Assessment of pressures caused by climate changes on wetlands in Romania based on MAES framework

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Abstract: - Ecosystems provide benefits to humanity, but lately they are affected by pressures such as habitat degradation, over-exploitation, invasive alien species, pollution and climate change. To meet the global target of the Convention of Biodiversity, European Union adopted the Biodiversity Strategy to 2020, settling 6 specific targets, with 20 concrete actions. Until 2020 EU Member States must prevent by proper measures the loss of biodiversity and degradation of ecosystem services. The action 5 of Target 2 it is implemented by the Working group MAES, which strongly cooperates with European Environment Agency and Joint Research Center in order to achieve de propose targets at European level. Firstly, this implies the necessity to implement the methodology proposed by MAES for ecosystem assessment at national and local level. In the present study is performed an assessment of pressures caused by climate changes on wetlands in Romania, taking into account the methodology proposed by MAES. Based on the set of indicators recommended by MAES framework and following the DPSIR (Drivers, Pressures, State, Impact and Response) framework, was highlighted the evolution of the main climatic parameters (temperature and precipitation), in two different periods: current climate (period 1950-2000) and future climate (2041-2060). For this, have been used data sets from the WorldClim5 database, selecting the output of global climate model HadGEM2-ES developed by the Met Office Hadley Centre, England, at the spatial resolution of 20 m, for RCP4.5 scenario. The future climate projections show a variation of air temperature parameter between 13.01 to 15 °C, affecting an area of 3256.1 km^2 of wetlands in Romania (85.98%). Regarding the differences in rainfall distribution between present and future climate, were observed differences between -50 and -25 mm affecting the largest area of wetlands at national level, of 2287.75 km^2 (60.40%).

Key-Words: - wetlands, climate change, pressures, MAES framework, EU Biodiversity Strategy, DPSIR framework

1 Introduction

The EU Biodiversity Strategy to 2020, adopted by EU States in March 2010, includes six targets and 20 associated actions, from which action 5 requires Member States to map and assess the state of ecosystems and their economic values at national level [1]. In order to assist the Member States to implement the EU Biodiversity Strategy at their national level, was set up the Working Group on Mapping and Assessment on Ecosystems and their Services (MAES), under the Common Implementation Framework (CIF). MAES propose various steps for assessing ecosystems and their services, to build a feasible methodology. One of the most important steps consist in developing a proper classification of ecosystem types following the MAES approach, mapping the extent of these ecosystems and assessing the pressures acting on ecosystems types identified [2]. Considering that pressures can interact with each other, the greatest challenge consists in mapping potential impacts of multiple pressures on ecosystems, to assess their combined effect on ecosystem service delivery, step which is in an early stage of development [3]. For example, droughts could affect the health of certain species, making them vulnerable to the effects of pollution and at the same time increasing pollution degree could make species vulnerable to the climate change impact. To analyze specific environmental problems and to identify the proper measures to resolve them, was developed the DPSIR (Drivers, Pressures, State, Impact and Response) framework by the European Environmental Agency (EEA), (Fig.1), which describes the interactions between society and the environment [4]. Under this framework, were settled the major drivers of ecosystem change: habitat changes, climate change, exploitation, invasive species, pollution and nutrient enrichment.

Fig. 1 DPSIR framework adapted to the ecosystem assessment (source: EEA, 2016)

Drivers produce various pressures on ecosystems which can exert negative effects on its functionality. For this, the major pressures need to be measured in order to assess their effect on the ecosystem condition. For quantifying these pressures, the development of indicators is essential, because they are providing an indication about changes in a system [5]. According to second MAES report from February, 2014, [6], the most assessed ecosystem types at European level are forests and agro-ecosystems, while indicators are mostly based on national statistical data. In Romania, there are identified 19 wetlands of international importance (Ramsar sites), distributed as can be seen in the Fig. 2. The present study aims to adapt to the peculiarities of wetlands in Romania, the framework proposed by the group MAES and at the same time to assess pressures caused by climate changes on wetlands in the present and future climate, by using data sets from the WorldClim5 database. For this, in first instance are presented the climatic characteristics of wetlands in Romania. Second, there will be presented in the Section 3 the importance of indicators proposed by MAES framework in assessing the pressures caused by climate change on wetlands in Romania.

