Site comparison method (SICOM) – a tool to generate maps and tables with administrative use as a basis for the evaluation of spatial equivalence of agri-environmental measures (AEM)

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Abstract

This paper presents a comparative method (SICOM) to evaluate complex site conditions at the level of a Federal State (Brandenburg) and at different areal units. The methodology uses primary site conditions and provides the possibility to objectively compare and judge different ecological questions. Objects with heterogeneous content are pooled in comparison groups. Consideration of the main site characteristics allows a goal-oriented allocation of subsidies. The use of SICOM is demonstrated for the wind and water erosion risk assessment across different scales from Federal State down to a parcel of land. The "parcel" aggregation-level proves to be useful to assess the erosion risk. Larger scales are less useful in the assessment of subsidies policy with regard to erosion risk. SICOM is demonstrated to be suitable for comparing and assessing regional aspects more objectively.

Keywords: wind erosion, water erosion, erosion risk, comparison method, site evaluation

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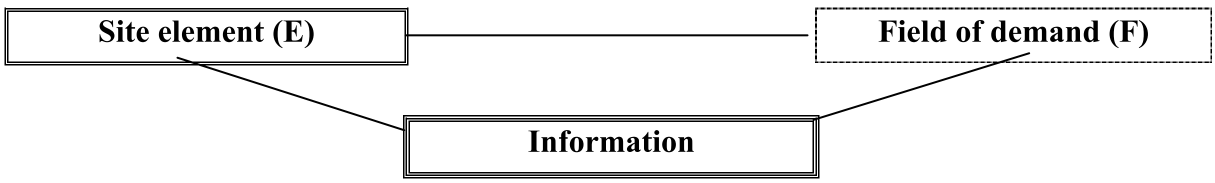
1 Introduction

Strategies for land development demand qualitative and quantitative information about the natural conditions of the site. It is necessary to compare this information with agri-environmental, ecological and economic measures or data. Those data provide a basis for evaluations of ecological measures in different regional scales (from smaller than NUTS-5 level (parcels - ≈1,2 km²) to NUTS-3 level (county - ≈120.0 km²) and greater units (e.g. catchments)). The results can be used among other things to check the handling of subsidies for a region. For that purpose a method is necessary to restructure and reduce the extensive spatial data -which characterises environmental conditions- objectively to be essential in limited areas (= regional units). SICOM follows a methodology of comparing the assessment of user-defined landscape-cut-outs regarding different area relations (Thiere et al. 1991, Deumlich et al. 1997). In such a manner, SICOM can support the sustainable land use. Essential indicators are deducible. SICOM is a valuable component to assist or control directives of AEM. The data concept, algorithms and some results for the Federal State Brandenburg as a basis for the realistic allocation of subsidies will be presented for two environmental examples – the indicators of water and wind erosion. The paper of Matzdorf et al. (2004) discusses the KULAP-strategies. SICOM serves as a basis to compare the natural conditions with the agricultural subsidy measures.

2 Method

2.1 Site comparison with SICOM

The character of the site judgement depends on the required information combining one or more site elements with a field of demand (Fig.1). A comparison requires an abstraction by essential site-specific contents. The principles in abstraction have to consider vertical and horizontal variation of attribute-specifications.



The site element (E) is the smallest component of a site. It can not be fractionised within a certain context.

The field of demand (F) is the sum of all site-depending criteria in the site judgement. The basis of SICOM is a standardised data concept (Thiere et al. 1991).

Mapped or empirical data are assessed by agrarian or other essential aspects (valuation background) and aggregated in 6 classes referring to their attributes. Through this classification the site conditions are already comparatively interpreted (Table 1). The classes are symbolised by increasing attribute characteristic from 0 to 5 (so called comparison steps – CST, 0 = favour, 5 = disfavour). Using GIS-techniques with the help of CST and the appending area further comparison data can be computed for complex area units.

Water and wind erosion risks can be compared in different contours (parcels = in German Flur, boundaries = Gemarkung, county, ….). The most important precondition is the interpretation of the basic data. The potential erosion risk increases with unfavourable site conditions (slope condition, high soil erodibility) with regard to the weather situation. The erodibility depends usually on soil texture and the content of organic matter. For water erosion processes the relevant properties are permeability, aggregate stability and stone content. For wind erosion the hydromorphy conditions are relevant. The erosion risk can be numeralised in CST using a qualitative combination matrix.

