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# Local spatial context measurements used to explore the relationship between land cover and land use functions

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ABSTRACT

Research making use of satellite data for land change science has developed in the last decades. However, analysis of land use has not developed with the same speed as development of new satellite sensors and available land cover data. Improvement of land use analysis is possible, but more advanced methods are needed which make it possible to link image data to analysis of land use functions. To make this linking possible, variable which affect farmer's long term decisions must be taken into account in analysis as well as the relative importance of the landscape itself.

A GIS-based tool for the measurement of local spatial context in satellite data is presented in this paper and used to explore the relationship between land covers present in satellite data and land use represented in official databases. By the use of the developed tool, a land configuration image (LCI) over the Siljan area in northern Sweden was produced and used for analysis. The results are twofold. First, the produced LCI holds new information about variables that are relevant for the interpretation of land use. Second, the comparison with statistics of agricultural production shows that production in the study area varies depending on the relative land configuration. Villages consisting of relatively large-scale arable fields and less diverse landscape are less diverse in production than villages which consist of smaller-scale and more heterogonous landscapes. The result is especially relevant for land use studies and policymakers working on environmental and agricultural policies. We conclude that local spatial context is an endogenous variable in the relation between landscape configuration and agricultural land use.



## 1. Introduction

Relative spatial scale is a key variable in many types of land use decisions and is well known in agricultural economics (Federico, 2009). However, there are no commonly used methods to measure these variables in satellite data by the use of GIS. It is also well known that the spatial composition of landscapes affects biodiversity (Fahrig, 2003), and landscape ecologists have focused on the interrelations between changes in landscape metrics and ecological processes. The increased focus of policymakers on sustainable development is a driving force encouraging researchers to determine good indicators of landscape composition and changes. However, Dramstad (2009) has argued that there is a lack of communication between policymakers and researchers that results in less use of spatial indicators in policymaking. Most geographers, ecologists, and planners agree that land uses and landscapes are inherently dynamic (Holmes, 2008; Kayhko and Skanes, 2006; Tscharntke et al., 2005). Rapid processes often exist parallel to slow ones, and a number of factors help catalyze them, which means that landscape changes are complex in character. Although there are some exceptions (Verburg et al., 2009; Bibby and Shepherd, 2000), most GIS and RS researchers have focused on the formal aspect of detecting change in absolute time-space (Boulila et al., 2011). Change detection has been based on per-pixel information reflected in images from different times. Less focus has been on the relative spatial composition that often follows different forms of land use (Boulila et al., 2011). To interpret and understand how land uses change, the inherent capacities of landscape itself need to be explored. One way to do this is to investigate the relationship between agricultural land use and the landscape's spatial structure.

There is an increased demand for systematic landscape studies both globally and regionally. One example is the Swedish ratification of the European Landscape Convention (ELC) in 2011, where the Swedish government agreed to honor Article 6a in the ELC (C.o. Europe, 2000), which includes the following requirements:

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[1] Wolter Arnberg died the autumn 2011 and never got the opportunity to see this paper finished, but he was convinced of its importance.

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i) to identify its own landscapes throughout its territory;
ii) to analyze the characteristics of those landscapes and the forces and pressures transforming them; and
iii) to take note of any changes that may occur.

The latter two requirements indicate that the demand for knowledge about land use analyzed from remotely sensed data will increase.

Agriculture production can relatively easily be recognized in remote sensed data, estimations of for example yield can be done by use of NDVI (Funk and Budde, 2009). Beyond intensification, expansion of area and changes of spatial structure into large scale industrialized agriculture is common. Theoretically production specialization most often is explained by distance to market (Serneels and Lambin, 2001). The classical geographical explanation of intensity and specialization of production comes from von Thunens work (Nelson, 2002). In the contemporary western world where transportation costs in relative terms are decreasing over time, this basic model no longer to the same extent explain variations in land use and production specialization (Harvey, 2006). However, on a local scale level the transport costs are still important as an explaining factor for production.

Different productions specializations are, over time, limited and dependent on former land use and changes, which means that there are path dependencies in land use in relation to the spatial structure, which implicitly means that knowledge about the interrelationship between spatial structures and land use can be used for interpretation of land use from spatial structure and vice versa. But this does not mean there is causality. The first question is if a relationship can be identified between the spatial structure and production specialization?

To explore this relationship at a local scale there is a problem in what and how to measure. We propose a focus on relative scale and local spatial context inside a simplified spatial village model.

In the following sections, a land configuration image (LCI) will be linked and compared with data about agricultural production to determine if there is a correspondence and if so, what the current characteristics are.

