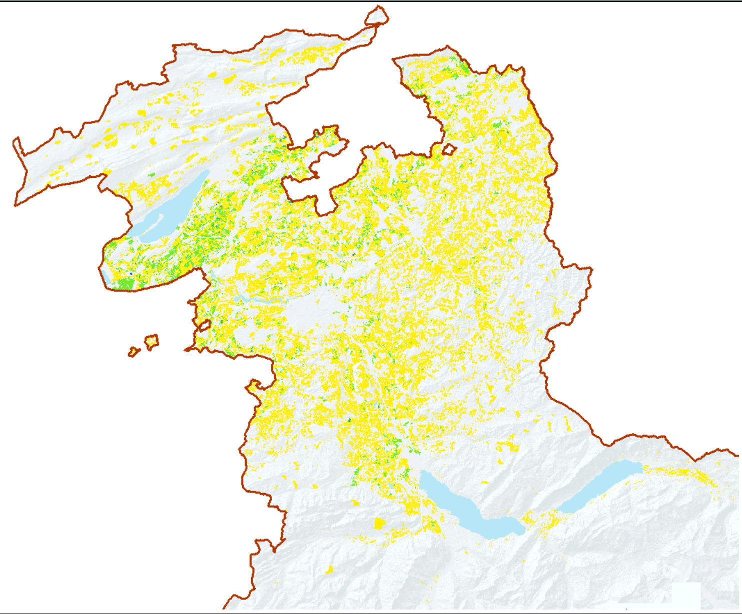


Comments: The influence of topography and the correlation with the zones of climatic suitability (see Figure 25) are evident at the new level of detail.

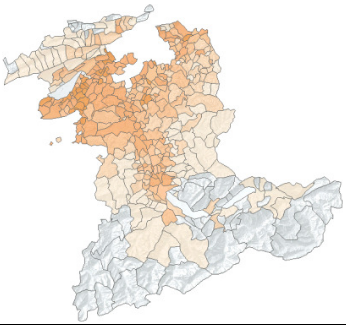
e. Maize

Proportion of maize to UAA per farm

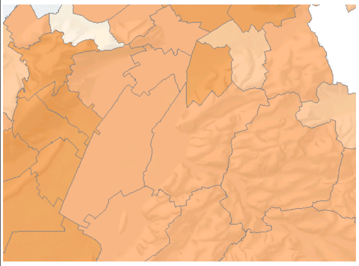
> 0- 0.20
0.21 - 0.40
0.41 - 0.60
0.61 - 0.80
0.81 - 1

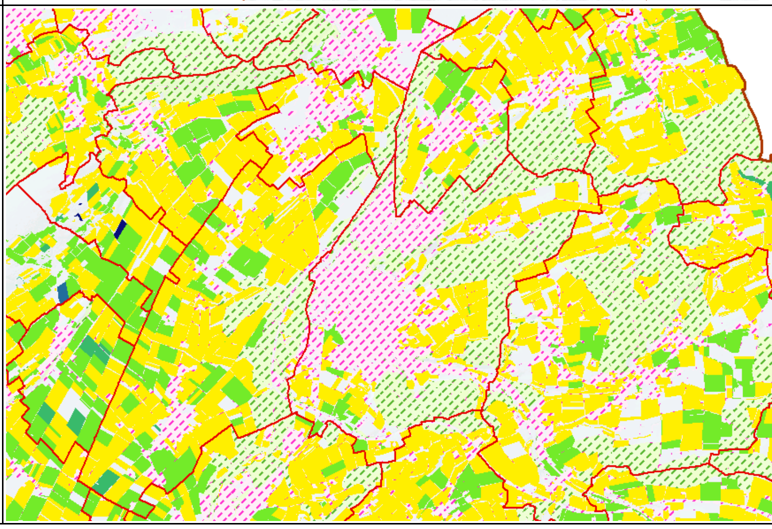


Overview density per ha UAA per municipality



Comparison of detail





Land cover

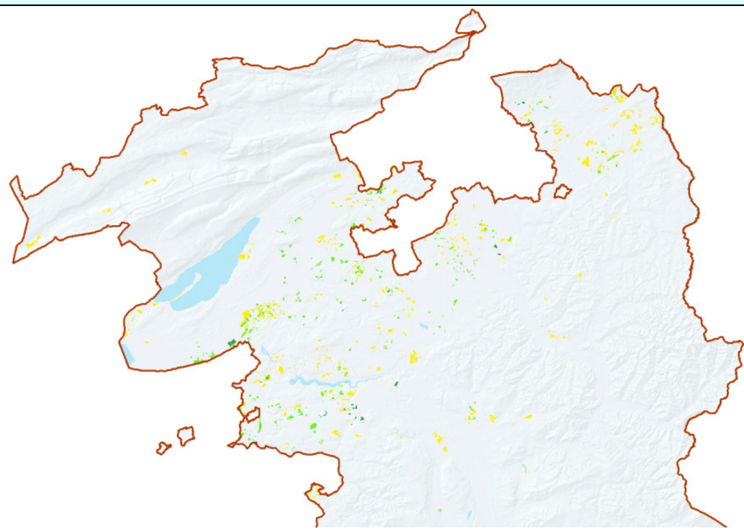
Unprod.
Forest

Comments: Zones of climatic suitablity and topography (see Figure 25) are reflected in the detailed distribution of this crop group.

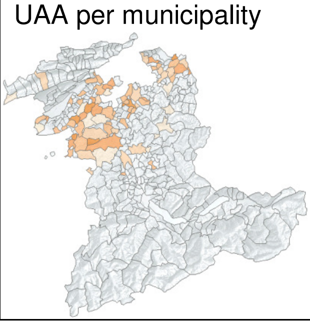
f. Tallgrowth crops

Proportion of maize to UAA per farm

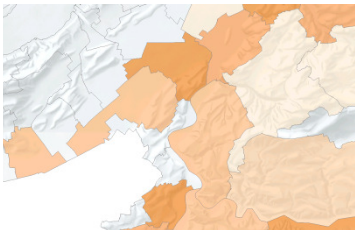
> 0 - 0.10
0.11 - 0.20
0.21 - 0.30



Overview density per ha UAA per municipality



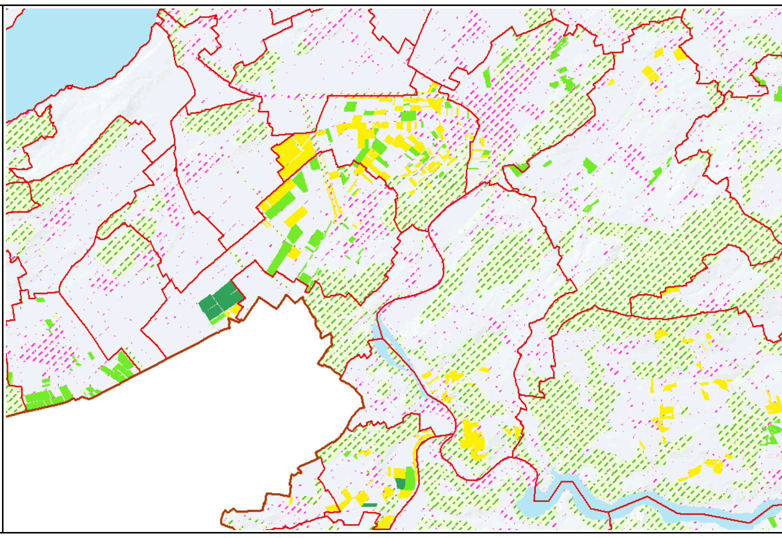
Comparison of detail



Land cover

Unprod.

Forest



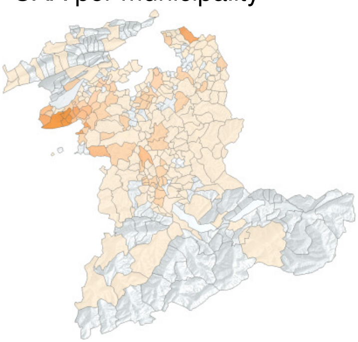
Comments: The concentration in mainly low-lying areas is evident with both methods, the difference in level of detail is considerable.

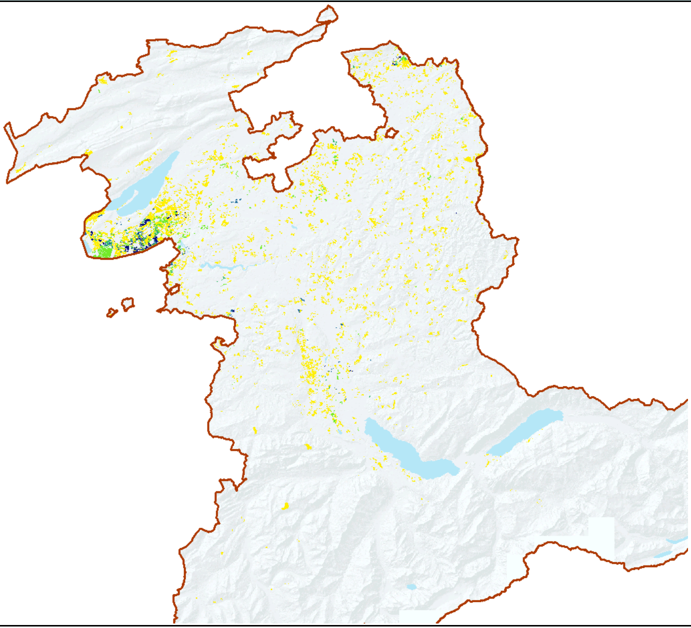
g. Vegetable crops

Proportion of vegetable crops to UAA per farm

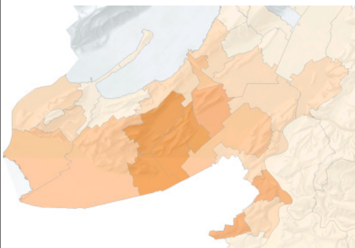
- > 0- 0.20
- 0.21 - 0.40
- 0.41 - 0.60
- 0.61 - 0.80
- 0.81 - 1

Overview density per ha UAA per municipality





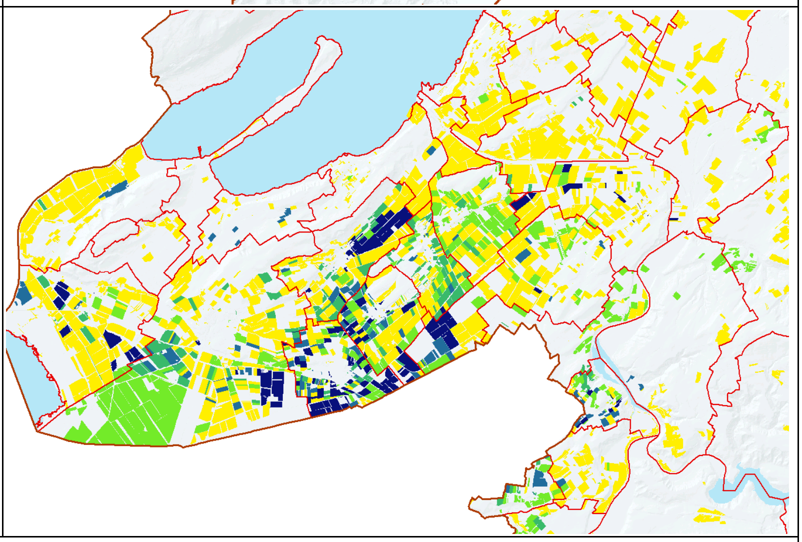
Comparison of detail



Land cover

Unprod.