The comparison of any natural landscape or administrative unit with SICOM is based on the symbolised features and their areal data (Deumlich et al. 1997). The area information are soil attribute data linked to their geometric data. They represent typical soil properties and are provided digitally. Parameters for comparison will be computed according to intersecting actions with the area units to assess. These are

triple of dominance – DT – It contains up to three area-wide dominant features (the first number represents the dominant, the second number the subdominant and the third number the attendant comparison step). DT is the basis for the following computations of contrast data. Using a contrast matrix, the main contrast (MC), attending contrast (AC) and the contrast group (CG) can be calculated (Thiere et al. 1991). The map legend is deduced by the frequency of triple variants.

level of dominance – DL - Referring to the first number of the DT it represents the degree (percentage of area) of dominance in 4 gradations to (1 - low < 40 %, 2 - middle > 40 to 60 %, 3 - high > 60 to 80 %, 4 - very high > 80 %).

pair of dominance - DP- It contains the two area wide dominant features (dominant, subdominant comp. step) and in the third position the number of the level of dominance.

comparison index – IND – It is a complex parameter representing all comparison steps and their area in one number between 0 and 100

$$IND = \frac{\sum_{i=1}^{5} \text{comparison step}_i * \text{percentage of area}_i}{5} \qquad (1)$$

index class – IC – The comparison index can be subdivided into 6 classes: IC0: < 22, IC1: 23-31, IC2: 32-44, IC3: 45-63, IC4: 64-80, IC5: > 80

2.2 Water erosion risk estimation

The Universal Soil Loss Equation (USLE adapted for Germany) with soil loss (A) = erosivity (R) * soil erodibility (K) * influence by topography (LS) * influence by vegetation cover and management (C) is applied (Schwertmann et al. 1990). Digital soil data are parameterised and multiplied with the specific regional factors R and C. The factor for soil protection (P) is not considered. The LS-value is computed using a DEM (grid-length 25 m, LVermBBG) with regard to the slope length, limited by structure elements. For each grid cell the potential soil losses were computed and classified into steps of comparison (Table 1). Using SICOM the grid data could be aggregated on parcels, boundaries and counties. The detailed data was clearly generalised in data for comparison.

Table 1: Classification of soil loss into comparison steps

comp. step	Potential soil loss in t/ha	Eroson risk
CST0	0	none
CST1	> 0 ... 0,5	very low
CST2	> 0,5 ... 1	low
CST3	> 1 ... 3	moderate
CST4	> 3 ... 8	high
CST5	> 8	very high

2.3 Wind erosion risk estimation

The basis for the estimation are spatial data of the ‘Medium Scale Agricultural Site Mapping’ (MMK, a map in the scale of 1:25.000) which includes 99 soil association groups and 15 hydromorphy association groups for all agricultural land. Soil association groups comprehend information about texture and stratification, hydromorphy association groups about the water regime and they are also used to gradate the soils in their humus content. The multitude of possible combinations between both factors is summarised in a simplified scheme to derive four risk classes (Table 2).

Table 2: Estimation of the wind erosion risk from soil and hydromorphy association groups (acc. to Lieberoth et al. 1983)

	Hydromorphy association groups		
Soil association groups	influenced by rainfall	influenced by rainfall and ground water	Influenced by ground water
Sandy soils	high (5)	medium (3)	none (0)
Loamy soils	medium (3)	medium (3)	none (0)
Loam, alluvial soils	low (2)	low (2)	none (0)
Peat soils, Moor	none (0)	none (0)	none (0)

Comparison steps for SICOM are in brackets

The influence of structural elements is estimated in the second step. As a structural element is defined: it is any obstacle in a landscape influencing the wind field by its height and extension. The structure of the landscape is the summarized effect of all relevant elements like woods, hedges, solitary trees or settlements and is revealed by the "Biotope and Land Use Mapping" (Luftbild Brandenburg 1992). This map contains all landscape elements in a very detailed encoded form as vectors or polygons. The main classes and the range of the given heights are shown in Table 3.

