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Software Description

Integrating ecosystem services into decision support for management of agroecosystems: Viva Grass tool

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Abstract

Background

The area covered by low-input agroecosystems (e.g. semi-natural and permanent grasslands) in Europe has considerably decreased throughout the last century. To support more sustainable management practices and to promote biodiversity and ecosystem service values of such agroecosystems, a decision support tool was developed. The tool aims to enhance the implementation of ecosystem services and address the challenge of their integration into spatial planning.

New information

The Viva Grass tool aims to enhance the maintenance of ecosystem services delivered by low-input agroecosystems. It does so by providing spatially-explicit decision support for land-use planning and sustainable management of agroecosystems. The Viva Grass tool is a multi-criteria decision analysis tool for integrated planning. It is designed for farmers, spatial planners and policy-makers to support decisions for management of agroecosystems. The tool has been tested to assess spatial planning in eight case studies across the Baltic States.

Keywords

ecosystem services, decision-support tool, agroecosystems, spatial planning, the Baltic States

Introduction

Ecosystem services (ES) are acknowledged as an important concept to support land-use decision making. They provide a holistic view on interactions between nature and humans and hold the potential to address conflicts and synergies between environmental and socio-economic goals. The ecosystem service concept offers a comprehensive framework for trade-off analysis, addressing compromises between competing land usesand can facilitate planning and development decisions across sectors, scales and administrative boundaries (Fürst et al. 2017). Ecosystem service mapping and assessment can provide various inputs and contextual information for spatial planning (Albert et al. 2017), including identification of areas of particular environmental sensitivity with high potential for ecosystem service supply (e.g. 'hot-spot' or 'cold-spot' areas). This type of mapping can provide a basis for green infrastructure planning, visualisation of the trade-offs of different land-use alternatives, assessment of the impacts of the planning solutions and enhance stakeholder engagement in communicating the overall benefits and shortcomings of planning proposals. Furthermore, the ecosystem service concept is strengthening its role also in policy-making in different land-use sectors, including agriculture (Bouwma et al. 2018). Results from recent studies have revealed that understanding of ecosystem functions and services can support better design of agri-environmental measures (Prager et al. 2012) and targeting of the intervention locations (Willemen et al. 2010, Frueh-Mueller et al. 2018) in order to increase the ES supply. Support for improving biodiversity and ecosystem services has also been highlighted in the new proposal for Regulation on support for strategic plans to be drawn up by member states of the European Union (EU) under the Common Agricultural Policy (European Comission 2018). The ES concept has been around for decades, but its application in spatial planning and land-use policies remains challenging (Grêt-Regamey et al. 2017a). Decision-support tools are a great way to implement ES, that is, to promote their use by decision-makers (Potschin and Haines-

Young 2013). However, implementing the ES concept so that it provides data to support descision-making processes still requires improvement (Jacobs et al. 2015).
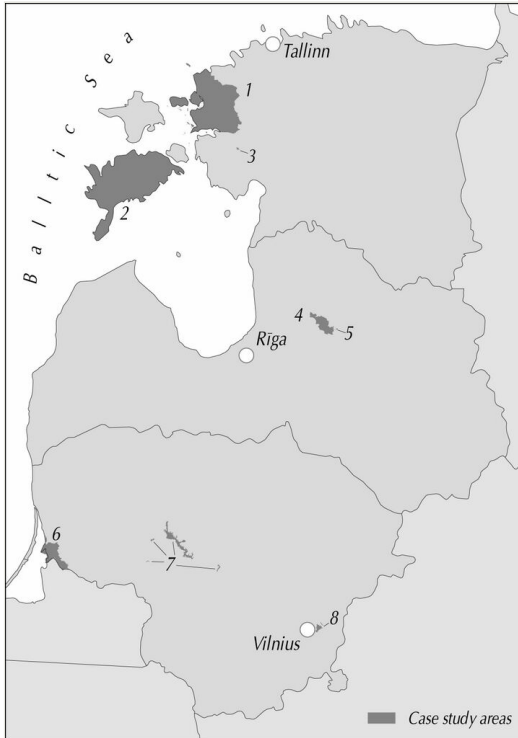

Figure 1.
Case studies.

