Analysis of the Loss of Natural Grasslands in Bulgaria's Protected Areas

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ABSTRACT

The current report explores the changes in land use in Bulgaria's protected areas under the European Commission's Habitats Directive between 1990 and 2018. It identifies the two protected areas with the greatest loss of natural grassland areas. It further examines them and calculates the values of several landscape descriptors aiming to evaluate the extent of landscape fragmentation.

INTRODUCTION

Grasslands represent important ecosystems, which play a crucial role in several processes. They aid agriculture and livestock herding, providing food for domestic livestock. They play an important role in carbon storage. They are home to numerous species, including threatened birds species like the Great bustard (*Otis tarda*), the Little bustard (*Tetrax tetrax)* and Montagu's harrier (*Circus pygargus*), small mammals including the protected European ground squirrel (*Spermophilus citellus*), and butterflies and other pollinators vulnerable to loss of grasslands such as the Marsh fritillary butterfly (*Euphydryas aurinia*) and the Large blue butterfly (*Maculinea arion*) (Biodiversity Information System for Europe 2021).

Despite their importance, European natural and semi-natural grasslands are disappearing at an alarming rate, mainly due to changes in land use and changes in agricultural practices. The purpose of the current study is to explore how natural and semi-natural grassland areas have changed within Bulgaria's protected areas, designated under the European Commission's (EC) Habitats Directive. Upon identifying the two areas with the largest absolute loss of natural and semi-natural grasslands, the study aims to explore the degree of landscape fragmentation using various parameters, and to compare the nature of the change between these two areas.

STUDY AREA

The study area is presented in Figure 1 and includes the Bulgaria's protected areas under the EC's Habitats Directive. The total area of protected sites under the Habitats Directive is 33 438.3 sq.km., which represents over 30% of the country's area.

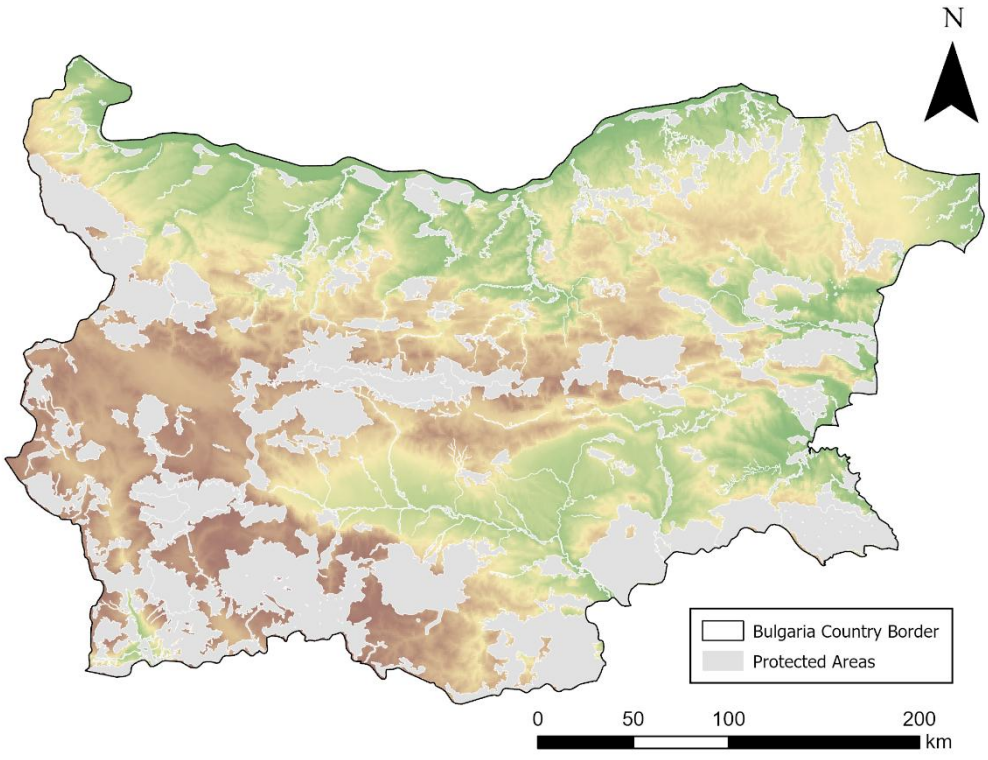

Figure 1 Scope of the study area

The study area spans a diverse range of climatic and land use conditions.

