Spatial Diversity Index Mapping of Classes in Grid Cell Maps

Charles J. Robinove
U. S. Geological Survey, Reston, VA 22092

ABSTRACT: The landscape diversity index indicates the number of classes of land that are in proximity to each point in a digital grid cell map. The index is $D = 100(i - 1)/(n - 1)$, where i = the number of landscape classes within a selected distance of each grid cell and n = the total number of mapped classes. The use of the index is illustrated by calculating the diversity index at each grid cell for each of five mapped classes and displaying the resulting diversity index map that portrays the complexity of the scene. The method is applicable to land-use planning, site selection, or description of landscape complexity.

THE DIVERSITY INDEX

THE CONCEPT OF DIVERSITY has been applied to the measure of variety in a population and it can be applied in both a nonspatial (statistical) or a spatial sense. The purpose of this report is to demonstrate the use of a simple index of diversity that can be applied spatially to a digital grid cell map of classes in a landscape.

Monmonier (1974, p. 163), Monmonier (1982, p. 168), and McEachern (1982) discuss map complexity and its measurement. Monmonier (1974, p. 163) introduces the fragmentation index

$$F = (m-1)/(n-1)$$

where m = the number of map regions, and
n = the number of areal units.

The value of F ranges from zero for a simple map to one for a highly complex map. The fragmentation index is applied to a map as a whole. Olson (1975) uses autocorrelation as a measure of map complexity, but also applies it to a map as a whole. McEachern (1982) also applies various measures of complexity to entire maps. Murphy (1985) developed a binary comparison matrix for characterizing diversity in a 3 by 3 pixel neighborhood for digital grid cell maps. The index uses both the number of classes in the neighborhood of a pixel and the frequency of occurrence of each class and ranges from one to 36 (lowest possible to highest possible) complexity. Its use is limited to the 3 by 3 pixel neighborhood. Fabos *et al*. (1973, p. 116) utilize Shannon's information entropy statistic for the measurement of land-use diversity in the form

$$D = \sum_{i=1}^{n} Pi.\log Pi$$

where D = the diversity metric,

n = the total number of different land uses in a parcel, and

Pi = the area of land-use type (i) expressed as a decimal percentage of the total area of a parcel.

The diversity metric ranges from zero to 100 and depends on identification of specific parcels of land as well as the type of land.

The diversity index developed in this report is applied to a digital grid cell map of land classes to determine the number of classes in proximity to each cell. When applied to a map of land classes, it indicates the "diversity" of the mapped landscape in a readily visualizable numerical form with values between zero and 100.

The diversity index (D) is calculated as

$$D = 100(i-1)/(n-1)$$

where D = diversity index, ranging from zero for a simple landscape to 100 for the most diverse landscape;

i = the number of classes that are in the vicinity of an individual grid cell. The vicinity may be defined as a radius of any number of grid cells; and

n = the total number of classes in the map.

The diversity index may be visualized as a measure of the "complexity" of a landscape at a given location. The index always ranges between zero and 100 and will have as many values between those bounds as there are classes in the mapped area. If, for example, one is in a boat in the middle of a large lake, the diversity index at his location would be zero because there is only one class of landscape (water) in his immediate vicinity. However, if one were standing on the shore of the lake, he might be in the vicinity of water, beach, forest, and farmland. This would indicate a higher diversity and, if they are the only classes of landscape in a large area, the index would be 100. The diversity index of two mapped areas may be compared, but only a relative

PHOTOGRAMMETRIC ENGINEERING AND REMOTE SENSING,
Vol. 52, No. 8, August 1986, pp. 1171–1173.

0099-1112/86/5208-1171$02.25/0

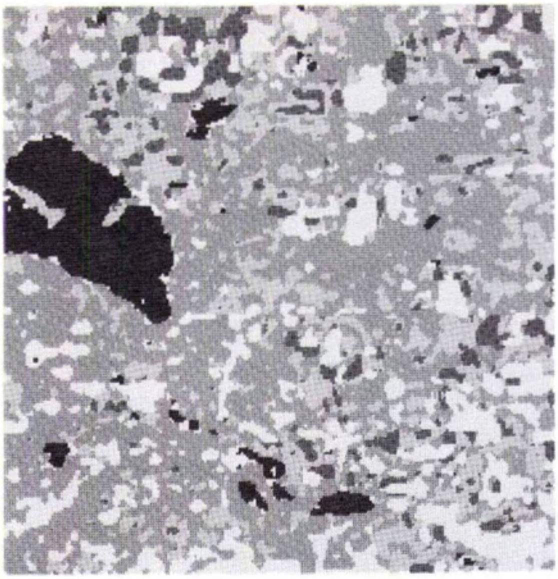

FIG. 1. A grid cell map showing five classes for which proximity and diversity will be mapped. The black class represents water, which will be used as an example in subsequent figures.

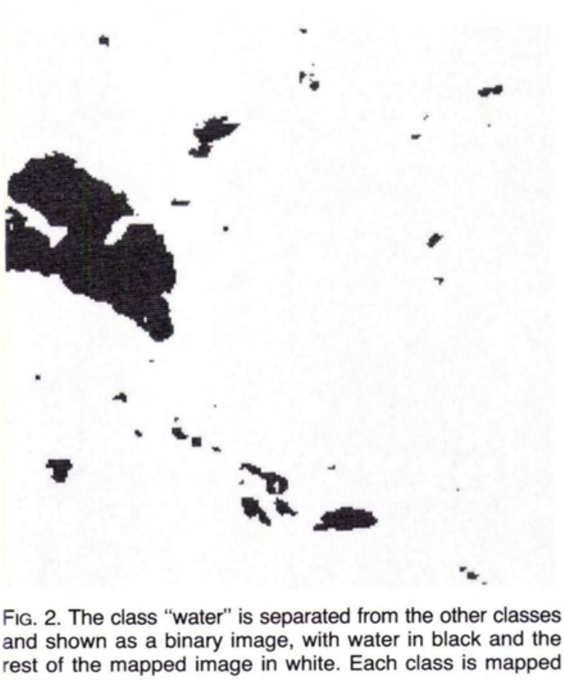

FIG. 2. The class "water" is separated from the other classes and shown as a binary image, with water in black and the rest of the mapped image in white. Each class is mapped in this manner.

comparison may be made unless the two areas have the same number of classes. The method is not limited in size, number of classes, or the size of the vicinity of a grid cell.

