“Land use intensity versus landscape complexity
-Analysis of landscape characteristics in an agricultural region of Southern Sweden ”

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Summary: *The main aim of this project was to study the relationship between land use intensity and landscape complexity. We analysed landscape data in 150 1km^2 plots and within a buffer zone of 2km around each plot. The plots were distributed over a large part of the region of Skåne (Scania), southernmost Sweden. We used spatially explicit digital data on land use, digitised aerial photographs, field surveys of landscape elements and agricultural statistics. A factor analysis suggests that there are three relevant axes, where the first can be interpreted as describing the intensity of land use while the other two are connected to landscape structure and amount of small patches of semi-natural habitat. Variables such as the level soil nitrogen, yield of spring barley and proportion arable land score highly on Factor 1 (land use intensity), while e.g. land use diversity and a structural index like the Contagion (Fragstats) score highly on Factor 2 (landscape structure) and the amount of semi-natural habitats has a medium score on both the second and third factor. We believe that it is important to consider intensity and complexity as somewhat separate landscape level factors when trying to explain patterns of biodiversity change in agricultural landscapes.*

Introduction:

Background

A large proportion of European landscapes has been shaped by their long history of agricultural activity. In these landscapes the traditional management practises sustained a range of both economical, social and environmental (or ecosystem) services and a high biodiversity (Jones-Walters 2007). The high value of dynamic human affected cultural landscapes for biodiversity, as opposed to the static reserve areas of “wild” nature, has only recently been recognised in conservation action and landscape planning (Bengtsson et al. 2003, Scherr & McNeely 2008).

Two initiatives on a European level have a clear focus on the landscape as a key element for sustainable development; the Pan-European Biological and Landscape Diversity Strategy (PEBLDS) from 1995 and the European Landscape Convention from 2000 (Jones-Walters 2007). The former states that “The issue of landscape diversity is as yet not adequately integrated into mechanisms aimed at protecting and enhancing the natural environment” (ref. website 1.). The latter acknowledges the importance of culturally shaped landscapes, both for biodiversity and for human identity, welfare, economical and ecological sustainability. It also stresses landscapes as a key unit for planning and landscape planning as one of the tools to reach sustainability. The spatial level of “landscape” is just as important to consider as each individual feature included (ref. website 2.). Landscapes are more and more becoming the focus of conservation action and planning, at least in a European perspective.

Agricultural development and modernisation has accelerated during the last 50 years and it has led to homogenisation of the landscape at several spatial levels: from common agricultural policies (CAP) acting over the whole EU, to technical development leading to larger and cleaner fields free from weeds and with a more homogeneous moisture and texture due to e.g. drainage (Benton et al. 2003). From a biodiversity perspective, intensification results in both loss and fragmentation of natural and semi-natural habitats and these changes can be seen both locally, at the farm level, and landscape wide. Local changes include increased field size and changes of management practises (e.g. increased use of agrochemicals and a subsequent increased harvest, choice of crops and rotation schemes). When these changes are combined over a region, i.e. when management becomes regionally homogeneous; the result is a landscape wide loss of habitat plus fragmentation of the remaining patches as they become more and more isolated from each other. Homogenisation in timing of management also leads to temporal simplification of the landscape (Benton et al. 2003, Tscharntke et al. 2005). At the same time, extensively managed and less productive areas run the risk of being “under managed” or completely abandoned. Landscape structure is thus changed and the heterogeneity created by traditional management is lost via two seemingly contrasting processes: intensification and abandonment.

During the last half-century many groups of organisms connected to the agricultural landscape have declined dramatically (Benton et al. 2003, Tscharntke et al. 2005). A decline in numbers is, for example, evident for many farmland birds (Shrubb 2003, Lindström & Svensson 2005) as well as for plants and insects (Baessler & Klotz 2006, Biesmeijer et al. 2006, Fitzpatrick et al. 2007). Several authors point to the loss of spatial and temporal heterogeneity, i.e. farmland becoming ever more simplified, as the general cause of this decline in biodiversity (Meek et al. 2002, Benton et al. 2003, Shrubb 2003, Pywell et al. 2005, Tscharntke et al. 2005) and Wretenberg et al. (2007) report that population trends among farmland birds correspond to periods of different agricultural policies.