According to the Köppen-Geiger climate classification, the territory of Bulgaria mainly falls within the Cfa (Humid subtropical climate) and Cfb (Temperate oceanic climate) climate types. Certain mountainious regions are classified as Dfb (Warm-summer humid continental climate) or Dfc (Subarctic climate), whereas small areas in the southeast of the country are classified as Csa (Hot-summer Mediterranean climate) and Csb (Warm-summer Mediterranean climate) (Malcheva and Bocheva 2023). Bulgaria's climate is characterized by four distinct seasons with cold winters, hot summers and strong regional variations.

In terms of land cover, Bulgaria's area features diverse land use types. According to the 2018 CORINE land cover data provided by the Copernicus Land Monitoring Service (2020), the territory of Bulgaria is primarily covered by agricultural land (43.82% of the country's area), followed by broad-leaved forests (20.72%), transitional woodland-shrub (6.85%), mixed forest (5.75%), coniferous forest (4.76%), natural grasslands[1] (3.68%), pastures (3.57%) and urban areas (3.45%).

Natural grasslands are an important component of traditional agricultural practices. There are mainly located in the higher altitude areas of the Stara Planina, Pirin, Rila and Rhodope mountain ranges, as shown in Figure 2.

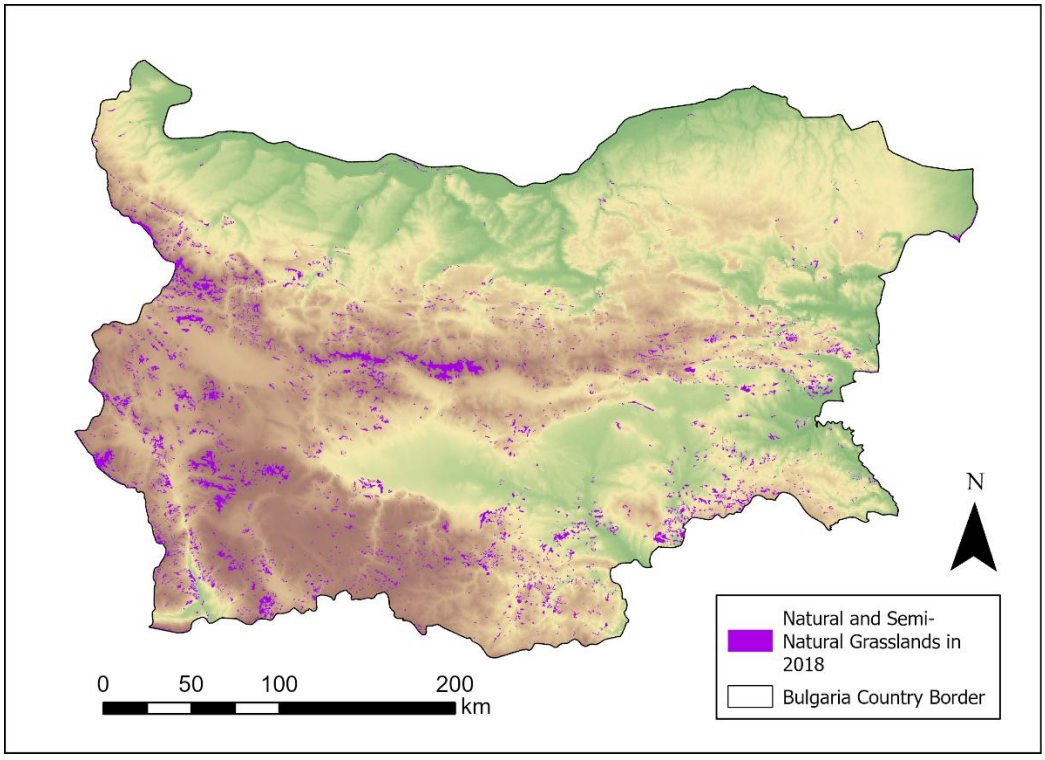

Figure 2 Natural and semi-natural grassland areas in Bulgaria according to CORINE land cover data for 2018

[1] According to the CORINE land cover classification, the land cover class 3.2.1 Natural grassland Includes low-productivity grasslands under no or moderate human influence, thereby encompassing both natural and semi-natural grasslands (Copernicus Land Monitoring Service).

DATA

The data used for this study is provided by the Copernicus Land Monitoring Service as part of the CORINE Land Cover programme (coordinated by the European Environment Agency). Two distinct data sources were used:

- CORINE Land Cover 1990: raster data with a resolution of 100m with a temporal extent between 1986 and 1998.
- CORINE Land Cover 2018: raster data with a resolution of 100m with a temporal extent between 2017 and 2018.

Both datasets are obtained via classification of satellite images into 44 distinct land cover classes. The 1990 dataset uses data from the Landsat-5 MSS/TM satellite and the 2018 dataset using data from the Sentinel-1 and Sentinel-2 satellites.