This study presents the Viva Grass tool aimed to create a simple decision-support system, which allows assessment of four provisioning ES (cultivated crops, reared animals and their outputs, fodder, biomass-bassed energy sources and herbs for medicine) and eight regulation and maintanance ES (bioremediation by micro-organisms, plants and animals, filtration/storage/accumulation by ecosystems, control of (water) erosion rates, pollination and seed dispersal, maintaining habitats for plant and animal nursery, weathering process, chemical condition of freshwaters, global climate regulations) and four cultural ES (physical and experiental interactions, educational, cultural heritage and aesthetics) and their change under various scenarios in agroecosystems (Villoslada et al. 2018). It can be used by different stakeholders (i.e. farmers, municipalities, state institutions). Unlike other tools (Daily et al. 2009, Bagstad et al. 2011, Boumans and Costanza 2007, Hu et al. 2015, Peh et al. 2013, Pickard et al. 2015, Grêt-Regamey et al. 2017b, Fürst et al. 2010, Jackson et al. 2013), it uses a land quality assessment index, historical soil maps specific to Eastern Europe, a digital elevation model (LIDAR data), Integrated Administration and Control System (IACS)*1 data and habitat mapping data, where available. The novelty of the presented tool is that it explicitly aims to assess and analyse ES at the field level, where

the service providing area is delineated by declared fields of farmers extracted from the IACS database and land parcel identification system (LPIS)*2. The service providing area is the spatial unit within which an ecosystem service is provided (Burkhard and Maes 2017).The Viva Grass tool was tested in eight case studies across Lithuania, Latvia and Estonia (including two farms, four municipalities, two protected areas and one county), each of them having different spatial and thematic scales. The Viva Grass tool captures the applicability of ES-related information at different planning scales and contexts, which requires a consistent, but flexible approach. In this paper, we first describe case studies and secondly, the structure and main functionalities of the Viva Grass tool. Thirdly, we test its application in various spatial planning contexts across eight case study areas for the analysis of ES bundles, hot-spot and cold-spot areas, as well as prioritisation of areas for particular management practices, based on ES potential.

Table 1.

Description of case studies.

Case studies	Nr. in Fig. 1	Planning level	Area (km^2)	Description
Lääne County	1	Regional	2413.8	Most of the farmland is permanent grassland. Large share of semi-natural grasslands with high proportion of coastal meadows and reed-beds.
Saaremaa Municipality	2	Regional	2703.9	Municipality is an island that has a mosaic landscape with a high share of semi-natural grasslands, mainly alvars, coastal meadows and wooded meadows and pastures.
Kurese Farm	3	Site	1.3	Alvars on thin limestone soils, contains a wide variety of cultural heritage and traditional landscape elements, such as stone walls, burial sites, old roads, limestone quarries and old farmhouses.
Cēsis Municipality	4	Local	171.7	Diverse mosaic landscape, undulated relief, dominating agricultural land use is grasslands, but very low share of semi-natural grasslands.
Kalnāji Farm	5	Site	1.0	Farm in transition from high to low-input farming, with high share of restored previously-abandoned farmland
Silute Municipality	6	Regional	1706.4	Nemunas river delta, polder landscape with high share of semi-natural grasslands important for bird migration.
Dubysa Regional Park	7	Local	106.2	Protected area of river valley surrounded by intensive agriculture lands with high share of semi-natural grasslands.
Pavilniai Regional Park	8	Local	21.8	Area is situated within the city on intense erosion relief alongside river valley. Most of the territory is covered by forest, low share, but high ecological value grasslands

Project description

Study area description: Case studies (Fig. 1) are chosen to represent various planning levels and contexts (agriculture land management, landscape management, nature

conservation, tourism and energy) in the three countries. Indicative qualities of case study areas are shown in Table 1.

Design description: The Viva Grass tool operates at two scales – site scale for mapping and assessing ES potential and landscape scale to elaborate decision support. At the site scale, the assessment is carried out for a basic agro-ecological unit – field or plot, which is defined as a continuous area with identical land use where the actual management decision is applied (Villoslada et al. 2018). Prioritisation is performed at landscape scale, which can be any user-defined area considered as applicable for a certain planning process. The following chapter outlines the functioning of the Viva Grass tool.

