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Mapping of ecosystems in Bulgaria for the needs of natural heritage assessment

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ABSTRACT

The main purpose of the paper is to explore the relationship between the CORINE Land Cover (CLC) classification and the MAES typology in order to develop a basis for mapping of ecosystems at national level in Bulgaria, which could ensure a spatial framework for mapping and assessment of the ecosystem services provided by the natural heritage. Identifying the necessary data for our purposes, we found that, in spatial terms, CLC data is the only appropriate data source. The subtypes of ecosystems at Level 3 of the classification of ecosystems in Bulgaria (based on the European MAES classification) are identified as mapping units. Firstly, we decided to analyze the links between the CLC and the MAES BG classes through five categories of correspondence: 1) full correspondence – one CLC class corresponds to one MAES BG subtype; 2) multi-directional links – one or more CLC classes correspond to one MAES BG subtype; 3) discrepancies that necessitate further analyses; 4) CLC classes that are not found in Bulgaria; 5) MAES BG subtypes that have no correspondence to a CLC class. Secondly, we prepared a comparison table to determine the correspondence between the CLC classes and ecosystem subtypes, which we integrated into the GIS environment. Thirdly, we developed an algorithm for modifications of the spatial distribution of ecosystem subtypes. The algorithm was applied particularly to grasslands, where at Level 3 of CLC there are two classes of "grassland", whereas at Level 3 of the classification of ecosystems in Bulgaria, the subtypes are five. This algorithm was applied to the 2018 CLC spatial data so as to develop a GIS database providing the basis for subsequent analyzes related to ecosystems. The database was used to delineate and map the ecosystems at national level in Bulgaria. Furthermore, a map of the potential of the natural heritage to provide ecosystem services was produced.

1. Introduction

Natural heritage (NH) includes natural features consisting of physical and biological formations, geological and physiographical formations, areas that constitute the habitat of indigenous species of animals and plants, which demonstrate natural significance from the point of view of science, conservation, or natural beauty (Harrison and O'Donnell 2010). In order to be considered as NH, all these features should be precisely delineated areas, which means that it is necessary to have robust spatial units which can be appropriately mapped. Natural significance refers to the importance of ecosystems, biodiversity, and geodiversity. Ecosystems incorporate biotic and abiotic elements (i.e. biodiversity and geodiversity) and can be considered as the spatial units which can represent the NH of a particular area in terms of their values to people (Ihtimanski et al. 2020). Ecosystems mapping is the spatial delineation of ecosystems following an agreed-upon ecosystems typology, which strongly depends on the mapping purpose and scale (Maes et al. 2013).

The MAES (Mapping and Assessment of Ecosystems and their Services) working group reports provide a methodological framework for mapping ecosystems at European and national level. Although that is a good basis, for specific needs such as the mapping of the NH at national level, it is necessary to develop an approach that corresponds to these needs and takes into account the data availability in the given country.

The core elements of the methodological framework for mapping of ecosystems and their services are: 1) mapping of ecosystems; 2) assessment of the ecosystems' condition; 3) mapping and assessment of ecosystem services. The mapping of ecosystems includes identification of ecosystem types (relevant to the question/theme and the region) and mapping of ecosystem types, based on CORINE Land Cover (CLC), remote sensing, national datasets, models (Burkhard et al. 2018). The MAES framework proposes a coherent typology to be used for the different types of broad ecosystems to be considered in the assessment, so as to ensure consistency across the Member States (Maes et al. 2013). These main classes are designed for consistent assessments of the state and services from local to national, regional, and European scale. Information from a more detailed classification at a higher spatial resolution could be combined with the European-wide classification, and could be aggregated in a consistent manner (Maes et al. 2013). The typology is organized in two main levels and its structure enables applying CLC data for spatial delineation. It is also adjusted with the European Nature Information System (EUNIS) habitat types where necessary in order to ensure that further subdivisions in the different countries would be performed in a uniform and compatible manner. The adoption of this typology has led also to an adaptation of other EU biodiversity activities, including the EEA biodiversity baseline, which revised its reports in order to provide the relevant facts and figures on the state and trends of the different biodiversity and ecosystem components (EEA, 2015).

The first and second MAES typology levels are based on the aggregation of the CLC classes into ecosystem types (Maes et al. 2013). CLC is the most appropriate source of spatial information as it is available in GIS-compatible format for all EU countries and ensures data quality, comparable to a map scale of 1:100 000. This ensures comparability of the results between the mapping activities in the different countries, and consistency from a methodological point of view. The CLC nomenclature has a hierarchical structure organized at three levels: the first level includes five main categories of land cover on Earth, the second level consists of 15 categories applicable to medium scale mapping, and the third level includes 44 classes appropriate for studies requiring large scale mapping. In Bulgaria, the ecosystem mapping and assessment process has been performed following the National Methodological Framework. It provides a national typology of ecosystems at the third level of the MAES typology that combines the CLC classes with the EUNIS habitat classification types. For each of the nine ecosystem types, a detailed typology based on the specific condition in Bulgaria has been developed.

Natural heritage can be described as a spatially explicit natural element of the social-ecological system, which incorporates material and spiritual values recognized by previous, present, and future generations (Nikolova et al. 2021). The natural elements have their origin in the natural systems, in the form of biotic and abiotic components. The natural systems on different scales can be recognized as ecosystems (on a larger scale) or landscapes (on a smaller scale). The mapping of the ecosystems (or landscapes) is crucial for the identification of the natural heritage, the assessment of its condition, and the services it provides. CLC data is the only available source at national level in Bulgaria. The integration of this data into the MAES typology at the third level, could provide an appropriate dataset for mapping of the ecosystems at national level. However, the relationship between the CLC and the MAES classes has not been studied so far.

The main objective of this study is to explore the relationship between the CLC classification and the MAES typology so as to develop a basis for mapping of ecosystems at national level in Bulgaria, which should provide an appropriate spatial framework for mapping and assessment of the ecosystem services provided by the natural heritage of Bulgaria.