Forest



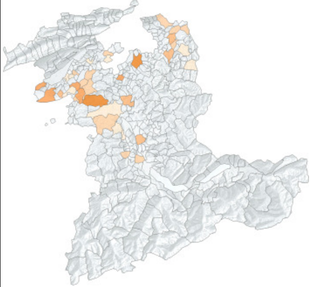
Comments: The spatial concentration of vegetable crops is more clearly evident with the new mapping technique

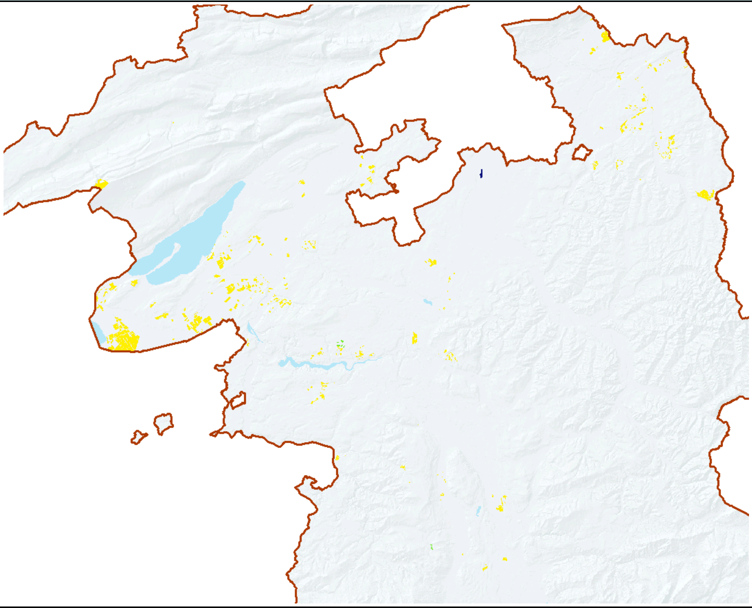
h. Biomass production crops

Proportion of biomass production crops to UAA per farm

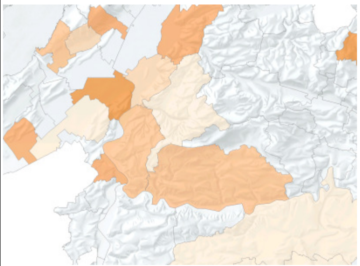
- > 0 - 0.10
- 0.11 - 0.20
- 0.21 - 0.30
- 0.31 - 0.40
- 0.41 - 0.50

Overview density per ha UAA per municipality



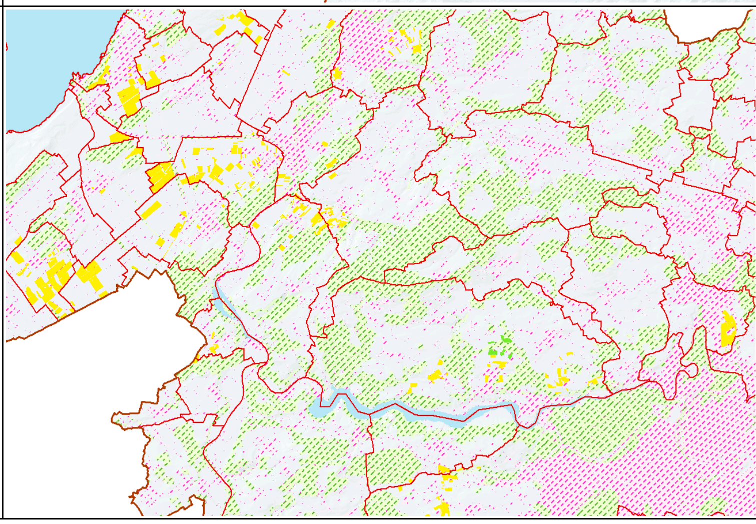


Comparison of detail



Land cover

- Unprod.
- Forest



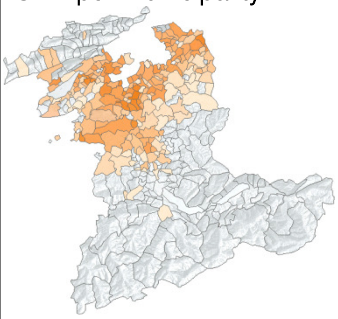
Comments: The sparse distribution and local concentration is more evident with the new mapping methods.

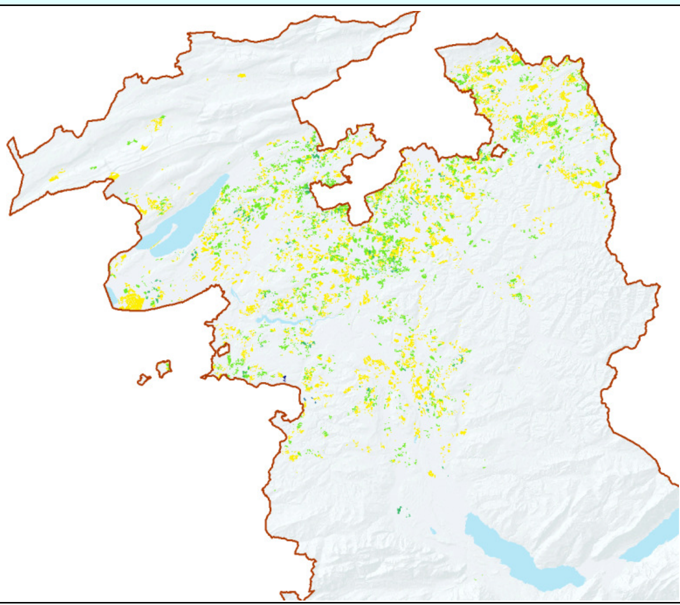
i. Rape and similar crops

Proportion of rape crops to UAA per farm

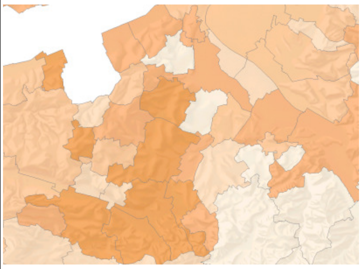
- > 0 - 0.10
- 0.11 - 0.20
- 0.21 - 0.30
- 0.31 - 0.40
- 0.41 - 0.50

Overview density per ha UAA per municipality



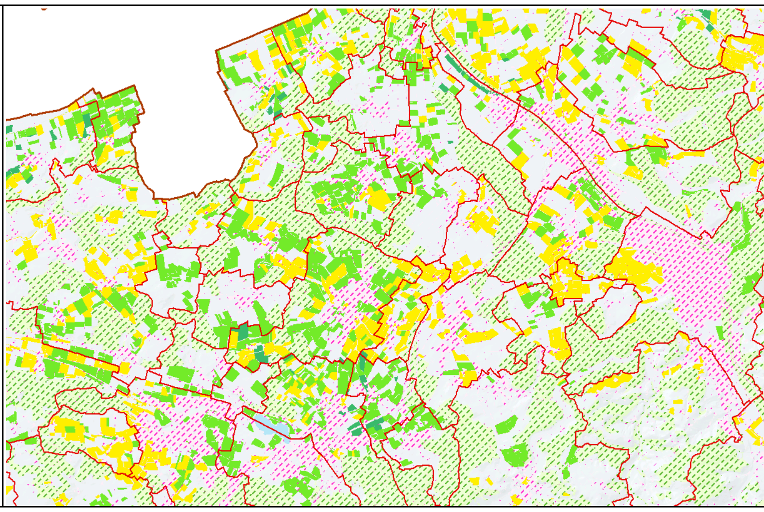


Comparison of detail



Land cover

- Unprod.
- Forest



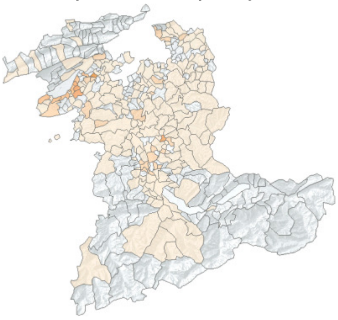
Comments: A concentration in lower lying areas and correlation with the topographical and climatical conditions is evident.

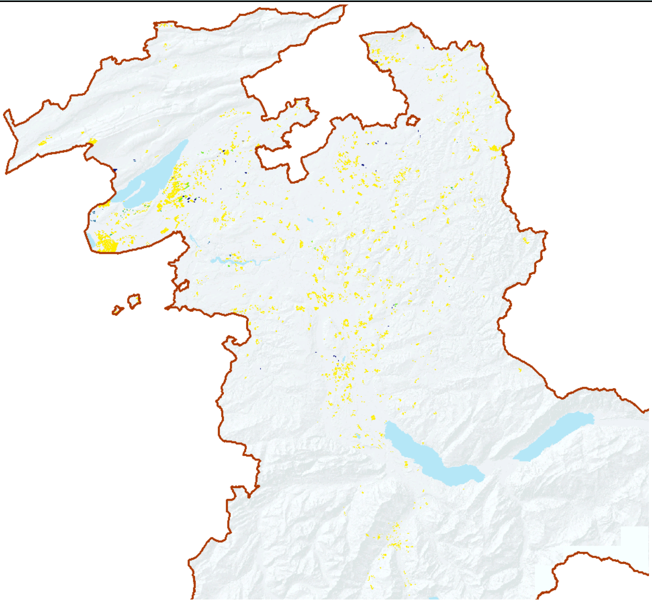
j. Fruit crops

Proportion of fruit crops to UAA per farm

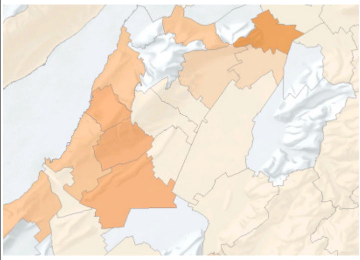
- > 0- 0.20
- 0.21 - 0.40
- 0.41 - 0.60
- 0.61 - 0.80
- 0.81 - 1

Overview density per ha UAA per municipality



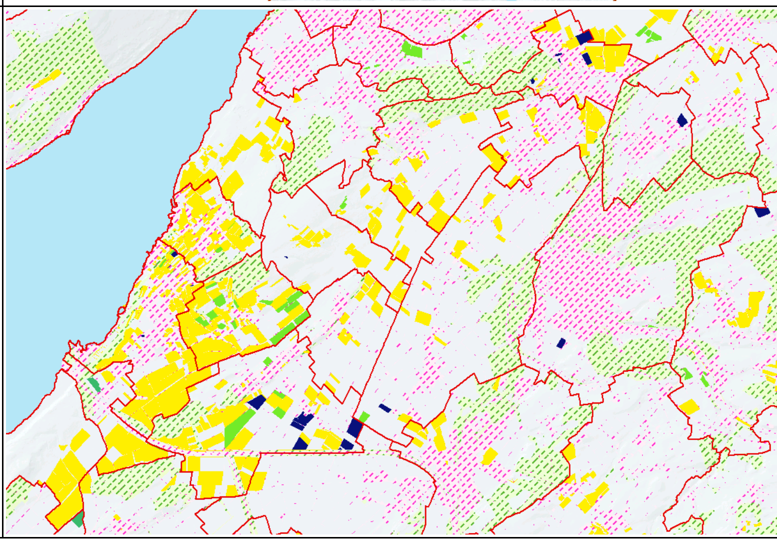


Comparison of detail



Land cover

- Unprod.
- Forest

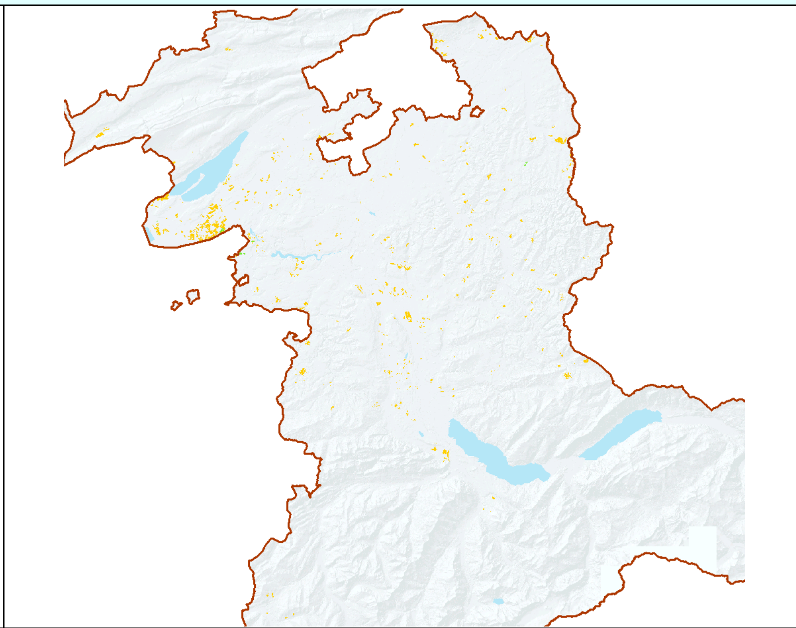


Comments: The new level of detail shows the variation in distrbution of crops and highlights the correlation with topography and climatic zones.