Additionally, a polygon feature class with the boundaries of all sites protected under the EC's Birds and Habitats Directive (i.e. sites from the Natura2000 network) was obtained from the website of the European Environment Agency. The data for protected sites was last updated in 2021.

The administrative boundary of Bulgaria was obtained from the website of DIVA-GIS.

METHODS

The analysis for this study was carried out using ArcGIS Pro and Microsoft Excel.

The following tools were used to complete the analysis:

- Land use data for Bulgaria for 1990 and 2018 was extracted from the original Pan-European land use data.
- Sites located in Bulgaria and protected under the Habitats Directive were extracted from all Natura2000 sites.
- Raster land use data was converted to polygons for subsequent analysis.
- The areas of Natural grasslands (which include both natural and semi-natural grasslands) were extracted for the protected sites separately for 1990 and 2018.
- Statistics tools were used to compute the total natural grassland area in each protected site in 1990 and 2018.
- The difference between the natural grassland area between 2018 and 1990 in each protected site was computed.
- The two protected sites with the highest negative difference (i.e. biggest reduction in natural grassland area) were selected.
- For each of these two sites, the following parameters were computed:
    - Shape index S1, defined as the ratio between patch perimeter (P) and patch area (A):

$$S1 = P/A$$

    - Shape index S2, representing the deviation from an iso diametric shape, where:

$$S2 = \frac{P}{2\sqrt{A\pi}}$$

    - Mean Patch Density (PD), defined as:

$$PD = \frac{N}{A} \times 10{,}000 \times 100$$

where N is the number of patches and A is the total landscape area in m^2 (Ene and McGarigal).

- Mean Patch Size (km^2)
- Maximum, minimum and mean Euclidean Nearest Neighbour Distance (in meters), representing the distance between a patch of natural grassland and its nearest neighbour.

RESULTS

The objective of the first part of the analysis in this study was to identify the two protected sites in Bulgaria with the highest decrease in natural grassland area (in km^2). The results of the computation of grassland change in each protected site is presented in Figure 3. Figure 4 shows the two protected sites with the greatest reduction in grassland area – BG0001014 Karlukovo and BG0001030 Rodopi-Zapadni – which were subject to the second part of the analysis.

