**Programa Diversity\_Index**



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The Diversity\_Index.exe program sums the different sub-indexes that are included in the definition of the diversity index, for example, the geological sub-index, the sub-index from the soil map, the geomorphological sub-index. The sub-indices correspond to the images that come from the **Map\_explor.exe** program.

The program calculates the sum of these indices and normalizes them according to the scale defined by the user.

In addition, it is possible to take into account the weights of each of these indices to perform the calculation. Some examples illustrate the role that this notion can play when calculating the diversity index.

Eventually, a grid can be transferred to the resulting image. The program is able to distinguish the type of treatment that was carried out to generate the input images: square cell mesh or sliding window.

When the program opens, you are asked to choose the working language: English, French or Spanish (Fig. 1).

The images must imperatively be located in the “images” folder of a disk (C, D or a disk defined by the user). In this folder, you also need to create a file where documents are stored, such as input images, reports, result images.

For example, C:\images\oaxaca\oax\_geologia.bmp, D:\images\pachuca\geol100.asc The input or resulting images can be in raster, bitmap or ascii format.

Opening an ascii format image indicates the UTM coordinate values; these coordinates may sometimes be needed to perform various treatments.

Secondly (Fig. 2), it is required to indicate on which disk (C, D or any other place) the “images” folder is located.

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| *Figure 1. Program opening.* |

Next, the name of the file is indicated, the number of images that will be taken into account to carry out the treatment, the type of format of these images and the weight attributed to each of them (Fig. 2).

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| *Figure 2. Input data.* |

Once the relative weights of each input image have been defined, the generic name of the output data is given. The output image format can be *raster*, *bitmap* or *ascii*. If at least one of the input images is in *ascii* format, it is not necessary to enter the UTM coordinate values ​​(*X\_min* and *Y\_min*), otherwise the program will ask for this information.

At this stage (Fig. 4), it is required to indicate the number of segments, for example, here, 5, which correspond to a scale of values ​​of the diversity *EVD* such as: *very weak*, *weak*, *medium*, *strong*, *very strong*; but this segmentation can be different.

The program looks for the maximum value *Vmax* of the result *Res* according to the following calculation:

where *nsegm* is the number of images taken into account, *pix(i,j)* the pixel value in the image *n* (*i* for rows and *j* for columns) and *wn* the weight assigned to image *n*.

The *VD* values ​​of diversity are calculated as follows:

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| *Figure 3. Name of the resulting image and number of segments.* |

A scan of the input data generates a table of values ​​(number of pixels and percentage of items in each input image); the information shown in Figure 4 is reported in a report (output image name with extension *\_info.txt*).

The program calculates and manages the data using the formulas reported above and if nothing else is specified, the program directly saves and saves the results in an image that is presented in various formats. But there is also the possibility of reporting on the image the mesh that was used to generate images of the sub-indices of diversity that serve as input data in this program.

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| *Figure 4. Exploring the input data.* |

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| *Figure 5. Final step of the program.* |

Figure 5 shows the orders that allow the drawing of the superimposed mesh. In fact, the drawing of the mesh is fully justified when the subindices were calculated using the cell mesh with the **Map\_explor.exe** program.

If the subindices are calculated with a moving window, the drawing of the mesh is mainly illustrative.

The program asks if the user wants to draw the mesh. In the case of a positive answer, taking into account structural criteria, the algorithm is able to distinguish the type of treatment (mesh or moving window) that generated the subindex images. However, the program asks if the answer is correct, leaving the possibility of modifying the diagnosis.

Once the type of treatment has been defined with certainty, the parameters that will be used to draw the mesh are indicated:

1) the size of the pixel side in meters; this value appears in the descriptive files of the input image (*raster* or *ascii*) or is specified when the input image is a *bitmap*.

2) the UTM coordinates of the lower left corner of the image; these data are retrieved if one of the input images have an *ascii* format, otherwise they need to be entered.

*Range R of the calculation window*.

As we saw in the documentation on the **Map\_explor.exe** program, this range *R* depends on the type of cell or mobile window used to generate the subindices; when it is a mobile window, *R* is larger (25 for an area of ​​20 km2 and a pixel of 100 × 100 meters) when the shape of the window is circular than when the shape is quadratic (22). This point is important and requires to be reported in the information accompanying the previous treatments. In the case of a treatment that used a cell mesh, *R* corresponds to the minimum value.

The output documents include:

- the image (*raster*, *bitmap* or *ascii*). Use a palette to view the result (Fig. 6).

- an information file with the extension *\_info.txt* (Fig. 7).

- an Excel file (Fig. 8) with the histogram of the diversity ranges (extension *\_histo.xls*)

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| Diagrama  Descripción generada automáticamente con confianza media | *Figure 6. Example of palette for 5 levels.* |