Studies on biodiversity in agricultural landscapes often claim to use either intensity or complexity/heterogeneity as explaining variables. Sometimes they are used in combination and quite often the words are used interchangeably, which causes some confusion. The variables used to represent intensity/heterogeneity are for example represented by: the proportion of arable land, permanent pasture or semi natural habitats, size of the fields, input of inorganic fertilisers and pesticides, crop harvest data, number of land use classes within an area or diversity indexes on land use (Steffan-Dewenter 2002, Jeanneret et al. 2003, Roschewitz et al. 2005, Sandkvist et al. 2005, Schweiger et al. 2005, Baessler and Klotz 2006, Rundlöf & Smith 2006). The proportion arable land is a popular and an easy measure to obtain and would in that way be a very useful one. But what is crucial to know before using this measure is exactly what it describes in the particular region where the study is made. As an example, the landscapes in southernmost Sweden may span a wider range of both intensity and complexity than the ones used in other studies and the linear correlation between complexity (represented by land use diversity) and the proportion arable land found in northern Germany by Roschewitz et al. (2005) might not be valid here. We need to know what, preferably simple to obtain, landscape measurement (or combination of measurements) we can use to describe landscapes and to be able to evaluate the value of different landscape types for biodiversity.

An alternative or complement to repeated correlations of landscape variables would be to use factor analysis to compose informative and hopefully meaningful combinations of landscape variables and agricultural statistics (Siriwardena et al. 2001, Millán de la Peña et al. 2003). This method has the advantage of letting us combine many variables into a small number of mutually independent (orthogonal) factors. The meaning of the factors is then interpreted via the variables that have high scores on each of them (Quinn & Keough 2002). We may then find something more in line with Millán de la Peña et al. (2003); one factor describing the intensity of farming and the another describing the openness (or complexity) of the landscape.

The relationship between landscape variables could depend on the spatial scale, or size, of the landscapes used. By comparisons of land use and management data on scales from 1*1km to 4*4km, Purtauf et al. (2005) showed that the strength of correlations between land use variables increase with scale. Also, the importance of land use data as explaining variables increased on behalf of management data and went from being large independent from each other to ending up in the same factor at larger scales (Purtauf et al. 2005).

We want to know how some of the most often used metrics of intensity and complexity are related to each other and how they can be used to describe the agricultural landscapes of Scania. We find this interesting both for its own sake and for further use in studies on biodiversity in this area. Some questions that arise are: Which elements and characteristics should be used to describe (agricultural) landscapes? Which characteristics matters to the organisms under study? Are there characteristics that matter more generally to biodiversity and ecosystem processes? The basic quest then becomes to understand how different metrics are connected and if, by using some of them in combination; it is possible to say something more general about the processes (social, economical, ecological) that caused the patterns we can see. This would then also makes it possible to suggest more general solutions to halt the loss of biodiversity from cultural landscapes, as called for by Benton et al. (2003).

The aims of this study are:

1. To study the relationships between several commonly used landscape variables.
2. To use factor analysis as a tool to find composite descriptors of landscapes, and if possible to disentangle the driving force, *intensity,* from the result of it, *complexity* or *landscape structure*.
3. To study the effect of the scale at which the variables are measured. Since many organisms can be expected to react or be affected by different mechanisms at different spatial scales, it would be useful to include information on scale in the analysis. We do this by including some variables both on a small (1*1km) and a larger scale (~5*5km).

Our hypotheses are that:

1. The proportion of arable land per landscape will be a general, however quite blunt, descriptor of landscape status. It will be more closely correlated to intensity than to complexity metrics.
2. Even though they are closely connected, intensity and complexity are not the same. In a factor analysis of farmland landscapes of many different degrees of intensity and complexity, we will be able to separate them and end up with one factor more management related (degree of intensity) and another one more structure related (degree of complexity).
3. The connection between land use intensity and landscape structure could be expected to be the same both at a local and a larger landscape scale.

Methods:
(figures, maps, Data collection)

Habitat and bird inventory: During 7 years, 1995 to 2002, an inventory of farmland bird abundance and land use in 161 1*1km plots in the region of Scania (Skåne), southernmost Sweden, was conducted. The plots were selected from the National Grid System in Sweden and the plots were distributed over an area of approximately 100 * 100 km, figure 1. The inventory was conducted by volunteers; amateurs as well as schooled birdwatchers. The overall aim of the study was to assess the number and distribution of farmland birds in relation to land use (Svensson 1995). All habitats and land use classes, except for continuous larger areas of forest, were included in the inventory (Svensson 1995). From this dataset we have collected information on crops and field size at the individual field level (sv. skiften) as well as information on the presence of small habitats like stonewalls and ditches.

