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PRELIMINARY BIOPHYSICAL ASSESSMENT OF FOREST ECOSYSTEM SERVICES: TWO MODEL AREA EXAMPLES

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Forest ecosystems provide a multiplicity of services to humans. The aim of the presented study is twofold: to develop a suitable method for assessment of forest ecosystem services (ESs) and to quantify the effects of forest management on the provision and quality of these services. Matrix model, allowing to analyze and visualize the relative value of selected ecosystem services in pre-defined geobiophysical spatial units, was used for this purpose. Two different model areas (catchments) were selected to demonstrate the wide range of ESs in both managed and protected forest areas. First, land use categories and core ES classes were identified for the model areas. Indicators for several regulating and provisioning services, including carbon stock, available energy wood and wild berry yield were then developed and quantified. A uniform scale was used for assessment of all indicators, where 0 values were assigned to spatial units where the corresponding ES is not delivered at all and 5 was assigned to spatial units with a high value of the corresponding ES. The use of the uniform scale aims at making different ecosystem services comparable with each other. GIS was further used to link the valued data with cartographic material, spatially displaying assessed values for all compartment units that provide corresponding services. Re-evaluation of the ESs after forestry operations will allow to assess the impact of forest management on different categories of forest ESs in a model area. Older forest stands usually have the highest value in provisional services (available timber resources), while young, healthy and productive stands have higher values in providing carbon sequestration. Indicators for ecosystem services have to be continuously improved, to precisely showcase their values.

Key words: Forest ecosystem services, matrix model, indicators, ecosystem service mapping.

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INTRODUCTION

Forests are the most widespread terrestrial ecosystem on Earth. In Europe, forest area has considerably increased over the last six decades. Today, forests cover nearly 40% of Europe including 3,07 mil. ha or 52% of Latvia (JRC 2017, VMD 2017). Forests are widely recognized as major providers of ecosystem services – in addition to the supply of wood, forests provide a multitude of benefits in terms of climate change mitigation, human health, recreation, habitats, fresh water supply, air quality and many others (JRC 2017). However, extensive areas of forests are actively managed for timber production, and actions aimed at increasing timber yields also affect other forest functions and services (Pohjanmies et al. 2017).

In Latvia, forest ecosystems provide a highly valued variety of regulatory and provisional services: carbon stocks and sequestration, wild berry production, timber, biomass for renewable energy and many others. The amount of different services provided, and their quality, indicates biodiversity in a broader sense of the term. In the context of sustainable management of natural resources and the effects of human demands on various ecosystems, including forests, assessing and mapping provided ecosystem services is important. Under the guidelines of Article 5 of the European Biodiversity Strategy to 2020, mapping of ecosystems and their services has become a target for EU member states (Maes et al. 2012, Maes et al. 2016). This implies the need for research and pilot projects concerning the topic.

Ecosystem service assessment and mapping methods have advanced over the past decade, with focus on the relations between supply and demand factors of ecosystem services, as well as the development of methods using land use data on a landscape level, in order to assess and map ecosystem services (Burkhard et al. 2009, Burkhard et al. 2013). Forest ecosystem service assessments and mapping projects can use the same approach, by further dividing forest land use categories in detailed sub-categories (clearcut areas, forest stands, bogs, overflowing areas, forest roads etc.).

The research project was focused on two goals – to assess the current state of selected forest ecosystem services in two model areas and to develop a practically applicable method for further mapping and assessment of forest ecosystem services. The method is currently focused on small scale, high resolution regions, that contain forest compartment information, although theoretical basis and created indicators can be applied in various scale assessments. The preliminary status of the research must be taken in consideration, as further developments and inclusion of new data (field data, remote sensing etc.) can change the results and approaches used.

MATERIAL AND METHODS

Two model territories were selected for the research: one protected forest area in Slītere National Park (Mazirbe river catchment), with very limited degree of forest management, and one area in central Latvia (Zalvīte brook catchment), with active forest management. In both areas forest cover exceeds 90%, and Zalvīte model area was especially selected due to planned diverse forest management activities in 2015-2020, including drainage system maintenance and road reconstruction. Ecosystem mapping and assessment in both areas is done to demonstrate the overall variety of ecosystem services, rather than to examine differences in the quality of selected services in managed and unmanaged forests.

Biophysical assessment method was used for this part of the research. Biophysical assessments can utilize various data sources – collected or modelled data, spatial proxy variables and other inputs. In this study, forest inventory data was used as the main resource. Biophysical assessment is important for further studies, because the obtained data serves as an important basis influencing the overall quality of evaluaton of the selected ecosystems.