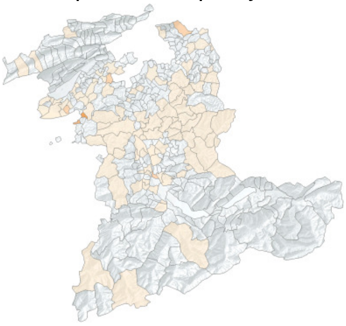
k. Covered crops

Proportion of covered crops to UAA per farm

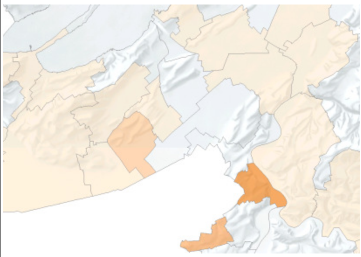
- > 0 - 0.15
- 0.16 - 0.30
- 0.31 - 0.45
- 0.46 - 0.60
- 0.61 - 0.75



Overview density per ha UAA per municipality

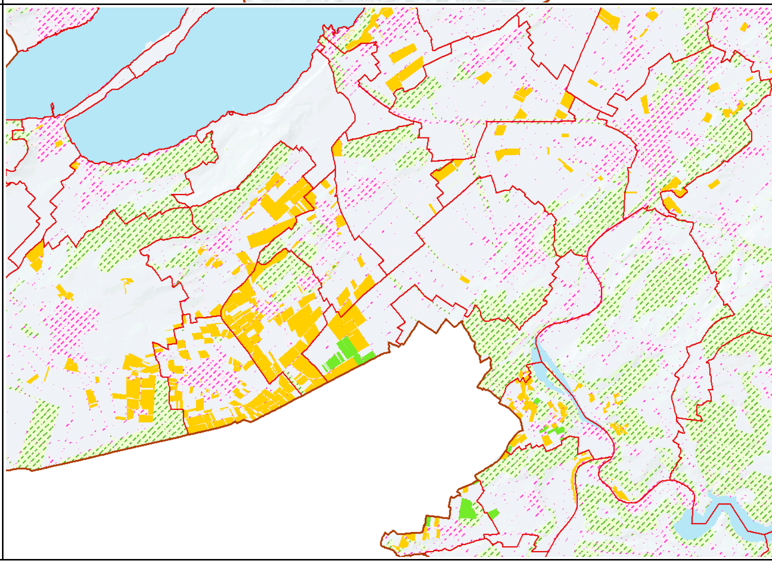


Comparison of detail



Land cover

- Unprod.
- Forest

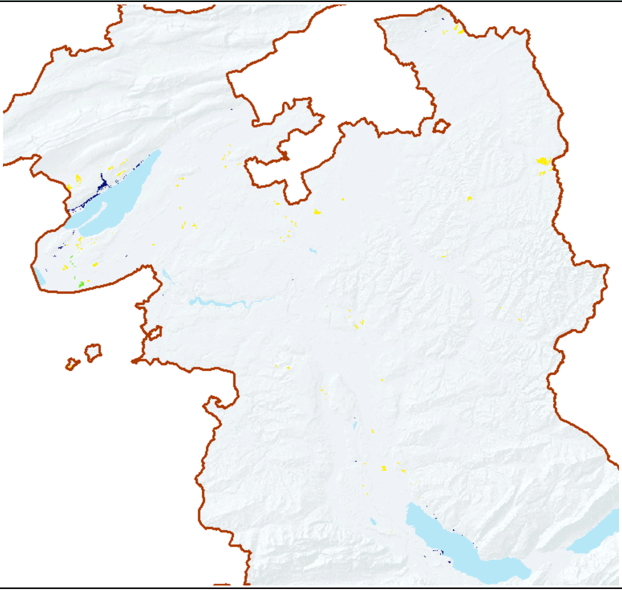


Comments: In general, these crops take up a small proportion of UAA, in the region shown in detail there is a particular concentration. The local variation is clearly evident in the new detailed mapping.

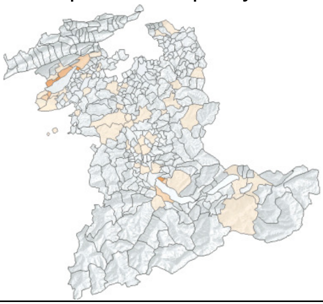
l. Vines

Proportion of vines to UAA per farm

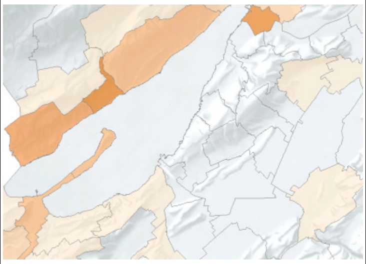
- > 0 - 0.20
- 0.21 - 0.40
- 0.41 - 0.60
- 0.61 - 0.80
- 0.81 - 1

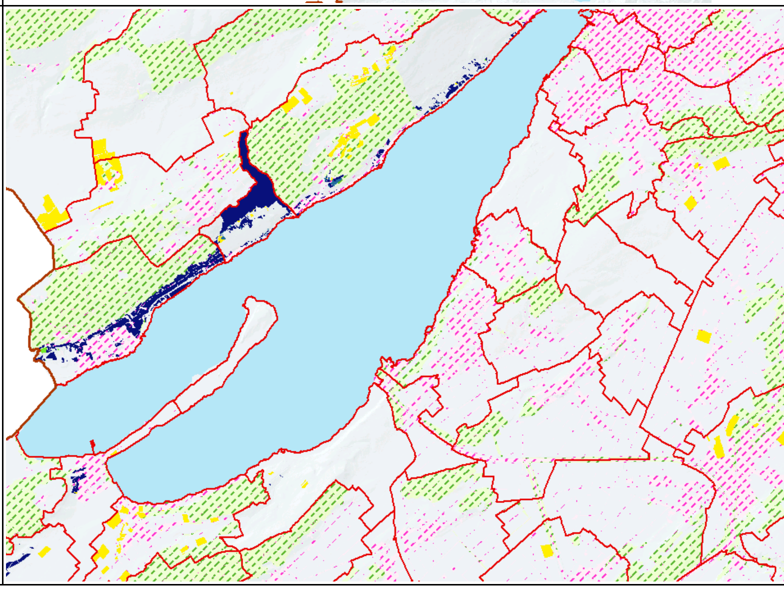


Overview density per ha UAA per municipality



Comparison of detail





Land cover

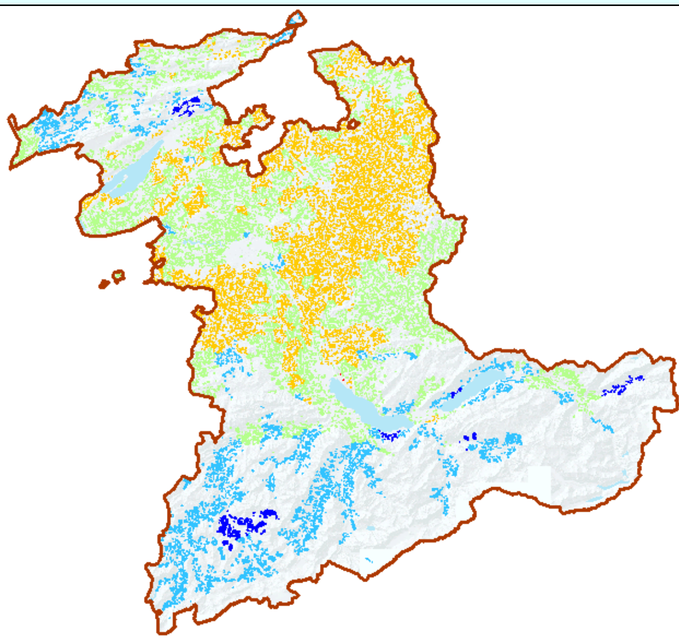
- Unprod.
- Forest

Comments: The very localised distribution is more evident with the new level of detail available.

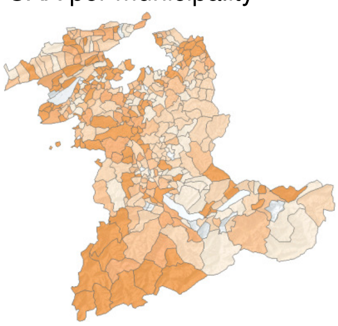
m. Grassland ECAs

Proportion of grassland ECAs to UAA per municipality

- 0.027 - 0.03
- 0.031 - 0.07
- 0.071 - 0.15
- 0.151 - 0.25
- 0.251 - 0.36



Overview density per ha UAA per municipality



<table>
<tr>
<td>Comparison of detail

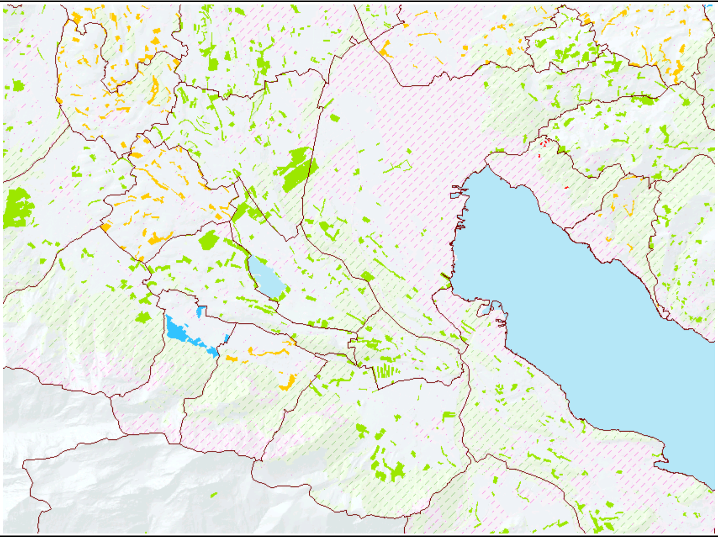
Land cover
Unprod.
Forest</td>
<td></td>
</tr>
<tr>
<td colspan="2">Comments: As grassland ECAs are available as spatial data, the effective area they cover is shown as opposed to the proportion of a farm's UAA they represent. For this reason the proportion of UAA per municipality is illustrated. The irregular scale chosen represents significant boundaries as regards direct payments eligibility (a minimum of 7%, or in certain circumstances 3%, is required). The differing proportions over the cantonal extent is evident, upland areas which are unsuitable for arable crops show a significantly higher proportion of grassland ECAs.</td>
</tr>
</table>

Table 28: Illustration of new spatially detailed mapping level

A number of examples in the table above illustrate one of the disadvantages of the only method previously available for visualisation of agricultural statistics. Mapping of agricultural statistics was only possible for data aggregated at municipality level. The effect of the residence principle employed for data gathering – whereby the statistical data is associated to where a farmer resides and not to where the land it applies to physically lies (as this was impossible until now) – on mapping that data is most illustrated in the mapping of covered crops and of grassland ECAs.

- Map k: the municipality shown in the centre of the detailed map, has no data shown on the statistical summary map. However, the georeferenced crop data shows that there is an area of farmland within its boundaries which potentially has that particular crop type on it.
- Map m: refers to the two municipality boundaries which are unshaded in the lower left section of the detailed maps. Although farmed land lies within their boundaries, as no farmer is registered as resident there, no data is shown in the statistical summary map.

These examples illustrate the advantage of the vastly improved level of detail which the mapping methods developed in this thesis provides.

The newly enabled mapping of crop groups, allows a much more detailed overview of agricultural land-use, and as such provides an indicator of agricultural intensity.

The distributions reflect the categories of climatic suitability for agriculture (refer to Figure 25).

