A Systematic Approach for Locating Optimum Sites[1]

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Abstract: The basic information collected for landscape planning studies may be given the form of a "s x m" matrix, where s is the number of landscape units and m the number of data gathered for each unit. The problem of finding the optimum location for a given project is translated in the problem of ranking the series of vectors in the matrix which represent landscape units. The paper describes a method to do this, solely on the basis of data gathered.

Landscape planning studies or projects frequently (and with some approaches always)have to face the problem of assigning optimal land uses according to certain objectives; this, of course, implies that a reliable framework, within which decisions can be taken, must be established beforehand.

Planning, nowadays, is multiobjective, even in its most classical forms. The consideration of ecological and visual aspects peculiar to landscape planning reinforces this multiobjectivity, simultaneously introducing further complications. Many objectives inherent in landscape planning are:

a) not commensurable with conventional objectives, nor even with one another.

b) not measurable or, when they are measurable, impossible to value.

The models designed over the last few years to solve this problem have come in for a good deal of criticism based mainly on the subjectivity of the evaluations (e.g., weighting according to the opinion of experts) or on the consideration that any attempt to objectivize something as personal as landscape perception is futile. These criticisms may be refuted with the same arguments in that they are totally subjectively bound within a system of measurement which, though hallowed through the ages, is incapable of measuring new factors of undeniable value, whether intrinsic or man-imposed. "The only substitutes for informed value judgments are uninformed value judgments" (Davidson 1967); considered value judgements are based on a knowledge of the facts, not on sentiment, and are, at the very least, to be respected.

This paper describes one such line of research carried out in our department, the search for methods to rank constitutive or defining elements of landscape and landscape units, according to their intrinsic significance (attractiveness, suitability, carrying capacity, vulnerability, fragility, etc.) or in relation to human activities. Ordinal scales are used, since it is easier to determine and therefore to accept, that one of two given elements makes a greater contribution to visual quality than to quantify that contribution.

DESCRIPTION OF THE METHOD

The aim is to order a series of

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vectors, representing points in the territory, whose coordinates are expressed in non-commensurable terms. The basic idea is to establish and make explicit ordinal relationships with adjustments according to certain criteria or factors conditioning the definition of the problem.

The observations relating to the ecological and landscape variables characterizing the environment usually refer to points on a network or particular territorial units; they may thus be expressed in a matrix:

$$((P)) = \begin{pmatrix} \bar{P}_1 \\ \cdot \\ \cdot \\ \cdot \\ \bar{P}_s \end{pmatrix} = \begin{pmatrix} p_{11} & ----- & p_{1m} \\ \cdot & & \\ \cdot & & \\ \cdot & & \\ p_{s1} & ----- & p_{sm} \end{pmatrix}$$

s = N° of points or territorial units
m = N° of elements defining the landscape

This information, gathered in the preliminary phases of the study, is merely descriptive, nominal and has no direct significance for planning; it must, therefore be made operative. One procedure consists in establishing an ordinal relationship, once each variable j (j=1, 2, ---, m) has been defined and the different j_k types presented by each have been characterized, between the partial descriptions and the values 1, 2, ----, n_j on an ordinal scale, where n_j is t1e number of values on the ordinal3scale with which the element j types have been related.

For instance, let us suppose that the visual vulnerability of landforms is to be considered and that this variable has been divided into three types. The relation, in this case, could be established as follows:

<u>Nominal description</u>	<u>Ordinal scale</u>
p_{j1} = steep slopes	1 (Highest)
p_{j2} = gentle slopes	2
p_{j3} - plain grounds	3 (Lowest)

The matrix ((P)) describing the territory is thus expressed as follows:

$$\begin{pmatrix} \bar{P}_1 \\ \bar{P}_2 \\ \cdot \\ \cdot \\ \bar{P}_2 \end{pmatrix} = \begin{pmatrix} n_{11} & n_{12} & ---- & n_{1m} \\ n_{21} & n_{22} & ---- & n_{2m} \\ \cdot & & & \cdot \\ \cdot & & & \cdot \\ n_{s1} & n_{s2} & ---- & n_{sm} \end{pmatrix} = ((n_{ij}))$$

$i = 1, 2, ----, s$
$n_{ij} \varepsilon 1, 2, ----, n_j$

Definitions

Given two points in the territory:
$A = (n_1, n_2, ---, n\ m)$ and
$B = (n_1', n_2', ---, n_m')$
we say that A precedes or is superior to B (A < B) if, and only if, $n_i \leq n_i'$, $\forall i = 1, 2, ---, m$.

Thus, A = (1,2,4,4) precedes to B= (2,2,5,6) since 1<2, 2=2, 4<5, 4<6. If $n_i < n_i'$ is not held for every i, as in A = (1,2,4,4) and C = (2,1,3,6), we say there are non-inferior points to each other.