The study uses the Common International Classification of Ecosystem Services (CICES), and class units were selected to fit the scale of the study. In total, seven ES classes were selected for this research, each supplemented with one or more indicators. This paper presents insight in four of these (see Table 1.). ES classes will be complemented with others, as the research project advances.

'Matrix model' was used to link the identified land use categories (mainly forest stands and clearcut areas) with assessment values of ecosystem services (Burkhard et al. 2009, Jacobs et al. 2015). Indicators were developed to assess and map the supply of the selected services. Indicators are unique for each ecosystem service class, and are developed using various data sources, including projected berry cover and yield models (from

Table 1. Descriptive statistics of selected ecosystem service indicator values

Descriptive factor	Estimated carbon stock in live above-ground tree biomass (Zalvīte)	Potential energywood with felling limits (Zalvīte)	Potential blueberry yield (Slītere)	Estimated noise reduction (Slītere)
Mean	2,22	2,87	1,31	3,59
Standard Error	0,03	0,04	0,05	0,04
Standard Deviation	1,26	1,72	1,56	1,20
Sample Variance	1,59	2,96	2,42	1,43
Kurtosis	-0,97	-1,31	0,62	0,97
Skewness	-0,32	-0,27	1,29	-1,14
Minimum	0,00	0,00	0,00	0,00
Maximum	5,00	5,00	5,00	5,00

Donis et al. 2013), forest stand inventory data, biomass growth data (Zālītis 2006; Lazdiņš, unpublished) and data based on literature reviews. The development of indicators is designed to fit the MAES framework.

All indicator values for the selected ecosystem services were scaled from zero to five. 0 – ecosystem service is not provided, 1 – ecosystem service value is very low, 2 – ecosystem service value is low, 3 – ecosystem service value is rated as average, 4 – ecosystem service value is high and 5 – ecosystem service value is very high. Indicators and the spatial placement of their values is highly dependent on the land use category. Indicators which take into account only forest stand compartments will not have a value in, for example, clearcut areas, since no data is available.

Mapping of the assessed services was done in ArcMAP 10.4.1. Basemap of the territory is needed to spatially showcase the assessments. In this study, land use categories and other criteria, as well as identification (ID) numbers for each land use unit (compartment) were used in the basemap. Calculated ecosystem service indicator values were imported in GIS and added to the basemap of the territories. ID codes of the assessment data and the ID codes of the basemap compartments need to match, in order to successfully combine the data. Cartographic details, which are crucial for the presentation of mapping results, such as scale bars, were added. Lower indicator values are marked with lighter shades, while higher indicator values - with darker ones.

RESULTS AND DISCUSSION

In 2011 countries which are party to the Convention of Biological Diversity (CBD) adopted a new strategic plan until 2020. This plan includes the so-called Aichi biodiversity targets, 20 ambitious objectives to stop biodiversity loss and to ensure healthy ecosystems providing essential services to people. Following the adoption of this global strategic plan, the European Union (EU), which also signed the CBD, proposed a European Biodiversity Strategy to 2020 (European Commission 2011). Thereby, in the EU, the mapping and assessment of ecosystems and their services is seen as a key action for the advancement of biodiversity objectives (Maes et al. 2016). In this study, resulting values from each compartment of the selected indicators were analyzed using basic statistics (see table 1). Results were also presented and analyzed in cartographic form, which shows spatial information of the assessed values in the two areas. This paper contains four cartographic images formatted in ArcMap 10.4.1. (see Fig. 1- 4).

Indicator values

The development of robust indicators for mapping and modelling ES is also an important step towards meeting the EU Biodiversity Targets for 2020 (JRC, 2012). An ecosystem service indicator is information, which communicates the characteristics and trends of ecosystem services, making it possible to demonstrate the condition, trends and rate of change in ecosystem services (Layke et al. 2012).

As seen in Table 1., all four selected indicators show mean values that range from low to average. Forest stand age structure and compartments with zero values where the respective services are not provided, are the major influences on the mean. Blueberry yields have the lowest mean value, while estimated noise reduction in Slītere is highest from the four, mainly due to the forest structure and very little clearcut areas. Negative skewness values for carbon stock, energy wood and estimated noise reduction suggest that values larger than the mean prevail but in case of potential blueberry yield the trend is opposite. Negative kurtosis values for estimated carbon stock and potential energy wood shows that considerable number of compartments have either high or low ES values, while positive kurtosis for potential blueberry yield suggests large number of compartments with the corresponding ES values close to the mean.