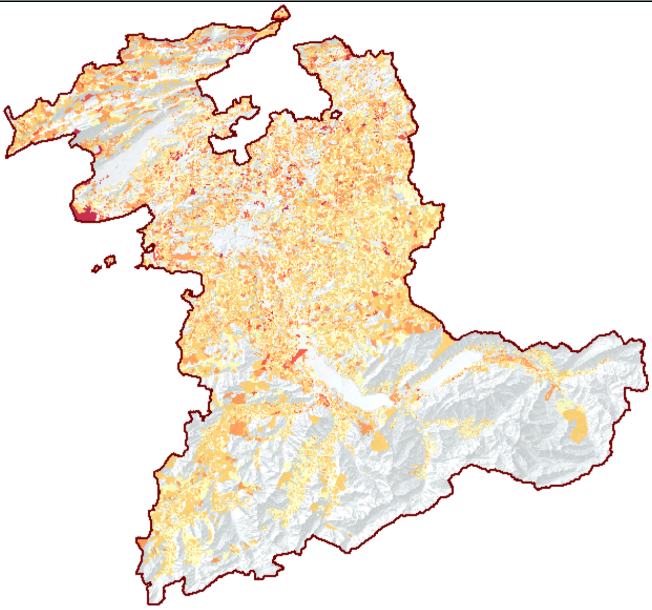
4.2.2.3 Georeferenced livestock data

This section documents the results of georeferencing statistics on livestock data and illustrates the new level of detail made available by the new method of mapping agricultural statistics. The statistics apply to an entire farm and there is presently no way of knowing which fields are used for livestock grazing. The value per farm is thus mapped on all its associated land parcels.

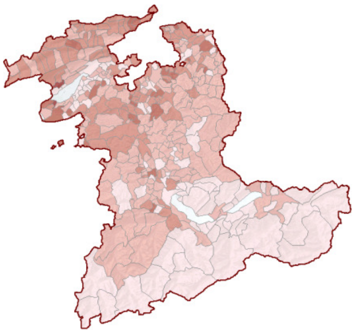
a. Livestock unit numbers

No of LU per farm

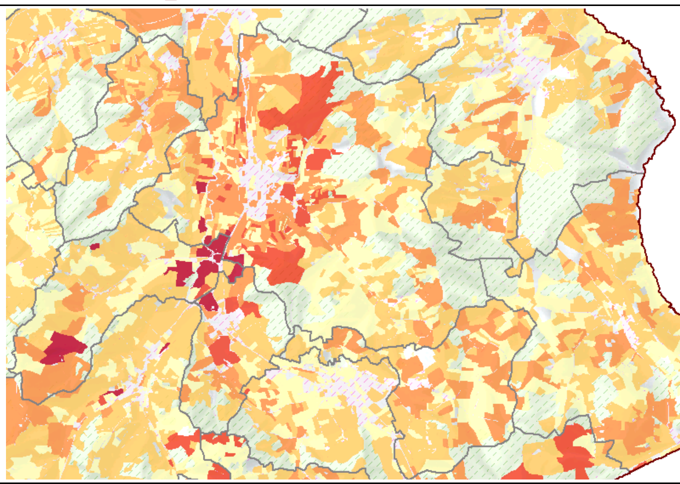
- 0.01 - 18.8
- 18.9 - 39.0
- 39.1 - 80.0
- 80.1 - 140.0
- 141 - 591.1



Overview average LU per municipality



Comparison of detail



Land cover

- Unprod.
- Forest

Comments: The overall impression of the distribution of livestock units is somewhat distorted by very high values on some large farms. Nevertheless some regional variation is visible. The detailed view shows a distinct concentration of higher livestock numbers in the region around the town of Madiswil (centre). The statistical summary per municipality provides a quite different impression of where the higher livestock numbers are to be found.

Table 29: Livestock unit numbers per farm

The mapping of simple livestock unit numbers is somewhat deceptive as regards agricultural intensity, as the available fertilizable area must also be taken into account to give a more accurate impression of the associated stocking densities. A number of larger farms with very large land holdings (e.g. state-owned farm) or high numbers of livestock units due to specialisation (e.g. large-scale poultry and pig farms).

The table below shows the density of livestock units per hectare of fertilizable land and as such gives a more accurate impression of the agricultural intensity.

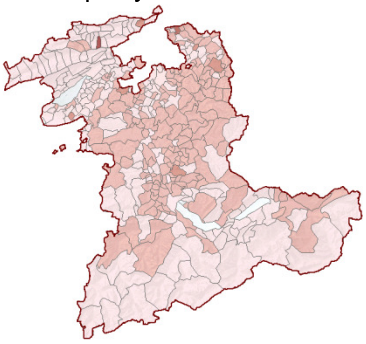
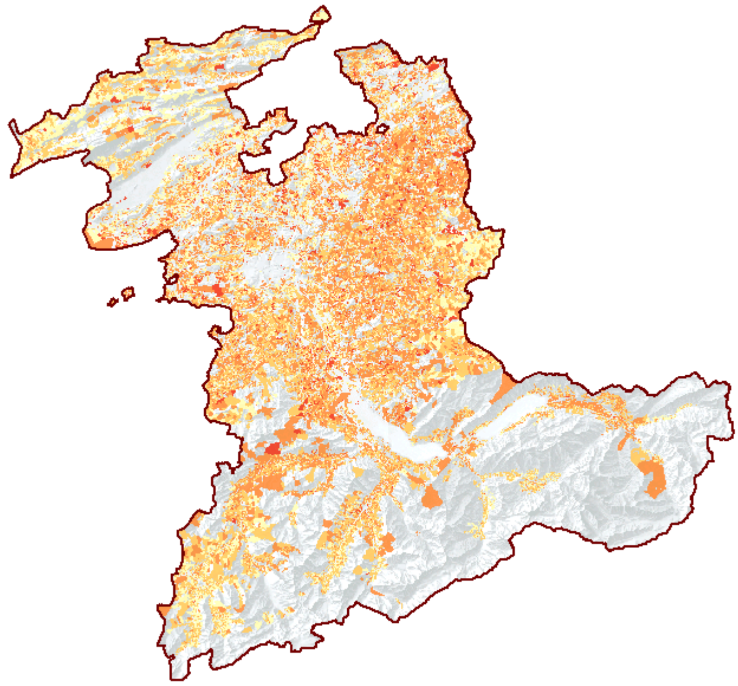
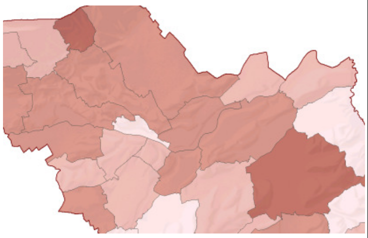
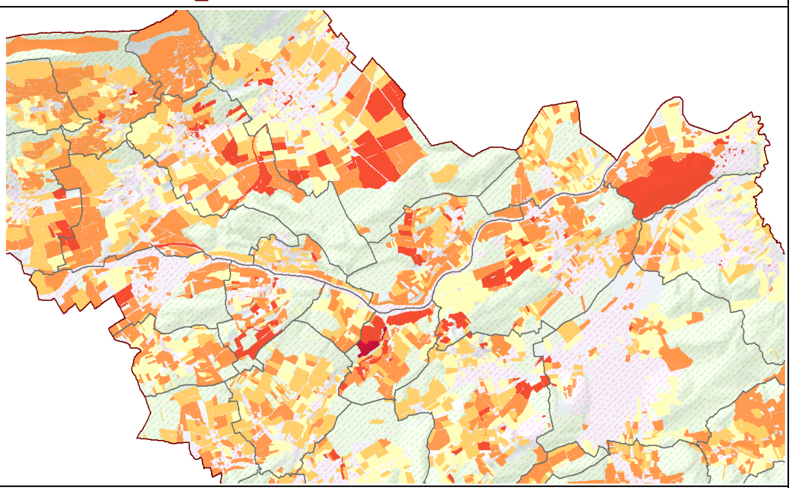
b. Livestock unit density	
No of LU per farm per ha fertilizable land > 0 - 1.00 1.01 - 1.50 1.51 - 3.00 3.01 - 15.0 15.1 - 111 Overview average LU per ha fertilizable land per municipality 	
Comparison of detail  Land cover Unprod. Forest	
Comments: The regional trend is similar in both overview maps. The detailed view highlights the increased level of detail which the new mapping method provides – the municipalities in the southeast corner show the difference between statistical aggregation and georeferencing.	

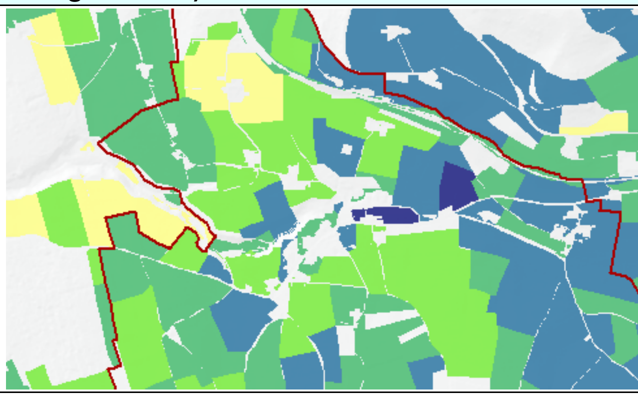
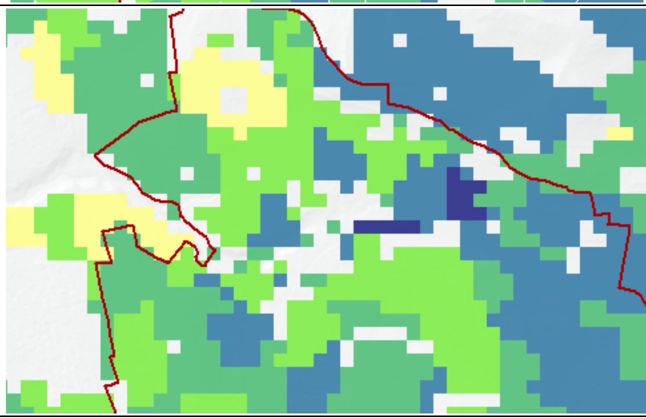
Table 30: Livestock unit density to fertilizable land area per farm

4.2.3 Exploring potential for application at small scale

Having obtained vector output from the georeferencing process for crop groups and livestock units, the use of that data at smaller scales as will be required by the Swiss Ornithological Institute was considered. The results of further analysis are presented in this section. The processes are not intended to be definitive merely exploratory and it is accepted that there are several possible approaches to generalizing the data or converting it to raster.

As preparation for conversion of the vector output to raster format, the overlaps inherent in the vector output where land parcels are associated with more than one farm had to be dealt with. The parcels, which were assigned to the extent of both farms for statistical purposes, were removed by averaging the crop group density of the overlapping farm data and assigning it to the area of overlap.

The next stage of processing was to convert the vector output to raster format as described in chapter 3.10. In order to leave the options open for any further analysis (e.g. involving further generalization), the data was rasterized at a 50m cell size – some examples of the results are shown below.

a. Crop Group D Example (permanent grassland)	
Vector output	
Rasterized output • 50m cell size • Combined maximum area per cell	
Comments: the same classification is used for the vector and raster data. Other settings for the rasterizing process are possible but combined maximum area was deemed the most accurate.	

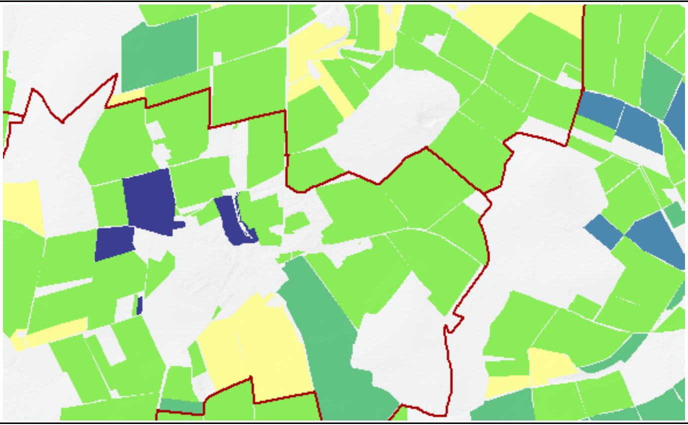
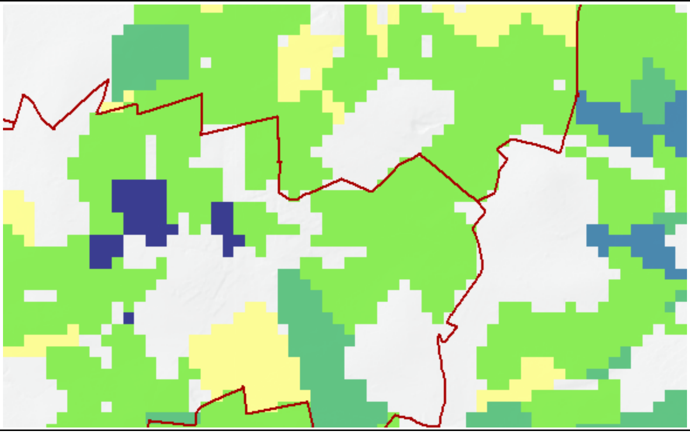
<table>
<tr><th colspan="2">b. Crop Group W Example (winter-planted cereals)</th></tr>
<tr><td>Vector output</td><td></td></tr>
<tr><td>Rasterized output
• 50m cell size
• Combined maximum area per cell</td><td></td></tr>
<tr><td colspan="2">Comments: the same classification is used for the vector and raster data. Other settings for the rasterizing process are possible but combined maximum area was deemed the most accurate.</td></tr>
</table>

Table 31: Comparison of vector and raster output

The requirement to be able to employ the output at small scales led to the decision to rasterize the vector data in order to illustrate the potential of the results. In the table below there is a reduction in detail from the original vector level of detail to the 200m raster cells, but the pattern of intensity is still evident and at a much more detailed level than the previously available maximum which the statistical aggregation to municipality level provided.