Development of the web-based integrated planning tool

The Viva Grass tool is based on an ArcGIS Enterprise platform. Data is stored in a common spatial database (PostgreSQL) and published as GIS services (maps). Web-based tool modules/applications are constructed using the ArcGIS Web application builder. Additional application widgets were developed to fulfil custom requirements (Fig. 2). The Viva Grass tool includes three main tool modules (Viva Grass Viewer, Viva Grass Bio-energy and Viva Grass Planner) targeted to particular users and decision-making contexts (Table 2). The three modules produce and use various data and information products, which can be linked with other information platforms.
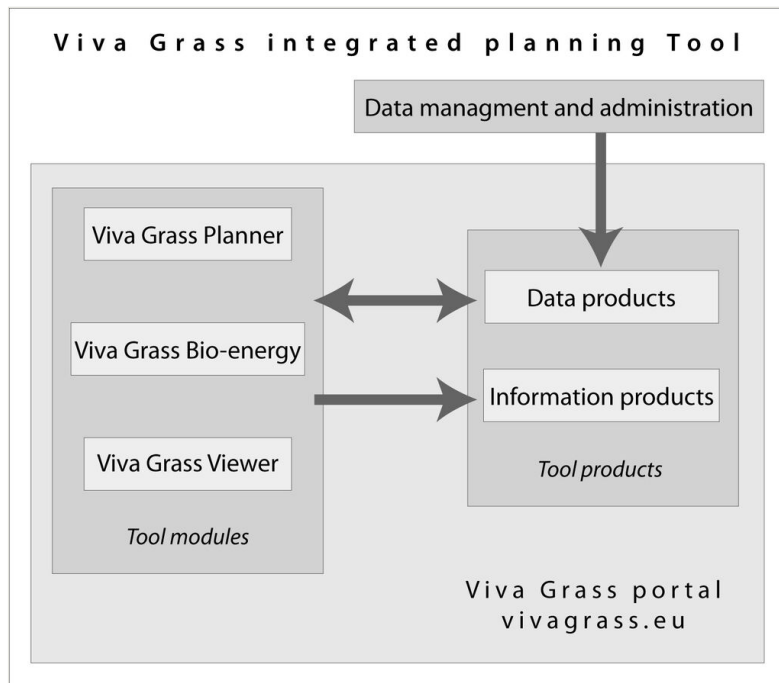

Figure 2.
Conceptual scheme of Viva Grass Tool.

Table 2.

Functionalities of the Viva Grass tool modules.

Tool modules	Functionalities								
	Land use (agricultural)	ES Assessment	ES bundles	ES Cold / hot spots	Biomass, bioenergy potential	Management recommen-dations	Prioritisation, classification	Export map as PDF	Edit, upload, download data
Viva Grass Viewer	X	X	X	X		X		X	
Viva Grass Bio-energy	X				X	X		X	
Viva Grass Planner	X	X	X	X		X	X	X	X

Data products. Common base-map information (agricultural land use, ES service values, agroecological conditions) is available as data services or downloadable datasets and can be re-used and integrated into other solutions and information products. Exportable thematic maps produced by the tool modules, tutorials and teaching materials on the ES concept and its application are products and project deliverables.

Data management and administration. The common farmland base-map data is updated by experts in each country. A new version of the data is prepared outside the tool using desktop GIS software and using predefined data structure. The data management workflow developed during the project allows us to provide only the field boundaries and management category. After uploading farmland fields, relief category and land quality, the SPA unit category can be determined automatically and then farmland type and default ecosystem service values can be calculated. Users needing to work with more detailed analysis options and custom data should use planning widgets and custom data that are available to authenticated users. Initially, organisation users can download part of the public base-map data, add custom land-use attributes, collect the required data and configure prioritisation and classification rules.

Contextual layers and criteria developed for the Viva Grass tool

Creation of the base-map. The base-map used in Viva Grass tool is an overlay of natural conditions and management regimes of farmlands and is displayed as contextual layer and separate natural conditions. The choice of parameters for ES assessment was based on availability of the same structure and detailed data over three countries. We included a composite land-quality index for evaluation of soil fertility that was used in the ex-USSR and other Eastern European countries, which included factors like soil texture, soil type, topography and stoniness (Vinogradovs et al. 2018). Data on soil composition were derived from digitised soil maps with scale of 1:10000. Farmland management regimes

were derived from the IACS database and categorised according to intensity of interference of a given management practice on topsoil (ploughing, fertilising) and species composition (seeding). Based on these variables, five categories of farmland management regimes were created – cultivated grassland, permanent grassland, semi-natural grassland, arable land and abandoned farmland. Land-use data is updated yearly when the annual IACS database is available and uploaded by the tool administrator. Each of the three layers were combined in a GIS environment and the outcome consisted of 50 possible combinations or "classes" of underlying natural conditions and management regimes i.e. "permanent grassland on steep slope, low land quality" or "semi-natural grassland on organic soil, plain surface" etc. (Villoslada et al. 2018).

Assessment of ES potential was conducted using a matrix approach (Burkhard et al. 2009), based on multiple datasets derived from natural conditions and management practices described above. Five provisioning services and eight regulating services (European Environment Agency 2015), relevant to agroecosystems, were chosen by an international expert panel and one indicator per service was defined. In another panel, experts individually assigned values of each ES for each class, based on a qualitative scale ranging from 0 (no relevant potential of the selected ES) to 5 (very high potential of the selected ES). A third expert panel consisted of several rounds as focus group discussions where final scores for each ES for every base-map class were reached through consensus of experts. As assigned ES potential values are based on common understanding of indicator values by experts, they are able to be substituted with actual values, when available.