Spatial representation of analyzed ecosystem services

Many landscapes, including forest areas, are complex human-environment systems operating at various spatio-temporal scales and provide a variety of ESs vital to human well-being. Ecosystem goods and services change over space and time as a result of management activities, changing patterns of land use or changes in the composition and structure of different vegetation types. Spatio-temporal assessment of ESs can provide valuable information on the consequences of changing land use and land cover for ESs and helps to deal with this complexity (Baral et al. 2013). We carried out an appraisal of selected ESs to demonstrate the overall variety of ecosystem services in two model territories with different degree of forest management.

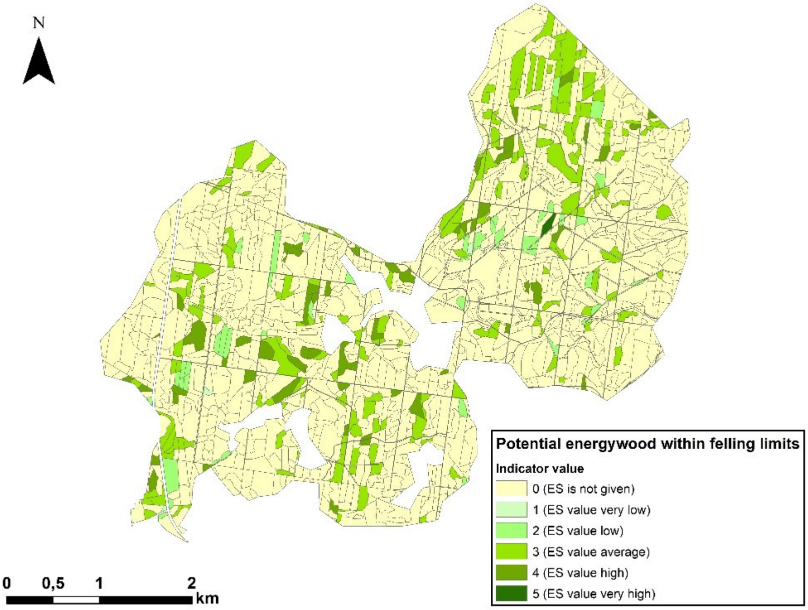

Fig.1. Ecosystem service class: biomass energy products. Indicator: potential energy wood supply within felling limits.

Felling limits considerably affect the quality of potential energy wood supply. Stands have different felling age or diameter, depending on the tree species, and due to the stand age structure in the model area, many compartments do not supply the corresponding service at this temporal point. Bioenergy supply can be an important factor in the context of climate change and sustainability, and this indicator provides spatial information that can be further used to assess accessibility of energy wood resources.

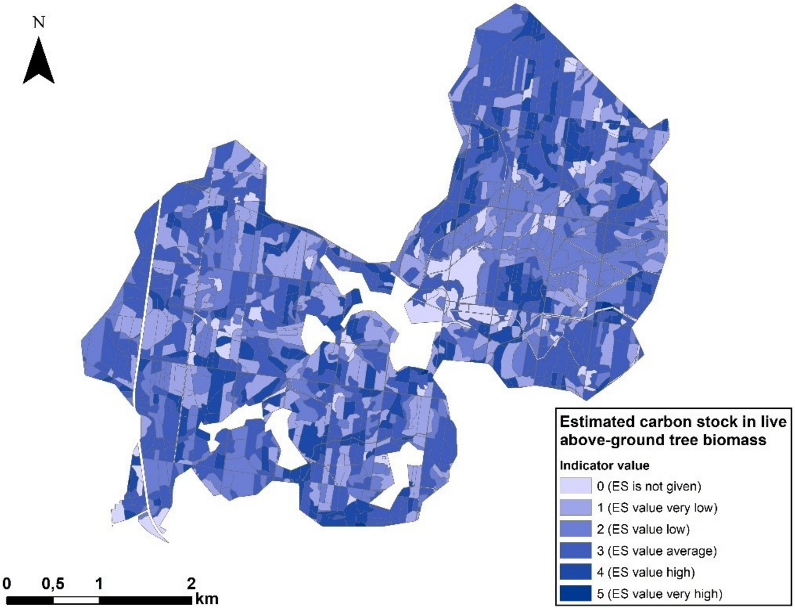

Fig. 2. Ecosystem service class: global climate regulation by reduction of GHG concentration. Indicator: Estimated carbon stock in live above-ground tree biomass.