The LCI consists of a systematic measurement of spatial context and the relative scale of different land covers within villages. The contextual information is collected from selected land covers derived from satellite data (selection is made in relation to a simple spatial village model and field interpretations). The appearance of each land cover class inside the village is measured by calculating the relative diversity and local scale. These different measurements are put together, thus producing the land configuration image. Based on the processing and initial selection of land covers, the village model appears in the resulting image as visible villages with different characteristics depending on their inherent characteristics.

### 1.1. Background

Recently, the Land Use and Land Cover Change (LUCC) program (Liverman and Roman, 2008; Verburg and Veldkamp, 2005) and the emerging discipline of land change science (Rindfuss et al., 2004) have focused on investigating land use and changes in land use based on remote sensing data. According to Verburg et al. (2009), it is necessary to develop new methods of quantifying land use and land function dynamics in relation to remote sensing data. Their work indicates the difficulties that arise in linking land cover data obtained using remote sensing to land functionalities because there is no one-to-one relationship between land cover and land use. They have also suggested that more attention should be paid to land use and land use functions. Similarly, Nagendra et al. (2004) argue that "there is a strong need to better understand the dynamics of the feedback mechanisms that relate environmental patterns to social processes". They have also indicated that it is essential to integrate patterns of land cover change with processes governing land use change.

Changes in land use and spatial structure are linked to technological and socioeconomic capacities, but they are not necessarily correlated in a linear fashion. The relative importance of the spatial scale and configuration at play varies from one landscape and socioeconomic context to the next.

A starting point could be that land use is not randomly organized spatially but rather obeys spatial organizational principles based on functional factors related to institutional forms of organization. Fundamentally, local spatial order is based on the principles of minimum transportation and labor, and these principles produce a concentric spatial layout on a theoretically flat landscape; the most labor- and manure-demanding cultivation occurs close to the farmsteads, and less labor- and resource-intensive forms of land use occur farther away (Chisholm, 1968). The degree to which the spatial organization of land approximates the most efficient spatial layout, depends, all other things being equal, on the different techniques which land-users choose to solve the problems of transportation and labor. Improved knowledge about the relationship between land use and land cover configuration is helpful in studies investigating changes in land use and land function (Verburg et al., 2009).

### 1.2. The study area

The study area is located in the county of Dalarna in the northwestern part of the Swedish inland area (Fig. 1). Agricultural cultivation in villages in this region is known to have occurred since at least medieval times. The area is well known for its folklore culture. However, land use has changed dramatically since World War II. Today, many farms are abandoned, and the number of farmers is

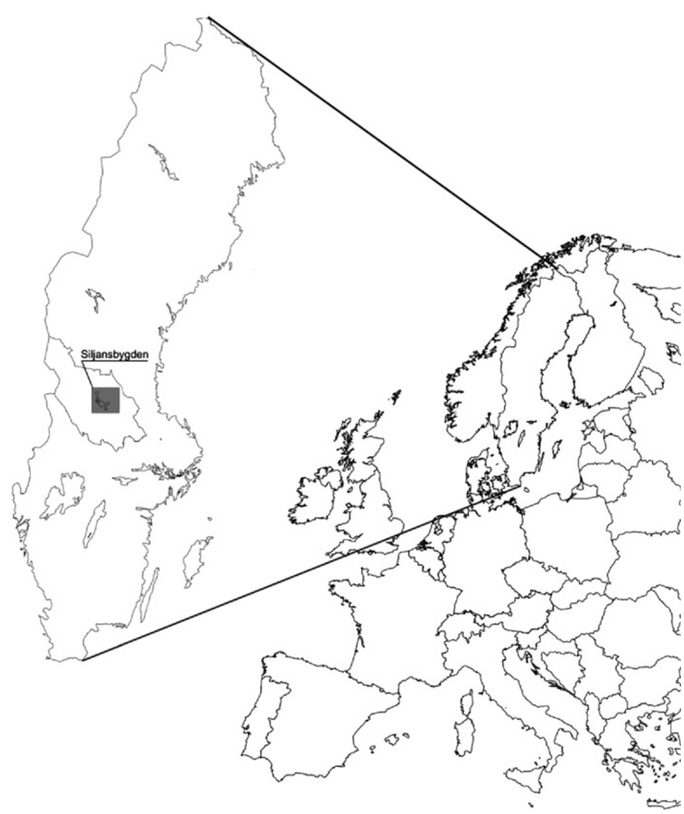


**Fig. 1.** Location map of the study area "Siljansbygden" in Sweden and a map of Sweden in Western Europe.