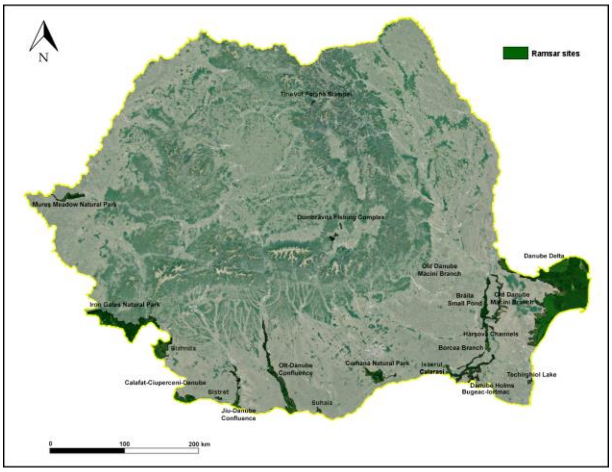

Fig. 2 RAMSAR sites in Romania (source of data: Ministry of Environment, Waters and Forests)

It will be taken into account the specific features at national level for developing a proper methodology to assess the identified pressures.

2 Climatic characteristic of wetlands in Romania

Wetlands covers an area of 3860 km^2 or 1.62% of Romania's territory, their extending varying according to climatic and environmental conditions in the long term. For mapping wetlands in Romania was used Wetland - Copernicus database which is based on processing high resolution satellite imageries with an accuracy of 0.5 m and a minimum mapping dimension of wetlands of at least 20 x 20 m [7]. Thus, it was obtained a pan-European raster with surfaces, on which were delineated wetlands in Romania. This raster has been used in wetland ecosystems mapping in Romania, to which, by the method of overlapping thematic layers [8] were determined environmental and ecosystem characteristics as arising from the bio-pedo-climatic and anthropogenic particularities (Fig. 3). The major relief units of Romania are presented in the Fig 4 while the distribution of wetland areas at national level by the relief units is shown in Table 1. Can be observed that mountain areas have the lowest wetlands surfaces (below 0.5%). Most wetlands in mountain areas are associated with altitudes that develops a glacial and semi-glacial climate, of over 1800 - 2000 meters. Related to temperature regime, wetlands in Romania are located in areas with annual average temperatures between 1-12 ° C (see Table 2). From Table 2 can be noticed that temperature values above 11 °C represents over 80% of the areas analyzed.

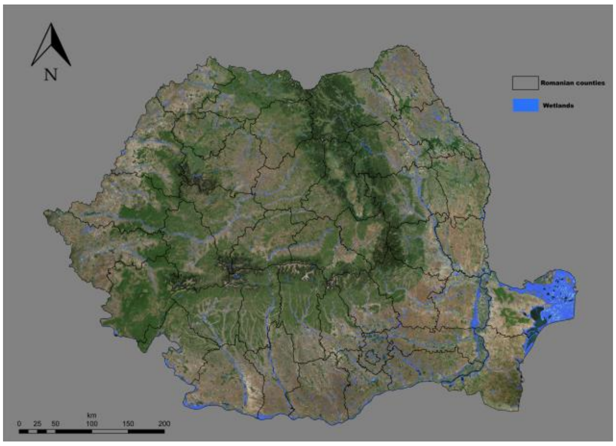

Fig.3 Location of wetlands in Romania (data source: Langanke, et al., 2015)

Table 1 Distribution of wetlands on relief units

No.	Area	Surface (km^2)	Percent from wetlands surface (%)
1.	Danube Delta and Small Marsh of Brăila Natural Park	2380	61.6
2.	Danube meadow without Small Marsh of Brăila Natural Park	655	17.0
3.	Lowland areas	685	17.7
4.	Hills areas	132	3.4
5.	Mountain areas	9	0.2
6.	Total	3861	100.0