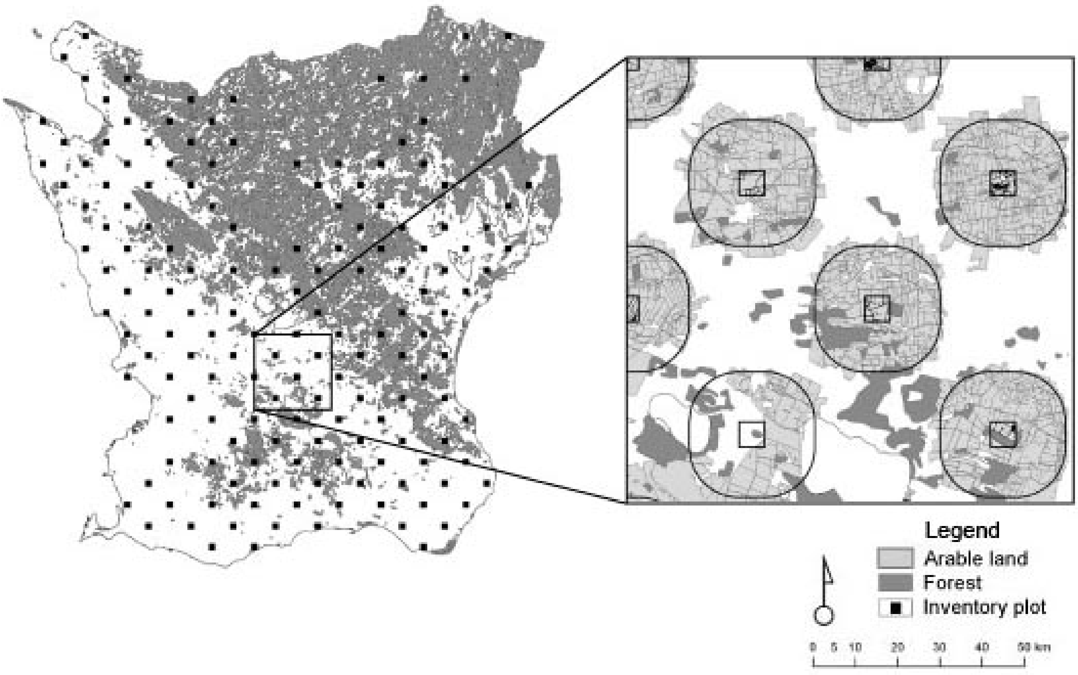

Figure 1. Map of the study area; the region of Skåne and the plots used in the study. The inserted picture shows some plots with buffer zones, farmland fields and forest drawn.

Digital information from the Swedish Board of Agriculture (JBV): We have access to the so called "Blockdatabasen", a yearly updated data base on all registered farmland fields in Sweden, including spatially explicit data on crops and other land uses (pasture, fallow, tree plantations etc.) on farmland. To match the time of the habitat/bird inventory we decided to use block data from 1999. From this data base we extracted information on the size of "blocks" of fields (see below) and on the proportion of arable land. We also had access to the block data bases from 1996 to 2002 and used this information to complete, or reconstruct land use data where it was missing on the inventory maps. Block data was also used to calculate the amount of non crop field borders. Since the delineation of fields provided by this digital dataset is based on border structures seen on aerial photographs, they are more in line with where fields are actually divided by non-crop border habitat, compared to the inventory maps where single fields are drawn. We used a template border width of 2,4 meters to calculate border area, since this is the average width found by two independent habitat inventories in Scania (Persson A. & Rundlöf M., unpublished data).

Aerial photographs: By studying aerial photographs (the Swedish Land Survey, Lantmäteriet) of each inventory plot, semi-natural habitats such as stone walls, ditches, small wood lots and single trees, field islands, permanent pastures and grasslands could be identified or verified and digitised. This gave us a uniquely detailed dataset on small, semi-natural habitats at the 1*1 km scale.

Corine land use data: From the satellite data of the EU programme CORINE (Coordination of Information on the Environment), data on forests and wetlands for the concerned areas was extracted and used to complement information from the above mentioned sources. CORINE data is available at 25*25m resolution.

Statistics on yield and nutrient input: We used data from Statistics Sweden (SCB) on normalised harvest of spring sown barley in 2006 and on plant available nitrogen in 2001. We chose to use data on plant available nitrogen (ammonium) since this is the part of total soil nitrogen that is most easily accessible to plants and is expected to contribute substantially to fertilisation during the current growth season (SCB, website 3.). The geographical resolution of nutrient data is very coarse, only three different areas, so called "production regions", are represented in Scania. The division is based on a nationwide structure of average production and Sweden is divided into in total eight production regions. The normalisation of harvest data is done to get a more robust estimate. It describes the harvest expected in 2006 based on data for the past 15 years and so the in data spans the whole study period (1995 to 2002) of this study. The geographical basis for calculations of harvest are the 17 "harvest regions" (skördeområden) of Scania; administrative regions originally based on collections of neighbouring parishes.