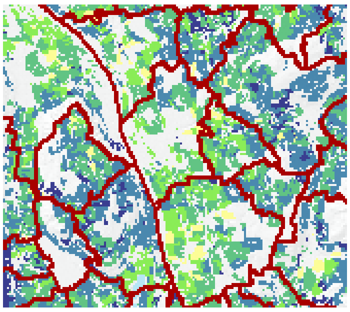
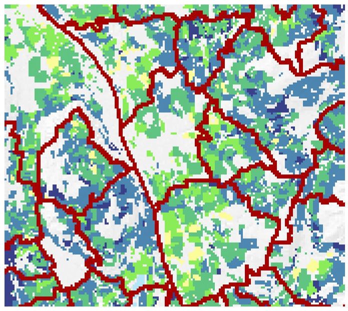
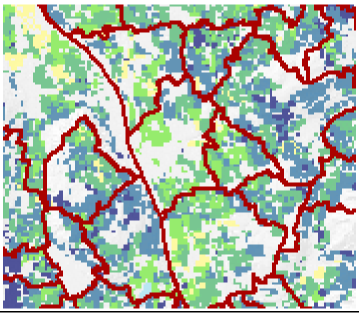
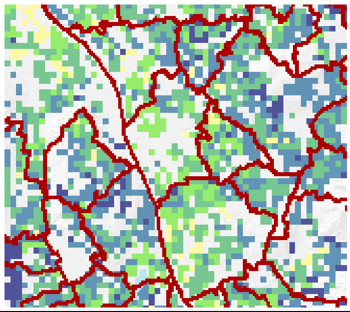
Small scale examples		
	Vector 	**Raster 50m** 
	Raster 100m 	**Raster 200m** 
Comments: the same scale and classification is used for each image – the general pattern emerges well at the lower resloution provided by resampled raster output. The raster data renders faster than the original vector data.		

Table 32: Examples of raster resampling

5 Analysis of Results

5.1 Questions posed – an analysis of success

This thesis set out to answer several questions; the success achieved and the results produced are set out below.

	Questions posed and their answers
Q1:	**Which data gathered as part of annual agricultural statistical surveys are relevant indicators of agricultural intensity?**
A:	After detailed analysis of the data collected, the data on crops grown and livestock numbers in association with utilized agricultural area and fertilizable area per farm were deemed the most relevant indicators.
Q2:	**How best can the relevant data be extracted and made available in a form suitable for further analysis?**
A:	The numerical data was most easily accessed by creating specific thematic database views. In this way the data from several physical tables could be filtered and made available in virtual tables with self-defined attribute names and including calculations if necessary. The inclusion of relevant fields enabled the data to be easily joined to the new georeferenced base. Central to success was being able to access numerical land parcel data which was used to establish a link to vector cadastral data. Through spatial aggregation of associated land parcel extents it was possible to georeference farm extent. Statistical data was then aggregated at farm level and linked to the newly defined farm extents. In this way, each crop group can be associated with a farm's extent and output in vector format. This data was then rasterized for test purposes. In this way, the methods developed in this thesis successfully provide new detailed agrarian geodata in vector or raster format and make it available for further analysis.
Q3:	**Can the data extracted from GELAN-IS provide new insight on the distribution of farmland of varying intensity?**
A:	The newly accessible data was successfully georeferenced and mapped on a cantonal scale. Patterns of varying intensity of the different crop groups and livestock data were clearly evident. The provisional data output was greeted with enthusiasm by staff at the Swiss Ornithological Institute and the emergence of significant new detail was confirmed.
Q4:	**What implications can be identified for similar work on a national scale?**
A:	If any canton maintains a link between a farm and the land parcels it actively farms, and where vector cadastral data is available and can be linked to this numerical data, the potential exists to georeference farmed land as is demonstrated in this study. The annual agricultural surveys are carried out nationally and the cantonal Offices for Agriculture are obliged to deliver the data to the Federal Office of Agricultural at regular intervals. The data must be prepared by the cantonal suppliers to comply with the structure required by the official federal interface and as such is basically available in the same format at a national scale. If a method could be developed to read this data format it could be made available for georeferencing in the way it was used in this thesis.

Results Level I

The methods developed enabled the successful georeferencing of relevant agricultural survey statistics. A large proportion of registered farmed land parcels in GELAN-IS were successfully linked to the vector cadastral data and by means of their association to one or more farm holdings, the spatial extent of farms could be mapped for the first time. The extent of all land parcels associated to a farm were aggregated to multipart features providing one GIS feature per farm holding – where land parcels are farmed by more than one farmer, these are duplicated and included in the extents of the individual farms.

The rate of success achieved in this phase was higher than anticipated and the fact that more and more cadastral data is becoming available bodes well for the potential of success on a larger scale. Nevertheless, the success of this phase is central to the whole process of georeferencing agricultural survey statistics and successful employment of the methods developed in this thesis depend on success in this phase and thus on the availability of suitable vector cadastral data.

It is also quite common that any given land parcel is farmed to varying extents by several individual farmers (see chapter 3.10). The fact that more than one farmer can share the same land parcel, and hence declare it in the agricultural surveys, is the cause of one of the inherent inaccuracies in this process. As no spatial delimitation of where on a shared parcel a farmer has his land is possible, these parcels (8% of farmed parcels in Ct. BE) are duplicated and assigned to all associated farm holdings. This is only significant at large scales and may require some adjustment as to how the layers are displayed. A method was also tested in this study to obtain a single value for any given area by identifying overlaps and averaging the values of overlapping farms for those areas. This averaged figure was then employed as the value for conversion to raster.

The flexibility and processing efficiency of FME and its adaptability for testing were central to the success of the processes in this phase.

Results Level II

Methods were developed to reduce the basic extent of land parcels to the extent of the potentially actively farmed land they contain and thus to the extent of farmland which is used for crop growing and livestock grazing. Using standard geoprocessing techniques, the official land cover data was overlayed with the farmed land parcel extents and only land attributed to eligible categories was retained. Ecological compensation areas already exist in spatial form for Canton Berne and these were also integrated into this process to some extent. Where land is given over to ECAs it is not used for intensive agricultural land-use and hence should be excluded from the farmland potentially given over to crops or livestock grazing. These processing steps led to the originally georeferenced farmland extent being significantly reduced as for example woodland or roads were subtracted. Although some land parcels are registered to active farms, they are often wholly or partly given over to other types of land-use other than active arable or livestock farming, and as such should not be attributed to the extent of land used for intensive farming practices.

Although not all cantons have their ECAs available in spatial form, where data is available it increases the precision of the output and can be regarded as an optional input. The availability of high precision land cover data for Canton Berne contributed to the accuracy of the output. This data can also be regarded as an optional input to the whole process, where it is available results are accurate to a higher level of detail.

Farmed land parcels are stored in the Gelan database with details on how much of the parcel area is actually farmland as well as how much of each land parcel is farmed by individual farmers. Farmers declare how much of any parcels they farm are given over to the three land-use categories of land, unproductive and forest. This information allows the exclusion of land parcels which are not farmed even though they are registered to an active farm – thus reducing the maximum potential area used for arable farming and livestock grazing. If a minimum area of 'land' was defined for inclusion in the farm's georeferenced farmland base, the overlapping problem might be slightly reduced and a farm's extent could be refined even if vector land cover data was unavailable. Only minor improvements in output quality for Canton Berne's data are to be expected by including such a step, but it might be significant for other cantons where vector land cover data is not available to the same extent as vector cadastral data.

The geoprocessing efficiency of ArcGIS 10 was central to the success of those processes employed in this phase.

Results Level III

The third level of results applies to the success of extracting the relevant statistical data and finding a means of georeferencing it. After analysing the content of the annual agricultural surveys and identifying which data was relevant in any assessment of the agricultural intensity, a means of extracting it in a suitable form from the Gelan database was found. The creation of database views to combine the relevant attributes from several physical database tables into theme-based virtual tables proved to be the best method to facilitate access to the numerical data held in GELAN-IS.

Once the database views were created, it simplified access to the data for the GIS tools and it was possible to experiment freely with the content. This facilitated the development of processes to link the numerical data to the spatially defined farmland extent, and therefore, to effectively georeference the statistical data per farm.

Working closely with the Swiss Ornithological Institute, it was decided that the most effective way to work with the long list of registered crop types was to aggregate them into groups with similar characteristics and work with those. This was achieved and 16 crop groups defined. If in the future there should be any requirement to change the allocation of individual crops to the groups or to combine groups, this can be quite easily achieved due to the way the georeferencing processes were designed.

In order to best access the data on livestock numbers, it was decided that the most appropriate technique allowing comparison between different categories would involve the standardised livestock unit (LU).

The crop statistics and livestock data were summarised per farm holding into thematic database views and this data was subsequently joined to the refined land parcel data which was pre-aggregated per farm holding. All farms are identified by unique IDs and this is included in the database views and also in the farm extent features and facilitates the joining of the numerical to the spatial data.

As mapping the total area of a crop group per farm provides no indication of how much of a farm's land is given over to that particular group of crops, the proportion of UAA per farm was calculated by dividing the aggregated crop group area by the total UAA. Output in this form enables easy comparison of the density of the different crop groups. A feature class per crop group was output and the data was successfully mapped for the extent of the canton where a georeferenced base was available. Details of the new level of spatial detail and a comparison with the output from previous methods of mapping agricultural survey statistics are illustrated.

In order to map the livestock data, once again density was chosen – this time the proportion of fertilizable land to the number of LUs per farm – and used to represent the differences between farms and regions. A feature class with the density value for farms with LUs was output for Canton Berne.

As is to be expected, the distributions of the various crop groups show correlation with mapped data on precipitation and sunshine duration (MeteoSwiss, 2010) and also with the data on climatic suitability for agriculture (see Figure 25). The data provide a valuable new resource for any studies in farmland habitat potential. They no longer have to rely on extrapolated inputs such as generalised climate data or zones suitable for specific crop types, or on generalised inputs such as aggregated agricultural statistics per municipality but have effective data at a very high level of detail.

Comparisons of the distribution of farmland bird species as documented in the Swiss Atlas of Breeding Birds (Schmid *et al.,* 1998) with the distribution of important crop groups could reveal areas of high potential for certain species and thus serve as important input for conservation projects targeting improving conditions for typical farmland birds.

Results Level IV

Although the focus of this thesis was on the data for Canton Berne held in GELAN-IS, the intention was always to consider potential at a national scale. Indeed, the principles and content involved apply to data which is included in the standard data deliveries from the cantons to the Federal Office of Agriculture. Hence the success here can be viewed as indicating the potential offered for being able to adapt the technique for use on a national scale. Whether or not it is possible to georeference a particular canton's agricultural survey statistics using the basic principles employed in this study, is dependent on the availability of suitable vector cadastral data and on being able to establish a link between that data and a farm's associated land parcels.

5.2 Shortcomings

As is only to be expected, there are some shortcomings in this study and these are discussed in this section.