2. Materials and methods

2.1 Study area and initial data

According to the main objective of this study, the initial data includes the CLC geodatabase for 2018 and the information on the ecosystem typology from nine national methodological frameworks for assessment and mapping of the ecosystems' condition and their services in Bulgaria (Apostolova et al. 2017a; Apostolova et al. 2017b; Kostov et al. 2017; Sopotlieva et al. 2017; Uzunov et al. 2017; Yordanov et al. 2017; Zhiyanski et al. 2017; Karamfilov et al. 2017; Yordanov et al. 2017). The study explores the relationship between the CLC classification and the MAES typology for the territory and the territorial waters of the Republic of Bulgaria.

According to the CLC classification, all 5 classes of Level 1 are represented in Bulgaria (Table 1). These classes include: 1) "Artificial surfaces"; 2) "Agricultural areas"; 3) "Forest and semi-natural areas"; 4) "Wetlands"; 5) "Water bodies" (Kosztra et al. 2017). Classes 2 (48.1%) and 3 (46.0%) cover more than 94% of Bulgaria's territory. Urbanized areas occupy less than 5% (4.8%), whereas classes of wetlands and water bodies cover less than 1% of the country's territory and its territorial water.

Table 1. Level 1 CLC classes in Bulgaria.

CLC (Level 1)	Total (ha)
1. Artificial surfaces	532 174.46
2. Agricultural areas	5 343 402.11
3. Forest and semi-natural areas	5 114 152.74
4. Wetlands	9 713.10
5. Water bodies	99 737.57

The nine national methodological frameworks for assessment and mapping of the ecosystems' condition and their services in Bulgaria (Apostolova et al. 2017a; Apostolova et al. 2017b; Kostov et al. 2017; Sopotlieva et al. 2017; Uzunov et al. 2017; Yordanov et al. 2017; Zhiyanski et al. 2017; Karamfilov et al. 2017; Velev et al. 2017) used in this study represent the final outputs of the BG03. PDP2 "Methodological assistance for ecosystems assessment and biophysical valuation" (MetEcoSMAP) project. As a result, the national methodological framework for assessment and mapping of the ecosystems' condition and ecosystem services in Bulgaria includes nine methodologies for the nine ecosystem types identified in Bulgaria.

Urban ecosystems are defined as social-ecological areas where most of the human population lives (Zhiyanski et al. 2017). Urban areas consist of mostly human habitats, but they are also inhabited by synanthropic species. The methodological framework for urban ecosystem assessment and mapping proposes ten ecosystem subtypes at Level 3 (J1 to J10 – see Suppl. material 1), which correspond to the National Concept for Spatial Development for the period 2013 – 2025 (NCSD, 2012). Seven of these ecosystem subtypes correspond to particular CLC classes in Bulgaria (Table 2), whereas three subtypes (J2, J4, J10 – see Suppl. material 1) – have no correspondence to the CLC classification.

The cropland ecosystems result from the manipulation of natural and biological resources by man. They comprise areas that are used for the production of crops such as grains, vegetables, fruit trees, and technical crops (Yordanov et al. 2017). This methodological framework proposes a cropland ecosystems typology at Level 3 that includes five ecosystem subtypes (I1 to I5 – see Suppl. material 1). They correspond to EUNIS (I.1, I.1.1, I.1.11/12 and 13) and to the ecosystem typology proposed by the MAES working group.

Grassland ecosystems consist of natural and primary semi-natural vegetation types (Apostolova et al. 2017b). They can be described as an interaction between social and ecological systems. Grassland ecosystems include pastures, meadows, hedges, uncultivated land, etc. These ecosystems are mainly used for the production of natural resources for animal consumption and livestock services (Apostolova et al. 2017b). The typology of grassland ecosystems proposed in the National Methodological Framework for Assessment and Mapping of Grassland Ecosystems and their Services, corresponds to the MAES classification and the EUNIS habitat classification types (Level 2). The typology of grassland ecosystems in Bulgaria at Level 3 includes five ecosystem subtypes (E1-E6 – see Suppl. material 1). Three of these ecosystem subtypes correspond to CLC classes 2.3.1. Pastures and 3.2.1. Natural grasslands. The other two ecosystem subtypes have no correspondence to any classes of the CLC classification (E1 and E6 – see Suppl. material 1).

The woodlands and forest ecosystems typology (Level 2) correlates with the MAES typology, the CLC classification, and the EUNIS habitat classification types (Kostov et al. 2017). The typology includes four ecosystem subtypes (G1-G4 – see Suppl. material 1). All of them are represented in the CLC forest classes.

The heathland and shrub ecosystems type includes shrub and dwarf shrub communities which can have a primary and secondary origin. They occupy territories in Bulgaria at different altitudes – from lowlands to the alpine belt (Velev et al. 2017). The typology of heathland and shrub ecosystems comprises three ecosystem subtypes (F2, F3, and F9 – see Suppl. material 1), of which only subtype "F2. Arctic, alpine and subalpine scrub" corresponds to the CLC classification.

Sparsely vegetated ecosystems are described as unvegetated or sparsely vegetated habitats (Sopotlieva et al. 2017). The natural conditions in these ecosystems are typically characterized by extreme variations. This determines distinct specialization or high species endemism. The typology of these ecosystems includes five ecosystem subtypes (B1-B3; H2-H3 – see Suppl. material 1). Two of these subtypes (B2 and B3) have no correspondence to the CLC classification.

Wetland ecosystems are areas in which the water table is at or above ground level for a certain part of the year. They are covered with herbaceous or peat-forming vegetation, while large shrubs and trees are not included in these ecosystems (Apostolova et al. 2017a). The typology of wetland ecosystems includes three ecosystem subtypes (D2, D4, and D5 – see Appendix 1), of which only subtype "D4. Base-rich fens and calcareous spring mires" does not correspond to the CLC classification.