The protected area is about the 25-fold of the height behind a shelterbelt and the 5-fold of the height in front of them (Nägeli 1943). The protected area in front and behind every structural element is calculated by using the 'hill shade'- procedure in ArcInfo to visualize a virtual wind shadow (2,3 ° representing the 25fold, 11,4 ° for the 5fold).

Table 3: Main units of the biotope type and land use mapping and classed heights

Code	Description	Span of Heights
01	Running water (with seam)	1 m
02	Stagnant water	0
04	Moor and swamps	1 m
05	Grassland	1 m
06	Small shrubs, heath land	1...5 m
07	deciduous shrubs, alleys, tree rows	1...5 m
08	Woods and forests	5...20 m
09	Farmland	0
10	Park areas outside of settlements	2...10 m
11	Special biotopes	0...5 m
12	Settlements and traffic areas	0...10 m

Long term records of meteorological data, provided by the Potsdam station, were evaluated with regard to the frequency of wind speeds above the threshold of 8 m/s for eight directions (0°, 45°, 90°...). The relative frequency of wind > 8 m/s of a given direction is used as a weighting factor (Table 4).

Table 4: Frequency of wind directions (Station Potsdam)

Direction	Frequency [%]	Direction	Frequency [%]
North	3,7	West	15,3
Northeast	4,9	Northwest	6,9
South	7,7	East	12,1
Southwest	12,4	Southeast	6,6

All spatial data were converted to grid data with a cell size of 10 x 10 m. In this case even obstacles of a one-meter height can be considered in the analysis. The shadows of structure elements are coloured with the grey scale using 255 for black and 0 for white. Then the numerical value of the grid cells covered by the shadow was multiplied with the relative frequency of wind > 8 m/s from the corresponding direction. The degree of protection of any cell depends on the distance to the structural element, the height of the element and their position related to the prevailing wind direction. After the calculation all results were classified into five protection groups (very low (1)…very good (5) (Table 5).

Table 5: Matrix to determine the new risk classes (comparison steps)

Risk classes	Protection group of the structural elements				
	very low (1)	low (2)	medium (3)	good (4)	very good (5)
high (5)	5	5	4	2	1
medium (3)	3	2	2	1	0
low (2)	2	1	1	0	0
none (0)	0	0	0	0	0

The aggregated data were calculated in the same manner as per description for water erosion.

3 Result and discussion

3.1 Water erosion

For Brandenburg the water erosion risk is classified into: 16% - none, 43% very low, 32% - low, 8% - moderate, 1% - high and 0,1% very high. Regions with higher risk are shown in figure 1.

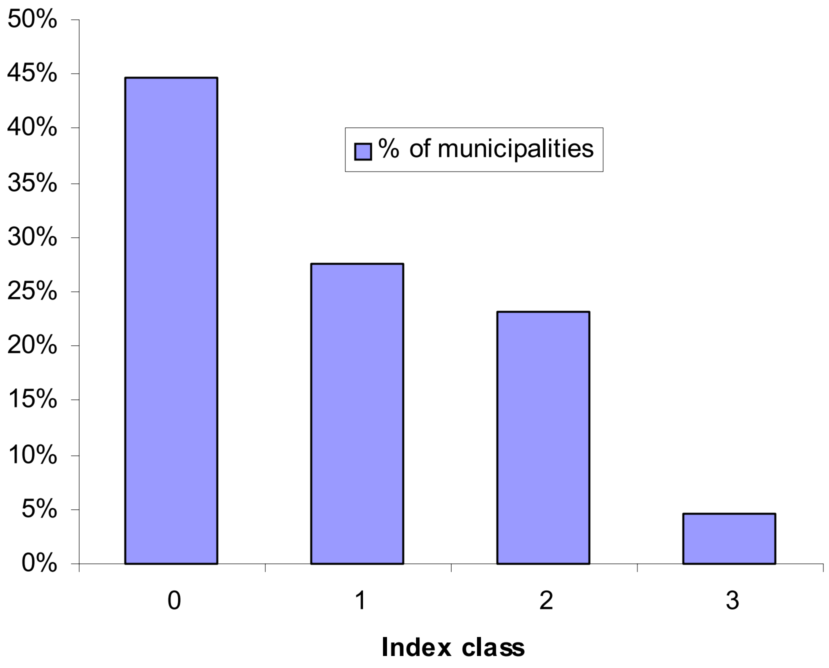
The heterogeneous spatial distribution will be summarised using SICOM on administrative units. The calculated data permit the assessment of complex regions with a standardised method based on the judgement of relative constant site conditions. Conclusions for the comparison by criteria of favour are possible by a precise combination, shown in Table 5 for the level of parcels, municipality, county. The organising principle is free, for example by the index or triple of dominance. The highest importance for integrating erosion protection measures is estimated for parcel 12118100 and 121170010. They show considerable shares with high erosion risk. The next essential step is the comparison of the estimated risk and the actual land use. Generally, grassland is managed with "good agricultural practice" or agricultural subsidy and good conditions are given to reduce the erosion risk. Otherwise erosion mitigation measures should be initiated. Actually, there are no protection measures for this parcels. But contemporarily about 20 % of the parcel is used as grassland. For this reason erosion can be reduced if the grassland is situated at the slopes.