Data treatment:

From the original 161 inventory plots 150 plots were selected for this study, based on a minimum amount of farmland (>10% crop land, pasture, fallow and hay fields). Plots where built up areas or water bodies took up more than 50% were removed from the analysis. All data was digitised and processed in ArcGis 9.1 (ESRI). The total area of different land use classes, field sizes and area of border habitats per landscape were calculated. We also used a buffer zone of 2km around each inventory plot (i.e. in total ~5*5km but with rounded corners, figure 1), and used blockdata and CORINE data to calculate average field size and area of major land use classes. For calculation of average field size at the 1*1km level, fields were weighted by the proportion being contained within the landscape. This way the influence of fields with only a small proportion actually within the landscape was lowered, while still being included in the calculation. Fragstats 3.3 (McGarigal et al. 2002) was used for calculation of landscape and diversity indices on raster data (vector to raster conversion in ArcGis) at the 1*1km level. For this calculation land use data was classified as belonging to one of 4 land use types: arable land (annually tilled fields, hay fields including silage, fallow land), forest (larger areas of forest, production forest and small wood lots), wetland and water or semi natural (permanent pasture, non crop border habitats, tree and hedge rows, solitary trees). The indices chosen were the Simpson diversity and the Contagion. The Contagion index is based on the probability of adjacent pixels belonging the same category as the focal one and thus expresses to what degree the land use categories are inter-dispersed (McGarigal et al. 2002). We used a resolution of 10 meters for the Fragstats calculations. The data extracted and used in the analyses is presented in table 1. Statistical analyses were done in SAS 9.1 using the procedures CORR and FACTOR. For the factor analysis 3 factors were retained and Varimax rotation method used. This method maximizes the total variation explained by allowing rotation of the axes while keeping them orthogonal. Where proportions of land uses were used they we arcsine-square-root transformed to avoid variance to be associated with the mean The 1*1km plots are here referred to as *local* plots and the ~5*5km bufferzone plots as *landscapes*.

Table 1. Local and landscape variables included in the analyses.

Variable	Explaination	Spatial Scale	Data Source	Year	Unit	Min	Max	Mean	Std Dev
Simpson Diversity crops	-ln(D) on crops divided into 8 categories	1*1km	Inventory and the block database, JBV	1995-2002	-	0	1.78	1.01	0.41
Field Size 1	Weighted size of blocks of individual fields	1*1km	Block database, JBV	1999	ha	0.34	108.9	11.2	15.5
Prop Arable 1	Proportion arable land per landscape	1*1km	Block database, JBV	1999	-	0	1	0.66	0.3
Prop Pasture 1	Proportion permanent pasture per landscape	1*1km	Block database, JBV	1999	-	0	0.64	0.11	0.13
Forest 1	Total area in of forest and wood lots per landscape	1*1km	Block database, JBV, CORINE, aerial photographs	1995-2002	ha	0	1.19	0.42	0.34
Small Habitats	Total area of stonewalls, ditches, field islands, roadverges, tree and hedgerows, solitary trees	1*1km	Block database, JBV, aerial photographs, inventory	1995-2002	ha	0	17.85	5.55	3.02
Simpson Diversity land use	-ln(D) on 4 landuse classes: arable, seminatural, wetland, forest	1*1km	Block database, JBV, CORINE, aerial photographs, inventory	1995-2002	-	0	1.18	0.52	0.33
Contagion index	Calculated in Fragstats on four land use classes: arable, semi-natural, water, forest	1*1km	Blockdatabasen, JBV, CORINE, aerial photographs, inventory	1995-2002	-	47.46	100	72.17	11.66
Field Size 2	Mean size of blocks of individual fields	5*5km	Block database, JBV	1999	ha	1.15	31.25	9.47	6.63
Prop Arable 2	Proportion arable land per landscape with buffer	5*5km	Block database, JBV	2000	-	0.06	0.98	0.64	0.27
Prop Pasture 2	Proportion permanent pasture per landscape with buffer	5*5km	Block database, JBV	2001	-	0	0,9995	0.16	0.16
Prop Forest 2	Total area in of forest per landscape with buffer	5*5km	Block database, JBV	2002	-	0	0.86	0.23	0.25
Harvest Barley	Normalised (15 year intervals) data on yield if spring sown barley	17 harvest regions of Scania	Statistics Sweden, SCB	2006	kg/ha	2591	6344	5022	999.7
Soil Nitrogen	Plant available nitrogen in soil	3 production regions of Scania.	Statistics Sweden, SCB	2001	kg/ha	97	136	119.67	15.89