The freshwater ecosystems typology consists of five subclasses at Level 2 – rivers, lakes, transitional/brackish, coastal marine waters, and man-made waters (Uzunov et al. 2017). The presence or absence of permanent water flow is the main difference between rivers and lakes. The group of transitional water ecosystems exhibits a high correlation with water salinity and its variations. The five subclasses include 14 subtypes (C1.1.-C1.6., C2.1.-C2.5; X01, X03; J5.2-J5.6. – see Suppl. material 1). Only two of these subtypes (C1.1. and C2.3.) correspond to the CLC classification in Bulgaria.

Marine ecosystems are habitats below the mean water level, located along the Bulgarian Black Sea coast (Karamfilov et al. 2017).

The typology at Level 2 consists of four classes – "Marine inlets and transitional waters"; "Coastal areas"; "Shelf and Open Ocean". Level 3 of the marine ecosystems typology corresponds to the EUNIS habitat classification. It includes eight ecosystem subtypes (A1-A6, B3, and X2 – see Suppl. material 1). Only one subtype "X2. Saline coastal lagoons" corresponds to the CLC classes.

2.2 Analysis of the correspondence between the CLC classes and the MAES BG classes

After a thorough analysis of the CLC and the MAES BG classifications, we identified five correspondence categories. The approach we use towards determining these categories is organized into five steps. The first step is to define whether a particular CLC class is found in Bulgaria (Fig.1). In case this CLC class is not found in the country, it corresponds to the 4th category – "CLC classes that are not found in Bulgaria". All other CLC classes, found in the territory of Bulgaria, go to the second step, which involves asking question №2: "Is there a correspondence between the CLC class and a MAES BG subtype?". In case the answer to the question is negative, then each of these CLC classes falls into the 5th category – "MAES BG subtypes that have no correspondence to a CLC class".

At step three, the classes for which the answer is positive are divided into two – full correspondence and partial correspondence. The full correspondence links to the 1st category – "Full correspondence – one CLC class corresponds to one MAES BG subtype". The partial compliance consists of two categories.

The fourth step includes the selection of one or more CLC classes that correspond to one MAES BG subtype and represents the 2nd category – "Multi-directional links".

Step five lists the classes in which there is no direct relationship between the two classifications. They belong to the 3rd category – "Discrepancies that necessitate further analyses".

2.3 Spatial analyses for delineation of subtypes characterized by discrepancies with the CLC classes

Analyzing the correspondence between the two classifications (see Suppl. material 1), and taking into consideration the scale (1:100 000), we found that the grassland ecosystems have the highest need for adjustment to the CLC classes. At the third CLC level, there are two classes of grassland, while at the third level of the Classification of Ecosystems in Bulgaria there are five classes. However, it is practically impossible to show all five CLC classes of grassland ecosystems on this scale, so we brought out the three most common in Bulgaria – Mesic grasslands, Seasonally wet and Wet grasslands, and Alpine and subalpine grasslands. This necessitated the development of an algorithm for modifications in the spatial distribution of the ecosystem subtypes (Fig. 2). In general, the implementation of the concept of deriving grass ecosystems is a consequence of the implementation of several main functions of ArcGIS – Erase, Clip, Buffer and Merge, described sequentially and in detail in Fig.2.

Due to the presence of a small number of small polygons of the Burnt areas CLC class, we had to make some modifications. These changes resulted in the reclassification of this class to another one, based on adjacent polygons and Basemaps / Orthophoto images. In this case, the Burnt areas were added to the Coniferous woodland ecosystem subtype.

2.4 Mapping of the ecosystems and the NH

NH is always associated with a specific territory in which it is located, i.e. it has a spatial dimension (Nikolova et al. 2021). As a geospatial element of the socio-ecological system, NH sites are in
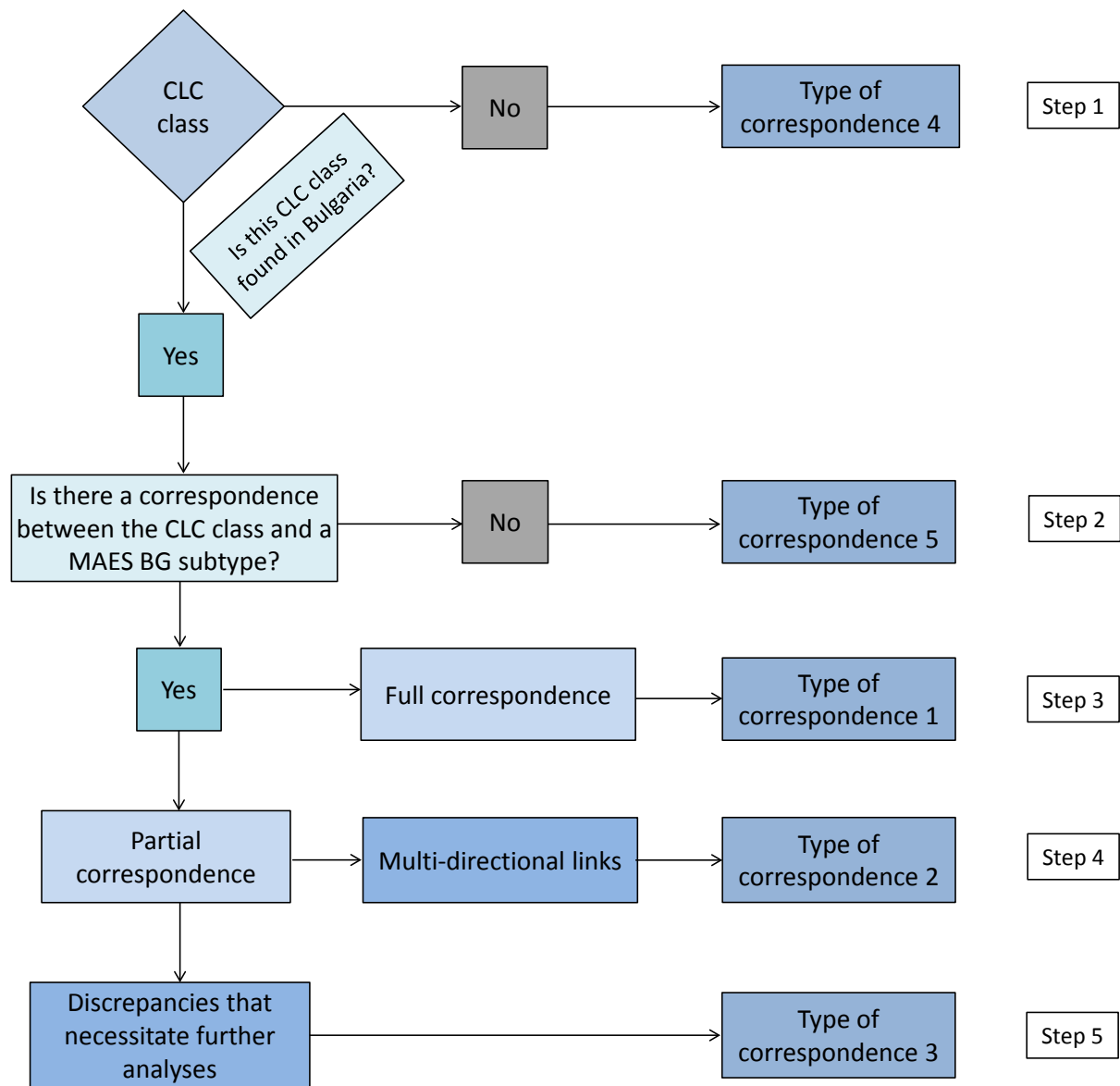
Figure 1. An algorithm for analysis of the links between the CLC classes and the MAES BG subtypes.

