Article

Founding RGB ecology: The ecology of synthesis

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Abstract

There is an arising need to interpret an amount of ecological information that is more and more available. It is not only the pursuit of an easy handling of a large amount of data, but above all the quest for a deep and multivariate interpretation of many sources of ecological info. To this aim, I introduce here RGB ecology as a new branch of ecology devoted to the cartographic synthesis of ecological information. RGB ecology has the following properties: (1) it can not be separated from GIS cartography; (2) it can compact ecological information along space and time; (3) it can create a decision space for management decisions; (4) it can go beyond the third dimension by using compressive statistical techniques. RGB ecology can also be an effective flanker of several branches of ecology, such as landscape ecology, conservation ecology, urban ecology, forest ecology and so forth.

Keywords ecological data compression; RGB composition; space dimension; time dimension; decision space; principal component analysis; GIS.

1 Introduction

Recently a plethora of new ecologies have been founded. Road ecology (Forman, 2000; Forman and Alexander, 1998; Forman and Deblinger, 2000; Forman et al., 2003) has been instituted as a branch of ecology dealing with the impacts of roads on populations and communities. Movement ecology has been recently introduced (Bullock and Nathan, 2008; Cain et al., 2003; Nathan, 2005; Nathan, 2008) as a branch of ecology dealing with the movements of plants and animals due to active (e.g. the search for food) or passive (e.g., seeds transported by wind) reasons.

In this manuscript, I introduce a new branch of ecology named RGB ecology. In fact, I observe that there's an arising need for the compression of more and more available ecological data, and above all for a deep interpretation of such complex, multivariate, sometimes diachronic, information.

I also provide here some illustrative examples of the four applications that I have in mind for RGB ecology, i.e. compression and interpretation 1) along space and 2) time dimension, 3) in a decision space, 4) beyond the third dimension in both space and time.

2 Theoretical Background for RGB Ecology

RGB composition is an additive color model in which red, green, and blue lights are added together to reproduce a broad array of colors. The name of the model is borrowed from the initials of the three additive primary colors. To form a color, three components (red, green, and blue) must be layered, each of them having an arbitrary intensity from 0 to its upper limit.

Zero intensity for each component gives black, while full saturation of each gives white. When the strengths for all the components are the same, the result is a shade of gray, darker or lighter depending on their saturation. When one of the components has the highest intensity, the result is similar to this color (reddish, greenish, bluish), while when two components have the same strongest saturation, then the color is a hue of a secondary color which is formed by the sum of two primary colors of equal intensity: cyan is green plus blue, magenta is red plus blue, yellow is red plus green.

A color in the RGB model is hence expressed as an RGB tuple <*r, g, b*> where each component can vary from 0 to a maximum value. These ranges may be quantified for each color in at least 4 different ways:

- as integer numbers in the 0-255 range;
- with an integer range from 0 to 65,535;
- with any fractional value between 0 and 1;
- from 0% to 100%.

3 RGB Ecology Along the Space Dimension

This is the most intuitive application of RGB ecology. One has 3 layered ecological informations, and tries to conceive them together. As an illustrative example, I employ the Ceno valley (province of Parma, Italy). To each GIS polygon, I have assigned 3 properties:

a) distance in meters to the nearest polygon belonging to the same code (isolation);
b) area in hectares;
c) shape compactness (unitless in the 0-1 interval; 1: most compact, 0: most elongated).

Then I have applied RGB composition as follows:

a) red layer: isolation;
b) green layer: area;
c) blue layer: compactness.

Now I suggest that there are two ways to compose a RGB map. First, one could think of dichotomizing the 3 values of each polygon with respect to median or the average value. For instance, if a polygon is above median for isolation, area and compactness receives the RGB tuple <1, 1, 1>. Hence, it will result white in the RGB composite map. Instead, a polygon with below-median values will receive a <0, 0, 0> RGB tuple, thus resulting black (Fig. 1).