Process

These definitions lead to a first obvious ordination, not sufficient however in most cases because the relation will only work for a few points. But the process may continue by calculating the number of points each precedes and is preceded by, and a new order may be established between the columns of the matrix, i.e., between the points in the territory.

A more general view is obtained if, instead of starting from the matrix $((n_{ij}))$, whose dimensions are s x m, another is considered which contains all theoretically possible cases, its dimensions being, therefore, n^m x m for a territory described by m elements each divided into n types. The real case may thus be considered a sub-set of the complete set of all possible cases and this sub-set may in turn be compared with the case considered in isolation.

Let a point $A=(n_1, n_2, ---, n_j, ---, n_m)$ in the theoretical general matrix containing the data: $n_j \varepsilon 1,2,---,n$.

If we consider only the first column of A, each point whose first element is lower than or equal to n_1, precedes A. By analogy, all points whose j column is occupied by values lesser than or equal to n. will precede A. Consequently, if equality is included among the precedences, the total number of compositions preceding A will be given by:

$$N_1 = n_1 x n_2 x\ ---\ x\ n_j\ x\ ---\ n_m = \prod_{j=1}^{j=m} n_j$$

Similarly, the points preceded by A will be all those whose j column is occupied by values higher than or equal to n., V.. If, in this case, equality is also included in the precedences, the number of compositions preceded by A will be

$$N_2=(n+1-n_1)\ (n+1-n_2)--(n+1-n_m)=\prod_{j=1}^{j=m}(n+1-n_j)$$

So, by calculating N_1 and N_2, a set of vectors with m coordinates (n_1, n_2, ---, n_m) is exchanged for another set of vectors with two coordinates (N_1, N_2), which are easier to order.

Now, a point A = (N_1, N_2) will be superior to or will precede another point, B = (N_i, N_2) if, and only if,

$$\begin{cases} N_1 < N_1' \\ N_2 \geq N_2' \end{cases} \quad \text{or} \quad \begin{cases} N_1 \leq N_1' \\ N_2 > N_2' \end{cases}$$

If the relation existing between A and B is:

$$\begin{cases} N_1 > N_1' \\ N_2 > N_2' \end{cases} \quad \text{or} \quad \begin{cases} N_1 < N_1' \\ N_2 < N_2' \end{cases}$$

we shall say that A and B are non-inferior to each other.

Coming back to the example of points A = (1,2,4,4) and C = (2,1,3,6), in which we now put n=6:

N_{1A} 1x2x4x4=32 $\quad$ N_{2A} 6x5x3x3=270

N_{1C}=2x1x3x6=36 $\quad$ N_{2C}=5x6x4x1=120

$$N_{1A} < N_{1C},\ N_{2A} > N_{2C},\ A < C$$

Therefore, points A and C, initially non-inferior, become ordinated in the first calculation of precedences: A precedes to C.

The simple structure of the general theoretical matrix, makes it possible to construct a "tree" to reflect an initial order of points (fig. 1). By calculating the precedences, the set of vectors with two coordinates (N_1, N_2) is obtained. These coordinates may also be arranged on a "tree" with a more clearly defined structure, again allowing the number of points preceding and preceded by each to be counted (fig.2). Thus, by repeating the process, the existing non-inferiori-ties will be resolved until the total order is obtained, at which point no further counts will be necessary (fig. 3).

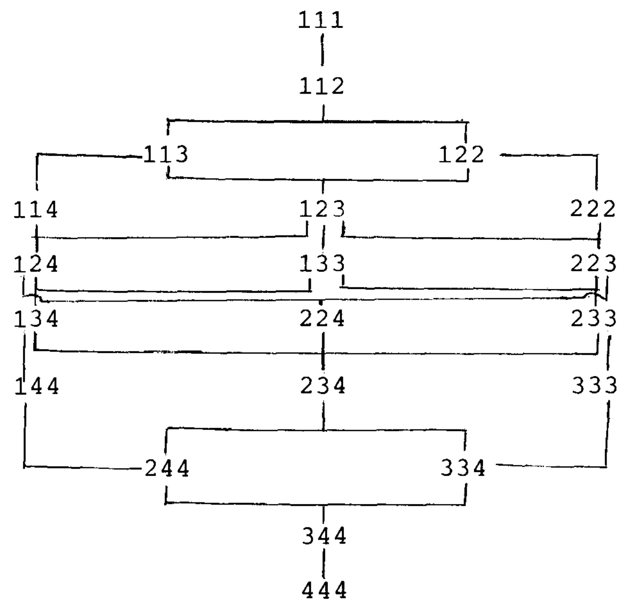

Figure 1--Initial tree, for m=3, n=4. Only the different combinations are used.