close interrelation with the embedding ecosystems and contribute to the benefits they provide to people. Therefore, the ecosystems can be used as a spatial unit for mapping of ecosystem services provided by the NH (Nedkov et al. 2021a). Maps of ES are made for a broad set of purposes and the main requirements for them are reliability, accuracy, resolution, and clarity, whose importance varies according to the mapping purpose (Jacobs et al. 2017). In this study, we produce maps to test whether the spatial database developed in accordance with the proposed approach (see 2.2 and 2.3) can be used for mapping and assessment of the NH in Bulgaria. We use the ES matrix approach (Burkhard et al. 2009) which estimates the capacities to provide ecosystem services based on land use or land cover data, and starts with an expert assessment. The approach uses a relatively simple matrix where the ecosystem services are presented as columns, and the geospatial units – as rows. In our case, we use the ecosystems subtypes outlined at the previous stages as geospatial units. We assume that each ecosystem subtype contains a particular range of NH objects (Nedkov et al. 2011a). The ecosystem's capacity to provide an ecosystem service is estimated at each intersection of ecosystem subtype and service. The scores for ecosystem services capacity are added as attributes to the GIS layer of ecosystem subtypes. Thus, the GIS database could be used to generate a map of the potential of the NH to provide ecosystem services.
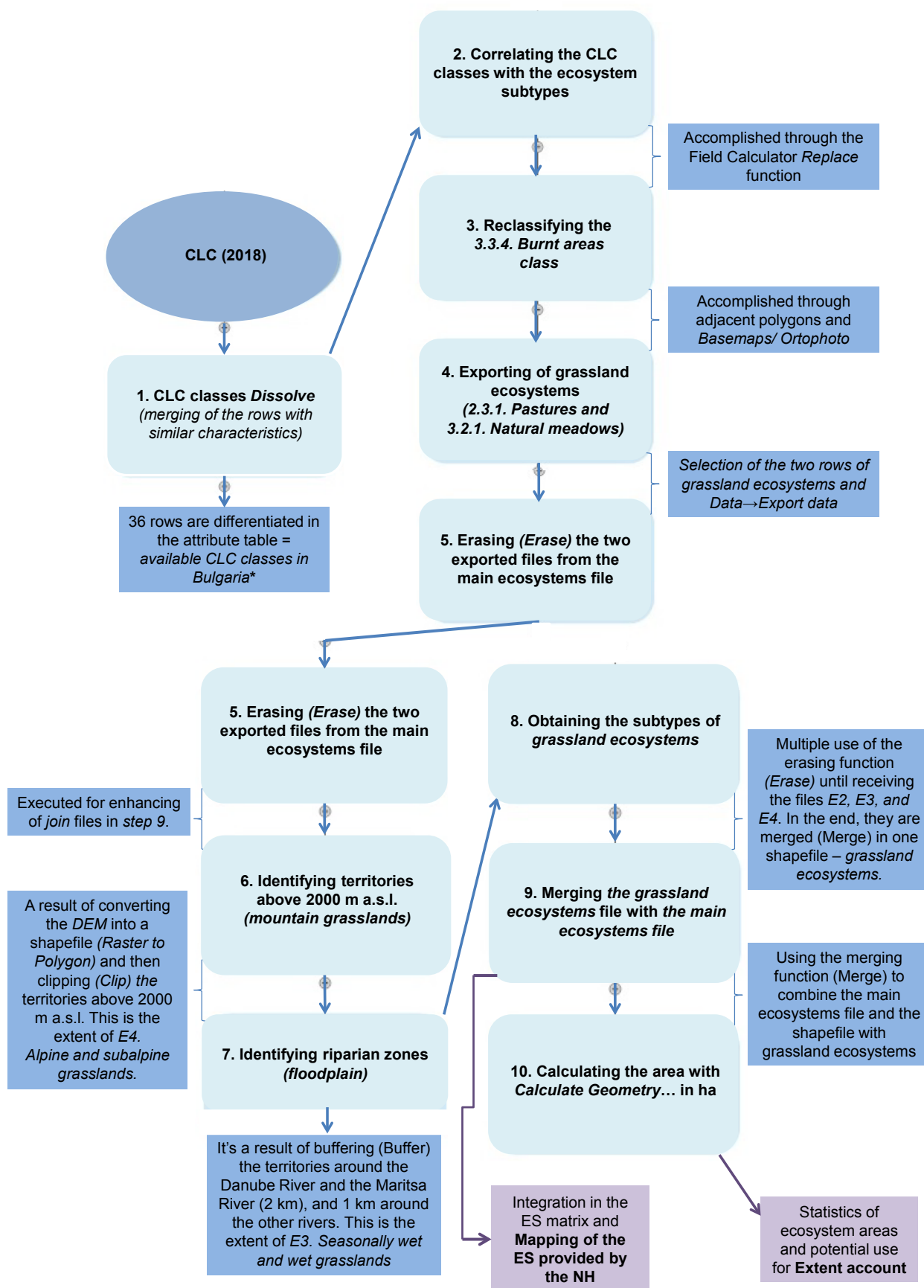
2. Correlating the CLC classes with the ecosystem subtypes

