FUNDAMENTALS OF ENVIRONMENTAL MONITORING AND DISPLAY OF VALUE OF ENVIRONMENT ON MAPS

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Abstract

To evaluate the quality of environment and to store it in databases or on maps is crucial not only for the environmental management but also for the control of the economy as well as of life of society. The paper summarizes the different systems of this evaluation methods. Then briefly describes the method of biotope goodness number as an evaluation model developed at the Chair of Environmental Management at the Forestry Faculty of University of Sopron.

1. Introduction

To describe the quality of environment of a given area on a map we have to have an evaluation model that is a specified set of environmental variables and an evaluation method. Then we measure these variables and on the base of the measured values and with the defined method the quality of environment can be calculated and shown on a map. The calculating-mapping system depends on the applied measuring grid and on our purpose to use this evaluation. We may use it to describe the quality of environment of an area, or of several points. Mostly we need the evaluation to follow the changes in time.

2. Mapping and calculation methods of quality of environment.

2.1 Mapping the quality of environment of areas.

In this method we calculate the quality of environment from avarage values of environmental variables. The method can be used when

a) the variation of environmental variables over the analysed area is not too high
b) we do not wish to record the coordinates of the sites of measurements
c) we want to follow the quality of environment of the whole area over a period of time
d) we want to follow an environmental varible over a period of time.

Generally:

$$e = f(M(p_1), M(p_2), \dots, s_1, s_2, \dots) \tag{1}$$

where:

e is the quality of environment
$M(p_1)$ and $M(p_2)$are the averages of p_1 and p_2 point related env. variables over area;
s_1, and s_2,are area related env. variables.

A point related variable can be the depth of (soil) water, thickness of a layer of soil, speed of wind, concentration of some salt in the soil, temperature and so on, while area related varibales are e.g. number of species on the analysed area, % rate of a special land use, data of diversion.

In many cases we regard *e* as vector with $M(p_1)$, $M(p_2)$, ..., s_1, s_2, ... it's components. Now to describe the quality of environment we give **e** that is we simply list these components. By this however it would be difficult to assess the quality of environment and it would be impossible to display it on a map which many times contains several landscape ecological units (forests, fields, lakes and so on). To each of these units different evaluation model may apply. Their qualities of environment can be shown on the same map only if these models are comparable. So comparability is a critical point for mapping. (E.g. different sets of environmental variables are to be measured in a forest and in a cornfield or in an inhabited place). To circumvent the problem we may apply a "calibration method" in which we use normated values instead of measured values of v:

$$\beta_i = \frac{|v_i - v_{i0}|}{|v_{i1} - v_{i0}|} = \frac{|v_i - v_{i0}|}{v_{i\max} - v_{i\min}} \tag{2}$$

where

v_i is the actually measured value of i. environmental variable,

β_i is it's normated value,

v_{i0} is the most detrimental, v_{i1} is the most favorable value of v_i regarding the health of environment,

$v_{i\min}$ is the minimum, $v_{i\max}$ is the maximum value of v_i

Now the length of **e** can be used to describe the condition of environment:

$$|\mathbf{e}| = \sqrt{\beta_1^2 + \beta_2^2 + \ldots + \beta_n^2} \tag{3}$$

The best quality of environment can be indicated by $\beta_i = 1$ or $\beta_i = 0$. The first solution is more preferable. In this case $|\mathbf{e}| = \sqrt{n}$ indicates the best, $|\mathbf{e}|=0$ the worst environment. Dependence of β_i of v_i is linear according to (2) however also a nonlinear independence is defineable.

Though this method is a bit subjective since we have to establish a worst and best value for each variable it enables us to take into consideration the effect of every variable on the quality of environment and to follow the changes over time.(Sometimes this can be based on statistical analyses presuming we have the needed quantitiy of preliminary data). However the comparison between two landscape ecological units is only possible if n is equal for both units. If we describe the quality of environment by $e=|\mathbf{e}|/\sqrt{n}$ also this problem is circumvented. In other words e is the square avarage of the normated values of the varibles. In this case e=1 indicates the best, e=0 the worst environment (or the reverse).

The results of this method can be further proved by usnig a "weighting-calibrating method" where we allocate various weights to the environmental variables according to their importance. This however adds another subjectiv factor to the modell.