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| Program DIVERSITY\_INDEX  JF Parrot (June 2023)  Name of the Disk where the directory is located:  D:\images  Name of the File Folder located in the Directory D:\images:  D:\images\Oaxaca  Number of images to mix: 2  Treatment  The image number 1  named D:\images\Oaxaca\oax\_geo\_div.asc  contains 6 items  item 1 code 1 pixels 530550 percent 23.88  item 2 code 2 pixels 899100 percent 40.47  item 3 code 3 pixels 540675 percent 24.34  item 4 code 4 pixels 139725 percent 6.29  item 5 code 5 pixels 30375 percent 1.37  item 6 code 6 pixels 2025 percent 0.09  The image number 2  named D:\images\Oaxaca\oax\_soil\_div.asc  contains 7 items  item 1 code 1 pixels 348300 percent 15.68  item 2 code 2 pixels 856575 percent 38.55  item 3 code 3 pixels 625725 percent 28.16  item 4 code 4 pixels 232875 percent 10.48  item 5 code 5 pixels 64800 percent 2.92  item 6 code 6 pixels 12150 percent 0.55  item 7 code 7 pixels 2025 percent 0.09  Cell mesh treatment has been used to generate the input images.  diversity levels histogram:  D:\images\Oaxaca\oax\_geol2\_soil1\_histo.xls  Two point files created:  - D:\images\Oaxaca\oax\_geol2\_soil1\_points\_ij.txt  D:\images\Oaxaca\oax\_geol2\_soil1\_points\_utm.txt    diversity levels histogram:  D:\images\Oaxaca\oax\_geol2\_soil1\_histo.xls  Name of the resulting image =  D:\images\Oaxaca\oax\_geol2\_soil1.bmp  Weight of the image 1 = 2.00  Weight of the image 2 = 1.00  Number of segments in the resulting image: 5  pixel size (decimal value in meters) = 100.00  cell mesh drawn | | *Figure 7. Report.* |
|  | *Figure 8. Histogram of diversity levels.* | |

- in the case of a quadratic cell mesh input treatment, two files that allow interpolations to be made based on the value of the center of each cell. The first (Fig. 9) with the extension *\_points\_ij.txt* contains the values ​​of *j*, *i* and the diversity index per cell; the second (Fig. 10) with the extension *\_point\_utm.txt* contains the values ​​of *X*, *Y* and the diversity index per cell.

Three examples of treatment are presented:

1) subindices calculated using a square cell mesh;

2) subindices calculated using a square moving window;

3) subindices calculated using a circular moving window.

**1) Subindices calculated using a square cell mesh**

In this example, a geological image (Fig. 9) and a soil image (Fig. 10) of the Oaxaca region were taken into account to carry out the treatment.

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| *Figura 9. Mapa geológico.* | *Figura 10. Mapa de los suelos.* |

The diversity index of each of the two images was calculated using a cell mesh process. These treatments were carried out with a cell size of 22; the **Map\_explor.exe** program (see corresponding Manual) has a function that allows defining the number of pixels of the edge *c* of the cells from a surface *S* in km2 and a pixel size TP in meters; thus, for a desired surface of 20 km2, the edge *c* of the cell is 22. The calculation is as follows:

*S* = *Skm* × 10000000

where *Rcircle* is the value of the range *R* for a circle and *Rsquare* the range *R* for a square.

Thus, applying the formula *c* = (*R* × 2) + 1 that links the value of the range *R* to the size *c* of the cell border, indicates that the size of the cell corresponds to (22 × 2) + 1 = 45.

The two subindices of figures 11 and 12 represent the base on which the calculation is performed by assigning the same weight to each of these indices.

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| *Figure 11. Diversity subindex (geology).* | *Figure 12. Diversity subindex (soils).* |

This calculation was made with five levels of diversity.

The result presented in Figure 13 corresponds only to the values ​​of the diversity index, and the cell grid is materialized in Figure 14.

The same weight was applied to the two sub-indices, contrary to what is presented in the following figures (Fig. 15 and 16).

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| *Figure 13. Diversity.* | *Figure 14. Diversity with cell mesh.* |

In Figure 15, the weight of the geology subindex is greater than the weight of the edaphology subindex; it is the reverse in Figure 16.

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| *Figure 15. Geology weight > soil weight.* | *Figure 16. Geology weight < soil weight.* |

**2) Subindices calculated with a moving window**

In this case, the same images are taken into account for the treatment: a geological image (Fig. 9) and a soil image (Fig. 10) of the Oaxaca region.

When using a moving window, there are two options: square or circular window. For a surface area of ​​20 km2, the cell edge *c* is 22 in the first case and 25 in the second. The stronger value in the case of the circle is related to the fact that a circle takes up less space than the square that contains it (Fig. 17). The surface area of ​​the circle represents 77.98% of the surface area of ​​the square.

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| *Figura 17. Relación ventana cuadrada / ventana circular.* |

Taking into account these values ​​of *R* and according to the size of the pixel's side *m*, the parameters of each of the treatments (square or circular moving window) are the following:

Parameters of the square moving window:

*c* = (*R* × 2) + 1 = (22 × 2) + 1

window size = 45 × 45

surface (in pixels) = 2025; surface (in km2)= 20.250

Parameters of the circular moving window:

Radius *rc* (in pixels) = *R* + 0.5 = 25.50

Surface of the circle (in pixels) = 2029

According to the pixel size (100 × 100 meters), the surface of the circular moving window is equal to 2029.000 ha (20.290 km2)

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| *Figure 18. Treatment with a square moving window (R = 22).* |
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| *Figure 19. Treatment with a circular moving window (R = 25).* |

Figures 18 and 19 show the drawing of the cell mesh, which is an illustration, but does not correspond to any reality.

In the two following images (Fig. 20 and 21), a detailed view of the response shows how the procedure using a circular moving window smooths the contours.

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| *Figure 20. Detail of the treatment with a square moving window (R = 22).* | *Figure 21. Detail of the treatment with a circular moving window (R = 25).* |

Dibujo en blanco y negro

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Mexico City, August 19, 2023