**Map\_Explor Program **

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**1. Generalities**

The calculation of various diversity sub-indices generally uses a grid of square cells within which the number of themes (e.g. geological formations) found in the image of the studied document is measured. Diversity is therefore an integer value indicating how many themes each cell contains.

The resulting image can be interpolated by kriging to obtain a more realistic view. It should be noted that this processing results, if the number of rows and/or columns of the studied document is not a multiple of the size c of the cells c × c, in the creation of a neutral border on the east and south sides of the resulting image. This disadvantage does not arise when using a "moving window" (see below).

The algorithm used, after reading the input document, which can be a raster image, a bitmap or an ascii document, indicates the number of themes found, giving for each of them, its number of pixels and the percentage it represents within the image.

Knowing the total number of themes (*num\_item*) allows defining the number of histograms *(hist[n]*) that will be used to perform the calculation. In the equations, the value of *n* is an abbreviation of the parameter *num\_item*. Before entering a cell, the histograms *hist[n]* are initialized to zero. When scanning the image within the cell, the *VP* value of the pixel causes the corresponding histogram *hist[VP]* to increase; thus, a representation of the distribution of values ​​is obtained; searching for the number of histograms whose content is greater than zero, the value of the diversity index *Indiv* is defined, which then corresponds directly to the number of active histograms *hist[VP].* On the other hand, the strongest value found in the chain of histograms *hist[n]* that characterize a cell allows calculating a homogeneity index.

There is an essential notion in the raster world: it is the relationship between the range *R* and the size of the side of a square element (pixel, cell, or even sliding window). Thus, the size *c* of the cell border *c × c* is calculated from the range *R* and the estimation of this range depends on the size of the pixel's border *m* and the surface area *S* (*c* × *c*) of the cell. A function allows, if the user needs it, to define the range from the value of the pixel's border *m* (in meters) and the surface area *S* of the cell (in km2). For example, for values ​​of *m* = 100 and *S* = 2 km2, *R* will be equal to 22. By definition, the cell edge *c* is equal to (*R* × 2) + 1.

Regarding the odd value of the cell edge, applying a value of *R* = 22 generates, according to a pixel size *m* equal to 100, an area *S* of 20.25 km2 (2025,000 ha). In addition, the program details the value of the parameters: cell border *c* (in pixels) = (*R* x 2) + 1 = (22 x 2) + 1 = 45

- cell size (in pixels) = 45 x 45

- cell area (in pixels) = 2025

- cell surface area = 2025 ha (20.25 km2)

On the other hand, it is possible to calculate a diversity index using a sliding window instead of a grid cell. The size of this window is defined in the same way, but in this case, two shapes of sliding window can be used: the square shape or the circular shape.

The size of the sliding window is also calculated based on its range *R*. If it is a square window, the *m* edges (in pixels) of the window are equal to *m* = (*R* x 2) + 1. In the case of a circular window, the radius of the circle *rc* will be equal to *rc* = *R* + 0.5.

Using the above function allows the range to be calculated from the value of the pixel's edge *m* (in meters) and the surface area *S* of the cell (in km2). For example, for values ​​of *m* = 100 and *S* = 2 km2, the program indicates that *R* will be equal to 22 for a square sliding window and 25 for a circular window. 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. 1). The surface area of ​​the circle represents 77.98% of the surface area of ​​the square.

For the same observation surface (20 km2), if it is a square, the edge *c* of the window or cell will be *c* = (*R* x 2) + 1 = (22 x 2) + 1 = 45 and the surface area will be 2025 pixels (20.25 km2 or 2025 ha). In the case of a circular window, taking into account the same values ​​of *m* and *S*, the radius *rc* corresponds to *R* + 0.5, that is, 25.50; the resulting surface area will be 2029 pixels (20.29 km2 or 2029 ha).

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| *Figure 1. Square window/circular window ratio.* |

The advantage of using a moving window is that the result can be obtained directly without the need to perform interpolation, since the resulting image is created by following the sweep of the moving window; as mentioned above, the result of the calculation obtained for a window centered on a pixel i, j is reported at position i, j of the resulting image. On the other hand, the border of neutral values ​​develops symmetrically to the north, east, south and west of the image; the width of this border is equal to the range *R* (Fig. 2).

**1. Use of the program**

The Map\_explor.exe program studies the regional arrangement of various geomorphological formations as they appear on a map. The program first looks for the number of formations present on the map, providing, among other things, the percentage of total occupation. Then, the program studies the distribution and arrangement of each of these formations, using a square mesh or a moving window. In the case of the moving window, it is possible to choose the shape of the moving window: square or circular.

It is worth mentioning that, in the case of using a circular window, the results are more intelligible when the radius size is small. The inverse is true for a square window.

When you open the program (Fig. 2), you need to specify which language will be used to perform the treatment.

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| *Figure 2. Start of the process and choice of language (English, French or Spanish).* |

The images to be processed can be in raster, bitmap or ascii format, but they must be in a sub-file to be defined in the “images” folder, a folder located on disk C, disk D or any disk that the user defines (see Fig. 2). In these folders (for example, D:\images), a subfolder must be generated where the data to be studied will be located, as well as the results. For example: C:\images\tuxpan\slope.bmp; D:\images\acapulco\Mde\_lazer.asc.

Once the name of the disk containing the “images” file has been defined, the name of the subfolder containing the input data is requested. Secondly, the name of the data is given without its extensions, which will be specified by answering the following questions.