DIVERSITY MAPPING PROCESS

Calculation of the diversity index begins with a digital grid cell map in which each grid cell is assigned to one of a number of classes. A grid cell map showing five classes (at five separate digital values) is displayed on the screen of an interactive image processing system (Figure 1). Each class is separated from the others and saved as an image with the class having a value of one and the background having a value of zero (Figure 2).

A proximity mapping maps all the grid cells that are within the desired distance of the class. A distance of three cells is used in the example here (Figure 3). A separate image of each proximity class is saved with the class having a value of one and the background having a value of zero. All the proximity maps are added together to produce a map with grid cell values that are the sum of the number of proximity classes at each grid cell. The proximity classes are numbered with the diversity indexes as shown in Table 1. For display, the image map may be scaled up to provide a contrasty map (Figure 4) or the classes may be displayed in various colors.

FIG. 3. All pixels within a circular radius of three pixels of the water class are mapped as black and the rest of the image is white. The "proximity" of each class is mapped in this manner.

TABLE 1. REPRESENTATION OF DIVERSITY INDEX CLASSES ON THE FINAL MAP (FIG. 4)

Number of classes in the vicinity of a grid cell	Diversity index	Gray shade on map
1	0	Black
2	25	Dark gray
3	50	Medium dark gray
4	75	Medium light gray
5	100	Light gray

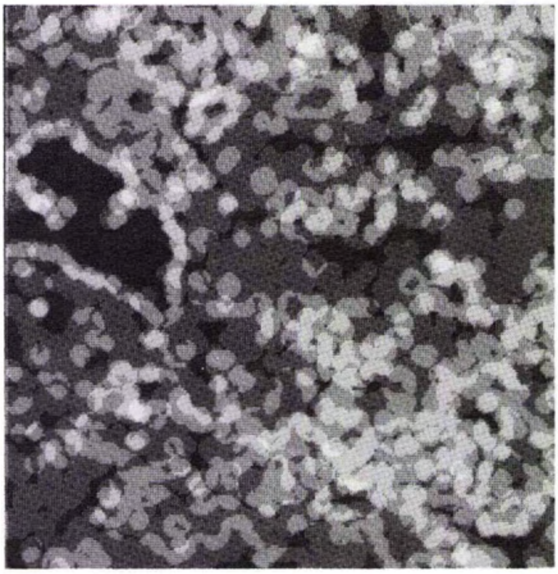

FIG. 4. The proximity maps, one for each of the five classes, are added together to indicate the diversity index. The gray scale ranges from black (index = 0, only one class in proximity) to very light gray (index = 100, all classes in proximity). There are five steps in all because there are five classes with diversity indexes of 0, 25, 50, 75, and 100.

CONCLUSIONS

A landscape diversity map may be readily produced from a grid cell map of landscape classes using an interactive digital image processing system. The complexity of the landscape may be readily visualized from the map and from the numerical values describing each diversity class. The spatial diversity map may be useful in route selection and land-use planning procedures.

ACKNOWLEDGMENTS

I would like to thank James R. Slack of the U.S. Geological Survey and James I. Ebert, archeologist, for their help in the development of the methods in this report.

REFERENCES

Fabos, J. G., R. Careaga, C. Greene, and S. Williston, 1973. Model for landscape resource assessment—Part 1 of the "Metropolitan Landscape Planning Model" (METLAND). Univ. of Massachusetts at Amherst, Agricultural Experiment Station. Research Bulletin no. 602, 141 p.

McEachern, A. M., 1982. Map complexity: Comparison and measurement. *American Cartographer*, Vol. 9, No. 1, pp. 31-46.

Monmonier, M. S., 1982. *Computer Assisted Cartography—Principles and Prospects*. Prentice-Hall, N.Y., 214 p.

———, 1974, Measures of pattern complexity for choropleth maps. *American Cartographer*, Vol. 1, No. 2, pp. 159-169.

Murphy, D., 1985. Estimating neighborhood variability with a binary comparison matrix. *Photogrammetric Engineering and Remote Sensing*, Vol. 51, No. 6, pp. 667-674.

Olson, V. M., 1975. Autocorrelation and visual map complexity. *Annals of Association of American Geographers*, Vol. 65, No. 2, pp. 189–204.

(Received 23 June 1984; revised and accepted 25 June 1985)

Second Industrial and Engineering Survey Conference

London, England
2-4 September 1987

This Conference — jointly supported by the International Society for Photogrammetry and Remote Sensing (ISPRS) Commission V and the International Federation of Surveyors (FIG) Commission 6 — will emphasize

- Design and analysis of measurement systems
- Instrumentation, including laser-based, photogrammetric, optical, and mechanical systems, as well as image correlation and understanding
- Applications in non-destructive testing, robotics, ships, turbines, rolling mills, automobile, and aircraft industries

For further information please contact

Dr. A. L. Allan
Department of Photogrammetry and Surveying
University College London
Gower Street
London WC1E 6BT, England