Cultural ES were not included in the matrix valuation as they are explicitly, i.e. distinctively, connected to their service providing areas (SPA) and were assessed through evaluation of criteria created by an expert panel, for example, value of physical and experiential interactions were estimated from the location of the SPA unit in relation to such landscape features as rural recreational enterprises, watching towers, tourist trails, hunting clubs, camping sites and social gathering sites (Villoslada et al. 2018).

Bundles and trade-offs. A principal component analysis was carried out using the qualitative scores for farmland plots (observations) and ecosystem services (variables), based on the matrix as input data. To assess potential trade-offs and synergies between ES services, pairwise correlation was carried out. The interactions found were discussed in expert panels to designate the underlying driver for each interaction. The Viva Grass Tool allows the users to choose the most suitable management regime for the underlying biophysical conditions, thus increasing the ES supply and minimising trade-offs.

Cold/hot spot analysis. We defined a cold spot as a spatial unit providing a great number of ecosystem services at low or very low values (none of provisioning or regulating services) and a hotspot as a spatial unit providing ES at high or very high values (average value above mean in both provisioning and regulating services). The number of services with particular values of interest (low/high) was derived from analysis of the ES assessment matrix.

Risk of abandonment was created as a composite indicator consisting of a sum of factors like land quality, field size, accessibility and distance to farms. Factors were chosen, based on results revealed in previous studies (Vinogradovs et al. 2018).

Web location (URIs)

Homepage: vivagrass.eu

Technical specification

Platform: ArcGIS Enterprise

Programming language: Python, Javascript, HTML, .NET

Operational system: Windows Server

Interface language: English

Service endpoint: https://vivagrass.eu/

Usage licence

Usage licence: Creative Commons Public Domain Waiver (CC-Zero)

Implementation

Implements specification

Viva Grass Viewer

The Viva Grass Viewer is a basic module of the Viva Grass tool that is accessible to the general public. It aims to present results of mapping and assessment of the potential of ES, as well the grouping of ES in bundles and interaction amongst ES in agroecosystems. The Viva Grass viewer was implemented for informative and educational purposes, where the user is able to become acquainted with the ES approach, the spatial representation of basic logic behind assessment of ES and the spatial interaction between ES. Contextual data layers available in the Viva Grass Viewer are farmland land use, the potential of selected ES, bundles and trade-offs of ES potential and cold/hot spots of ES potential. The default view (Fig. 3) of the Viewer is a background map with land use data obtained from the IACS database land parcel identification system, representing the main classes of land use in agro-ecosystems: grasslands – semi-natural, permanent, cultivated and arable land. Additionally, abandoned farmland is shown when there is available data. By clicking on the land block of interest, the user can view the potential of ES in a selected field. For informative and educational purposes, the user can change land-use type to view changes in ES potential in case of land-use change. Short descriptions and recommended

maintenance practices are provided when available. The potential of ES is the contextual data layer, which is derived from the expert based ES assessment matrix. Distribution of particular ES potential is visualised by selecting the particular service from a drop-down menu. For example, cultivated grassland, which is a monoculture agro-ecosystem, is ploughed at least once in 5 years, fertilised and seeded and, under certain natural conditions, can provide a greater amount of provisioning services associated with biomass production, but has less ability to provide regulating services. Semi-natural grassland, a low-input agro-ecosystem dominated by natural species, potentially delivers an abundance of regulating services, especially those associated with habitat maintenance. Bundles and trade-offs of ES potential are presented in a contextual data layer showing spatial grouping and interactions of ES. The user is able to explore groupings and interactions by choosing one in a drop-down menu. Cold/hot spots of ES potential are available in a contextual layer that gives the number of ES with either low or high values. The user is able to choose different representations of cold/hot spots of ES potential from a drop-down menu. The default choice for "cold/hot spots" is the combined value of "number of ES with high values" and "number of ES with low values". Willemen et al. (2010) defined cold spots as areas with conflicts between two or more landscape functions, which, in our case, can be described as inappropriate management practice in given natural conditions. Moderate cold spots mostly display one of the trade-offs and planning decisions should be based on these. For defining the meaning of "hotspot", we follow Bagstad et al. (2016) who defined it as an area which should draw attention of decision-makers, because of high conservation value and high vulnerability. This selection gives a general overview of a selected territory in the context of its current potential to deliver ES. To obtain a specific view on the character of the territory in the context of shortages or abundance of ES potential, the user can choose between additional selections ("Number of ES with high values" or "Number of ES with low values") to view the actual number of ES with high/low values or by choosing a specific ranked 1-5 value.
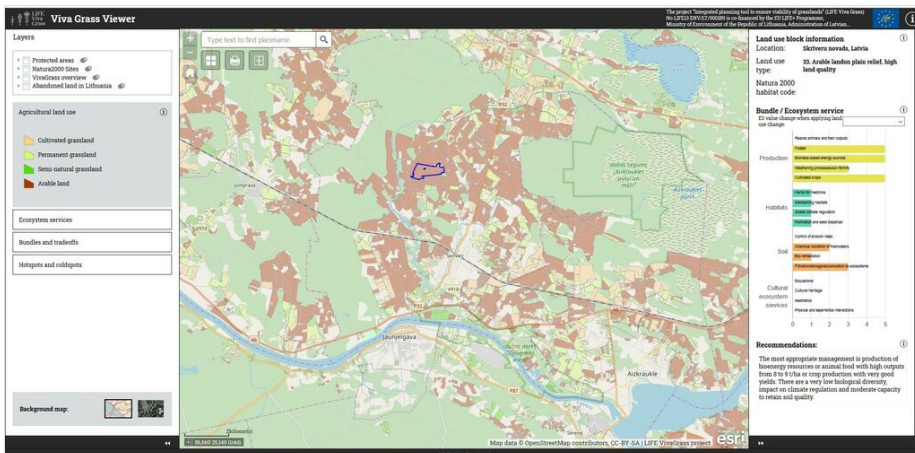