Results

Correlations

A correlation matrix between all included variables, table 2, showed that as expected, the proportion arable land at both spatial scales is closely and positively correlated to typical management intensity variables; harvest of winter barley (local r= 0.59 P<0.0001; landscape r= 0.82 P<0.0001) and the soil nitrogen (local r=0.50 P<0.0001; landscaper=0.72 P<0.0001). Proportion arable land is also correlated to the structural components Contagion index and (negatively) correlated to the Simpson diversity of general land use, but to a to a much lesser degree (local: r= 0.27 and -0.35 respectively P< 0.0001 for both). The structural component, the Contagion index, is more closely correlated to the proportion pasture (local r=-0.56 P<0.0001) and the Simpson diversity index on land use (r= -0.93 P<0.0001). The amount of small habitats shows overall low correlations to other variables, the highest being to local proportion arable land (r= 0.34 P<0.0001), the Contagion index (r= -0.33 P<0.0001) and Simpson diversity index on land use (r= 0.33 P<0.0001).

The correlation between data measured at two spatial scales are very high for proportion arable land (r= 0.77 P<0.0001) and forest (r= 0.68 P<0.0001), but low or medium for proportion pasture (r= 0.36 P<0.0001) and the size of fields (r= 0.55 P<0.0001).

When comparing correlations of the same variable at the two spatial scales measured, the proportion arable land and proportion forest are closely correlated (table 2), whereas proportion permanent pasture is somewhat less closely correlated between the two scales investigated (r= 0.36 P<0.0001). This indicates the robustness of proportion arable land as an indicator of intensity.

Factor analysis

The results of the three factor analyses in the form of the factor loadings after rotation are presented in table 3 and the variance explained by the factors in table 4. In total the analysis combining local and landscape variables explain more of the variation in the material; the total communality estimate is 10.19 compared to 7.11 and 7.19 respectively for local and landscape variables only. This is of course the result of using fewer variables when local and landscape variables are separated and thus being able to explain less of the variation in the material

Factor analysis on local and landscape variables: The first factor explains 60.9% of total variation in the material. Proportion arable land (factor loadings: 0.84; 0.94) and forest (-0.81; -0.91) at local and landscape scales, proportion pasture at landscape scale (-0.75), harvest of barley (0.90) and nitrogen levels (0.85) score highest and are thus closely related to this factor. The second factor explains 26.5% of variation and the contagion index (-0.86), land use diversity (0.86) and proportion pasture at the landscape scale (-0.73) score high on this factor while the amount of small habitats has a medium score (0.45). The third factor only explains 12.6% of variation. It is closely associated with crop diversity (0.71) and local field size (-0.64) and to some degree also to the amount of small habitats (0.36) and the landscape scale field size (-0.39).

Table 2. Results of the correlations between variables, local and landscape scale

	Simpson Diversity crops	Field Size 1	Prop Arable 1	Prop Pasture 1	Forest 1	Small Habitats	Simpson Diversity land use	Contagion Index	Field size 2	Prop Arable 2	Prop Pasture 2	Prop Forest 2	Harvest Barley	Soil Nitrogen
Simpson Diversity crops		r =-0.11 P=0.19	r =0.32 P<0.0001	r =-0.13 P=0.10	r =-0.34 P<0.0001	r =0.12 P=0.12	r =-0.042 P=0.61	r =0.036 P=0.66	r =0.12 P=0.14	r =0.34 P<0.0001	r =-0.25 P=0.0020	r =-0.28 P=0.0005	r =0.31 P=0.0001	r =0.21 P=0.0091
Field Size 1			r =0.30 P=0.0001	r =-0.30 P=0.0001	r =-0.24 P=0.0019	r =0.068 P=0.40	r =-0.33 P<0.0001	r =0.33 P<0.0001	r =0.55 P<0.0001	r =0.30 P=0.0001	r =-0.31 P<0.0001	r =-0.27 P=0.0004	r =0.25 P=0.0017	r =0.26 P=0.0008
Prop Arable 1				r =-0.0052 P=0.95	r =-0.65 P<0.0001	r =0.34 <0.0001	r =-0.35 P<0.0001	r =0.27 P=0.0008	r =0.40 P<0.0001	r =0.77 P<0.0001	r =-0.61 P<0.0001	r =-0.169 P<0.0001	r =0.59 P<0.0001	r =0.50 P<0.0001
Prop Pastur e 1					r =0.25 P=0.0011	r =0.23 P=0.0031	r =0.61 P<0.0001	r =-0.56 P<0.0001	r =-0.32 P<0.0001	r =-0.22 P=0.0041	r =0.36 P<0.0001	r =0.25 P=0.0011	r =-0.29 P=0.0002	r =-0.27 P=0.0005
Forest 1						r =-0.067 P=0.39	r =0.46 P<0.0001	r =-0.40 P<0.0001	r =-0.51 <0.0001	r =-0.69 P<0.0001	r =0.46 P<0.0001	r =0.68 P<0.0001	r =-0.63 P<0.0001	r =-0.52 P<0.0001
Small Habitats							r =0.33 P<0.0001	r =-0.33 P<0.0001	r =-0.18 P=0.019	r =0.62 P=0.042	r =-0.12 P=0.11	r =-0.11 P=0.16	r =0.036 P=0.65	r =-0.0052 P=0.95
Simpson Diversity land use								r =-0.93 P<0.0001	r =-0.47 P<0.0001	r =0.32 P<0.0001	r =-0.42 P<0.0001	r =0.41 P<0.0001	r =-0.39 P<0.0001	r =-0.33 P<0.0001
Contagion Index									r =0.38 P<0.0001	r =0.32 P<0.0001	r =0.32 <=0.0001	r =-0.29 P=0.0003	r =0.28 P=0.0004	r =0.22 P=0.0061
Field Size 2										r =0.63 P<0.0001	r =-0.44 P<0.0001	r =-0.63 P<0.0001	r =0.70 P<0.0001	r =0.67 P<0.0001
Prop Arable 2											r =-0.73 P<0.0001	r =-0.96 P<0.0001	r =0.82 P<0.0001	r =0.72 P<0.0001
Prop Pasture 2												r =0.71 P<0.0001	r =-0.61 P<0.0001	r =-0.59 P<0.0001
Prop Forest 2													r =-0.81 P<0.0001	r =-0.75 P<0.0001
Harvest Barley														r =0.82 P<0.0001
Soil Nitrogen														