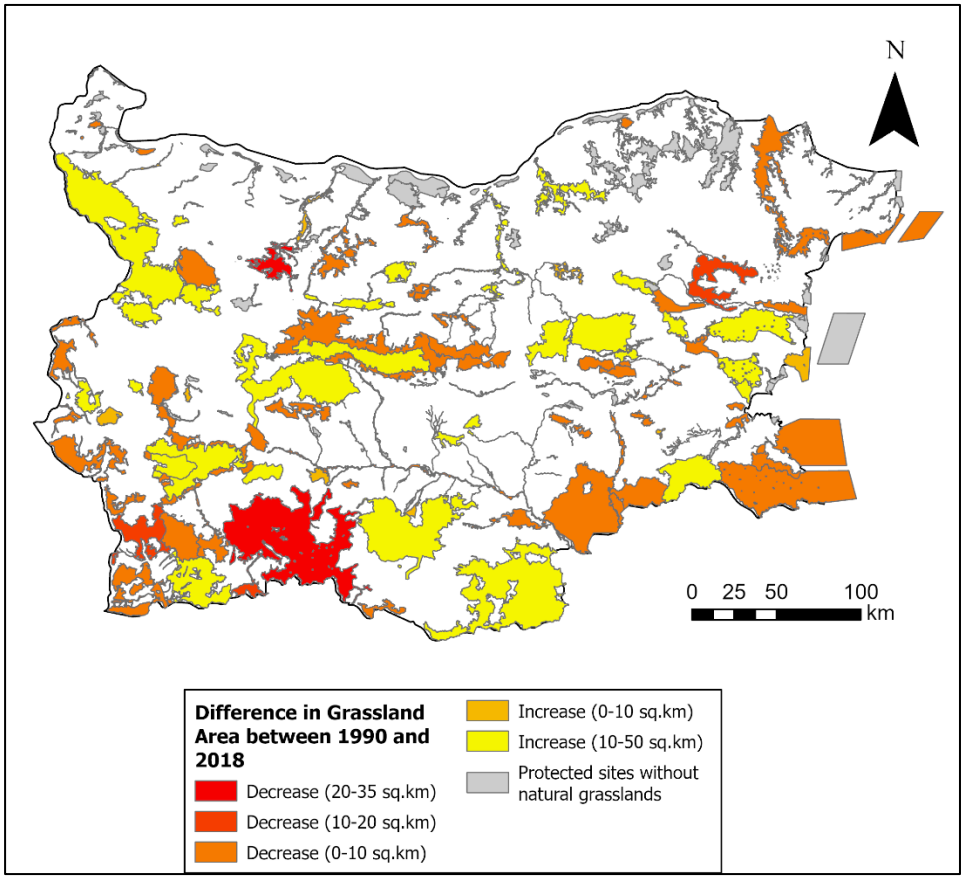

Figure 3 Difference in Grassland Area between 1990 and 2018 for protected sites in Bulgaria under the EC's Habitats Directive