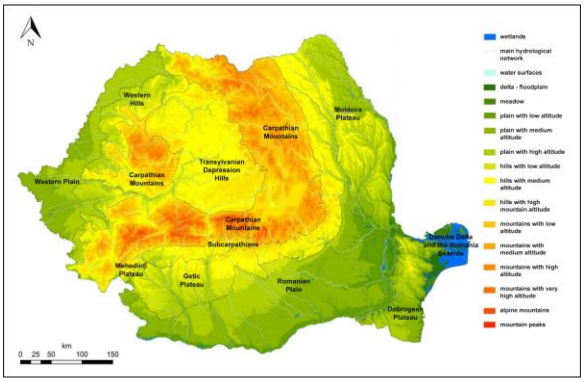

Fig. 4 Romania's major relief units

Wetlands in Romania, from which around 75% are located in plains, in the meadows and in the Danube Delta region, are characterized in particular by rainfall below 500 mm/year.

Table 2 Distribution of wetlands in Romania by average annual temperature

Temperature (°C)	Surface (km^2)	Percent from wetlands surface (%)
1-3	1.0	0.03
4-6	23.2	0.6
7-9	324.7	8.4
10-11	348.2	9.0
>11	3163.8	81.9
Total	3861	100.0

Rainfall range between 501 and 1.000 mm/year and includes approximately 25% of the wetland, while values above 1.000 mm/ year are occupying only a small area (Table 3).

Table 3 Distribution of wetlands in Romania according to the multiannual average rainfall

Precipitations (mm)	Surface (km^2)	Percent from wetlands surface (%)
$\leq$ 400	2.088	54.1
401-500	791.8	20.5
501-700	936.8	24.3
701-1000	43.9	1.1
$\geq$ 1000	0.5	0.01
Total	3861	100.0

2.1 deMartonne climate index

Considering that annual average temperatures and average annual rainfall, does not indicate particular features of the climate when are analyzed separately, [9], to describe the features of climate are usually used climate indicators that can provide bio-climatic features of analyzed regions. For example, by applying deMartonne Index on climate classification, the analyzed areas can be differentiated according to the humidity regime. The formula for calculating deMartonne index, which is used in the present study, is shown and explained below [10]:

$$A = P/\ T + 10 \quad (1)$$

where:
A – deMartonne aridity indicator;
T – average annual temperature;
P – average annual rainfall;
$0 < A < 10$ dry climate;
$10 < A < 20$ semi-dry climate;
$20 < A < 30$ semi-humid climate;
$30 < A < 60$ humid climate;
$60 < A$ excessively humid climate.

deMartonne index values are dimensionless and present a good correlation with specific types of vegetation located in temperate continental climate. Table below (Table 4) shows the wetlands distribution in different classes, observing that about 65% of the total area are included in the category of dry and semi-dry climate, specific to the Danube Delta region. Humid and excessively humid surfaces, including wetlands in the mountains area account about 6% of all wetlands (Fig. 5).

Table 4 Distribution of wetlands surfaces in Romania according to deMartonne index

Climate regime	Surface (km^2)	Percent from wetlands surface (%)
dry climate	1.0	0.03
semi-dry climate	23.2	0.6
semi-humid climate	324.7	8.4
humid climate	348.2	9.0
excessively humid climate	3163.8	81.9
Total	3861	100.0

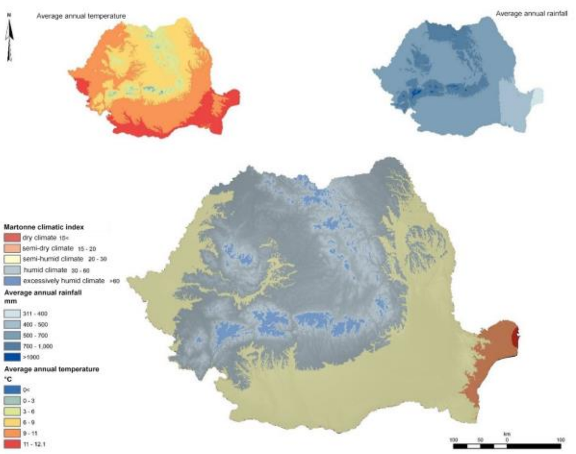

Fig. 5 Distribution of average annual temperatures in Romania (top left); distribution of multiannual average rainfall in Romania (right up); deMartonne Index distribution in Romania (center)

From the figure above can be observed that most part of the country presents a semi-humid climate according to deMartonne index, while some regions of the Danube Delta are located in a dry and semi-dry climate.

