The Framework of the Maintenance Ecosystem Services Provided by Agroecosystems on the Territory of Bulgaria

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Abstract. Over the past decade, efforts to value and protect ecosystem services have been promoted by many as the last, best hope for making conservation mainstream. Here, we present the results from the evaluation of the maintenance ecosystem services, provided by the agroecosystems in Bulgaria. The evaluation was conducted on a range of national, European and international databases following the methodology of MAES and classification system of CICES adapted by the Bulgarian Ministry of Environment and Water. During the study, 213857 agroecosystems were evaluated referring to their capacity to maintain pollinators, natural pest control, soil quality and atmospheric carbon sequestration. The capacity of agroecosystems to provide the above mentioned ecosystem services was ranged from moderate to very high, tending the mountainous agroecosystems to be more beneficial than that located in the plains and lowlands. The intensive management of the latter in order to achieve perceived efficiencies in the production of agricultural goods reduces their importance for local and regional ecological processes.

1. Introduction

The ecosystem approach is at the heart of analysing the links between humans and their environment. It is approved by the UN Convention on Biological Diversity and fully compatible with the objectives of the International Work Program Millennium Ecosystem Assessment – MEA, 2005. The ecosystem approach is a strategy for integrated land, water and resource management, thus promoting the conservation of biodiversity and sustainable consumption [1]. Ecosystem services are the goods and benefits that people receive from ecosystems [2]. These benefits are food, access to clean air and water, health, safety and aesthetic delight [3]. To implement Activity 5, the European Commission set up an expert working group „Mapping and assessment of ecosystems and their services - MAES“ with the participation of Member State officials, experts from different services to the European Commission and the European Environment Agency, as well as independent scientists. The MAES Working Group monitors the mapping of ecosystems, the assessment of their status and the services they provide at national and European level [3]. The process of mapping and assessing the ecosystems and their services...
begins with mapping the ecosystems themselves. When mapping, all 28 Member States use a unified ecosystem typology in order to integrate and compare their information [3,4]. The second step is to assess the state of ecosystems defined as physical, chemical and biological status at a certain moment in a specific location. The condition can also be seen as the ecosystem quality. The third step is to evaluate ecosystem services on the basis of their "stock" and "demand" evaluation through groups of specific indicators for ecosystem functions and processes respectively and the public need for these services [3]. The last step - making an integrated assessment of ecosystems - is currently under development.

In Bulgaria (BG), the agroecosystems are the most widespread type of ecosystems, especially outside the scope of the NATURA 2000 network. Traditionally, the agroecosystems have been considered primarily as sources of provisioning services, but more recently their contributions to other types of ecosystem services have been recognized [1]. Agroecosystems take part in regulating and maintenance processes like the control of erosion, buffering mass flows, pollination potential, maintaining wild species and habitats.

The aim of this work is to assess the maintenance services of the agroecosystems (MES) located outside of the Nature 2000 network, focusing on certain indicators. The data are obtained during the implementation of the project BG03 “Mapping and assessment of agroecosystem services” supported by the EEA Financial Mechanism and the Norwegian Financial Mechanism through the Bulgarian Ministry of Environment and Water.

2. Materials and Methods

2.1. Study area

The typology of agroecosystems (AEs) was applied based on maps of Physical Blocks (provided by the Ministry of Agriculture, Food and Forestry), CORINE Land Cover and EUNIS habitat classification [5], and the results are presented in Table 1.

| Number | Subtype AE | Physical blocks |
|--------|------------|----------------|
| 201    | Annual crops (mostly cereals) | 010 Arable Lands (fields planted with corn, wheat, barley, rye, sunflower, rapeseed, etc.) |
| 202    | Perennial crops (fruit gardens and vineyards) | 020 Permanent Crops (perennial crops) 021 Vineyards 022 Orchards 023 Other permanent crops (lavender, oil rose, raspberry, etc.) |
| 203    | Perennial crops (mostly legumes) | 010 Arable Lands (only field with perennial legumes - mainly alfalfa, less others such as sainfoin and clover) |
| 204    | Mixed cropland | 050 Mixed Cropland |
| 205    | Livestock farms for large and small animals including bees | 030 Settlements (family gardens) 031 Yards 032 Areas around settlements (only those that do not fall into urban territories) |

The work is focused on 213,857 AEs with a total area of 3,516,342 ha (32%), belonging to the annuals, mostly cereals (81%), mixed crops (11%), perennials – vineyards, orchards, oil rose, lavender, raspberries, etc. (5%), legumes - mainly alfalfa (2%), and animal farms and greenhouses (1%) (Figure 1).