Many times the researchers use scores instead of normated values. Otherwise the calculation of e is similar to the methods discussed so far. So alltogether we have 8 methods which are summarized as follows. (First formulas represent the min. results the second ones the max. results).

i. normated, calibrated, vector length,	0	$\sqrt{n}$
ii. normated, calibrated, average,	0	1
iii. normated, weighted-calibrated, vector length,	0	$\sqrt{\sum w_i^2}$
iv. normated, weighted-calibrated, average,	0	$\sqrt{\sum w_i^2 / n}$
v. scores, calibrated, vector length,	$\sqrt{\sum \beta_{i\min}^2}$	$\sqrt{\sum \beta_{i\max}^2}$

vi. scores, calibrated, average, $\sqrt{\sum \beta_{i\min}^2 / n}$ $\sqrt{\sum \beta_{i\max}^2 / n}$

vii. scores, weighted-calibrated, vector length, $\sqrt{\sum w_i \beta_{i\min}^2}$ $\sqrt{\sum w_i \beta_{i\max}^2}$

viii. scores, weighted-calibrated, average. $\sqrt{\sum w_i \ \beta_{i\min}^2 / n}$ $\sqrt{\sum w_i \ \beta_{i\max}^2 / n}$

(Some researchers use arithmetical avarage instead of square avarage). In case ii. we appaerently have no problem with comparebility. In all other cases landscape ecological units are comparable only if max. and min. qualities are equal for the two units. If these requirements cannot be met we have to apply normated environment qualities (ε). The calculation is the same as that according to (2) we only apply calculated e values instead of measured v values. Further problem arises if β can be stated only as multivaribale function: $\beta = f(v_i, v_j, \dots v_n)$. Such cases complicate a bit our evaluation model especially when there is an interdependence between v_i, v_j and v_n and it isn't recognized by the developer of the model.

To get a reliable value of environmental quality we have to sample the analysed area. The sampling technics must meet the demands of random sampling. Sampling units may be the natural units of land within the analysed area e.g. parcels of cultivated land or of forest or districts of inhabited places.

On maps showing environmental conditions of areas we have use double indication system: e.g. we use graphical signs to indicate the landscape ecological units and a colouring to indicate their environmental values.

2.2 Mapping the quality of environment of points.

This method can be used when

a) the variation of environmental quality is presumably high over a given area and we want to follow the changes in quality over the area;

b) we want to follow the environmental quality of some given points over time.

In this case we have to analyse the environmental quality of these defined points of the area separately. It is most recommendable that these points make up a systematical grid. It is justified by interpolation reasons and besides such a grid more or less meets the demand of random sampling. Thus we are enabled also to

c) follow the quality of environment of the whole area over a period of time

d) to follow an environmental varible over a period of time.

Now we measure the environmental variables required by the evaluation model on each predefined point - measuring points. If we want to gain a picture of the environmental quality of the whole area then we have to calculate an average:

$$e = M(e_i(p_1, p_2, \dots p_m)) + a(s_1, s_2, \dots s_n) = M(e_i(p_1, p_2, \dots p_m) + a(s_1, s_2, \dots s_n)) \qquad (4)$$

$$\text{or} \quad e = M(e_i(p_1, p_2, \dots p_m, s_1, s_2, \dots s_n) \qquad (5)$$

where e_i is the quality of environment for i. point; it is calculated from point related variables and a is the quality calculated from area related variables - other variables as by (1). (4) and (5) represent different evaluation philosophies.

For the purpose of a systematical grid of measuring points an UTM (Universal Transverse Mercator) grid seems the most expedient where the measuring points are located at the center of the cells. If we want to show e_i as function over the area we may regard e_i valid 1) only for the measuring point 2) for the whole UTM square (Fig.1/a). In case 2) our map can bear more information if we indicate not only the env.quality but also the landscape ecological unit. This can be done UTM raster based (Fig. 1/b). or precisely indicating the borders of these units (Fig. 1/c).

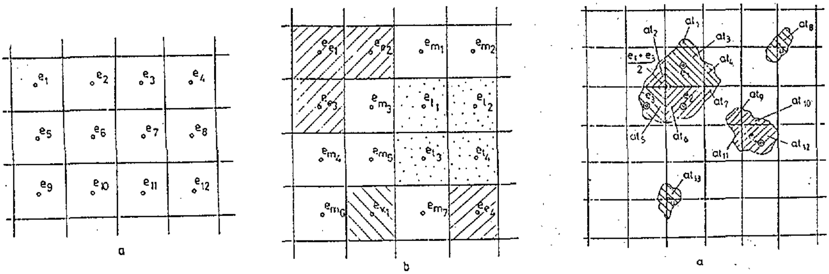

Figure 1. Basic mapping technics of condition of environment (e).