Table 3. Results of factor analyses including local and landscape variables, local only or landscape only but with local variables of structure (Contagion and Land use diversity).

	Local and landscape variables			Local variables			Landscape variables		
Varible	**Factor 1**	**Factor 2**	**Factor 3**	**Factor 1**	**Factor 2**	**Factor 3**	**Factor 1**	**Factor 2**	**Factor 3**
Simpson diversity crops	0.33	-0.07	0.71	0.47	-0.01	-0.69			
Field size 1	0.36	-0.25	-0.64	0.29	-0.23	0.73			
Prop Arable 1	0.84	-0.19	0.15	0.89	-0.12	0.08			
Prop Pasture 1	-0.22	0.73	-0.03	-0.27	0.64	-0.13			
Forest 1	-0.81	0.20	-0.17	-0.87	0.14	-0.13			
Small habitats	0.17	0.45	0.36	0.29	0.69	0.15			
Simpson diversity land use	-0.37	0.86	0.09	-0.41	0.81	-0.21	-0.23	-0.94	-0.17
Contagion index	0.31	-0.86	-0.09	0.36	-0.79	0.24	0.12	0.97	0.10
Field size 2	0.76	-0.25	-0.39				0.42	0.27	0.81
Prop Arable 2	0.94	-0.18	0.09				0.91	0.18	0.27
Prop Pasture 2	-0.75	0.41	-0.04				-0.80	-0.32	-0.23
Prop Forest 2	-0.91	0.20	0.05				-0.92	-0.16	-0.25
Yield barley	0.90	-0.14	0.03	0.86	-0.17	-0.02	0.78	0.13	0.48
Nitrogen	0.82	-0.12	-0.10	0.76	-0.19	0.02	0.67	0.06	0.60

Table 4. Total variance explained by each factor and final communality estimates after rotation of the three factors retained.

	% Variance explained			
	Factor 1	**Factor 2**	**Factor 3**	**Final communality estimate**
Local and landscape	60.9	26.5	12.6	10.19
Local	51.0	32.8	16.2	7.11
Landscape	50.6	29.0	20.4	7.19

Factor analysis on local variables: In this analysis the first factor explains 51.0% of variation. Just as for the combined analysis, it is most associated with the proportion arable land (0.89) and forest (-0.87) and with harvest of barley (0.86) and soil nitrogen level (0.76). The second factor explains 32.8% and also shows the same association of variables as the combined analysis; Contagion index (-0.79), land use diversity (0.81), proportion pasture (0.64) and amount of small habitats (0.69). The small habitats variable has a higher score here compared to the combined analysis (0.45). The third factor explains 16.2% and is associated with field size (-0.69) and diversity of crops (0.73).