A great advantage of SICOM is that more than one parameter exists to deduce a decision for the areal unit. There are comprehensive information from the shares of risk, the heterogeneity up to the classification.

The spatial variation of the risk in a Federal State demands - according the top-down-principle – a more detailed consideration of the threatened area. Thus, further conclusions are possible in a bigger scale. A look at the county (a rough level) shows that no county is completely without erosion risk, recognizable by the first number of the triple (DT) Table 7). Normally, at parcel level - the finest aggregation of the grid data - this case is possible (Table 6, parcel 121181009). The Index class gives a more realistic overview of the risks compared with the first number of the triple of dominance seen in table 7 (figure 1). Therein is integrated not only the dominant comparison step but also all other specifications using equation (1) and is following grouped. Hence, this comparison data IC is mostly used to compare areal units.

The special areal risk is only recognizable in big scales. This is shown for parcels and boundaries (Figure 2). The summarised SICOM-results at the parcel level show that there is no parcel with a dominant high erosion risk (CST5 at the first number in triple). On the other hand, there are such areas, but their occurrence is linked to special soil and topographical conditions. This area is only identifiable with GIS-methods at the grid level. GIS permits us to obtain results for planning/control of subsidies in a scale up to 1:10.000 also in the parcel or arable field. This allows a detailed result as a basis to initiate measures at the point where the risk starts or is present.

Figure 1: Frequency of water erosion risk (level municipality)



The water erosion risk of agricultural used areas in Brandenburg primarily exists in step 1 (very low) and 2 (low). A concentration of the classes with the highest amount occurs in the finest resolution in up-scaling processes.

Figure 2: Potential water erosion risk in different area (Federal State, cut-out)