3 Indicators to assess pressures caused by climate change on wetlands in Romania

Assessing the state/condition is part of the evaluation methodology of ecosystems and their services, recommended by the conceptual framework proposed by MAES. By using the DPSIR framework can be linked the pressures on ecosystems together with condition and impact on ecosystem services. These links can be analyzed by using specific indicators of each pressures, as components of ecosystem or ecosystem service. One of the major pressures of ecosystem change, is represented by anthropogenic climate change, which affects life-cycles of plants and animals [11]. In the Fig. 6 are shown the main pressures of climate change impacts on ecosystems and the data used to assess their effects at European level [12].

Climate change

Pressure	Indicator	Datasets	Cropland	Grassland	Woodland and forest	Heath-land and shub	Wetlands	Rivers and lakes	Marine	Reference year
Climate change	Temperature	Global and European temperature EEA indicator CSI012	**	**	**	**	**	**	**	Since 1850
Climate change	Precipitation	Mean precipitation EEA indicator Clim002	**	**	**	**	**	**	**	Since 1960
Extreme events	Precipitation extremes	Precipitation extremes EEA indicator Clim004	**	**	**	**	**	**	0	Since 1960
Regional sensitivity to CC effects	Level of degradation due to climate change	Environmental sensitivity to climate change — ESPON climate	**	*	**	*	**	*	**	2010
Coastal storm	Change in exposure to coastal storm surge events (ESPON CC)	Inundated areas due to coastal storms	0	0	0	0	0	*	*	2071–2100
Floods	Human induced floods (e.g. climate change, canalisation)	Change in exposure to river flooding.	0	0	0	0	*	*	0	2071–2100
Fires — extreme events	Human induced fires (e.g. climate change, human related) Forest frequency (area affected by recurrent fires/ time)	Pot. impacts on forest fires (ESPON CC), Average of forest fire density (n of fires/yr./1km²) fires history data — EFFIS), Seasonal severity index (JRC) SSR future projection (2071–2100) (JRC) http://forest.jrc.ec.europa.eu/effis/	–	–	**	**	0	–	–	2000–2100
Drought — extreme events	Induced droughts (e.g. climate change, overexploi-tation)	Pot. Impacts of climate change on soil organic carbon content	**	*	**	*	0	–	–	2071–2100
Increase in sea-surface temperature	SST	ESaTDOR — ESPON (NOAA-OI-SST)	0	0	0	0	0	0	**	1981–2011
Sea-level change	Predicted sea level change (mm / year)	EEA-hydrodynamics and sea-level rise	0	0	0	0	0	0	**	2005
Ocean acidication	Changes in ocean ph	N ceas	–	–	–	–	–	–	*	n/a

Note: * = data available but not mapped; ** = mapped; 0 = no data; – = not relevant / not applicable.

Fig. 6 Main pressures of climate change impacts on ecosystems and the data used to assess their effects (source: EEA, 2015)

Regarding the pressure of climate change on wetlands, can be noticed that available and mapped data are related to temperature, precipitation and precipitation extremes. At the same time, since 2010 there are available information of regional sensitivity to climate change expressed in level of degradation. The data are available from ESPON Climate Project which has developed a series of climate change indicators [13]. The results of ESPON Climate relates to possible vulnerability scenario showing the Europe’s future peculiarities from climate sensitivity point of view. By identifying regional typologies of climate change, can be advanced solutions for proper implementation of adaptation measures. Moreover, to assess the state of the environment at European level, the European Environment Agency (EEA), established in 2004 a set of 52 indicators of climate change, of which 7 are basic indicators (Core Set Indicators - CSI). Besides these indicators were defined alternative indicators (CLIM, 45 indicators) to assess better cause-effect relationship between society and climate change. The above set of indicators, recommended by MAES framework, was adapted to national level. In next table (Table 5) are presented indicators of climate change pressures, recommended by EEA and adapted for Romania, with the possibility of application at local level, for the assessment of specific ecosystems. They were selected on the basis of the report of the European Environment Agency released in 2015 [12], climate characteristics of wetlands in Romania and data availability [14]. The following figure (Fig. 7), schematic illustrates these links in the biophysical assessment of ecosystems, which can be measured by indicators.