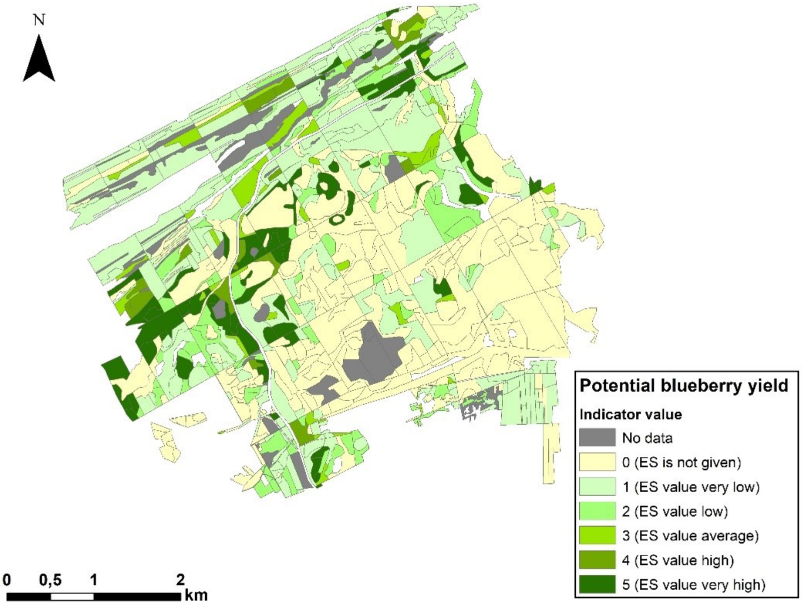

Fig. 3. Ecosystem service class: wild plants and their outputs, indicator: Potential blueberry yield.

Complex indicators, like carbon stock, require precise definitions, due to the complexity of the ecosystem service as a whole. Various factors such as soil type and composition, dead above-ground and below-ground biomass and others affect the carbon stock and carbon balance. This study has produced a specific indicator for above-ground live tree biomass assessment, which requires further development.

Berry yield indicators are important for assessing the quality and supply of non-timber forest products. No indicator values are given for some compartments, due to the current data gaps for the model development. This indicator is largely based on the forest type of each compartment. To accurately assess the supply of this kind of service, however, resource accessibility has to be taken into account and included in further development of the indicator.

Slītere model area offers good noise reduction service, due to factors such as forest stand density and land use types (clear cuts do not supply noise reduction in the defined indicator). Noise reduction also takes into account the forest stand species' structure – conifers offer more noise reduction than broadleaved trees due to higher leaf area index and the fact that needles remain on the trees for the whole year (Aylor, 1972; Samara and Tsitsoni, 2007; Ozer at al.,2008).

CONCLUSIONS

First results show potential for further development of the used ecosystem service assessment and mapping method, but broader accessibility depends on the available software and knowledge. Both model areas offer a wide variety of ecosystem services and the mean value of provided services ranges from low to high. The effects of forest management or potential inaccessibility of some services can reduce their value. Land use categories strongly affect the precision of indicators due to their limitations. In biophysical terms, forest stand age and species structure define most of the ecosystem service supply quality. Assessments of carbon stocks, energy wood and their spatial mapping can prove to be important, in the context of climate change and bioenergy policies. Continued development of indicators is required to gain more precise assessment data.

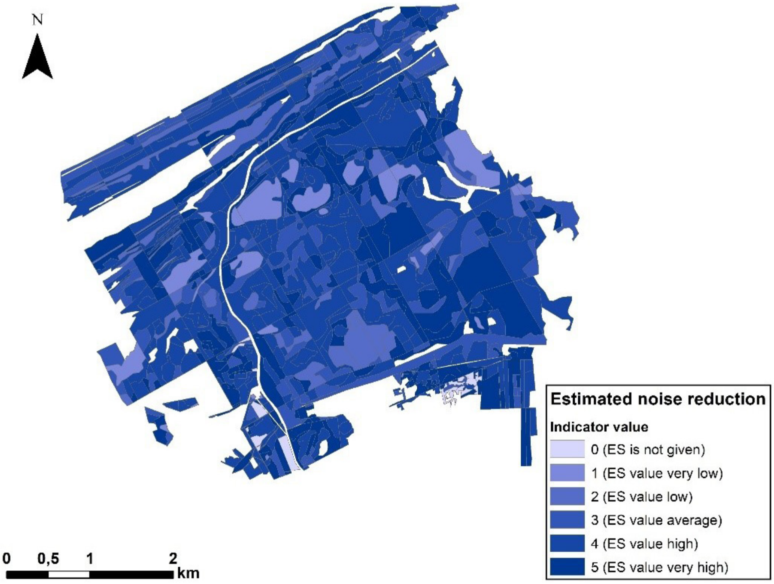

Fig. 4. Ecosystem class: mediation of noise impacts, indicator: Estimated noise reduction.