The analysis of ESs (including provisioning, regulating and maintenance and cultural) are conducted on the basis of experiences gathered with spatial and biophysical evaluation of ESs as described in the scientific literature as well as national and global assessments such as MEA [1], TEEB [6], CICES [7],
EC [8], UK NEA [9], and other national (BG methodology) and European maps and documents that were available. Spatial data on land cover, soil and water quality, together with data from the field interviews with stakeholders (data are not shown) were used. Field interviews were conducted in 25 representative municipalities across the territory of the country. GIS (ESRI ArcGIS Software) was used to spatially analyze and visualize the distribution and provision of ecosystem services. Geostatistical interpolation techniques were used to predict the value of un-sampled pixels on the basis of nearby pixels in combination with other characteristics of the pixel.

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**Figure 1.** Share (%) of agroecosystem (AE) subtypes according to the area occupied by them

The AE capacity to provide ecosystem services (ESs) was estimated by an ES ranking table [10]. Based on expert judgement each ES is ranked between 0 and 5 separately. For more details of the methodological aspects of biophysical valuation of ecosystem service in Bulgaria, see the website of Bulgarian Executive Agency of Environment and Water [11].

In this paper only results from the biophysical analysis of MESs are presented. The below listed biophysical indicators for ESs were chosen with aim to evaluate the MESs as developed in CICES.

### 2.2. Biophysical indicators for evaluation of MESs

**Maintenance of pollinators.** The indicator provides information on the agriculture management concerning the practice to crop plants, capable to support pollinators. The ES was evaluated spatially (GIS) calculating the share (%) of the croplands planted with entomophilous crops to the total area of AEs on the territory of the respective municipality. The data were provided by the Ministry of Agriculture, Food and Forestry - MAFF [12], and cover the years 2013 – 2015. **Pest control.** The indicator evaluates AEs referring to the implemented biological pest control in crop landing practice. The calculation accounts the share (%) of natural areas to the total area of the respective municipality, and was conducted on the base of physical blocks (2014), provided by the Ministry of Environment and Water [13]. **Soil weathering.** The indicator was evaluated as soil degradation rate (kg/ha/yr), assessing the capacity of AEs to avoid soil deterioration due to the land use. A digital map [14, 15] was used for soil degradation generated as difference in the net primary productivity (NPP) per year (on average) for a period from 1981 to 2003. The difference in NPP was derived from the Normalized Difference Vegetation Index (NDVI) measured by remote sensing images. **Soil organic carbon.** The indicator was used to evaluate the capacity of AEs to balance fixing and decomposing processes providing a stock of nutrients for high soil productivity. It was applied a digital map for soil organic carbon (1 km x 1 km) in Europe [16], showing the percentage of organic carbon content in the surface soil horizon (0 – 30 cm). The map was based on the work of Jones et al. [17], who calculated the soil organic carbon content, using European Soil Database and combining refined pedo-transfer rules with spatial thematic data.
layers of land cover and temperature, as 1 km raster layers. **Water conditions.** Water quality, expressed by ecological index, was used as an indicator for evaluation of the AEs’ capacity to protect surface- and ground- waters. The ecological index was calculated taking into account: (a) biological quality elements: macrophytes, phytoplankton, fish, macrozoobenthos, phytobenthos; (b) water quality elements: color, transparency, odor, conductivity, pH, temperature regime, total hardness, carbonates and hydrochlorides, sulphates, oxygen regime, suspended solids, organic pollution, biogenic components, total nitrogen, total phosphorus, Fe, Mn, specific pollutants; and (c) hydromorphological properties: hydrological mode, river continuity; morphological conditions (depth changes, river processes, bank erosion). The data were provided by the Danube [18], Black Sea [19], East Aegan [20], and West Aegan [21] River Basin Directorates (in Bulgarian).

**Climate regulation.** IPCC Tier-1 global biomass carbon map [22] was used to quantify the capacity of AEs to carbon sequestration in t C/ha (above and belowground living vegetation). The map was created for year 2000 using the International Panel on Climate Change (IPCC) Good Practice Guidance for reporting national greenhouse gas inventories [23].

3. **Results and discussion**

The importance of AEs to human society is not limited only to their provisioning services, but also to their potential to regulate and maintain a range of local and regional ecological processes, including wild lifestyle. In the study maintenance ESs of AEs were evaluated, using biophysical indicators.