Accomplished through the Field Calculator *Replace* function

CLC (2018)

3. Reclassifying the *3.3.4. Burnt areas class*

Accomplished through adjacent polygons and *Basemaps/ Ortophoto*

1. CLC classes *Dissolve* (merging of the rows with similar characteristics)

4. Exporting of grassland ecosystems (*2.3.1. Pastures* and *3.2.1. Natural meadows*)

Selection of the two rows of grassland ecosystems and Data→Export data

36 rows are differentiated in the attribute table = *available CLC classes in Bulgaria**

5. Erasing *(Erase)* the two exported files from the main ecosystems file

5. Erasing *(Erase)* the two exported files from the main ecosystems file

8. Obtaining the subtypes of *grassland ecosystems*

Multiple use of the erasing function *(Erase)* until receiving the files *E2, E3, and E4*. In the end, they are merged (Merge) in one shapefile – *grassland ecosystems.*

Executed for enhancing of *join* files in *step 9*.

6. Identifying territories above 2000 m a.s.l. (*mountain grasslands*)

9. Merging *the grassland ecosystems* file with *the main ecosystems file*

A result of converting the *DEM* into a shapefile *(Raster to Polygon)* and then clipping *(Clip) the* territories above 2000 m a.s.l. This is the extent of *E4. Alpine and subalpine grasslands.*

Using the merging function (Merge) to combine the main ecosystems file and the shapefile with grassland ecosystems

7. Identifying riparian zones (*floodplain*)

10. Calculating the area with *Calculate Geometry… in ha*

It's a result of buffering (Buffer) the territories around the Danube River and the Maritsa River (2 km), and 1 km around the other rivers. This is the extent of *E3. Seasonally wet and wet grasslands*

Integration in the ES matrix and **Mapping of the ES provided by the NH**

Statistics of ecosystem areas and potential use for **Extent account**

Figure 2. Workflow of the spatial analyses for delineation of grassland subtypes.

3. Results

3.1 Correspondence between the CLC classes and the MAES BG subtypes

The analysis of the links between the CLC classes and the MAES BG subtypes resulted in defining five cases of correspondence between them: 1) full correspondence – one CLC class corresponds to one MAES BG subtype; 2) multi-directional links – one or more CLC classes correspond to one MAES BG subtype; 3) discrepancies that necessitate further analyses; 4) CLC classes that are not found in Bulgaria; 5) MAES BG subtypes that have no correspondence to a CLC class (Fig. 3).

Full correspondence between the CLC classes and the MAES BG subtypes has been established in 16 cases (Fig. 3A). The highest number of cases (4) has been established between artificial surfaces (CLC) and urban ecosystems (MAES BG), as well as between forest and semi-natural areas and woodland and forest ecosystems. The CLC classes with the lowest level of full correspondence are the agricultural areas – with just one case, and wetlands – with two cases. The artificial surfaces, agricultural areas, and wetlands are directly linked to just one ecosystem type. Therefore, the two classifications are quite similar in their urban, agriculture, and wetlands parts. As far as the other classes are concerned, the correspondence can be described as "one-to-many". For instance, the classes from the forest and semi-natural areas are linked to three different ecosystem types – woodland and forest, headland and shrub, and sparsely vegetated lands.

The second category (multi-directional links) is represented by seven cases (Fig.3B). The following pairs are characterized by the largest number of cases (3): artificial surfaces (with seven CLC classes) and urban ecosystems (with three MAES BG subtypes), and agricultural areas (with six CLC classes) and cropland (with three MAES BG subtypes). There is one case of multi-directional links concerning two classes of wetlands (CLC) that correspond to one marine ecosystem subtype (MAES BG).

The third category is represented by two cases (Fig. 3C) – one of them concerns one ecosystem type (grassland) from the MAES BG classification, while the other case concerns two CLC classes (Level 1) – agricultural areas and forest and semi-natural areas. In both cases, two ecosystem subtypes correspond to one CLC class.

The fourth category of interactions covers CLC classes that are not found in Bulgaria (Fig. 3C). There are a few missing CLC classes in the country's territory (in four of the five Level 1 units): three classes are not represented in agricultural areas and forest and semi-natural areas, one class is missing from wetlands, and two classes are missing from water bodies.