One obvious shortcoming of the technique described, is its dependency on the availability of vector cadastral data. As a result, agricultural survey statistics can not be adequately georeferenced where vector cadastral coverage is lacking, where the link between parcel and farmer is non-existent or where the link between numerical parcel and vector parcel can not be established.

Despite being a vast improvement on what was possible until now, the fact that the statistics are mapped onto the total extent of the eligible farmland on all land parcels associated with any particular farm holding, can lead to some slightly misleading mapping. For instance, where a farm's land is widely distributed – with some at altitude or in different climatic zones – all crops grown on that farm are mapped to it meaning some incongruent examples with high altitude vines or cereals are part of the current output. However, as such examples form the exception rather than the rule they do not detract significantly from the results.

With respect to the applicability of the methods employed to other cantons, the following factors show where some limitations lie:

- not all cantons store their data with the link from farm to farmed land parcels;
- the extent of potential coverage is limited by the availability of vector cadastral data and being able to link that to numerical data;
- the federal data delivery interface is in transition to XML format – to apply the techniques effectively at a national scale it would be most efficient to be able to use these XML data deliveries as input to the georeferencing process, which would require process adaptation but offers significant potential;
- for historical data a method of accessing national data in the form used until 2011 would be required;
- the question of data access including data protection aspects needs clarification.

The fact that the output is not refined to a single layer as a general indicator of agricultural intensity could be seen as a shortcoming. However, with respect to the requirements of the Swiss Ornithological Institute, this is not the case as monofactorial output allows the recipient maximum freedom for further analysis.

The aspect of language, which writing about a subject in English where the working language of the data environment is German, should also be mentioned. As a consequence some abbreviations or terminology are perhaps not completely logical in English and certain attribute names or table names are not translated.

6 Summary, Discussion and Outlook

6.1 Summary

The objectives of this thesis were to explore the potential within the GELAN-IS agrarian information system for the spatial implementation of its numerical contents. Through intensive data analysis and the development of appropriate georeferencing processes a method was developed to successfully link agricultural statistics gathered at individual farm holding level to the spatial extent to which they apply.

The first challenge was to find a means of extracting relevant data from a complex agrarian database storing agricultural survey statistics. Although data are held in the system for three cantons (Berne, Fribourg and Solothurn), the analysis concentrated solely on establishing a method for exploiting Canton Berne's data. Methods were successfully developed to isolate and extract the relevant numerical data and then to georeference it.

Of a total of 126,113 land parcels registered to Bernese farms in 2010, 93.9% of those were georeferenced by linking the numerical data to the vector cadastral data. The small proportion of farmed land which cannot be located by this means is considered not to be significant. After discussion with the Swiss Ornithological Institute it was decided that the success rate with cadastral data was sufficient and no further data need be integrated.

As a result of the effective georeferencing of farmed land parcels, 164,860 ha (88.3%) from 172,701 ha registered farmland were successfully georeferenced. This new base map of georeferenced farmed land parcels was then successively reduced to the extent of potential farmed land within that by removing areas of ineligible land cover categories from the georeferenced perimeter. The resulting dataset delimits the extent of farmland per farm holding and serves as a base on which to distribute the statistical data.

Detailed analysis of the agricultural survey content ensued to identify relevant agricultural statistics for georeferencing. In this case, data on crops grown and livestock held per farm holding were deemed relevant indicators of agricultural intensity. Further examination of the database content showed over 200 different crop categories were valid for 2010. Working together with the Swiss Ornithological

Institute, a method of aggregating the many individual crop types registered in the GELAN-IS into groups of crops with similar characteristics from the point of view of attractiveness for bird populations was developed. The statistical crop data held per farm holding was then aggregated into the 16 newly defined crop groups for the further stages of processing.

Canton Berne's crop data as a proportion of utilized agricultural area (UAA) per farm and livestock units per hectare of fertilized land were thus successfully georeferenced at farm holding level from annual agricultural survey statistics. The crop groups were mapped individually to suit the requirements of the Swiss Ornithological Institute, whose preference was for monofactorial output, allowing them the most scope for their own experimentation with the resulting data. Thus the aim of making the numerical data available in a spatial form suitable for further analysis was successfully fulfilled.

The methods developed in this thesis have allowed the mapping of agricultural survey statistics at a much more detailed level than was previously possible by aggregation of the numerical data per municipality. This makes the agricultural survey statistical data – which for Canton Berne stretches back to 2000 in its present structure – accessible for meaningful mapping and geospatial analysis for the first time. The techniques developed take account of the need to provide fine-grained detail as this can be significant for conservation planning.

Some of the problems faced were with handling the very large amounts of data available for Canton Berne and in finding ways of identifying a representative statistic to map at cantonal scale. A huge gain in the level of detail has been made by the mapping methods developed for this thesis, and through a combination of the individually mapped layers the base has been laid for the development of spatially explicit indicators of agricultural intensity.

6.2 Discussion

Most commonly, the visualisation of regional statistical values is carried out on the basis of administrative or organisational boundaries. The use of administrative units is an inadequate means of representing the distribution of many types of spatially relevant numerical data as often large parts of the geographical area do not apply to the statistics being visualised. This in turn can have a significant effect on the outcome – e.g. the mapping of agricultural statistics in an area with a large proportion of non-farmed land area can give a false impression of overall low density. While the results of this thesis illustrate the weaknesses of this method, they also go some way to remedying the situation with regard to agricultural survey statistics, or indeed any other statistical mapping with a farmland base. The visualisation of the results in raster form (possible at varying resolution) as opposed to aggregation to administrative units, generally gives a spatially more representative impression of reality than the classical regionalised view (Wonka *et al.,* 2007), thus facilitating improved comparability of regions independent of the size of administrative units

On the whole, the high success rate achieved in georeferencing farmed land parcels – the foundation for accessing agricultural survey statistics from a spatial point of view – was encouraging and confirmed the potential this thesis was seeking to exploit. Despite the large data quantity involved, the step-by-step process development was eased by being able to employ several powerful geoprocessing tools. The advantages of FME Workbench for flexible process development and testing were key to progress. Where FME was less practical for a process step, ArcGIS was often better suited, and vice versa, leading to relatively few troublesome technical hurdles. The uncomplicated access to the business data and to a variety of powerful software which my position with Gelan Informatik provides were significant advantages in facilitating the analysis this thesis required. The proximity to knowledgeable colleagues was a further benefit to examining a topic in my work environment.

One further positive aspect was being able to present the first results to the Swiss Ornithological Institute – the intended beneficiary – and receive their positive and constructive input at different stages in the process. Being able to work towards providing a new source of information to studies in the field of ornithology was also a motivating factor. The chance to open the door to a vast amount of relevant statistical data as yet barely exploited but potentially relevant in numerous areas was an additional encouragement.

There were also several positive side-effects of note. From a technical point of view, a few more aspects of the incredibly powerful combination of FME Workbench and ArcGIS were encountered. From the core business point of view, I gained knowledge of the database structure which will serve me well in the future. From a project development point of view, some of the processes, data output and experience gained will be valuable in upcoming projects involving online digitising of the extent of farmed land and certain crops and are to some extent already being employed.

At the outset, before the Swiss Ornithological Institute was involved and able to appreciate which data were stored in GELAN-IS, the development of a combined indicator of intensity appeared a feasible aim. Once the potential, scale and limitations of the data content were further examined and discussed with the Swiss Ornithological Institute, it became apparent that the first phase of data exploitation required development of a means of numerical data aggregation. The first successfully georeferenced output highlighted the potential which a more monofactorial approach could expose. The advantages this would offer the Swiss Ornithological Institute were deemed significant as such data could theoretically be employed in a variety of ways and serve as a new more detailed form of input for their established mapping and geostatistical analysis.

Examination of the first basic output met with an enthusiastic response and it became evident for the first time how patterns of farming emphasis might emerge from the new detailed mapping possibilities. Tests with pilot regions and crop grouping confirmed the potential within the data and the processes were refined. At this point, it was decided that the most gain would be made for the Swiss Ornithological Institute by working with the detailed monofactorial output and using those layers in various combinations depending on the specific requirements in any project. It was considered that designing a new GIS layer as an indicator of agricultural intensity in the context of the requirements of the Swiss Ornithological Institute, would not be feasible without much more detailed analysis including integration of their own field data. Depending on the particular emphasis of any research, the relevance of the different crop group and livestock data layers would vary and thus finding a practical recipe for one new GIS layer as an indicator of agricultural intensity was not considered expedient.

Of course, any discussion of the results achieved with this thesis must also consider the shortcomings (for details refer to chapter 5.2). The dependency of the methods developed on the availability of vector cadastral data and the limitations this currently imposes where data is not available will become less significant in the coming years. Data coverage is growing and coordinated efforts at federal level (GeoIG) will see a significant growth in spatial data availability. Farmland will be directly mapped in years to come and agricultural survey statistics will be linked to the new base. However until then, the methods developed in this study will allow new spatial insights into current agricultural statistics and to some extent allow mapping of historical data.

Although in the end it was unfeasible to produce a single layer as an indicator of agricultural intensity as was originally considered and as hoped for by the Swiss Institute of Ornithology, significant inputs towards the establishment of such a layer have been made available in spatial form for the first time. New fine-grained output of crop and livestock data provides significant new data (e.g. livestock density on any given area of farmland) which they hope to incorporate in their own spatial correlation analyses.

Finally, it should also be noted that knowledge of the available data and awareness of its potential, as well as the ability to access it freely for the purposes of this study, were benefits of my position with Gelan Informatik within the Office for Agricultural and Nature of Canton Berne. As a result of work on this thesis, the general potential held within numerical agricultural survey statistics in Switzerland can be exposed to a wider audience and will provide an important new data source for interested parties.

6.3 Applicability to other Cantons

Providing that agricultural survey data are stored with reference to a farm's land parcels (be that directly per land parcel or indirectly as a list of land parcels per farm as in the case of GELAN-IS) and cadastral data exists in a georeferenced vector format, it is theoretically possible to georeference agricultural survey statistics as described in the foregoing chapters.

The Offices for Agriculture from the individual cantons are obliged to make data exports from their management systems and deliver them at regular intervals in a form compatible with the interface provided for the purpose by the Federal Office for Agriculture (FOAG). The data content and structure is defined by FOAG and the data is delivered as text files at regular intervals. There are three categories of data which the cantons are required to deliver: register data containing details of farm structure; production data containing details of crops planted and livestock held; payment details calculated from the production and other data at rates defined in the payment calculation model.

At the time of writing, the format of this data exchange process is in transition and will soon be fully defined in XML format. The data exchanged with the federal government in this way has a data structure consistent over the entire country and as such offers considerable potential if the methods outlined in this thesis are to be applied on a broad or nationwide scale. Ongoing efforts to establish a nationwide cadastral geodataset also contribute to the potential of this approach. The possibility of applying the approach used in this study is a very attractive one from the point of view of the Swiss Ornithological Institute. The scope of their work and the habitat of bird populations affected by farming practices are nationwide topics.

6.4 Future Perspectives

As far as future perspectives are concerned, there are numerous ways in which this study will be built upon or could potentially be extended.

Some of the output from this thesis has already been employed in a major current project being undertaken by Gelan Informatik. The first steps towards digitizing the limits of farmed land and of certain crop groups are currently being undertaken and the process of linking vector cadastral data to the numerical data per farm as developed in this thesis has been employed as inputs for the first phase of development. Some of the knowledge gained with recognition of certain difficulties which can be encountered will also be valuable as the project develops.

As the methods of managing data on direct payments evolve and the emphasis lies increasingly on spatial data, more and more agrarian data will become available for spatial analysis. Techniques developed in this thesis could easily be adapted to take account of new spatial data inputs.

The integration of nutrient balance information would be of interest to many of those wishing to employ the new geodata base this thesis provides. Although the data is gathered per farm holding, it is not known to what extent the data on nutrient balance is available in digital form. If this data could be included and thus georeferenced, it would significantly enhance the role of the new dataset as an indicator of agricultural intensity.

The ever increasing availability of vector cadastral data also contributes to the growing potential which can be offered by georeferencing agricultural survey statistics. Although the techniques in this thesis were developed on the basis of data from 2010, they can be easily adapted to georeference statistics from previous years where the data is stored in the same structure. Tests were in fact carried out for certain phases with data from 2005. This would facilitate the analysis of change in crop distributions and livestock numbers over time and would be of interest to the Swiss Ornithological Institute, allowing them to relate field surveys to agricultural data at a high level of detail for the first time. The availability of vector cadastral data has increased significantly in recent years, and any work with historical data will potentially have a reduced parcel base to work with. It may be feasible to integrate non-contemporary vector data where it has remained stable (e.g. where no land re-allocation has taken place) in order to increase coverage.