Figure 3.
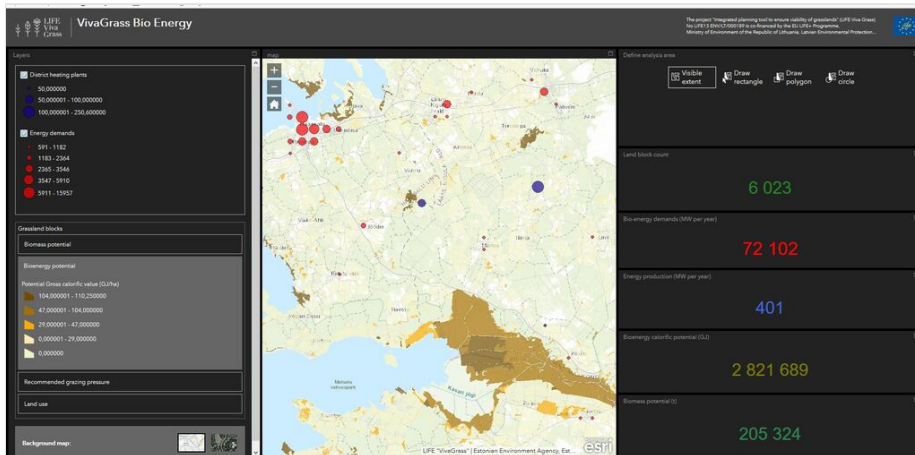Default view of the Viva Grass Viewer.

Figure 4.

Viva Grass Bio-energy module displaying potential gross calorific value and heating plants and demands.

Viva Grass Bio-energy

The Viva Grass Bio-energy decision support system was developed as a tool for assessing grass-based energy resources (Fig. 4) to inform relevant planners/stakeholders about areas with the highest potential for grass for energy (prioritising). It is accessible for registered users only. The analysis of the energy potential includes parameters like grassland area, biomass production and calorific potential for district heating. The Viva Grass Bio-energy module uses additional sources of information to enrich both the base-map and the ES assessment. The 10 semi-natural grassland classes are updated with information about the Annex I*3 habitat type they belong to. Subsequently, quantitative data collected from scientific literature sources is linked to the Annex I habitat types. The module is, therefore, able to provide detailed information to the user about the average biomass production and average grass calorific power per semi-natural grassland type and allows us to select and summarise bio-energy potential from several grasslands. Additionally, the module provides information on the current management status of the selected grasslands, as well as information about the presence of reed encroachment and recommended grazing pressures per habitat type. The bio-energy sub-module was designed with the aim of assessing the availability of grass-based energy sources. It was approbated in Lääne County, Estonia. Grasslands have a potential for energy production as solid biomass heating fuels. Whether grasslands are specifically cultivated for this purpose or the grass mown from permanent and semi-natural meadows is used, grass can be burnt in co-fuelled plants for heat generation. In many cases, the use of grass bales for heating is a feasible alternative to regular biomass-based resources, such as woodchips. The bioenergy sub-module specifically aims at assessing the area, distribution, average production and average calorific potential of different semi-natural grasslands and it is designed to inform relevant planners/stakeholders about areas with the highest potential for grass for energy (prioritising). This is achieved by enriching the Viva Grass base-map

with additional information on biomass production and calorific potential in Estonian semi-natural meadows, which is collected from several literature sources (Heinsoo et al. 2010, Melts et al. 2013, Melts et al. 2014b, Melts et al. 2014a). Additionally, the bioenergy sub-module includes information on the estimated demand of heating from grass biomass sources, understood as the amount of inhabitants living in district-heated blockhouses.