Instead of median, one could also think of the average value as threshold for assigning 1 or 0 to the polygon. Using dichotomised values provides crisp RGB maps (Fig. 1) with full (or none) intensity of colors and no grey values.

Second, one could also think of standardizing the 3 values of each polygon in the 0-255 interval and assigning a percent of the full color to the resulting RGB tuple. For instance, a polygon with a <140, 210, 255> tuple would result whitish (not white, which would require <255, 255, 255>), while a <210, 50, 20> tuple is reddish (not red, which would require <255, 0, 0>). In other words, the standardized RGB approach provides fuzzy RGB maps instead of crisp ones.

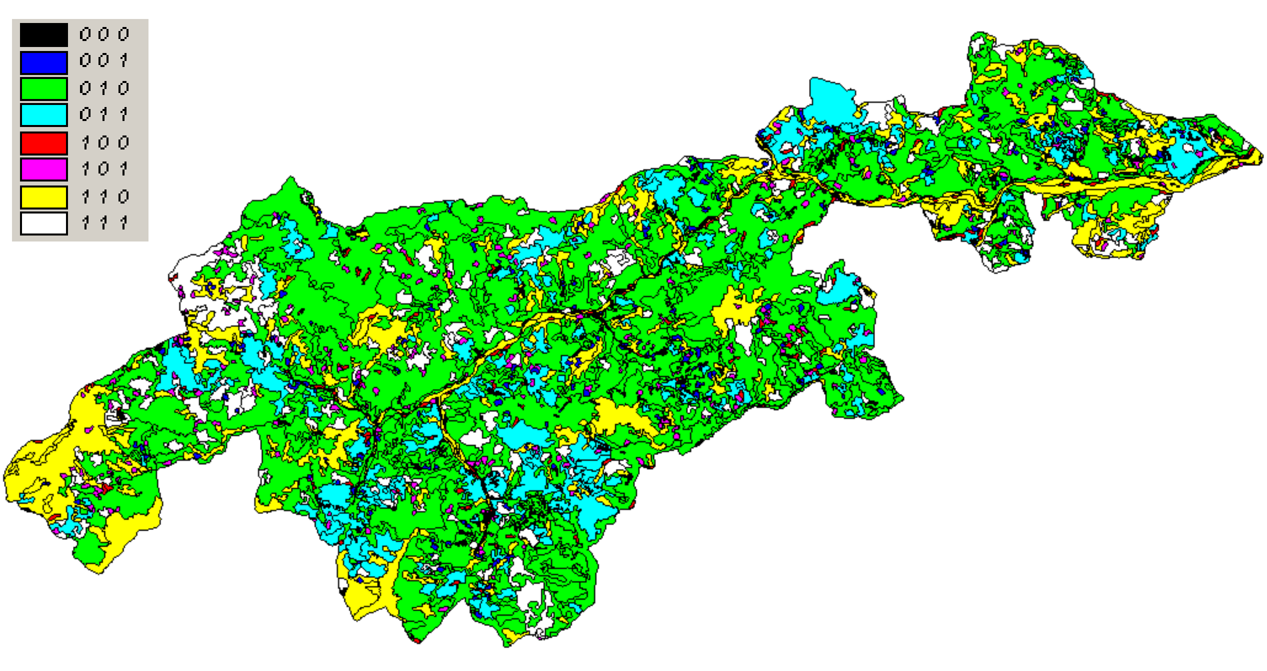

Fig. 1 RGB map of the Ceno valley with respect to isolation (red), area (green) and compactness (blue). For instance, green polygons are above median for their area, but below median for isolation and compactness (i.e., big, not isolated and not compact polygons). Yellow polygons are isolated, big, not compact. And so forth.