Table 5 The correspondence of climate change indicators recommended by EEA and the adapted indicators for Romania

Indicators (EEA)	Indicators Romania	Pressure type (according to MAES guide)
CSI 012 - Air temperature at global and European level	The average air temperature change for future scenarios	Climate change
CLIM 002 - Precipitation amount	The average amounts of rainfall change	Climate change

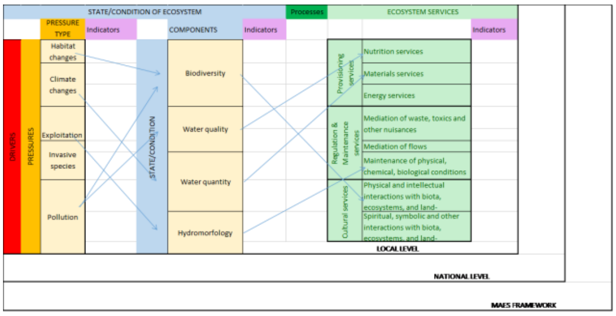

Fig. 7 The relationship between adaptation of DPSIR framework and indicators from MAES framework to local level

In the next section is exposed the methodology and the assessment of the indicators presented in the above table.

3.1 Analysis of selected indicators in the present and future climate

In the following, are presented methodological indicators of pressure caused by climate change at national level, with the possibility to apply locally to areas of interest. For each indicator, it was completed a fiche containing information about pressure type, class, indicator, data source, scale, description and calculation method as can be seen in the Table 6. Aiming to highlight the evolution of the main climatic parameters (temperature and precipitation) at national level and their influence on the operating mode of wetlands, have been used data sets from the WorldClim5 database for current climate (period 1950-2000) and future climate (2041-2060).

Table 6. The fiche completed for each indicator

Pressure type: Climate change/Extreme events	Class: Air temperature/Rainfall
Method of estimation condition: indirect	
Indicator:	
Data source:	
Scale:	
Indicator description [measurement unit]:	
Calculation method:	

Available data are the projections obtained using global climate models (Global Climate Models-GCM's) for four representative concentrations of greenhouse gases. In this case, were used the output of global climate model HadGEM2-ES developed by the Met Office Hadley Centre, England, at the spatial resolution of 20 m, for RCP4.5 (under this scenario, greenhouse gas emissions have a peak around 2040 and then start to decline). The figure below (Fig. 8), presents the annual average temperature values in proximity of wetlands in the current climate (period 1950-2000), in which it can be seen that the highest values up to 12 °C are recorded in the Danube Delta, in regions the Danube meadow and the western part of the country. The lowest values of between 3-5 °C are recorded in mountainous regions and in north-east. For future climate (Fig. 9), annual average air temperature values reach and even exceed the 15 °C in most regions analyzed excepting isolated regions of the mountainous area where the temperatures annual average air reach up to 11 °C. For a more detailed analysis, in Table 7 is shown the distribution of mean annual temperature on class values. Thus, the temperature class has been divided from values between 1.01 to 3 °C, to a projected increase of more than 15 °C. It can be seen that in the current climate an area of 3028.51 km^2 (79.97%) was affected by changes in temperature regime that ranged from 11.01 to 13 °C. On the other side, the future climate projections show a variation of this parameter between 13.01 to 15 °C, for an area of 3256.1 km^2 (85.98%).

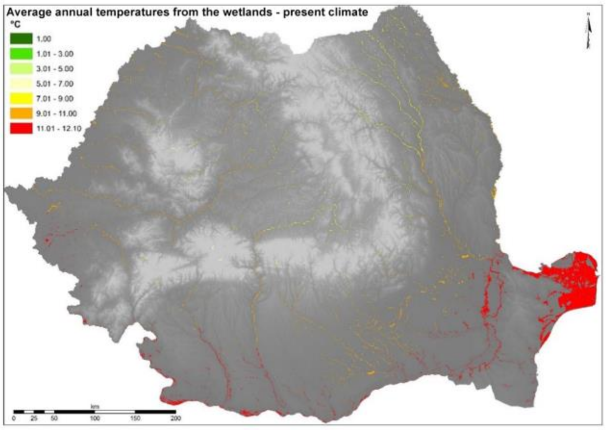

Fig. 8 Annual average air temperature values in proximity of wetlands in the present climate