The fifth category includes MAES BG subtypes that do not correspond to any CLC classes (Fig. 3C). Discrepancies are observed in eight of the nine types of ecosystems. For 12 of the 14 ecosystem subtypes of freshwater, no compliance with the CLC classes was found. Seven out of eight ecosystem subtypes of marine ecosystems did not match. Cropland and wetlands are represented by one ecosystem subtype, while the other ecosystem subtypes are dominated by cases of non-compliance of two and/or three subtypes.
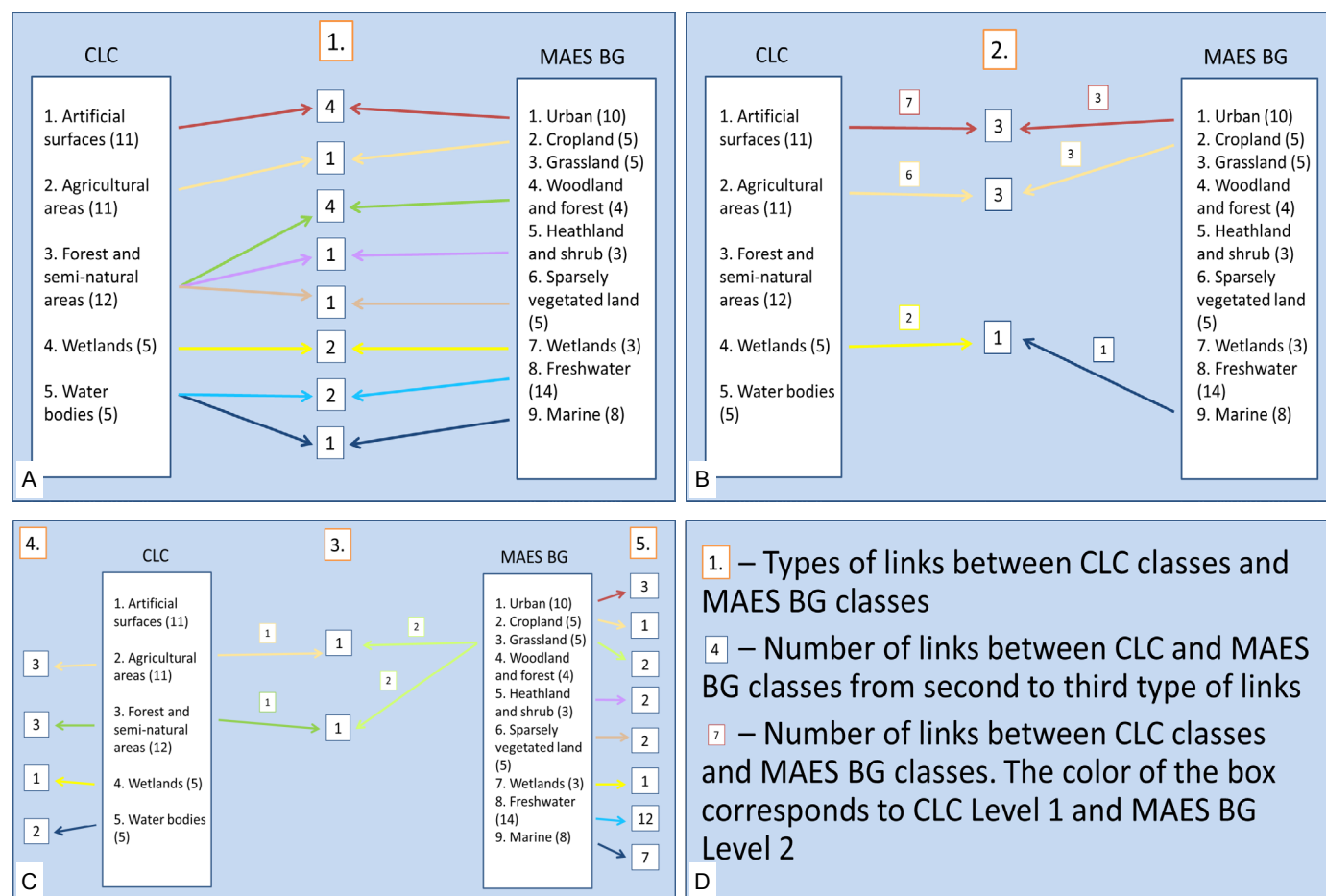

Figure 3. Correspondence between the CLC classes and the MAES BG subtypes.

3.2 Mapping of the ecosystems

The CLC provides an appropriate dataset for the whole country, which allows mapping of ecosystems at national level. However, the ecosystem classification of Bulgaria (based on the European classification of MAES) is better for the identification of the natural heritage at ecosystem level. Therefore, we used the correspondence between these classifications (see 3.1) to develop a spatial dataset of ecosystems in Bulgaria based on the CLC spatial units and the MAES BG subtypes. To illustrate the results (Fig. 3), we used the coloring characteristic of the ecosystem types in the 2013 MAES document.

Table 2 shows the areas in hectares of each ecosystem subtype in Bulgaria. Some polygons are difficult to distinguish due to their small size. These polygons belong to the following ecosystem types: Wetlands (distributed unevenly throughout the country, mainly along the Black Sea coast and the Danube River), Sparsely vegetated land (located mainly in mountainous areas and along the coast), and Marine (located near the Black Sea)

3.3 Potential of the NH to provide ES

The 15 ES provided by the NH and defined as highly relevant to the tourism prioritization procedure (Nedkov et al. 2021b, in this issue) were tested for mapping at national level using the express matrix assessment method. The scores in the matrix were given by experts, asked to estimate the potential of the NH of each ecosystem subtype. The expert assessment scores were used to generate maps of the ES at national level (Fig. 5). The results show that the areas of very high NH potential were located mainly in the mountain, plateau, and hilly areas, as well as some floodplains with riparian vegetation, where forest ecosystems are the predominant type. The subalpine areas in Rila Mountain and Pirin Mountain had lower scores mainly due to the absence of forest ecosystems in those areas. These results fully correspond to the maps produced in a similar study by Nedkov et al. 2021b.

Table 2. MAES BG ecosystem subtypes based on CLC data.