Viva Grass Planner

The Viva Grass Planner is a decision support system designed to implementthe ES concept for spatial planning. The Viva Grass Planner is accessible for registered users; registration is carried out by the system administrator. The Viva Grass Planner consists of two basic sub-modules designed to carry out prioritisation and classification functions, subsequent representation of the results in a map and to provide the possibility to export processed data. Prioritisation is performed by applying Multi-Criteria Decision Support (MCDS) – an accepted scheme for supporting complex decision-making situations with multiple and often conflicting objectives that stakeholders groups and/or researchers value differently (Saarikoski et al. 2016). We developed a MCDS approach for viable grassland management through assessment of ecosystem services and site-specific factors. We followed the scheme proposed by Langemeyer et al. (2016) (Fig. 5). MCDS was carried out in consecutive steps involving definition of a problem, collaborative definition of preferred criteria by stakeholders and experts, weighting of criteria and prioritisation of alternatives. Problems addressed in MCDS were elaborated and defined in round-table meetings of experts and local stakeholders at selected case studies. Round-table meetings began with presentation of ES assessment, ES trade-offs and cold/hotspots, followed by problem-orientated discussion to define MCDS objectives. To evaluate adequacy of different alternatives, clear criteria must be defined. As the whole process of definition of the problem was contextualised in ES assessment, it was possible to use the outcomes of it to define a core set of criteria, thus making them directly connected to ecosystem structure and functions. Additional criteria were developed to meet objectives of a particular MCDS. Thus, the criteria relevant for a particular decision-making context could be selected from the available attributes consisting of the results of ES assessment or from additional data on case specific attributes that were added by the user. To indicate a relative importance of chosen criteria, a weighted sum model was applied. The weighted sum is commonly used to form a comprehensive judgement in case of problematic ranking (Rowley et al. 2012). The Tool user can assign weights ranging from 0-100%, such that the sum of all percentages is equal to 100% (Fig. 6). The total weight index is the sum of the selected components. Weighting scales can be saved and edited. The resulting weighted index can be further divided into priority classes. To create final prioritisation of alternatives, additional classification can be performed by employing supplementary data specified by the objective of the MCDS. Classification can be done both based on performed prioritisation and stand-alone. To perform classification, some GIS skills are needed – writing an expression in SQL syntax. The user also requires knowledge of data structure. To improve the quality of performed analysis, data editing and additional data upload is provided. The user is able to edit and store underlying natural conditions of a selected field in cases when more precise information is available. The calculations of ES potential and

interactions amongst ES are recalculated and updated by the Viva Grass tool and subsequently stored in the user account. To indicate a relative importance of a chosen criteria, the tool user can assign weights ranging from 0-100%, such that the sum of all percentages is equal to 100%.
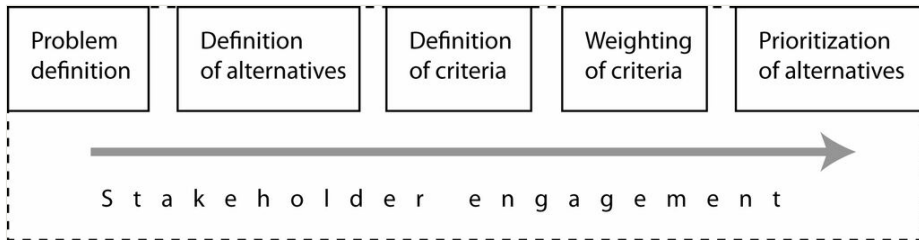

Figure 5.

Multi-criteria decision support workflow (adapted from Langemeyer et al. (2016)).
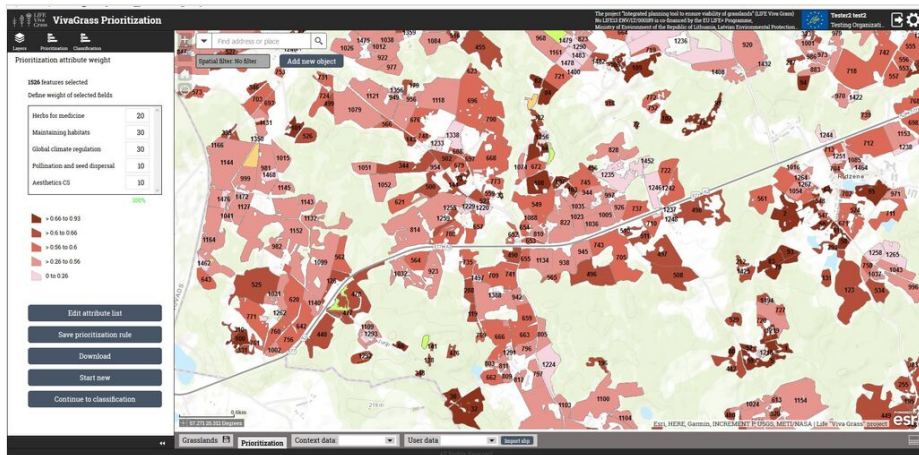

Figure 6.