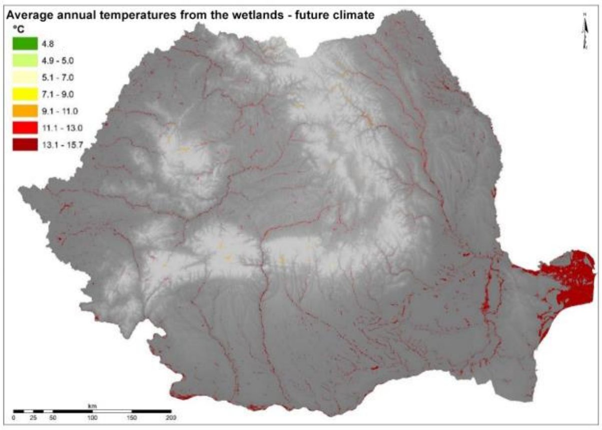

Fig. 9 Annual average air temperature values in proximity of wetlands in the future climate

Table 7 Distribution of mean annual temperature on class values

Temperature classes	Present climate		Future climate	
	Surface (km^2)	%	Surface (km^2)	%
1,01-3	0.17	0.00	0	0.00
3,01-5	2.34	0.06	0.02	0.00
5,01-7	23.06	0.61	0.22	0.01
7,01-9	168.87	4.46	3.08	0.08
9,01-11	564.3	14.90	26.92	0.71
11,01-13	3028.51	79.97	202.15	5.34
13,01-15	0	0.00	3256.1	85.98
>15,01	0	0.00	300.8	7.94

In Table 8 can be observed differences in rainfall distribution between present and future climate. The differences between -50 and -25 mm affect the largest area of wetlands at national level, of 2287.75 km^2 (60.40%). The figure below (Fig. 10), shows the distribution of these differences at national level, the changes observed being distributed especially in south-east regions of the country for values ranging between -49 mm and -25 mm. In the west of the country differences observed are between -75 mm and -50 mm, while in the southwest regions are recorded differences between 1 and 50 mm.

Table 8 Differences in rainfall distribution between present and future climate

Differences in rainfall [mm]	Surface [km^2]	%
< -75	6.41	0.17
-75; -50	145.8	3.85
-50; -25	2287.75	60.40
-25; -0	1109.53	29.29
0 - 25	148.55	3.92
25 -50	89.35	2.36
>50	0.1	0.003

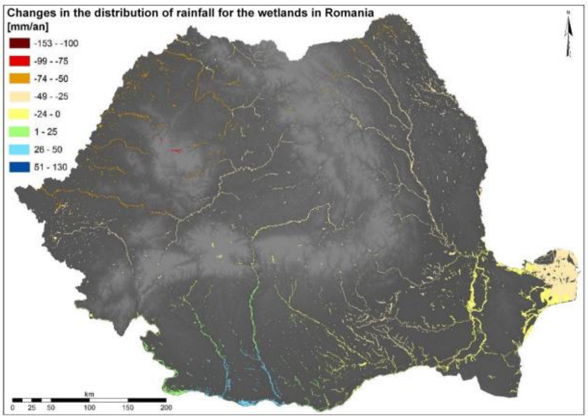

Fig. 10 Changes in rainfall distribution for wetlands in Romania

4 Conclusion

The analysis performed shows that the influence of climate change on wetlands through the distribution of rainfall and average air temperature regime will continue to be higher in the future. The climate change signal will most probably continue to increase in the future and can be one of the causes of biodiversity loss, affecting wetlands in particular by increasing extreme weather events. MAES methodology propose a set of indicators for the quantification of pressures affecting the ecosystem, and also for the ecosystem services. The indicators presented in this paper are related to the climate change pressure. The results are presented spatially on maps representing the extent of wetlands in Romania, overlapping with the values of the climatic indicators that were analyzed (temperature and precipitations), for detecting changes in their regime.