3.1. **Maintenance of pollinators**

Pollination is an ES offered by natural ecosystems and significantly influenced by human activities in AEs. Worldwide and also in BG, a number of economic and less environmental factors determine the type and area of crops. The main entomophiles (insect pollinated) crops in BG are perennials - orchards, oil-bearing rose, lavender, sainfoin, alfalfa, and etc, except vineyard, being wind-pollinated. Much of the cropped annuals (cereal and some vegetables) are anemophilous, except sunflower, rapeseed, tomatoes, cucumbers, zucchini, fodder vegetables, etc., which belong to the group of entomophyles. About 70% of the AEs were assessed with a very high relevant capacity for “pollinator maintenance” (Figure 2).

![Figure 2. Relative capacity of agroecosystems (AEs) to maintain pollinators](image)
AEs that offer the high relevant capacity to "maintenance of pollinators" are located in the north-central part of the country – one of the places with the most suitable conditions for agriculture development. The high capacity of AEs to maintain pollinators resulted from the extensive cropping of sunflower and rapeseed, planted on, respectively, more than 820 000 ha and 168 000 ha in 2016/2017 [24]. The croplands with sunflowers and rapeseed represented around 35% and 28% of the total area planted with annuals and crops, respectively. The conducted interview with local residents (data are not shown) proved our opinion that the cropping practice is driven by the agriculture market, and it is out of interest for farmers to plan entomophilous in order to maintain pollinators.

3.2. Pest control

There are many approaches for pest control on agricultural crops. The most widely used of them is the chemical treatment of crops, which does not comply with the environmental principles and leads to the destruction of not only pest but also non-target species populations, some of which are useful for the agroecosystem itself. The use of plant protection products causes reduction of biodiversity, soil and water pollution, accumulation of chemicals in the produced food as well as their transmission through the food chain. More than 48% (on average) of the croplands in Bulgaria planted with annuals in 2016 were treated with insecticides for plant protection [25], and their share increases up to 65% and 75% in wheat and rapeseed production, respectively.

An alternative method of controlling the pests is prevention - reducing the risk of pest over-spreading, balancing the "victim-predator" relationship (host-parasite). The balance can be achieved by maintaining large natural areas around and between agroecosystems.

In the respect of natural pest control, it was evaluated that predominantly AEs fall into categories with moderate (41%), and high to very high (in total, 38%) relevant capacity (Figure 3). AEs, which were characterized with moderate capacity for natural pest control are these planted with cereals, vegetables, legumes, lavender, oil-rose, etc. - most of them located in the plain areas of the country. Mixed croplands (subtype 204), orchards and vineyards (subtype 202), and small farms (subtype 205) showed high to very high capacity for natural pest control, being located in the hilly and mountain areas of Bulgaria (north-west, north-central and south-west parts of the country) in municipalities with high natural cover (over 90% of their territory).

![Figure 3. Capacity of agroecosystems (AEs) to provide natural pest control](image-url)
3.3. Soil weathering
Agriculture intensification through the use of tillage, fertilizers, and pesticides alter soil physical, chemical, and biological properties, and thus increase yields at the cost of other ESs. Reduced primary production can be considered as a sign of soil deterioration. The deterioration in soil quality in BG is not recorded on a large scale, suggesting a high buffering capacity of AEs to limit soil degradation (Figure 4). Although limited, more significant losses of primary production (15-20 kg/ha/year) were registered in a number of municipalities, all located in the north-central and north-eastern parts of BG. Similar processes of primary production loss were registered for the region around the capital of BG - Sofia city.

![Figure 4. Capacity of agroecosystems (AEs) to protect soils from degradation](image)

3.4. Soil organic carbon
Soil organic matter is an important indicator of the MES related to the carbon cycle and in particular its biological transformations. The organic matter determines many of soil properties such as fertility, buffering capacity, moisture-holding capacity, adsorption and degradation of soil pollutants, etc. Over 60% of the AEs fell into categories with a high and very high capacity to protect soils from organic carbon loss (Figure 5). The ES of AEs to protect soils from carbon loss was more widespread in mountainous regions of the country (occupied by subtypes 202, 204 and 205), where the soil organic carbon reaches up to 15%. In a contrast, soils of many plains (occupied by subtypes 201 and 203) under intensive cropping activities (north and south-east parts of the country) are stocked with organic carbon not much than 1%. The high soil organic carbon in mountainous terrains is a result of the prevailing of the carbon fixing over the degradation of soil organic matter, due to the inhibition of soil decomposers (year-round lower temperature than in the plains).