Screenshot of results of weighting the criteria for landscape management in Viva Grass Planner in Cēsis case study. User defined weights (upper left), legend of ranges of results based on natural brakes (middle left), map of management priority with individual score for each field (map window).

Audience

All Viva Grass tool modules were tested and improved in case studies through stakeholder engagement and, based on that, the beta version was developed. Later, the tool was tested in regional workshops in all three countries; all together 150 practitioners in various fields (spatial planning, agricultural consultancy, farmers, researchers) participated in seven all-day workshops. The entire populations of spatial planners and agriculture planners in the respective regions were approached and all who could come to the training sessions participated. Some interested students and farmers participated as well. During

the workshops, participants were introduced to the concept of ES and its application in different fields. In the second part of the workshop, participants were introduced to the main functionalities of the Viva Grass tool and how the main results were generated for case studies. Participants were introduced to all modules of the tool and were familiarised with working and weighting different criteria. They developed, in small groups, preliminary case studies for their own localities, discussed weights and assessed the suitability of the tool to support decisions in their cases. Participants were assisted by researchers, who supported implementation of tool functionalities to local cases. After the workshop, participants filled in reports in which they expressed their opinion on the tool's applicability in their field of activity, its advantages and disadvantages, as well stated their suggestions for further improvement of the Viva Grass tool. These comments were partially incorporated into the final version of the tool.
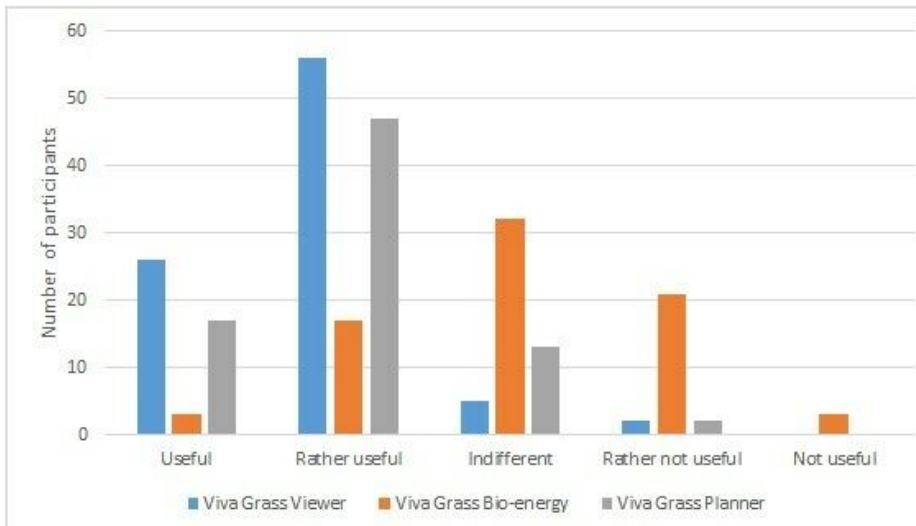

Figure 7.

Valued usefulness of Viva Grass Tool modules by workshop participants

The Viva Grass Viewer was evaluated as the most usable of the modules (Fig. 7) and Viva Grass Bio-energy as the least usable in the daily work of participants of the workshops. Spatial planning, alongside land management and land-use transformation, were valued as the most suitable applications of the Viva Grass tool, reported by participants of workshops. The main disadvantages, named by the participants of the workshops, were base map data accuracy and reliability (especially soil data), language barrier as the tool's working language is English and slow performance. The main advantages, named by participants of the workshops, were that the tool was simple and reviewable, it was possible to conduct data processing without having a GIS software and that the tool was novel.