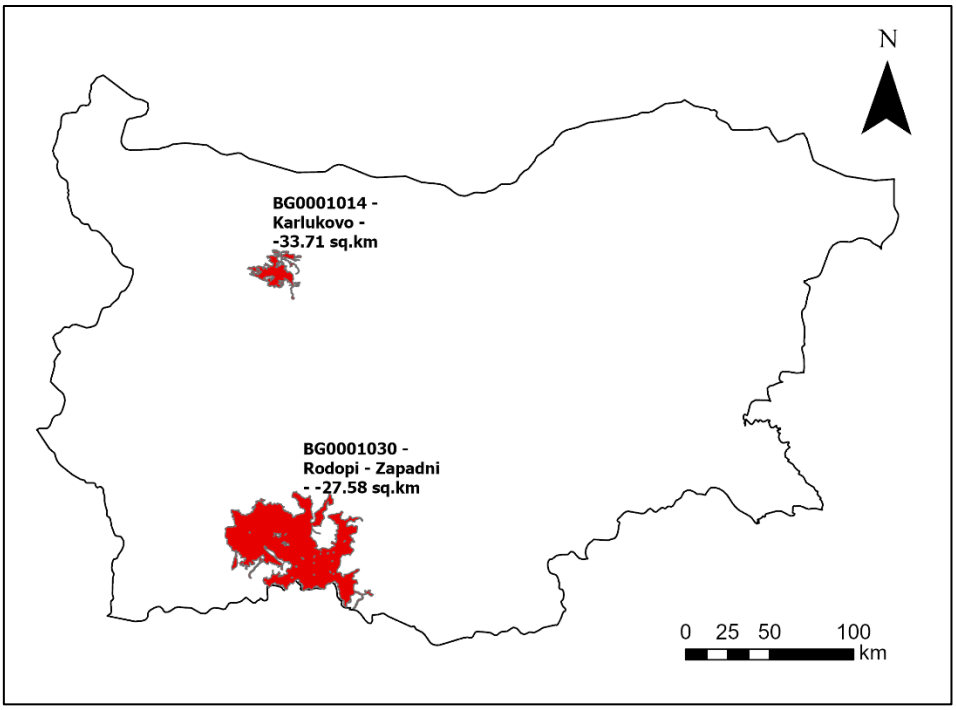

Figure 4 The two protected sites in Bulgaria with the largest reduction in grassland area between 1990 and 2018

The results of the second part of the analysis are presented in Table 1 and Table 2. For each of the two identified protected sites with a large reduction in grassland area, the values of several parameters were computed – the shape indices S1 and S2, and additional measures of landscape fragmentation – in order to explore and compare the ways in which the landscape has changes in the two sites between 1990 and 2018.

Table 1 Values of shape indices and descriptors of landscape fragmentation for site BG0001014 - Karlukovo

BG0001014 - Karlukovo	1990	2018	% change
S1 (mean)	1.79	1.87	+4.47%
S2 (mean)	1.75	1.65	-5.71%
Patch Density (mean)	0.111	0.094	-15.32%
Mean Patch Size (km^2)	1.74	0.82	-52.87%
Euclidean Nearest Neighbour Distance (min, m)	136.4	136.4	0.00%
Euclidean Nearest Neighbour Distance (mean, m)	1,239.6	1,153.7	-6.93%
Euclidean Nearest Neighbour Distance (max, m)	3,240.3	4,047.2	+24.90%

Table 2 Values of shape indices and descriptors of landscape fragmentation for site BG0001030 - Rodopi-Zapadni

BG0001030 – Rodopi-Zapadni	1990	2018	% change
S1 (mean)	2.82	2.05	-27.30%
S2 (mean)	1.62	1.64	+1.23%

BG0001030 – Rodopi-Zapadni	1990	2018	% change
Patch Density (mean)	0.106	0.066	-37.74%
Mean Patch Size (km^2)	0.358	0.421	+17.60%
Euclidean Nearest Neighbour Distance (min, m)	136.4	178.9	+31.16%
Euclidean Nearest Neighbour Distance (mean, m)	1,173.6	1,572.8	+34.01%
Euclidean Nearest Neighbour Distance (max, m)	9,551.5	10,780	+12.86%

DISCUSSION

The results of this study confirm the ongoing trend of natural and semi-natural grassland decline across Bulgaria's protected areas, consistent with patterns observed across Europe (Copernicus 2021). As highlighted earlier, grasslands are key habitats supporting a range of species and ecological functions (Biodiversity Information System for Europe 2021). Despite being located within protected sites under the Habitats Directive, the findings demonstrate that these ecosystems continue to be vulnerable to land use change and fragmentation pressures.

The two sites identified with the greatest reduction in grassland area - Karlukovo and Rodopi - Zapadni - showed distinct patterns of landscape change. In Karlukovo, a substantial 52.9% decrease in mean patch size and a 15.3% decline in patch density suggest a pronounced fragmentation of the grassland landscape. The increase in maximum nearest neighbour distance (+24.9%) further indicates a growing isolation of remaining patches. Habitat fragmentation is often described as a combination of habitat loss and isolation (Forman 2006). Hence, these results imply that despite the formal protection status, the area is experiencing significant loss of habitat connectivity. This is likely driven by agricultural expansion or natural succession to scrub and woodland as suggested by an analysis carried out by Copernicus Land Monitoring Service on the effectiveness of protecting Natura 2000 grasslands (Copernicus 2021).