The main conclusions that can be drawn from the present study are:

-The presented climatic indicators correspond to the set of indicators recommended by MAES framework, specifically as climate change pressures: extreme values of temperature and precipitations

-The values of climatic indicators are represented on maps and analyzed as climate change pressures related to the location of wetlands in Romania

-The presented indicators of pressures can be used to assess the changes in condition of ecosystems, by analyzing the sets of indicators recommended by MAES framework (e.g. water quantity, vegetation, etc). Following the DPSIR framework the impact of pressures on the ecosystem services can be assessed by the use of specific indicators

-The validation at local level of indicators recommended by MAES is in progress for one case study in Romania: Divici-Pojejena wetland, located in the southwestern part of the country.

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References:

[1] European Commission, *An analytical framework for ecosystem assessments under Action 5 of the EU Biodiversity Strategy to 2020*, ISBN 978-92-79-29369-6, 2013

[2] European Commission, *Mapping and assessing the condition of Europe's ecosystems: Progress and challenges,* ISBN 978-92-79-55019-5, 2016

[3] Maes, J., Barbosa, A., Baranzelli, C., Zulian G., Silva F.B., Vandecasteele I., Hiederer R., Liquete C., Paracchini M.P, Mubareka S., Jacobs-Crisioni C., Castillo C.P., Lavalle C., *More green infrastructure is required to maintain ecosystem services under current trends in land-use change in Europe,* Landscape Ecology, (30) 517–534, 2015

[4] European Environment Agency (EEA), *Halting the loss of biodiversity by 2010: proposal for a first set of indicators to monitor progress in Europe*, EEA Technical Report no. 11/2007, European Environment Agency, Copenhagen

[5] ETC/SIA, 2014d, *Assessment of European ecosystem pressures - concept, data, and methodology*,(http://projects.eionet.europa.eu/eea-ecosystem-assessments/library/) accessed 05 September 2016

[6] European Commission, *Indicators for ecosystems assessments under Action 5 of the Biodiversity Strategy to 2020*, 2nd Report-Final, ISNB 978-92-79-36161-6, 2014

[7] Langanke, T. et. all,. *Forest HRL - Tree Cover Density - GIO land (GMES/Copernicus initial operations land) High Resolution Layers (HRLs) –summary of product specification,* 2016, Luxembourg: European Environment Agency

[8] Bailey, J., Budgen, D., Turner, M., Kitchenham, B., Brereton, P. & Linkman, S., *Evidence relating to Object-Oriented software design: A survey*, in 'Proceedings of Empirical Software Engineering & Measurement, 2007', IEEE Computer, Society Press, pp. 482–484

[9] Busuioc, A., Caian, M., Cheval, S., Bojariu, R., Boroneant, C., Baciu, M., Dumitrescu, A, *Variability and climate change in Romania*, Ed. Pro Universitaria, 2010a, ISBN: 978-973-129-549-7, Bucuresti, 226 pp.

[10] deMartonne, E., *Une nouvelle fonction climatologique: L'indice d'aridité*. La Meteorologie, 1926, pp. 449-458

[11] Maes J, Teller A, Erhard M, Liquete C, Braat L, Berry P, Egoh B, Puydarrieux P, Fiorina C, Santos F, Paracchini ML, Keune H, Wittmer H, Hauck J, Fiala I, Verburg PH, Condé S, Schägner JP, San Miguel J, Estreguil C, Ostermann O, Barredo JI, Pereira HM, Stott A, Laporte V, Meiner A, Olah B, Royo Gelabert E, Spyropoulou R, Petersen JE, Maguire C, Zal N, Achilleos E, Rubin A, Ledoux L, Brown C, Raes C, Jacobs S, Vandewalle M, Connor D, Bidoglio G, *An analytical framework for ecosystem assessments under action 5 of the EU biodiversity strategy to 2020,* Publications office of the European Union, Luxembourg, 2013

[12] European Environment Agency, *'European ecosystem assessment: Concept, data, and implementation'*, EEA Technical Report 6/2015a

[13] ESPON Climate, *Climate Change and Territorial Effects on Regions and Local Economies*, 2011, Version 25/2/2011 Summary Report

[14] EEA, *Climate change, Impacts and vulnerability in Europe*, 2012, European Environment Agency, Copenhagen.