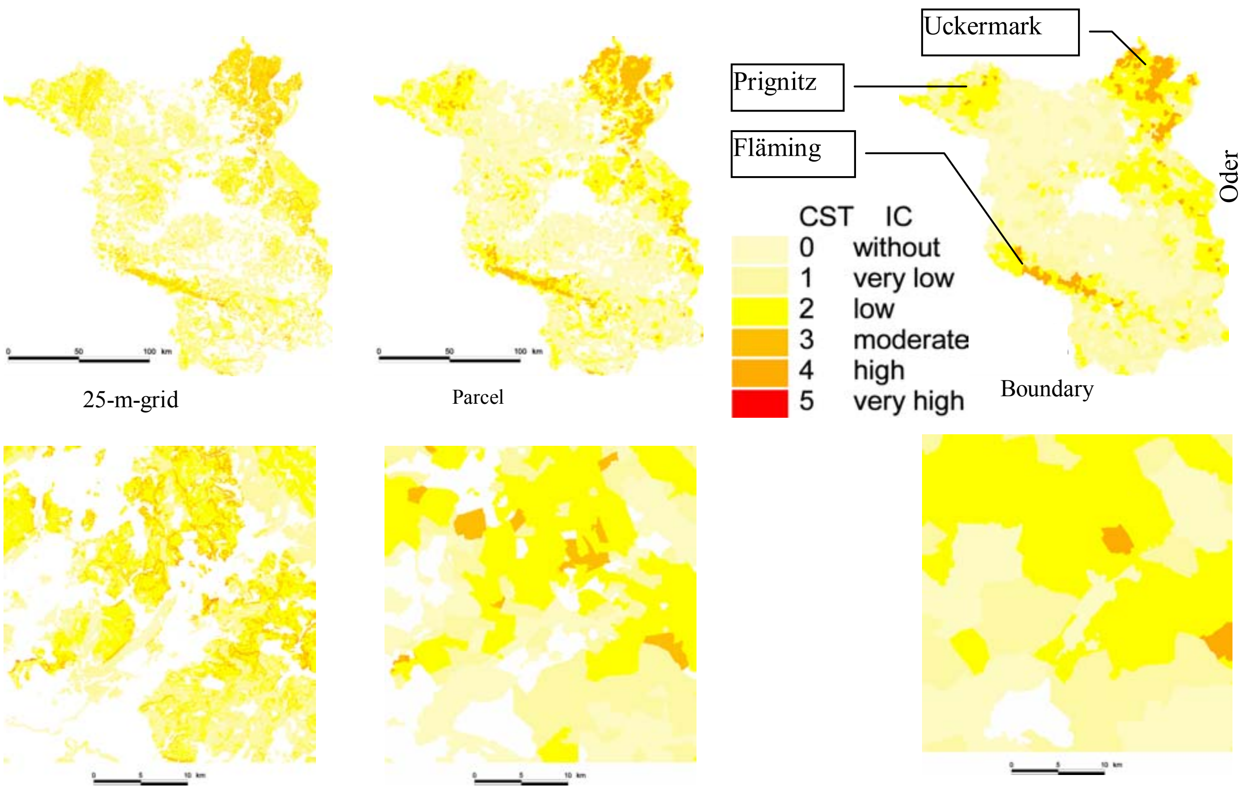


Table 6: Estimated comparison data for some different areal data

	Comparison step						Comparison data								
	0	1	2	3	4	5	DT	DL	DP	IND	IC	MC	AC	CG	GIS-ha
Parcel (Flur)															
122928011	59,5	40,5	0,0	0,0	0,0	0,0	01-	2	012	8	0	1	0	1	61,9
124311003	0,0	49,4	50,6	0,0	0,0	0,0	21-	2	212	30	1	1	0	1	67,6
121722009	1,8	35,8	59,5	2,9	0,0	0,0	213	2	212	33	2	1	3	1	56,3
121181009	0,2	1,7	22,1	41,9	27,1	7,0	342	2	342	63	3	2	3	1	235
121170010	0,0	0,0	3,7	38,8	54,7	2,8	432	2	432	71	4	2	3	1	13,4
Boundary (Gemarkung)															
121751	60	37	2	0	0	0	012	2	012	9	0	1	2	1	1080
123921	3	0	34	61	2	0	320	3	323	52	3	2	3	1	960
123916	0	0	22	65	11	2	324	3	323	58	3	2	3	1	716
Municipality (Gemeinde)															
12063192	34,2	60,1	4,6	1,0	0,0	0,0	102	2	102	14	0	1	2	1	473
12064316	9,0	35,0	41,7	13,0	1,2	0,1	213	2	212	33	2	1	3	1	3754
12073592	7,1	5,8	33,3	44,8	8,0	1,0	324	2	322	49	3	2	3	1	1644
County (Landkreis)															
UM	13,3	12,9	38,8	31,4	3,3	0,3	230	1	231	40	2	2	3	1	215280
MOL	5,1	34,3	51,7	7,6	1,1	0,1	213	2	212	33	2	1	3	1	149700

Table 7: Frequency and area portion of triples of dominance in Brandenburg (% of GIS-LN)

Water erosion

Level	1. number of DT					
	0	1	2	3	4	5
County	0	64,3	35,7	0	0	0
Municipality	8,2	52,6	34,4	4,8	0	0
Boundary	9,5	50,6	34,8	5,1	0	0
Parcel	12,7	47,5	34,2	5,7	0,01	0