Conversely, in Rodopi - Zapadni, while the total grassland area also decreased, the structural indicators suggest a different dynamic. Patch density decreased by 37.7%, but the mean patch size increased by 17.6%, and the mean nearest neighbour distance rose by 34%. This pattern may reflect consolidation or merging of remaining grassland areas in certain zones while other patches were lost entirely. The relatively stable shape indices (S1 and S2) point to limited change in patch geometry, possibly indicating less intensive fragmentation and more uniform loss across the site. The mountainous terrain and ongoing land abandonment in parts of the Western Rhodopes could also explain this pattern, as abandoned pastures often undergo gradual succession into shrubs or forests.

Overall, both sites exhibit trends consistent with previous research showing that land use intensification and abandonment can simultaneously drive grassland decline in Europe

(Copernicus 2021). The findings reinforce that designation under Natura 2000 alone does not guarantee effective protection against land cover transformation. Effective management, including support for traditional low-intensity grazing practices, support for diversification of livestock with different foraging practices, and control of shrub encroachment, remains crucial for preserving grassland biodiversity and ecosystem function (Shipley et al., 2024).

CONCLUSION

This study examined the loss of natural and semi-natural grasslands in Bulgaria's protected areas under the EU Habitats Directive between 1990 and 2018. Using CORINE Land Cover data, the analysis identified Karlukovo and Rodopi - Zapadni as the sites with the greatest reductions in grassland area and assessed changes in several landscape metrics to understand fragmentation dynamics.

The results show substantial decreases in total grassland area and evidence of increased fragmentation and isolation of grassland patches, particularly in Karlukovo. Although both sites remain part of the Natura 2000 network, their grassland habitats continue to decline, highlighting limitations in the current management and protection measures.

In conclusion, the study underscores the urgent need for active grassland conservation within Bulgaria's protected areas. Management actions such as restoration of traditional grazing, prevention of shrub encroachment, and monitoring of land use changes are essential to halt further habitat loss and ensure the long-term sustainability of these valuable ecosystems.

FUTURE WORK

Future research could build on this study in several ways. First, a temporal analysis using additional CORINE datasets (e.g. 2000 and 2006) would allow for a more detailed assessment of when the most significant changes occurred, especially relative to the sites' designation dates.

Second, future studies could include field surveys and biodiversity monitoring to link land cover change to specific impacts on flora and fauna, particularly species of conservation concern.

Finally, socio-economic analyses of land use drivers - such as agricultural abandonment, grazing intensity, or policy implementation effectiveness - would provide a broader understanding of the processes behind grassland loss and support the development of targeted management strategies.