| Ecosystem type	Ecosystem subtype (Level 3)	Area (ha)	%
1. Urban	J1. Residential and public areas of cities and towns	814,21	0.01
	J3. Residential and public low density areas	388046,20	3.50
	J5. Urban green areas (incl. sport and leisure facilities)	17720,45	0.16
	J6. Industrial sites (incl. commercial sites)	77928,02	0.70
	J7. Transport networks and other constructed hard surfaced sites	11479,95	0.10
	J8. Extractive industrial sites (incl. active underground mines and active opencast mineral extraction sites, and quarries)	32108,59	0.29
	J9. Waste deposits	4077,05	0.04
2. Cropland	I.1. Annual crops (mostly cereals)	3821663,00	34.43
	I.2. Perennial crops (fruit gardens and vineyards)	160997,90	1.45
	I.3. Perennial crops (mostly legumes)	36891,21	0.33
	I.4. Mixed cropland	1323850,00	11.93
3. Grassland	E2. Mesic grasslands	654404,10	5.90
	E3. Seasonally wet and wet grasslands	116989,10	1.05
	E4. Alpine and subalpine grasslands	28625,99	0.26
4. Woodland and forest	G1. Broadleaved deciduous woodland	2297472,00	20.70
	G1. Broadleaved deciduous woodland - coppice	762294,70	6.87
	G3. Coniferous woodland	533630,00	4.81
	G4. Mixed deciduous and coniferous woodland	644870,30	5.81
5. Heathland and shrub	F2. Arctic, alpine and subalpine scrub	22931,07	0.21
6. Sparsely vegetated land	B1. Coastal dunes and sandy shores	1898,04	0.02
	H2. Screes	12632,85	0.11
	H3. Inland cliffs, rock pavements and outcrops	38404,60	0.35
7. Wetlands	D2. Valley mires, poor fens and transition mires	8394,92	0.08
	D5. Sedge and reedbeds, normally without freestanding water	1318,18	0.01
8. Rivers and lakes	C1.1. Permanent oligotrophic lakes, ponds and pools	64847,68	0.58
	C2.3. Permanent non-tidal, smooth-flowing watercourses	32537,14	0.29
9. Marine	X2. Saline coastal lagoons	2352,76	0.02
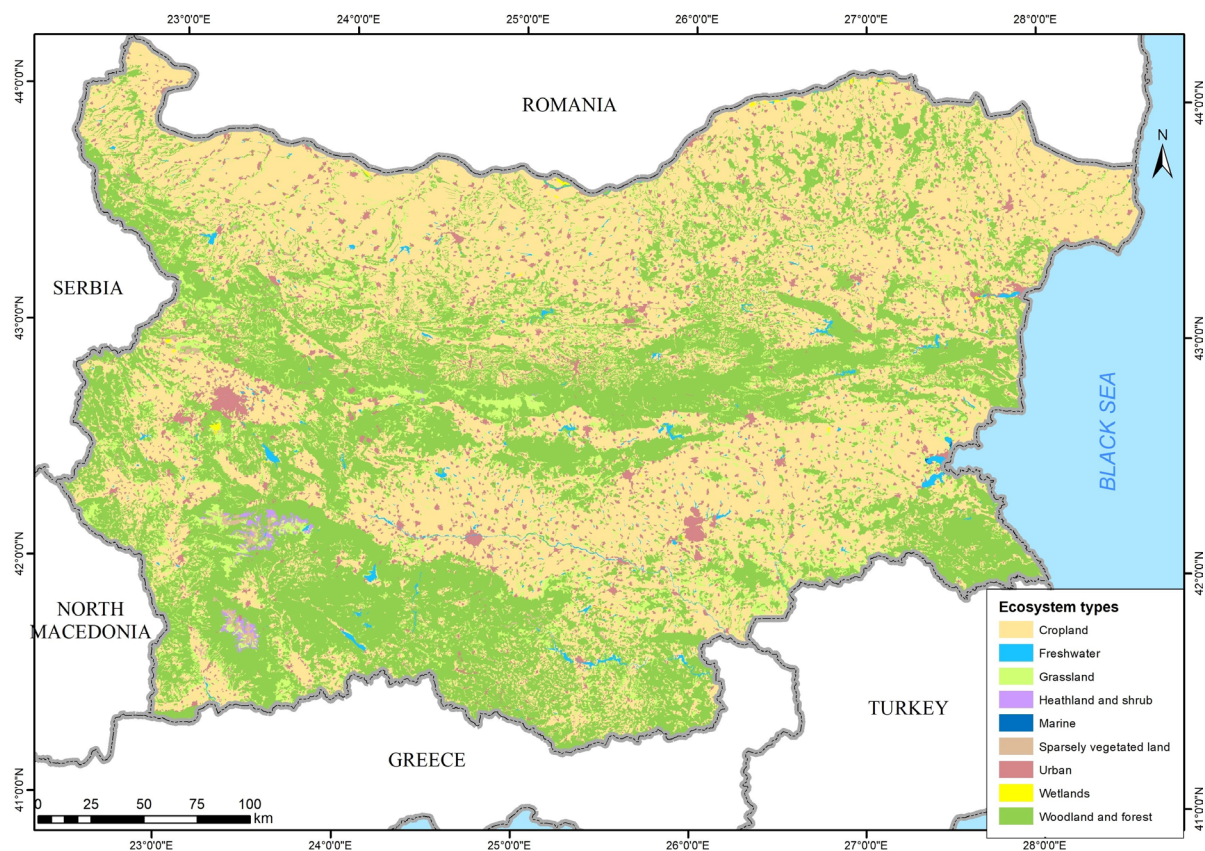
Figure 4. MAES BG ecosystem types based on CLC data.
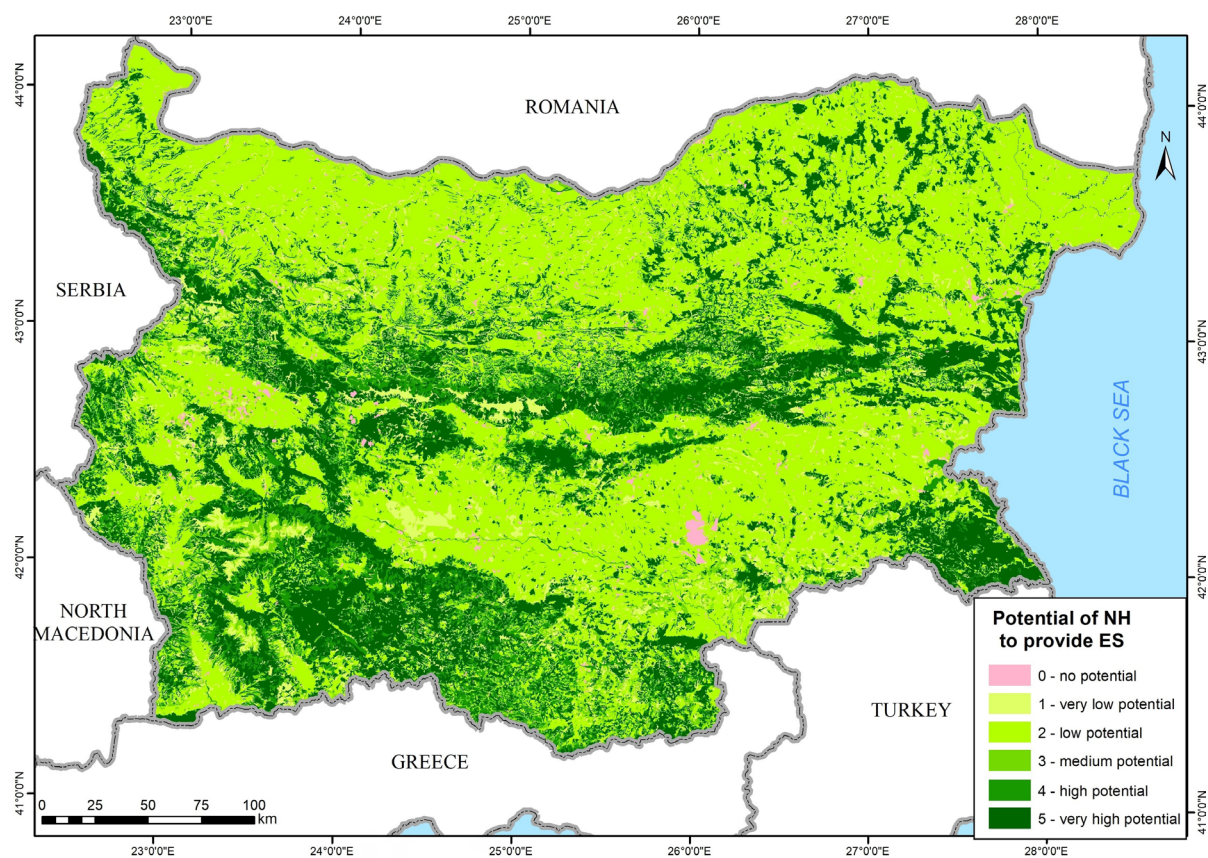