2.3 Scale of evaluation of environment

For the mapping of quality of environment the mapping can be done on global, regional or local level. Therefore it is important that we see the ways which there are to change the scale of environment evaluation. A smaller scale means a higher detail of evaluation. The detail of evaluation can be increased if:

- the grid of measuring points is densed proportional to the decrease in the evaluation area;
- the density of grid remains unchanged however the evaluation model uses more environmental variable;
- we use a more sophisticated definition for landscape units therefore more landscape units within the evaluation area.

3. The method of biotope goodness number to evaluate the quality of environment.

This method, developed at the Chair of Environmental Protection of University of Forestry and Wood Sciences at Sopron, Hungary, is a scoring calibrating one with mathematical average to describe the condition of environment. It applies four major divisions of environmental variables to be measured with subdivisions within each division. Sets of env.variables are defined for arable lands, forests, waters and inhibited places. Scores are given according to the measured values. Max. scores are 100 in each division so the average ranges from 0 to 100 and the comparability between landscape ecological units is assured. 0 indicates the worst, 100 the best environment. To qualify the environment the so called "biotope goodness number or ability index" (Bj) is used:

$$B_j = \frac{P_1\mu_1 + P_2\mu_2 + P_3\mu_3 + (100 - P_4\mu_4)}{4} \qquad (6)$$

where P_i are the given scores on basis of measured env. values in the i. division

μ_i is a precising factor in the i. division.

The divisions and their subdivisions with their max. scores are as follows:

1. Operation of environmental system (P_1):

a) net primary production	30
b) biomass generation	50
c) leaf surface index	20

2. Populations and their biotope (P_2):

a) relationship between population and biotope 30
b) number of populations 20
c) changes in populations genetics 20
d) keeping ability of environment 20
d) changes in material and energy flow 10

3. Non renewable resources (P_3):

a) quantity 60
b) accessebility 30
c) quality for exploitation 10

4. Effect of constructed (artificial) environment (P_4):

a) condition and contamination of air 35
b) condition and contamination of waters 35
c) condition and quantity of wastes 20
d) level of noise. 10

The measured values of the environmental variables or the given scores respectively indicates the condition of environment. These conditions and their characterizing scores in the major divisions are as follows:

Condition of environment	Operation of environmental sys.	Populations and their biotope	Non renewable resources	Effect of constructed environment
Perstable	80	80	80	20
Stable	55-80	55-80	55-80	20-45
Indifferent	45-55	45-55	45-55	45-55
Unstable	20-45	20-45	20-45	55-80
Collapsing	20	20	20	80

An example using these cathegories to evaluate the environment is shown by Fig. 2.

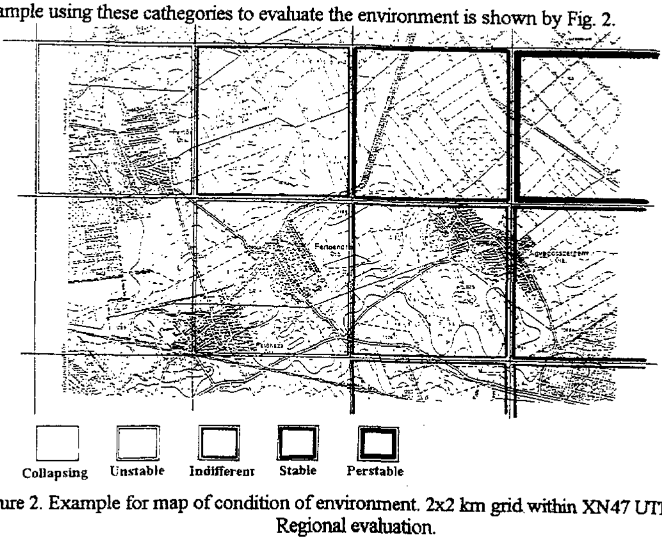

Figure 2. Example for map of condition of environment. 2x2 km grid within XN47 UTM square. Regional evaluation.