One aspect which was briefly touched upon, involves the potential for further analysis and perhaps raster processing which the new geodata this study provides offers. The combination with the existing geodata on ECAs could be employed to analyse the density or distribution of for example hedges or orchards, or their proximity to other important features. Crop diversity could also be analysed to some extent from the study data – this would allow analysis of general trends over the last decade. The flexibility of the data produced makes detailed data available for use at large scales, while aggregation of the data makes it available for analysis/mapping at smaller scales. The Swiss Ornithological Institute is interested in applying moving window analysis to the output.

An important consideration is the potential of the methods developed for use on a national scale. If the regular data deliveries (AGIS data) which cantons are required to make to the federal government could be exploited, the door would be opened for potential application at a national scale. If a means of integrating the data which is delivered in a standard XML format could be found, the principles could theoretically be applied on a national scale dependent on the availability of suitable cadastral data. Efforts are also being made to establish a centrally held dataset of national cadastral data – a development which would help the georeferencing of agrarian data on a national scale as a standardised format of cadastral data would be available for all cantons.

As far as further potential is concerned, there are numerous areas in which the data or methods from this study could feasibly be built upon. For example, the concept of "High Nature Value farmland" (HNV) could also be integrated into further research using the new geodata source this thesis provides. The data could serve as spatially explicit input to the assessment of HNV potential. It could also be interesting to integrate 3D data into the process in order to further refine or analyse the distribution of farmed land using information on altitude, slope or aspect.

Bibliography

Agridea, FOAG (2010): *Wegleitung Suisse-Bilanz 2010*. [online] Available at: http://www.blw.admin.ch/themen/00006/00049/01163/index.html?lang=de&download=NHzLpZeg7t,lnp6I0NTU042l2Z6ln1acy4Zn4Z2qZpnO2Yuq2Z6gpJCEdnx_gWym162epYbg2c_JjKbNoKSn6A [Accessed: 4 August 2011]

VON Arx, G., Bosshard, A. and Dietz, H. (2002): Land-use intensity and border structures as determinants of vegetation diversity in an agricultural area. *Bulletin of the Geobotanical Institute ETH,* **68,** pp.3–15 [online] Available at: http://www.geobot.umnw.ethz.ch/publications/periodicals/download/68_03_vonArx.pdf [Accessed: 4 August 2011]

Backhaus, R., Weiers, S. (2000): Der Raumbezug von Nachhaltigkeitsindikatoren. *TA-Datenbank-Nachrichten,* vol. **2**, pp.53-56. [online] Available at: http://www.itas.fzk.de/deu/tadn/tadn002/bawe00a.htm [Accessed: 7 August 2011]

Báldi, A., Batáry, P. and Sarolta E. (2005): Effects of grazing intensity on bird assemblages and populations of Hungarian grasslands. *Agriculture, Ecosystems and Environment* **108,** pp.251–263. [online] Available at: http://www.nhmus.hu/~baldi/Baldi%20AGEE%20grazing%20intensity.pdf [Accessed: 10 August 2011]

Báldi, A. and Sándor, F. (2007): Long-term changes of farmland game populations in a post-socialist country (Hungary). *Agriculture, Ecosystems & Environment,* **118**, (1-4) pp.307-311. [online] Available at: http://www.sciencedirect.com/science/article/pii/S0167880906001800 [Accessed: 20 August 2010]

Bas, Y. (2009): Nesting strategy predicts farmland bird response to agricultural intensity. *Agriculture, Ecosystems and Environment* **134**, (3-4), pp. 143-147.

Benedetti, R., Bee, M., Espa, G. and Piersimoni, F. (2010): *Agricultural Survey Methods*. Chichester, West Sussex: Wiley. Available at: http://www.gbv.de/dms/zbw/617735220.pdf [Accessed: 02 October 2011]

Berry, J.K. (2007): *Beyond Mapping III: Procedures and Applications in GIS Modeling.* Published by Berry & Associates // Spatial Information Systems, Inc. [e-book] Available at: http://www.gbv.de/dms/zbw/617735220.pdf [Accessed: 02 October 2011]

BFS (2011*): Arealstatistik – Bodennutzung und Bodenbedeckung.* Available at: http://www.bfs.admin.ch/bfs/portal/de/index/themen/02/03/blank/data/gemeindedaten.html [Accessed: 2 October 2011]

BFS (1998): *Swiss Land Use in the European Context - Integration of Swiss Land Use Statistics with CORINE Land Cover*. [PDF] Available at: http://www.bfs.admin.ch/bfs/portal/de/index/dienstleistungen/geostat/datenbeschreibung/corine_land_cover.parsys.0003.downloadList.00031.DownloadFile.tmp/eh501.pdf [Accessed: 2 October 2011]

Birrer, S., Kohli L. and Spiess M. (2007): Haben ökologische Ausgleichsflächen einen Einfluss auf die Bestandsentwicklung von Kulturland-Vogelarten im Mittelland? *Der Ornithologische Beobachter* **104**, pp.189-208.

de Smith, M.J., Goodchild, M.F. and Longley, P.A. (2011): *Geospatial Analysis: A Comprehensive Guide to Principles, Techniques and Software Tools.* (3rd Edition), The Winchelsea Press, Winchelsea. [e-book].
Available online at: http://www.spatialanalysisonline.com/output/ [Accessed: 2 October 2011]

Donald P.F., Sanderson F.J., Burfield I.J. and Bommel, F.P.J. (2006): Further evidence of continent-wide impacts of agricultural intensification on European farmland birds, 1990-2000. *Agriculture, Ecosystems and Environment* **116,** (3-4), pp.189-196.

Doxa, A., Bas Y., Paracchini M.L., Pointereau P., Terres, J-M. and Jiguet F. (2010): Low-intensity agriculture increases farmland bird abundances in France. *Journal of Applied Ecology* **47**, pp.1348-1356, [Accessed: 5 August 2011]

Durr, P.A., Froggatt, A.E.A. (2002): How best to geo-reference farms? A case study from Cornwall, England, *Preventive Veterinary Medicine* **56**, (1), pp.51-62. Available at: http://www.sciencedirect.com/science/article/pii/S016758770200123X [Accessed: 6 August 2011]

Eurostat (2001): *Towards agri-environmental indicators – Integrating statistical and administrative data with land cover information.* (Topic report No 6.) [online] Available at: http://reports.eea.eu.int/topic_report_2001_06/en/Topic_6_2001.pdf [Accessed: 6 August 2011]

FAO (2006): *European Union accession and land tenure data in Central and Eastern Europe* [Pdf] Available at: ftp://ftp.fao.org/docrep/fao/009/a0464e/a0464e00.pdf [Accessed: 2 October 2011]

FOAG (2011): *Direktzahlungen (inkl. Erhebungsformulare)* [online] Available at: http://www.blw.admin.ch/themen/00006/ [Accessed: 29 September 2011]

Geiger, F. *et al* (2010): Landscape composition influences farm management effects on farmland birds in winter: A pan-European approach. *Agriculture, Ecosystems and Environment* **139**, pp.571-577. Available at:

http://www.uam.es/personal_pdi/ciencias/jonate/Investigacion/ASCI/ASCII-17.pdf [Accessed: 3 August 2011]

GELAN (2011): *Wegleitung: Agrardatenerhebung 2011 (Frühling)* [online] Available at: http://www.gelan.ch/images/content/erhebungen/fruehling/2011/Gelan.WGL2011web.dt.pdf [Accessed: 30 September 2011]

Grandgirard, D. and Zielinski R. (2008): Land Parcel Identification System (LPIS) Anomalies' Sampling and Spatial Pattern – Towards convergence of ecological methodologies and GIS technologies [online] (JRC Scientific and Technical Reports) Luxembourg: Office for Official Publications of the European Communities. Available at: http://publications.jrc.ec.europa.eu/repository/bitstream/111111111/888/1/reqno_jrc46971_grandgirard_zielinski_2008_jrc46971%5B2%5D.pdf [Accessed: 12 November 2010]

Henderson, I.G., Ravenscroft, N., Smith, G. and Holloway S. (2009): Effects of crop diversification and low pesticide inputs on bird populations on arable land. *Agriculture, Ecosystems and Environment* **129** pp.149-156. Available at: http://www.sciencedirect.com/science/article/pii/S0167880908002405 [Accessed: 4 November 2010]

IBM (2002): *SQL Reference Volume 1***,** *Version 8* [online] Available at: ftp://ftp.software.ibm.com/ps/products/db2/info/vr8/pdf/letter/db2s1e80.pdf [Accessed: 2 October 2011]

IBM (2002): *SQL Reference Volume 2***,** *Version 8* [online] Available at: ftp://ftp.software.ibm.com/ps/products/db2/info/vr8/pdf/letter/db2s2e80.pdf [Accessed: 2 October 2011]

Lundström-Gilliéron, C. (2003): Hare abundance as an indicator for urbanisation and intensification of agriculture in Western Europe. *Ecological Modelling* **168**, pp.283-301. Available at: http://www.sciencedirect.com/science/article/pii/S030438000300142X [Accessed: 18 September 2011]

MeteoSwiss (2011): Climate Maps 1961-90. Available at: http://www.meteoschweiz.admin.ch/web/de/klima/klima_schweiz/Klimakarten_schweiz_1961-90.html [Accessed: 18 September 2011]

Newton (2004): The recent declines of farmland bird populations in Britain: an appraisal of causal factors and conservation actions. *Ibis*, **146**, pp.579–600. Available at: http://onlinelibrary.wiley.com/doi/10.1111/j.1474-919X.2004.00375.x/pdf [Accessed: 2 October 2011]

Oppel, A. and Sheldon, R. (2009): *SQL – A Beginner's Guide*. Third Edition. New York: McGraw-Hill

Ormerod, S.J. and Watkinson, A.R. (2000): SPECIAL PROFILE: BIRDS AND AGRICULTURE, Editors' Introduction: Birds and Agriculture, *Journal of Applied Ecology*, **37**, pp.699–705. Available at: http://onlinelibrary.wiley.com/doi/10.1046/j.1365-2664.2000.00576.x/pdf [Accessed: 4 August 2011]

Pointereau, P., Paracchini, M.L., Terres, J-M., Jiguet, F., Bas, Y. and Biala K. (2007): *Identification of High Nature Value farmland in France through statistical information and farm practice surv*eys. (European Commission, Joint Research Centre, Institute for Environment and Sustainability) Available online at http://agrienv.jrc.ec.europa.eu/publications/pdfs/JRC_HNV_France.pdf [Accessed: 11 August 2011]

Prinz, T., Strobl, J. and Wonka, E. (2004): *Flexible Aggregation regionalstatistischer Erhebungen – neue Produkte der Statistik Austria.* In: *Angewandte Geographische Informationsverarbeitung XVI*, Beiträge zum AGIT Symposium. Salzburg [online] Available at: http://ispace.researchstudio.at/downloads/2004/prinz_strobl_wonka_2004_agit_regionalstatistik.pdf [Accessed: 7 August 2011]

Prinz, T., Herbst, S. and Spitzer, W. (2007): *Räumliche Indikatoren für die nachhaltige Raumentwicklung.* Studio iSPACE. Available at: http://sat.researchstudio.at/werkstatt/wp-content/uploads/2007/08/prinz_herbst_spitzer_raeumliche_indikatoren.doc [Accessed: 7 August 2011]

Robinson, R.A. (2001): The Importance of Arable Habitat for Farmland Birds in Grassland Landscapes. *Journal of Applied Ecology,* **38**, (5), pp.1059-1069. Available at: http://www.jstor.org/stable/827243 [Accessed: 5 November.2010]

Schmid, H., Luder, R., Naef-Daenzer, B., Graf, R. and Zbinden, N. (1998): *Schweizer Brutvogelatlas – Verbreitung der Brutvögel in der Schweiz und im Fürstentum Liechtenstein 1993-1996.* Sempach: Schweizerische Vogelwarte.