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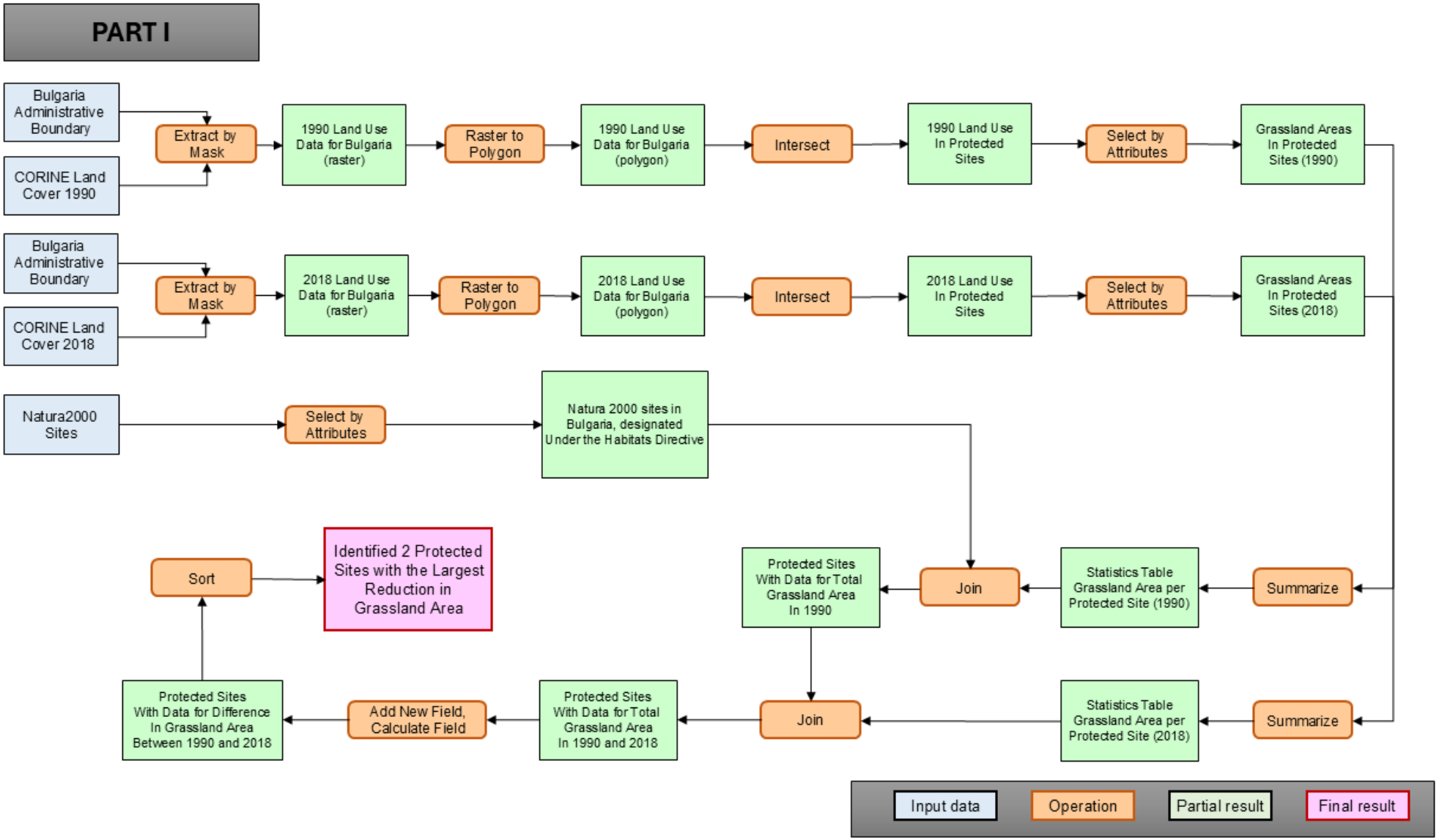
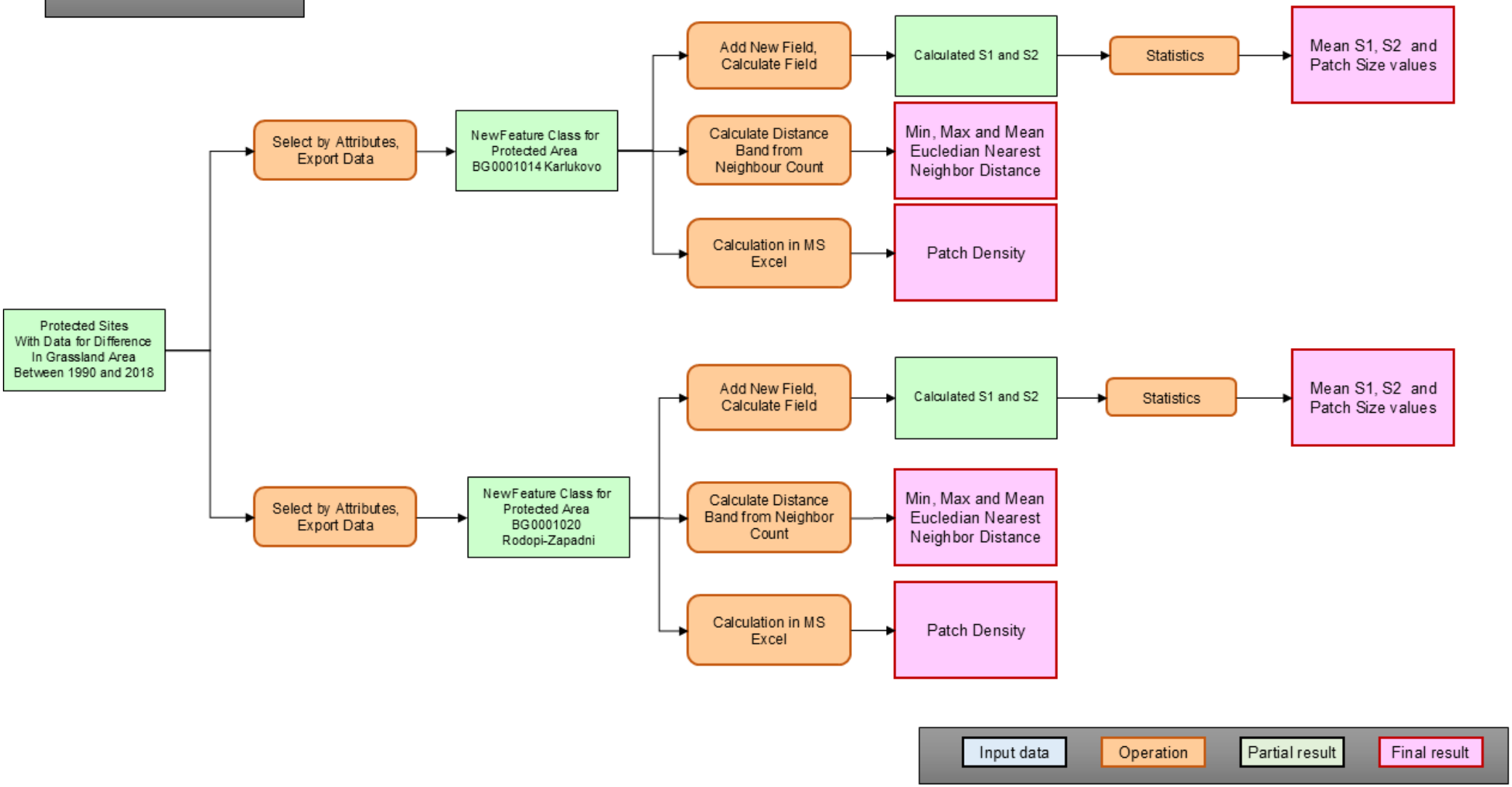
APPENDIX A: FLOWCHART



PART II


Protected Sites With Data for Difference In Grassland Area Between 1990 and 2018
Select by Attributes, Export Data
NewFeature Class for Protected Area BG0001014 Karlukovo
Add New Field, Calculate Field
Calculated S1 and S2
Statistics
Mean S1, S2 and Patch Size values
Calculate Distance Band from Neighbour Count
Min, Max and Mean Eucledian Nearest Neighbor Distance
Calculation in MS Excel
Patch Density
Select by Attributes, Export Data
NewFeature Class for Protected Area BG0001020 Rodopi-Zapadni
Add New Field, Calculate Field
Calculated S1 and S2
Statistics
Mean S1, S2 and Patch Size values
Calculate Distance Band from Neighbor Count
Min, Max and Mean Eucledian Nearest Neighbor Distance
Calculation in MS Excel
Patch Density
Input data
Operation
Partial result
Final result