4 RGB Ecology Along the Time Dimension

RGB ecology can manage ecological info in time too, as follows:

RED layer: T_0 values

GREEN layer: T_1 values

BLUE layer: T_2 values

Here, the same spatial indicator (e.g., human pressure acting upon each GIS polygon) is represented at 3 different time steps. The resulting composite map immediately reveals its temporal trend. For instance, polygons with reddish colors reveal that the indicator is decreasing from T0 to T2. Instead, polygons with blue or bluish colors reveal the opposite, and so forth.

5 RGB Ecology as A Decision Space

RGB ecology could also be used to create a decision space for management and conservation purposes. For instance, it could be very useful if applied to protected areas assigning the three colors to environmental variables such as human pressure (red), ecological value (green) and ecological sensitivity (blue). I suggest that one could use, for each GIS polygon of the study area, *n* indicators of human pressure and then calculate an overall pressure index; the same for ecological value and ecological sensitivity. Last, one can summarize the three indices into a single RGB map where, for instance, white regions of the protected area stand for high-priority areas for conservation because they're ecologically valuable, but also very sensitive and subject to human pressure. Instead, black areas stand far from priority because they are not sensitive, not valuable and not subject to human pressure. Intermediate situations (e.g., sensitive but not subject to pressure; sensitive but not valuable, and so forth) come immediately to the attention of the user after the application of the RGB composition.

Hence, RGB ecology as a decision space requires:

RED layer: decision criterion 1

GREEN layer: decision criterion 2

BLUE layer: decision criterion 3

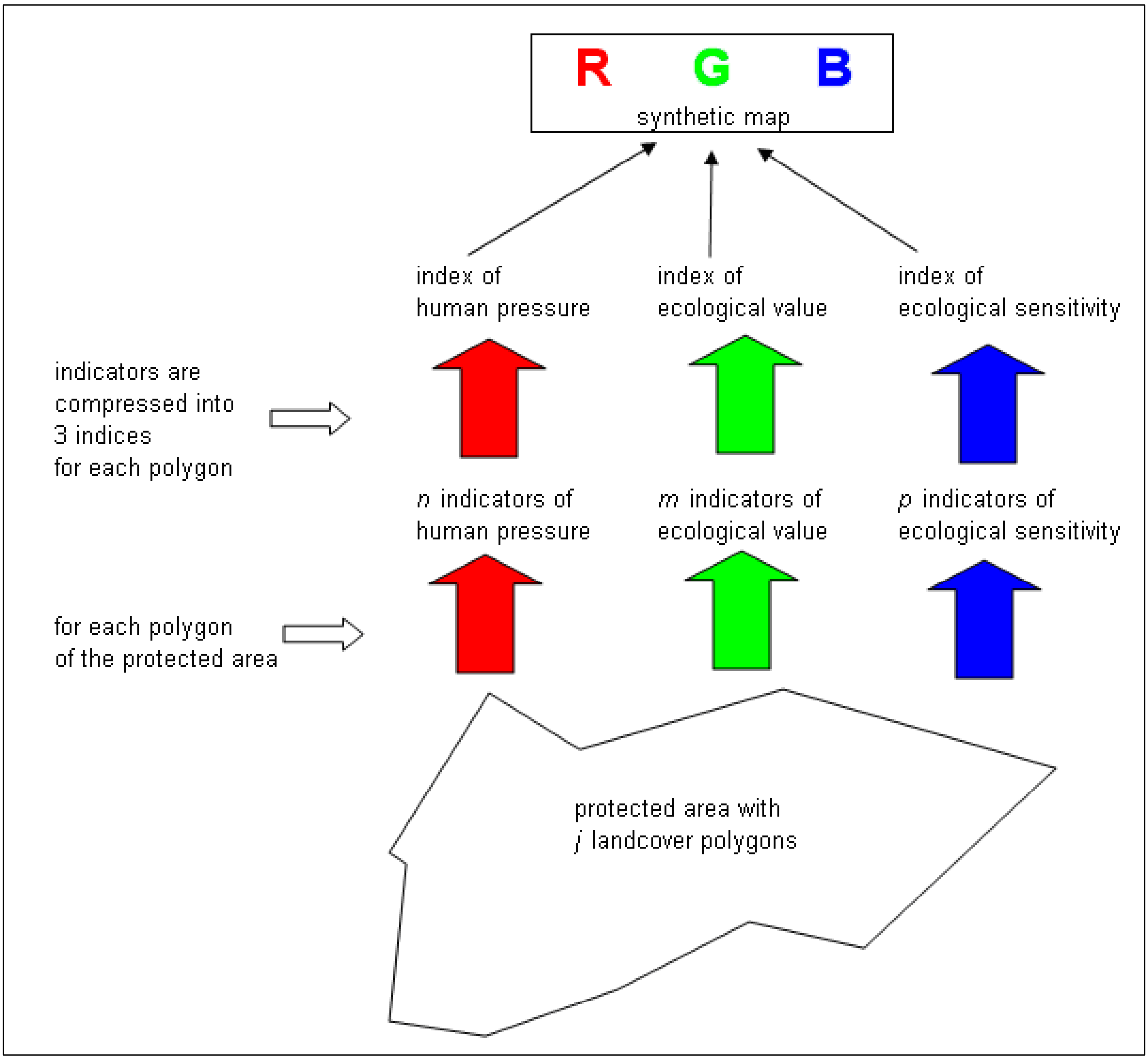

Fig. 2 Use of RGB ecology as a decision space. A single RGB map of a protected area can synthesize as many indicators of human pressure, ecological value and ecological sensitivity as needed. The resulting map is very useful as a decision tool for the choice of the polygons on which proper actions are necessary.

6 RGB Ecology: Beyond the Third Dimension in Space and Time

One could wonder if RGB ecology is limited to 3 dimensions. The answer is no. Let's suppose to have *n* maps (variables to be cartographically represented), with $n > 3$. For instance, one could have *n* indicators of environmental sustainability at the municipal level (Ferrarini et al., 2001; Clerici et al., 2004). We can apply principal components (PC) analysis, and assign PC scores to each municipality. Now we can represent scores of the first PC using the red layer, second PC scores using green layer, third PC scores with the blue one, and then compose the correspondent RGB cartography. Looking at the RGB map, one can immediately interpret the *n* starting indicators. For instance, reddish municipalities will have high values on the first PC, and low ones on the second and third PCs. At this point, one has to go back to the PC loadings and interpret reddish color in terms of the starting indicators.

Of course, PC analysis can also be applied to a single variable measured at different times, for instance the number of inhabitants of municipalities taken at *n* different times. In this case, the 3 PCs capture temporal information about the number of inhabitants for each municipality, and the resulting RGB map is a synthesis along time of such variable. The only limitation to PC-RGB ecology is that the first 3 PCs should preserve at least 70% of the starting variance, which is a rule-of-thumb when choosing how many PCs are necessary to keep a satisfying portion of the starting information. In synthesis, under the constraint that 3 PCs capture at least 70% of the starting information, RGB ecology can go beyond 3 dimensions using the following combination:

RED layer: first PC scores
GREEN layer: second PC scores
BLUE layer: third PC scores

7 Conclusions

RGB ecology has been founded here as a new branch of ecology devoted to the synthesis of ecological information. RGB ecology has the following properties:

- it can't be separated from GIS cartography;
- although it could be applied to points and polylines as well, I suggest that RGB ecology is well-suited for polygonal or pixel-based maps (i.e., land cover, land use, vegetation etc)
- it can compact ecological information along space and time;
- it can create a decision space for management decisions;
- it can go beyond the third dimension by means of compressive statistical techniques.

Although I conceived it as a stand-alone discipline, RGB ecology can also be an effective flanker of several other branches of ecology, such as landscape ecology, conservation ecology, urban ecology, forest ecology and so forth.

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