Figure 5. The potential of the natural heritage in Bulgaria to provide ecosystem services for the needs of recreation and tourism.

4. Discussion

CLC data has been used in this study as the most appropriate data source for mapping of ecosystems at national level, and for consistency with the MAES mapping at EU level. However, CLC has some limitations, especially in relation to the scale to which the data correspond, and for mapping on a smaller scale, data sources with higher resolution and precision should be used.

The defined relationships between Level 3 CLC classes and the MAES BG ecosystem subtypes, cover all possible cases which could exist, except for one, where multi-directional links between one or more ecosystem subtypes to one CLC class are exhibited. Thus, the full range of relationships could be used in other studies aiming to find the correlation between different classifications of ecological, landscape, or other kinds of spatial land units. The comparison between CLC and MAES BG shows that although CLC has more classes at Level 3, many more MAES BG ecosystem subtypes could not be delineated using the proposed approach. The main reason for that is the difference in the spatial resolution established in the methodologies for the two classifications: the CLC dataset is developed for a scale of 1:100 000 and area of the minimum mapping unit of 25ha (Kosztra et al. 2017), while the methodology for mapping and assessment of the ecosystems in Bulgaria (Bratanova-Doncheva et al. 2017) defines a scale of 1:25 000 and area of the minimum mapping unit of 0.25ha. Therefore, the database developed in this study is applicable for mapping and assessment on a larger scale – predominantly at national level. For more detailed studies on a finer scale – at regional, and especially local level – other datasets are needed.

The proposed approach includes two main elements – an algorithm for analysis of the links between the two classifications, and a workflow for spatial analyses of classes with no clear correspondence. The first one enables to define the relationships between the classifications and to establish whether an interlinkage between them is possible. In our case, the correspondence between CLC and MAES BG is high, with more than 75% of the classes from CLC available in MAES BG. Further studies need to define threshold values that would determine if that correspondence is satisfactory. Uncertainty analysis would be an appropriate tool for such a procedure. The second element enables the user to increase the level of correspondence by application of specific spatial analysis techniques. The workflow presented in this study is applicable for the specific case of grassland ecosystems. It could be used as an example, but for each specific case another workflow should be developed.

5. Conclusions

The main outcome of this study is the established correspondence between the CLC classes at Level 3 and the MAES BG subtypes. The proposed approach for comparison and identification of the linkages enables the development of a spatial database of the ecosystems, by using the widely available CLC data. This work builds on the mapping of ecosystems at European level by further development of ecosystem subtypes that correspond to the third level of the MAES typology (Maes et al. 2013). This is in line with the need for further classification at third and fourth levels to be developed specifically for the individual EU Member States to reveal the country specifics (Burkhard et al. 2018).

The results of the study complement the findings of Nedkov et al. 2017, according to which the territory of Bulgaria is dominated by two types of ecosystems – croplands and forests. The annual crops and mixed cropland are the predominant subtypes in the cropland ecosystems, while broadleaved deciduous forests dominate in the forest type. Despite their important ecological significance, coniferous forests have a relatively limited extent in the country. The proposed approach ensures appropriate delineation of most of the ecosystem subtypes identified in Bulgaria under the MAES mapping process (Bratanova-Doncheva et al. 2017), but there are still some subtypes that are missing in this dataset because the CLC data is too coarse for their delineation. This is especially valid for freshwater ecosystems, which have to be delineated on a finer scale due to their limited size.

The dataset about the ecosystems in Bulgaria, developed in this study, will be used as a spatial framework for the mapping and assessment of ecosystem services provided by the natural heritage at national level (Nedkov et al. 2021a). Furthermore, that dataset is an important source for the delineation of spatial units for the needs of ecosystem accounting. These spatial units represent an aggregation of ecosystem types that have heterogeneous biophysical properties, for which the ecosystem services accounts are presented in supply and use tables (UN 2021). Thus, they can be used as a basis for development of the ecosystem extent account of Bulgaria.

Funding program

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Supplementary materials

Suppl. material 1: Correspondence between the CLC classes and the MAES BG ecosystem subtypes

Authors: Hristova D, Stoycheva V

Data type: Table, .pdf

Brief description: Correspondence between the CORINE Land Cover classes and the MAES BG ecosystem subtypes

Size: 129 KB

Link: https://doi.org/10.3897/jbgs.e76457.suppl1