As specified in figure 3, it is necessary to specify the format of the studied image: raster, bitmap or ascii.

The program reads the image and displays on the screen its size in lines and columns.

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| *Figure 3. Input image characteristics.* |

After giving the name of the image to be studied, its location and its type, the program reads the document and indicates the number of items found in the image, as well as the number of pixels and the percentage of each item (Fig. 4).

So, as the program mentions in the screen in figure 5, the treatment offers two types of treatment. The first is performed on a grid of quadratic cells and the second uses a mobile window that scans the image from the top left corner to the bottom right corner. In the case of a treatment performed with a grid of cells, the result obtained is reported on the entire cell under study. In the case of using a mobile window, the result is reported on the resulting image on the pixel that corresponds to the center of the mobile window.

The parameters that characterize the cell or the mobile window are related to the range R of the cell or the window. This range also corresponds to the width of the border of the image where a calculation cannot be performed. It is necessary to choose between the two values ​​of R, the one that corresponds to the type of treatment to be carried out.

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The program proposes to help the user in choosing the value of *R* (Fig. 6).

In fact, the value *m* of the side of the moving window or of a grid cell is equal to *m* = (*R* × 2) + 1, but when it comes to a circle that is inscribed in a box defined from the value of the range, the radius of the circle *rc* will be equal to *rc* = *R* + 0.5 and, as mentioned in the first section, for the same parameters, the box that circumscribes the circle is larger than in the first case (see figure 1).

In fact, an *R* value of 22 is given for a square cell or moving window and a value of 25 for a circular moving window.

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| *Figure 6. Definition of the R value.* |

The help needs to know what the pixel size is (value in meters) and the area that you want to give to the cell or the mobile window (value in km2).

The calculation is as follows:

* for a circle:
* for a square:

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After choosing the value of *R* (circle or square), the menu in Figure 7 is displayed, asking for the type of treatment (cellular mesh or sliding window).

The parameters of the quadratic cell (in this case, but there are two other possibilities) characterize the treatment: cell surface in pixels and cell surface (in hectares and km2).

An agreement on these characteristics leads to the first question in Figure 8, which asks for the name and format of the resulting image. If the input image is in ASCII format, the recording of the output image in this format will be done without another question, otherwise the UTM coordinates of the lower left corner (X\_min, Y\_min) will be required.

In case of disagreement, the program will return to the first question in Figure 6, which allows assigning other values ​​to the parameters used to define the value of *R*.

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| *Figure 7. Choice of treatment type.* |

To exit the program, you only need to press any key.

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| *Figure 8. Start of treatment and exit from the program.* |

Two images are generated, the first concerns diversity, the second homogeneity which corresponds to the “invasion” of a theme at the cell or mobile window level.

A report is also created (Fig. 9) giving information about the program and the operating conditions. The English version of the report is presented here, which also exists in French and Spanish.

**2. Results**

Some examples of results obtained using the **Map\_explor.exe** program are presented.

The first concerns the geology of the Pachuca region. The second describes the diversity of geomorphology in the ensemble of the Mexican Republic.

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In the case of the image of the geology of the Pachuca region (Fig. 10), three types of treatment are presented:

* - Cell mesh
* - Square mobile window
* - Circular mobile window.

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| *Figure 10. Geological map of Pachuca.* |

In this case, the program indicates that the geological map image contains 37 items. The list of these items shows the code for each item on the map (Fig. 11).

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| Texto  Descripción generada automáticamente | *Figure 11. Codes of the 37 items.* |

In addition, the value of the parameters used (Fig. 12) to generate the geological subindex (Fig. 13) and the homogeneity subindex (Fig. 14) of the Pachuca region are specified.

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| Texto  Descripción generada automáticamente | Figure 12. Treatment parameters. |

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| *Figure 13. Diversity subindex (Geology).* | |

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| *Figure 14. Homogeneity subindex (Geology).* | |

Also, **Map\_explor.exe** calculates these two subscripts using a moving window. The image in Figure 15 corresponds to the treatment done using a square window and the following figure (Fig. 16) to a treatment using a circular window.

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| *Figure 15. Treatment with a square mobile window.* | |

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| *Figure 16. Treatment with a circular mobile window.* | |

The second example concerns the study of diversity in the ensemble of the territory of the Mexican Republic.

As shown here, the size of the cell represents an important element, because the larger the size of the cell, the more cells with a high index value are found.

In the three images of the figure 17, the conditions are as follows:

- Image 17A: pixel size (500m × 500m), cell side 25 km, i.e., an area *S* equal to 625 km2; the value of *R* will be 25 and the pixel area of ​​the cell is equivalent to 51 × 51 pixels.

- Image 17B: pixel size (500m × 500m), cell side 50 km, i.e., an area *S* equal to 2500 km2; the value of *R* will be 50 and the pixel area of ​​the cell is equivalent to 101 × 101 pixels.

- Image 17C: pixel size (500m × 500m), cell side 100 km, i.e., an area *S* equal to 10 000 km2; the value of *R* will be 100 and the pixel area of ​​the cell is equivalent to 201 × 201 pixels.

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| A 51 × 51 | B 101 × 101 | C 201 × 201 |
| *Figure 17. Variation in response as a function of cell size.* | | |

Dibujo en blanco y negro

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Mexico City, on August 19, 2023.