Factor analysis on landscape variables: The first factor explains 50.6% of variation and proportion arable land (0.91), pasture (-0.80) and forest (-0.92) as well as the harvest data (0.78) and nitrogen level (0.67) score high. The second factor explains 32% and here the structural variables Contagion (0.97) and land use diversity (-0.94) score high. The third factor explaining 16.4% is mainly associated with field size (0.81) but also to some extent to harvest data (0.48) and nitrogen levels (0.60). Overall, leaving out local data (except for Contagion and land use diversity) changes the outcome of the analysis.

Discussion

Indicators of land use intensity

The proportion arable land is strongly correlated to the management intensity variables; plant available nitrogen and harvest of spring barley, and less strongly to the structural variables; Contagion and land use diversity. The connection between proportion arable land and intensity is equally strong over both spatial scales. We can thus draw the conclusion that this, easy to obtain measurement is a good and robust indicator of general land use intensity and that it is equally useful to obtain data on a local as on a landscape scale. The size of fields on the other hand, is not as robust a measure of intensity. From the factor analyses we see that, depending on if local or landscape scale data is used, field size ends up in the first or the third factor and it also switches factor depending or if local or landscape variable are included among the other variables. This indicates that field size depends on the spatial scale used; it can either be regarded as a structural measure or intensity related one. Not so surprisingly maybe since if you look at the average field size over a larger area, local areas of small field will be averaged out and the general pattern of a region of intensive farming connected to large fields will be the only visible one.

Factor analysis

From the analysis including both local and buffer zone data we interpret the first factor as being intensity related. We base this on the high positive score of proportion arable land, nitrogen availability and harvest data. The high negative score of proportion forest is also in line with this; more forest means less area available for farming and also describes an area where farming does not pay off, i.e. harvests are low. Factor 1 thus moves from the intensively farmed plain region in the south west of Scania to the more forested and extensively farmed north east, figure 2. It is interesting to note that it is only in Factor 1 that the buffer zone variables have high scores. This could mean that intensity is manifested at a larger spatial scale than complexity, something also explaining the possibility of finding complex local landscapes within a region of intense land use. On the other hand we did not compute the Contagion and land use diversity indices on a landscape scale (since it included time consuming digitising of small habitats from aerial photographs), and so can only hypothesise about how detailed structural variables behave at larger spatial scales.

We interpret the second factor as a descriptor of structure or degree of complexity, based on the high score of the Contagion index and Simpson diversity index of land use. The high positive score of local proportion permanent pasture is also quite reasonable since pastures contributes to splitting up areas of annually tilled land and thus contributes to complexity. According to factors 1 and 2, which are orthogonal, landscapes containing large amounts of pastures locally are not necessarily situated in a pasture rich larger landscape. A pasture rich landscape can be seen as being of low intensity (according to factor 1), while an area locally rich in pastures can be situated in a less pasture rich landscape and may also contain some intensively managed crop fields and a high proportion arable land, figure 2. The amount of small habitats has a medium score on factor 2. This also strengthens the structural component of this factor since small habitats are most often borders between fields and areas of different land use types.

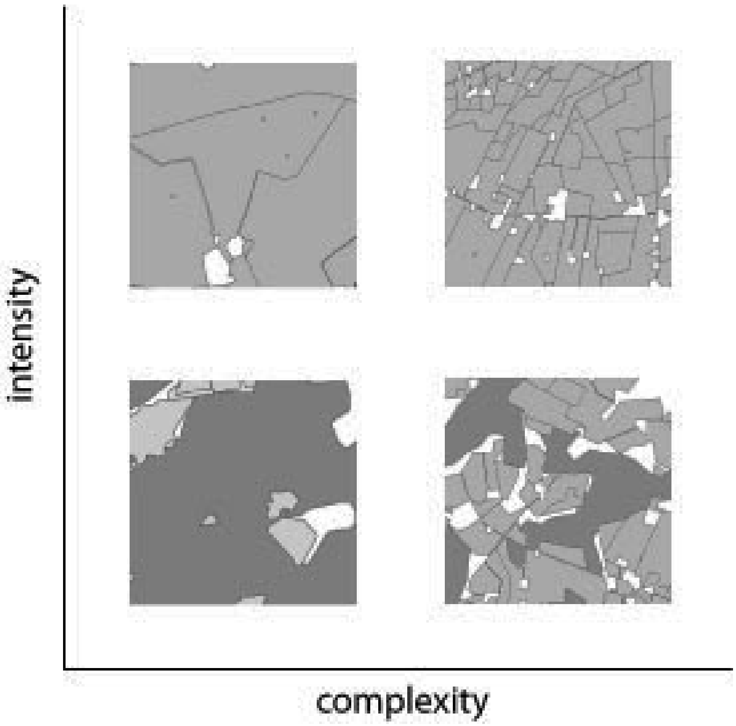

Figure 2. A conceptual graph of how two of the factors from the analysis, representing intensity and complexity, can be visualised. As an example I have placed four landscapes from the study area in the graph to depict the landscape types indicated at the four positions respectively. Medium grey represents farmland and dark grey represents forest.