3.5. Ecological state of freshwater
Agricultural activity refers to diffuse sources of water pollution, especially in the case of unauthorized use of plant protecting products, fertilizers and contaminated water for irrigation. Livestock breeding has also negative effect on the water quality. Additionally, the water quality is under the impact of non-agriculture activities like industry, ballast extraction, waste disposal, etc. Concerning the above
mentioned facts, the capacity of AEs to protect waters from pollution is interpreted as relative one. The ES of the AEs to protect the water (surface / underground) has been assessed according to the ecological status of the water bodies in the areas of AEs localization (Figure 6, 7).

![Figure 5. Capacity of agroecosystems (AEs) to protect soils from organic carbon loss](image)

![Figure 6. Capacity of agroecosystems (AEs) to protect groundwater from pollution](image)

The AEs capacity to protect underground waters was higher (predominantly high relative capacity (score 4)) compared to that of the surface waters (predominantly moderate relative capacity (score 3)).
AEs located in the karst areas (districts of Lovech, Veliko Tarnovo, Razgrad, Shumen and Pazardzhik) had lower capacity to protect the groundwater than the AEs from the other parts of the country. The reported lower capacity of AEs for surface water protection is due to: (a) most of the AEs were located in the middle and lower reaches of the rivers, where, in general, water was of lower quality and (b) lack or very limited plant belts between croplands and river beds, leading to low retention of liquid flows from land to water-net.

![Image](image.png)

Figure 7. Capacity of agroecosystems (AEs) to protect surface water from pollution

3.6. Sequestered organic carbon

Human activity causes accumulation of CO$_2$ in the air, resulting in global climate changes with increasing actuality in recent years due to the caused damage to economy, agriculture and environment. Climate changes are dynamic and they are also a threat for the future development of mankind. The main reason for this is an increase in the frequency of disasters and natural catastrophes, which repeatedly increases the losses from agricultural production.

The natural reaction of the vegetation to increased CO$_2$ content in the atmosphere is to accelerate the photosynthesis and synthesize larger quantities of biomass. This natural buffering process reduces the CO$_2$ content of the atmosphere by converting the inorganic carbon into a resistant organic form.

It should be noted that the accumulation of organic carbon in vegetation which has a positive effect on global warming was relevant only for subtype 202 AEs. For the remaining AE subtypes, the balance of accumulated and released carbon after harvesting was close to zero. More than half of the AEs offered the service of sequestration of atmospheric carbon with moderate capacity (Figure 8). Better capacity for atmospheric carbon sequestration had fruit trees and vineyards compared to other permanent crops (lavenders, oil-roses, raspberries, etc.).

3.7. General characteristic of MESs, provided by AEs

Calculating the average score of MESs per AE, we established that most of the AEs provided MESs with high capacity (84% of AEs’ area) (Figure 9 and 10), except that of protecting surface water from pollution (moderate capacity) and soils from degradation (very high capacity).
Based on the latter results, we think that the indicators “protection of surface water from pollution” and “protection of soils from degradation” have to be revised referring to the database used. At the time of study, we could not find more accurate database which can (1) differentiate the surface water pollution caused by agriculture from that caused by the other anthropogenic sources, and (2) manifest the rate of soil deterioration – probably 22-years period of study is not long enough to detect changes in soil quality by changes in the net primary production, especially as the soil deterioration can be compensate by fertilization, irrigation and plant protection.
Figure 10. Average capacity of AEs to provide ESs to maintain soil and water quality, and wild lifestyle

Relationship between the score value and average AE size is recorded – the higher the score value the smaller is the average AE size, manifesting that agriculture practice to keep high landscape heterogeneity reflect in high ecological value of AEs.

4. Conclusions
It was the first assessment of the AEs in Bulgaria to provide different ecosystem services as well it was the first applying of the methodology of MAES and it is adapted to Bulgaria version. The capacity of 213 857 AEs with a total area of 3 516 342 ha has been assessed to provide MESs. Most of them have high to very high capacity to protect and maintenance wildlife and soil quality, and this trend is more obvious for mountainous AEs than that located in plains and lowlands. The intensive manner of AE use in plains and lowlands reduces their capacity to provide MESs in a higher rate than that in mountainous regions. The recent study could be an example to continue these researches in the future and to expand them, also, to the territories inside NATURA 2000 network in Bulgaria.

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