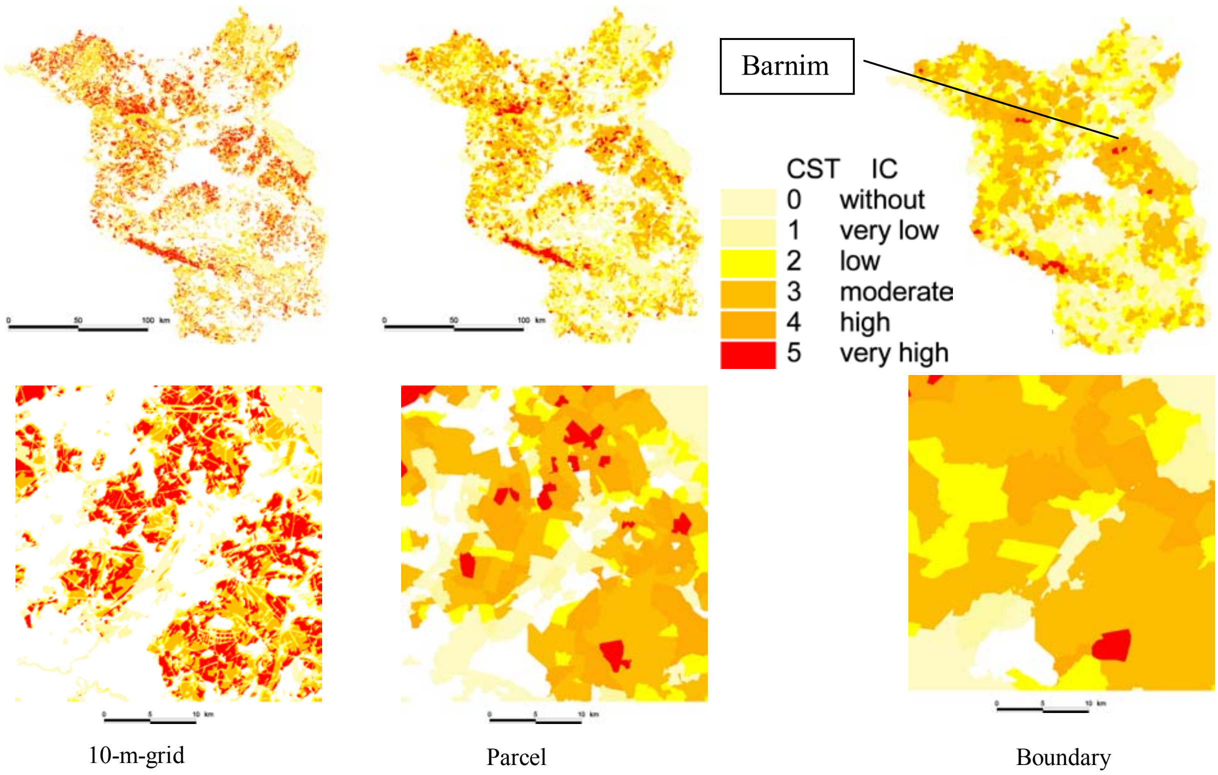
Wind erosion

Level	1. number of DT					
	0	1	2	3	4	5
County, n = 18	75,6	15,3	0	0	0	9,10
Municipality, n = 1.237	46,7	14,3	1,1	12,2		25,8
Boundary, n = 2.562	43,7	15,6	21,1	15	0,001	23,7
Parcel, n = 12.547	37,1	17,3	4,3	17	0,2	24,2

3.2 Wind erosion

The basic data for water erosion is calculated using a quantifying model (USLE, empirical model), then classified and aggregated. The procedure in wind erosion differs. The basic data comes from a classification in 4 classes made by experts (Table 2 and 5). Hence, after aggregation, class 4 is less represented. Therefore, the amount of triples of dominance with 4 is also seldom at the first position (Table 5). In the future, a changed method or the use of a quantifying model considering the actual land use is necessary. In this case a better distribution and classification into steps of comparison seems possible. For the entire state the wind erosion risk is estimated with 32% - none, 18% - very low, 13% low, 14% moderate, 6% high and 17% very high endangered agricultural used area. Regions with fine sandy or silty top soil texture show higher erosion risks (seen in figure 3, Prignitz, Fläming, Barnim).