The third factor only explains 12.6% of the total variation in the material, but even so it is interesting to discuss its meaning. It contains the local crop diversity, the local field size and, with a lower scores, regional field size and the amount of small habitats. Crop diversity is calculated on the individual field level, while field size and amount field borders are based on the “block data base” structure where fields are lumped into blocks delineated by border structures. Individual fields on the other hand do not necessarily have a non crop border. This means that a large block can contain several fields but that a small one most often contain only one or two fields. Even if a large block can contain several fields, these fields are on average larger than the ones contained by small blocks. Individual field size was not used in the factor analyses since it so closely correlated to block size (data not presented here) and was deemed redundant information. The block structure can thus be used as a proxy for field size. This means that the high crop diversity represented in factor 3 corresponds to small fields but also to small blocks and thus a higher amount of border structures. However, factor 3 does not correlate to proportion of any of the main land use categories (arable, pasture and forest), again indicating that local richness of small semi natural habitats is to some degree independent of land use intensity. We interpret this factor as a second component of structure. It is more connected to the presence of small, non crop habitats where as factor 2 was more governed by the distribution of major land use classes, as described by the Contagion and diversity indices.

Using the results from the factor analyses of the local, the landscape and the combined spatial scales we can draw some conclusions on the value of including data at different spatial scales. The local only and the local and landscape factors are very similar and differ only in that the small habitat variable becomes more clearly associated with factor 2 when landscape variables are excluded, giving this factor an even stronger structural component while factor 3 now represents field size and crop diversity only. The small difference between the factors of these two analyses might indicate that it is sufficient to use only local variables. When comparing the combined and the landscape only analyses, the difference is larger. Here the third factor now represents field size plus the two clearly intensity related variables nitrogen level and harvest of spring barely. This means that both the first and the third factor now represent intensity, but since they are orthogonal to each other they describe different components of intensity. The first factor is related to proportion arable land and the third to field size, again indicating that using only one of these to variables does not tell the whole story of either intensity or structure. It is also evident from these comparisons that there is great value in detailed local information on structural components like field size and amount of small habitats to explain landscape variation, but that even when including only two structural measures all three analyses divides the information into a first factor representing intensity and a second one representing structure. Overall, leaving out local data (except for Contagion and land use diversity) changes the outcome of the analysis.

The scale dependency of the relationship between management and land use variables highlighted by Purtauf et al. (2005) are not directly visible in this study, quite possibly since we were not able to include all variables at both spatial scales. On the other hand, when comparing the factors resulting from the three factor analyses and by evaluating the correlations between variables at different scales, we see that some variables seem to be robust over scales while others are less tightly correlated and also switch factor depending on scale. Maybe this doesn't prove a scale dependency but it draws our attention to the importance of considering at which scale your variables have been attained.

Land use intensity versus landscape complexity

From the results shown here it is quite clear that it is possible to separate intensification and complexity from each other. Of course the result of a factor analysis depends on the variables you put into to it. The variables we have chosen are a mixture of clearly intensity related ones (nitrogen level, harvest data, proportion of arable land), clearly structural ones (Contagion index, land use diversity, amount of small habitats) and some that are not that easy to classify (proportion of pastures, field size). Some, like the proportion of arable land, have previously been used as a descriptor of both intensity and complexity (Roschewitz et al. 2005) and it is thus very useful to see in which factor it ends up and how it correlates to the other variables.

In general we interpret factor 1 as a descriptor of intensity of land use, and the factors 2 and 3 as two different components of landscape complexity and structure. This means that at least for this study region, Scania, we cannot equal intensity and complexity but rather we should look at these parameters as two separate axes, (see figure 2 for a conceptual picture).

Conclusions

Our results show that the proportion arable land at a local or at a landscape scale is a good descriptor of land use intensity. So are harvest and nutrient data, but since this data is often less detailed unless questionnaires to individual farmers are used, the proportion arable land seems to be the better choice. The size of fields seems to represent a combination of intensity and complexity and is thus less useful if the objective is to be able to analyse data in relation to these two factors separately. To describe complexity we suggest to use a structural index like the Contagion or Simpson diversity index on major land use classes and small semi-natural habitats plus the amount of small habitats, or to let a factor analysis compute factors from your landscape data. Most importantly, the terms “intensity” and “complexity” or “heterogeneity” are not interchangeable and care should be taken to state what meaning one puts into them.

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