Sjödin, N.E., Bengtsson, J. and Ekbom, B. (2008): The influence of grazing intensity and landscape composition on the diversity and abundance of flower-visiting insects. *Journal of Applied Ecology* **45**, pp.763-772. Available at: http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2664.2007.01443.x/abstract;jsessionid=E99898181A4CAD65FD6B05C3A2A27BD1.d01t03 [Accessed: 4 November.2010]

Steinnocher, K., Köstl, M., Petrini, F. and Hoffmann, C. (2005): *European spatial indicators in the frame of geoland*. Project geoland GMES: AESOP Conference proceedings, Vienna. Available at [Accessed: 5 November.2011]

Strobl, J. (2005): Hierarchische Aggregation: Detailinformation versus Datenschutz am Beispiel adressbezogen georeferenzierter Datensätze. *Salzburger Geographische Arbeiten,* **38**, pp.163 – 171. Salzburg. Available at: http://www.zgis.at/team/strobl/pub/sga38_jstrobl.pdf [Accessed: 6 August 2011]

Vickery, J.A., Bradbury, R.B., Henderson, I.G., Eaton, M.A. and Grice, P.V. (2004): The role of agri-environment schemes and farm management practices in reversing the decline of farmland birds in England. *Biological Conservation* **119** (1), pp.19-39. Available at: http://www.sciencedirect.com/science/article/pii/S0006320703003380 [Accessed: 2 October 2011]

Wonka, E., Kaminger I. and Kuzma, I. (2007): Regionalstatistisches grenzübergreifendes Projekt zwischen Slowenien und Österreich zum Thema Raster. *Statistische Nachrichten* **62**, (1) pp.72-78. Available at: http://www.statistik.at/web_de/static/regionalstatistisches_grenzuebergreifendes_projekt_zwischen_slowenien_und__018910.pdf [Accessed: 10 August 2011]

Wonka, E. (2009): *Regionalstatistik in Österreich auf der räumlichen Bezugsbasis von regionalstatistischen Rastereinheiten.* 2. Auflage (Josef Strobl, GIScience). [Online] Available at: http://www.oeaw-giscience.org/download/RasterStatistikWonka2A.pdf [Accessed: 10 August 2011]

Zbinden, N., Schmid, H., Kéry, M. and Keller, V. (2005): Swiss Bird Index SBI® – Kombinierte Indices für die Bestandsentwicklung von Artengruppen regelmässig brütender Vogelarten der Schweiz 1990–2004. *Der Ornithologische Beobachter,* **102,** pp.283–291. Available at: http://infonet.vogelwarte.ch/upload/44906443.pdf [Accessed: 8 August 2010]

Appendix

A Annual survey participants

Survey	Participating farms/farmers
Spring data survey	• all farmers with farm holdings who wish to register for direct payments. • all those keeping livestock • all farms practicing viticulture • all farmers with nature management contracts → *the completed surveys also count as an application for direct payments* *No of surveys completed 2010: 13,994*
Alpine pasture survey (qualifying farms)	• farmers summering livestock on a summer pasture farm holding, a mountain-pasture holding or common grazing land. *No of surveys completed 2010: 1,619*
Autumn data survey	• all farms registering for a label • all farms submitting to certain controls (a pre-condition for farms applying for direct payments) • registration for various schemes • all those keeping livestock – obligatory registration for Epizootic Fund *No of surveys completed 2010: 11,451*

Table 1: Annual survey participants

B Maps and copyright details

As mentioned in chapter 1.6, the development of suitable legend classification schemes to optimally represent the data mapped at various stages throughout this thesis, is beyond the scope of this study. While an effort was made to provide as accurate an impression of the data range as possible, the representation is by no means optimized.

The maps integrated throughout the thesis use a selection of geodata from the cantonal geodatabase. These are listed in the following table including their associated copyright details.

Geodata product	Details / Copyright
ASG85	Arealstatistik 1992/97, © BFS GEOSTAT
AVR	Amtliche Vermessung Reduziert (AVR) © Amt für Geoinformation des Kantons Bern
BIOGREG	Biogeographische Regionen der Schweiz, © BFS GEOSTAT / BAFU CH 3003 Bern
DTMAV2; DTMAV5	DTM-AV © swisstopo (DV002380)
GENGRZ25	Generalisierte Gemeindegrenzen der Schweiz, © BFS GEOSTAT / swisstopo
GRENZ5	Politische Grenzen des Kantons Bern 1:5'000, © Amt für Geoinformation des Kantons Bern
KL	Klimaeignungskarte für die Landwirtschaft © Bundesamt für Landwirtschaft (BLW)
PK25	Pixelkarte PK25 © 2006 swisstopo (DV569)
PK50	Pixelkarte PK50 © 2006 swisstopo (DV480.2)
PK100	Pixelkarte PK100 © 2005 swisstopo (DV480.2)
SWISSI	Orthphotos: SWISSIMAGE, © swisstopo (DV5704002406/000010)
VECTOR25	VECTOR25 © 2008 swisstopo (DV012391)

Table 2: Geodata employed and copyright details

C Crop data

The table below lists the crop groups and the list of associated individual crops (excluding grape varieties).

Abbreviation	Crop Group	Crop (Kultur)[37]
D	**Permanent grassland**	Kunstwiesen (ohne Weiden)
		Übrige Dauerwiesen (ohne Weiden)
		Weiden (ohne Gem.- & Sömmerungsweiden)
		Weiden für Schweine, nicht anr. für Ber. der RGVE
		Heuwiesen im Sömmerungsgebiet
		Futterleguminose Samenproduktion
		Futtergräser für Samenproduktion
		Uebrige Futterpflanzen für Samenproduktion
		Übr. Grünfläche, anr. für Berechnung der RGVE
		Übr. Grünfläche, nicht anr. für Ber. der RGVE
S	**Spring planted cereals**	Sommergerste
		Hafer
		Sommerweizen
		Hirse
W	**Winter planted cereals**	Wintergerste
		Triticale
		Mischel Futtergetreide
		Futterweizen
		Emmer, Einkorn
		Winterweizen
		Roggen
		Mischel Brotgetreide
		Dinkel (Korn)

[37] Abbreviations in crop name and language (German) are as stored in the Gelan database

M	**Maize**	Körnermais
		Saatmais
		Silo- und Grünmais
R	**Rapeseed (& similar)**	Sommerraps zur Speiseölgewinnung
		Winterraps zur Speiseölgewinnung
		Sommerraps als nachwachsender Rohstoff
		Winterraps als nachwachsender Rohstoff
H	**Tall-growth crops**	Sonnenblumen zur Speiseölgewinnung
		Hanf (THC-arme Sorten nach BLW-Sortenliste)
		Hanf (andere Sorten)
		Flachs
		Hanf mit Beitrag
		Lupinen
		Tabak
		Einjährige nachw. Rohstoffe (Kenaf, usw.)
		Sonnenblumen als nachwachsender Rohstoff
		Hopfen
NH	**Root crops**	Zuckerrüben
		Futterrüben
		Kartoffeln
		Soja
		Ackerbohnen
		Eiweisserbsen zu Futterzwecken
G	**Vegetables etc. (unprotected)**	Oelkürbisse
		Einj. Freilandgemüse ohne Konservengemüse
		Freiland-Konservengemüse
		Wurzel der Treibzichorie
		Einjährige Gewürz- und Medizinalpflanzen
		Einj. gärt. Freilandkult. (Blumen, usw.)
		Mehrjährige Gewürz- und Medizinalpflanzen
		Rhabarber
		Spargel
P	**Vegetables/crops under glass/plastic**	Pilze
		Gemüsekult. Gew.haus mit festem Fundament
		Übr. Spez.kult. Gew.haus mit festem Fundament
		Gärt. Kult. Gew.haus mit festem Fundament
		Gemüsekult. in gesch. Anb. ohne festes Fund.
		Übr. Spez.kult. in gesch. Anb. ohne festes Fund.
		Gärt. Kult. in gesch. Anb. ohne festes Fundament
		Übr. Kult. in gesch. Anb. ohne festes Fund.
		Übr. Kult. in gesch. Anb. mit festem Fund.
		Johannisbeeren rot gA mit festem Fundament
		Cassis gA mit festem Fundament
		Stachelbereeren gA mit festem Fundament
		Sommerhimbeeren gA mit festem Fundament
		Herbsthimbeeren gA mit festem Fundament
		Heidelbeeren gA mit festem Fundament
		Brombeeren gA mit festem Fundament
		Erdbeereb gA mit festem Fundament
		Andere Beeren gA mit festem Fundament
N	**Renewable resources (biomass crops)**	Mehrj. nachw. Rohstoffe (Chinaschilf, usw.)

O	**Fruit (trees/bushes)**	Einjährige Beeren (z.B. Erdbeeren)
		Obstanlagen (Äpfel)
		Obstanlagen (Birnen)
		Obstanlagen (Steinobst)
		Mehrjährige Beeren
		Andere Obstanlagen (Kiwis, Holunder)
		Johannisbeeren rot
		Cassis
		Stachelbeeren
		Sommerhimbeeren
		Herbsthimbeeren
		Heidelbeeren
		Brombeeren
		Andere Beerenarten
		Johannisbeeren rot gA ohne festes Fundament
		Cassis gA ohne festes Fundament
		Stachelbeeren gA ohne festes Fundament
		Sommerhimbeeren gA ohne festes Fundament
		Herbsthimbeerren gA ohne festes Fundament
		Heidelbeeren gA ohne festes Fundament
		Brombeeren gA ohne festes Fundament
		Erdbeeren gA ohne festes Fundament
		Andere Beerenarten gA ohne festes Fundament
		Erwerbsobstanlagen
		Privates Schutzobjekt
		Apfel
		Birne
		Steinobst
V	**Vines**	A list of 72 grape varieties – e.g. Pinot gris, syrah
GOAF	**Grassland ECAs**	Saum auf Ackerfläche
		Extensiv genutzte Wiesen (ohne Weiden)
		Wenig intensiv genutzte Wiesen (ohne Weiden)
		Ext. genutzte Weiden (ohne Gem.- & Sö.w.)
		Waldweiden (ohne bewald. Fl., ohne Gem.- & Sö.-w.)
		Extensives Wiesland auf Sömmerungsgebiet
		Wenig int. genutzte Wiesen im Sömmerungsgebiet
		Ext. Wiesen auf stillg. Ackerland (bis Ende 2000)
		Waldweide nicht OeAA
		Uebrige Grünfläche, anrechenbar Ber. RGVE und ÖAF
OAF	**Non-grassland ECAs**	Buntbrache
		Rotationsbrache
		Grünbrache (nur noch 1999!)
		Streueflächen
		Hecken, Feld- und Ufergehölze (mit Krauts.)
		Hecken, Feld- und Ufergehölze (o. Krauts.)
		artenreiche Hecken, Feld/Ufergehölz
		Hecken, Feld/Ufergehölz (mit Pufferstreifen)
		Übr. Flächen innerhalb der LN, beitragsber.
		Übr. Flächen innerhalb der LN, beitragsber.
		Übr. Flächen innerh. der LN, nicht beitr.ber.
		Weitere ökologische Ausgleichsflächen
		Wassergräben, Tümpel, Teiche
		Ruderalflächen, Steinhaufen und -wälle
		Trockenmauern
		Unbefestigte, natürliche Wege
		Weitere ökologische Ausgleichsflächen
		Hochstammfeldobstbäume
		Einheimische standortger. Einzelbäume und Alleen
		Ackerschonstreifen

F	**Forest (& similar)**	Christbäume
		Baumschule von Forstpfl. ausserhalb Forstzone
		Ziersträucher, -gehölze und -stauden
		Übrige Baumschulen (Rosen, Früchte, usw.)
		Wald
		Baumschule mit Wirtspflanzen
		Baumschule ohne Wirtspflanzen
Div	**Miscellaneous**	Übr. offene Ackerfläche, beitragsberechtigt
		Übr. offene Ackerfläche, nicht beitragsber.
		Übr. Fl. mit Dauerkult., beitragsberechtigt
		Übr. Fl. mit Dauerkult., nicht beitragsber.
		Flächen ohne landw. Hauptzweckbestimmung
		Hausgärten
		Sömmerungsweiden
		Übrige Flächen ausserhalb der LN

Table 3: Crop groups with their associated crops