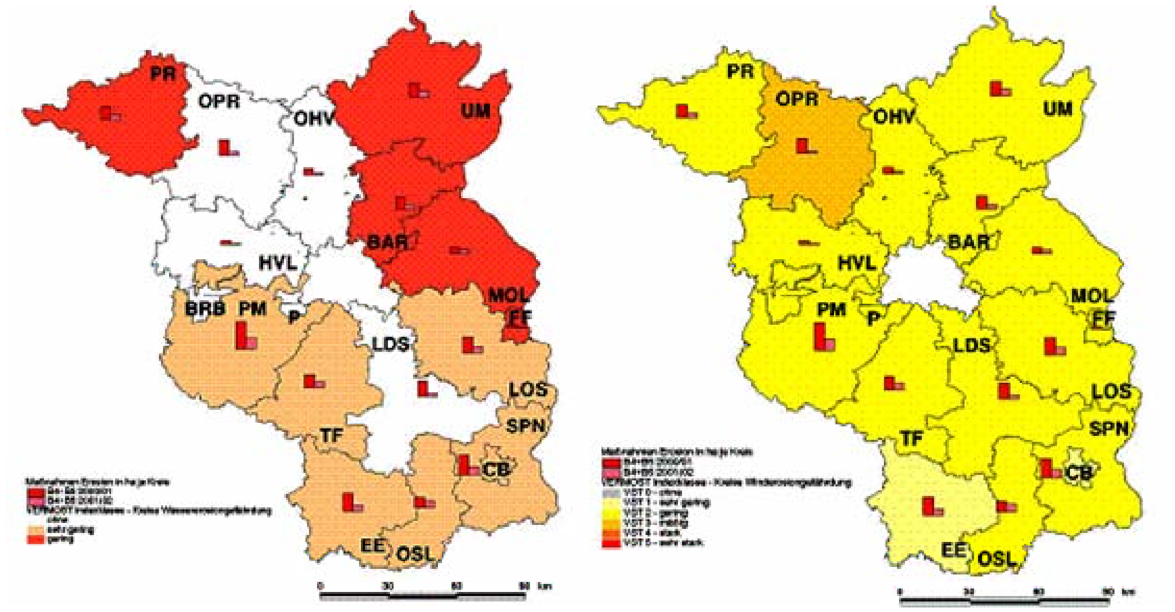
Figure 3: Potential wind erosion risk in different areas (Federal State, cut-out)



3.3 Regional evaluation of AEM

The spatial distribution of KULAP-measures to mitigate the erosion risk is important. Relevant measures are the change from arable land to grassland (B5) and practices that reduce erosion, protect the soil fertility and diversified crop rotation on arable land and open-cast mining areas (B4, integrating alfalfa, clover cultivation in the crop rotation, catch and undersown crops). Figure 4 shows the threat-space-oriented distribution of B4- and B5-measures. This results will be discussed in Matzdorf et al. 2004 more detailed. Here it is obvious that the regional acceptance of wind erosion threatened area is marginal higher than in such threatened by water erosion. But the amount of this measures is only applied at 6,4 % (2000/01) or 2,9 % (2001/02) of 375.000 ha wind erosion threatened area. Subsided measures against water erosion are applied only at 5 % (00/01) resp. 2,2 % (01/02) of around 88.000 ha endangered area. Only a small amount of relevant measures is applied on areas with higher risk. In the future it is necessary to increase the awareness of farmers, equally in special environment indicators for wind and water erosion.

Figure 4: B4 and B5 measures against water erosion (left) and wind erosion (right) and their threat-space-oriented distribution in Brandenburg



4 Summary

Using primary site data SICOM opens the possibility to compare and judge different ecological questions objectively. Objects with heterogeneous contents can be summarised to comparison groups. Sorting by index, triple or others is possible. The summarisation of the basic grid data and a focus on the essential allows the generalised examination of the purposive use of subsidies, in this case demonstrated for water and wind erosion. The aggregation level, 'parcel', proves to be useful to compare the measures to mitigate the erosion risk and the real risks. The areal and concrete combination of SICOM-data and the agri-environment-(KULAP)-measures will be discussed in the paper by MATZDORF et al. (2004).

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