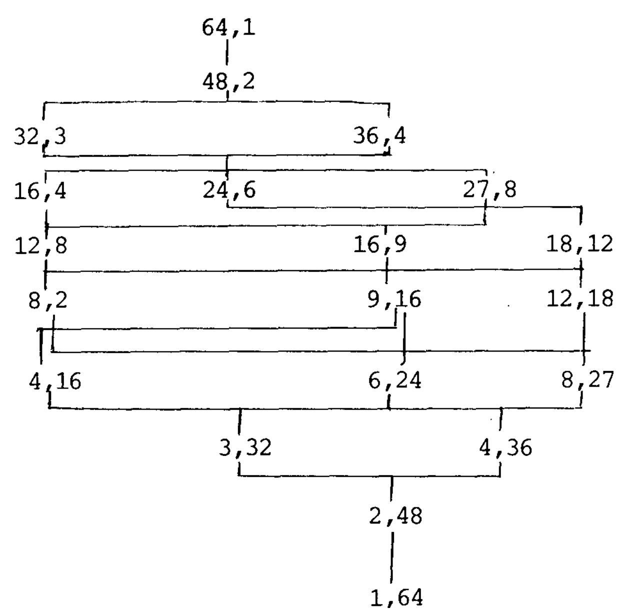

Figure 2--Tree of precedences, first iteration. Calculations are made on the number of variations.

111 (19,0)
112 (18,1)
122 (16,2) — 113 (16,2)
123 (13,4) — 222 (13,4)
114 (12,4)
223 (10,6
124 (10,7) — 133 (10,7)
224 (7,10) — 134 (9,10)
233 (6,10)
144 (4,12)
234 (4,13) — 333 (4,13)
334 (2,16) — 244 (2,16)
344 (1,18)
444 (0,19)

Figure 3-- Tree of precedences, second iteration. Final result.

GENERAL ALGORITHM

Given m and n:

-Make $\binom{n + m \quad 1}{n}$ possible combinations of $(n_1, n_2, ---, n_m)$

- Calculate for each:

$$N_1 = \prod_{j=1}^{j=m} n_j$$

$$N_2 = \prod_{j=1}^{j=m} (n+1-n_j)$$

- Establish order relationships

$$A=(N_1, N_2) < B=(N_1', N_2')$$

if, and only if,

$$\begin{cases} N_1 > N_1' \\ N_2 \leq N_2' \end{cases} \text{ or } \begin{cases} N_1 \geq N_1' \\ N_2 < N_2' \end{cases}$$

$$A=(N1, N2) > B=(Nj, N2)$$

if, and only if,

$$\begin{cases} N_1 > N_1' \\ N_2 \leq N_2' \end{cases} \text{ or } \begin{cases} N_1 \geq N_1' \\ N_2 < N_2' \end{cases}$$

- Calculate, for each point, the number of combinations preceding it, N3, and the number preceded by it, N4.

-Repeat the process with the new values (N_3, N_4).

-Make successive repeats until no further ordering is possible.

-Tabulate the final order, indicating the combinations corresponding to each level.

Comments

The algorithm is based on the formation of combinations rather than variations; thus, for example, the point (1,1,2,2,) is not differentiated from the point (1,2,1,2). This is only possible if each element considered descriptive of the landscape is divided into an equal number of classes, since, in this case, all the variations derived from the same combination will have the same (N_1, N_2) values and will consequently be situated on the same level.

Calculations are made on the total number of variations, although only the distinct combinations are used. When the number of descriptive elements -m- is high, this simplification becomes necessary, as the number of possible variations is several orders of magnitude greater than the number of combinations and the excessive volume of data would render the system inoperative. Thus, for example, in a fairly common case, 10 descriptive elements divided into 6 classes (m=10, n=6) might be considered; the number of possible combinations would be $\binom{10 + 6 \quad 1}{10} = \binom{15}{10} = 3003$, and the number of variations somewhat over $6x10^7$.

When $n_1 \neq n_2 \neq .... \neq n_m$ (n_j is the number of classes into which each element j is divided), the values of N_1 and N_2 will be:

$$N_1 = \prod_{j=1}^{j=m} h_j$$

$$N_2 = \prod_{j=1}^{j=m} (h_j+1-h_j)$$

for a point $(h_1, h_2, ---, h_m)$

Once these values have been deduced the process continues exactly as is the case where $n_1=n_2=...=nm$.

If the points are ordered taking all possible combinations into account, classifications from two different territories may be compared, since the levels will have the same meaning in both. There will, however, be no equivalence between levels of two trees based on real data.

If a project has to be made for a given territory, it may be more practical to consider real units for, in this case, the order will more faithfully reflect the characteristics of the area, in that the best points will appear at the first level, even though they may not be of excellent quality.

Nevertheless, the structure of the territory under study may be better understood if the real data are situated in a more general framework. Moreover, if only slight differentiation is required, all points being grouped in a small number of classes, it may be advisable to deduce the classification from the total number of possible combinations and, subsequently, place the combinations occurring in reality at the appropriate level.

LITERATURE CITED

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