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REFERENCES

*A*ylor D. 1972. Noise Reduction by Vegetation and Ground. *Journal of Acoustic Society of America* 51

Baral, H., Keenan, R. J., Fox, J. C., Stork, N. E. & Kasel, S. (2013). Spatial assessment of ecosystem goods and services in complex production landscapes: A case study from south-eastern Australia. *Ecological Complexity*, 13: 35–45.

Burkhard B., Kandziora M., Hou Y., Muller F. 2014. Ecosystem Service Potentials, Flows and Demands – Concepts for Spatial Localisation, Indication and Quantification. *Landscape Online*, 34: 1-32.

Burkhard B., Kroll F., Muller F., Windhorst W. 2009. Landscapes‘ Capacities to Provide Ecosystem Services – a Concept for Land-Cover Based Assessments. *Landscape Online*, 15: 1-22.

European Commission 2011. Our life insurance, Our Natural Capital: An EU Biodiversity Strategy to 2020. European Commission, Brussels (2011)

Donis J. 2013. Latvijas meža resursu ilgtspējīgas, ekonomiski pamatotas izmantošanas un prognozēšanas modeļu izstrāde (Development of models for sustainable, economically justified use and forecast of Latvian forest resources). Pārskats par Meža attīstības fonda finansēta pētījuma rezultātiem, 107 lpp. (in Latvian)

Jacobs, S., Burkhardb, B., Van Daelea, T., Staesd, J., Schneidersa A. 2015. ‘The Matrix Reloaded’: A review of expert knowledge use for mapping ecosystem services. *Ecological Modelling*, 295: 21–30.

JRC, 2012. Indicators for mapping ecosystem services: a review. JRC Scientific and polict reports, Italy, 113 p. https://www.researchgate.net/profile/Benis_Egoh/publication/233831375_Indicators_for_mapping_ecosystem_services_a_review/links/09e4150beea3cf1f6e000000.pdf

JRC, 2017 http://forest.jrc.ec.europa.eu/activities/forest-ecosystem-services/

Layke C., Mapendembe A., Brown C., Walpole M., Winn J. 2012. Indicators from the global and sub-global Millennium Ecosystem Assessments: an analysis and next stepsEcol. Indic., 17 (2012), Pp. 77–87

Maes J., Liquete C., Teller A., Erhard M., et al. 2016. An indicator framework for assessing ecosystem services in support of the EU Biodiversity Strategy to 2020. *Ecosystem Services*, 17: 14-23.

Maes, J., Liquete, C., Teller, A., Erhard, M., Paracchini, M. L., Barredo, J. I., Grizzetti, B., Cardoso, A., Somma, F., Petersen, J.-E., Meiner, A., Gelabert, E. R., Zal, N., Kristensen, P., Bastrup-Birk, A., Biala, K., Piroddi, C., Egoh, B., Degeorges, P., Fiorina, C., Santos-Martín, F., Naruševičius, V., Verboven, J., Pereira, H. M., Bengtsson, J., Gocheva, K., Marta-Pedroso, C., Snäll, T., Estreguil, C., San-Miguel-Ayanz, J., Pérez-Soba, M., Grêt-Regamey, A., Lillebø, A. I., Malak, D. A., Condé, S., Moen, J., Czúcz, B., Drakou, E. G., Zulian, G. & Lavalle, C. (2016). An indicator framework for assessing ecosystem services in support of the EU Biodiversity Strategy to 2020. Ecosystem Services, 17, Pp 14–23.

Ozer at al. 2008. Determination of roadside noise reduction effectiveness of *Pinus sylvestris* L.

and Populus nigra L. in Erzurum, Turkey. Environmental Monitoring and Assessment 144 (1,) 191-197

Pohjanmies T., Triviño M., Le Tortorec E. et al. 2017. Impacts of forestry on boreal forests: An ecosystem services perspective. Ambio, DOI: 10.1007/s13280-017-0919-5.

Samara and Tsitsoni. 2007. Road traffic noise reduction by vegetation in the ring road of a big city. In: Kungolos et al. (Eds). Proceedings of the International Conference on Environmental Management, Engineering, Planning and Economics Skiathos, June 24-28, 2007, 2591-2596

VMD, 2017 http://www.vmd.gov.lv/valsts-meza-dienests/statiskas-lapas/-meza-apsaimniekosana-?nid=1472

Zālītis P. 2006. Mežkopības priekšnosacījumi (Preconditions of Forest Management). Rīga, et cetera, 217 lpp. (in Latvian)

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