Additional information

Examples of application of Viva Grass Planner

Prioritisation of areas for landscape maintenance in the Cēsis case study area

The Viva Grass Planner was tested in the Cēsis Municipality case study. The aim was to support landscape management planning at the municipality level. Since 56% of the rural area in the Cēsis Municipality is covered by forest, maintenance of grasslands, as well as removal of shrub in abandoned agriculture land, are essential to preserve the characteristics of the mosaic landscape. The prioritisation model, based on MCDS, was applied to select sites for landscape maintenance or restoration measures. The criteria for prioritisation included the value of four cultural services (recreational, educational, cultural heritage and aesthetic), as well as ecological value (based on the habitats bundle – herbs for medicine, maintaining habitats, global climate regulation, pollination and seed dispersal) (Table 3). The prioritisation model for landscape maintenance is presented in Fig. 8. The results of application of the landscape management prioritisation model are shown in Fig. 9. The testing of the prioritisation model of the Viva Grass planner in the Cēsis case study was performed through an iterative process of stakeholder engagement, including two rounds of meeting with groups of 15 Municipality representatives (spatial planners and tourism experts from the Municipality, farmers and local entrepreneurs). During the first round, the stakeholders assigned weights to the selected ES potential criteria, while during the second round, the prioritisation results, derived from the tool, were examined, weighting of the criteria were adjusted to the priorities of the planning area and concrete management proposals for the specific areas were elaborated. The results are used to formulate proposals to the Cēsis Municipality Development Plan and related Action Plan, defining areas where specific management was required to maintain or improve the landscape value.
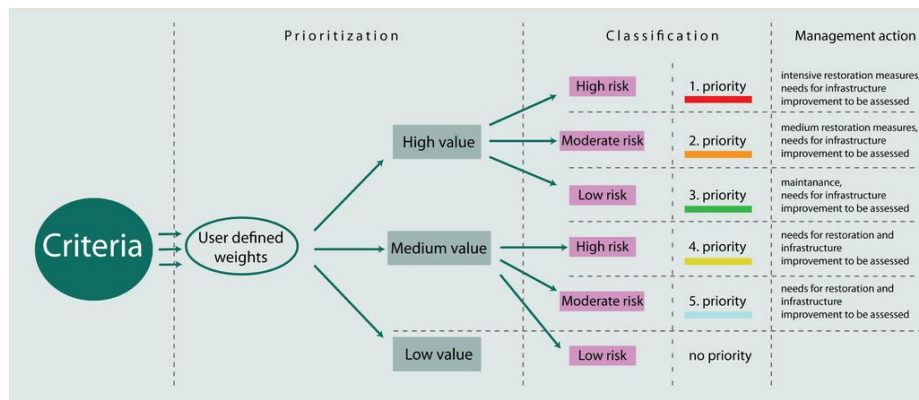

Figure 8.

Prioritisation scheme for landscape planning in Cēsis case study showing workflow (consecutive steps from left to right) for decision support: defining criteria, assigning weights, arranging weighting results, adding additional values (risk index) for classifying priorities of management and assigning management action.

Table 3.

Criteria identified and mapped for landscape planning in Cēsis case study.

Criteria	Type	Description
Physical and experiential interactions	Cultural ES	Vicinity to recreational objects and territories
Educational value	Cultural ES	Vicinity to educational objects and territories
Cultural heritage value	Cultural ES	Vicinity to cultural heritage objects and territories
Landscape aesthetics value	Cultural ES	Selected landscape features (openness of landscape, relief undulation, vicinity to water bodies and streams, character of land use and character of surrounding land use
Ecological value	Aggregated ES values	Average value of ES in "Habitats" bundle
Risk of farmland abandonment	Composite indicator	Agro-ecological qualities of farmland, vicinity to farms, roads and settlements
Risk of Hogweed Sosnowsky invasion	Composite indicator	Vicinity to invaded sites, position in seeding corridor (streams, roads)

Green network planning support. The aim of green network (GN) planning MCDS is to guide planners in adaptation of a county-level GN into a rural municipality general plan, stressing the role of grasslands in GN and to identify possible land-use conflicts in GN implementation. The criteria for the inclusion of semi-natural grasslands in the GN of a rural municipality General Plan is based on their capacity to potentially deliver a certain set of ES (Table 4). In terms of the role of semi-natural grasslands inside the GN, ES belonging to the "habitats" and "soils" bundles offer a wide array of environmental benefits. These benefits, such as soil protection or pollination, are not only constrained to a grassland plot itself, but have a wider spatial effect (e.g. increased pollination benefits also in surrounding agricultural land). The GN MCDS scheme is presented in Fig. 10 and output maps in Fig. 11.

Table 4.

Criteria identified and mapped for Green Network planning module.

| Criteria	Type	Description
Pollination and seed dispersal	Regulating ES	Diversity and occurrence of insect pollinators
Maintaining habitats for plant and animal nursery	Regulating ES	Number of species
Global climate regulation	Regulating ES	Carbon sequestration in vegetation and soils
Control of erosion rates	Regulating ES	Amount of soil retained
Chemical conditions of freshwaters	Regulating ES	Absorption of nutrients
Bio-remediation	Regulating ES	Soil capacity to enhance bio-remediation
Filtration-storage accumulation	Regulating ES	Soil capacity to store/accumulate nutrients
Protected species distribution	Location factor	Presence of protected species in grassland
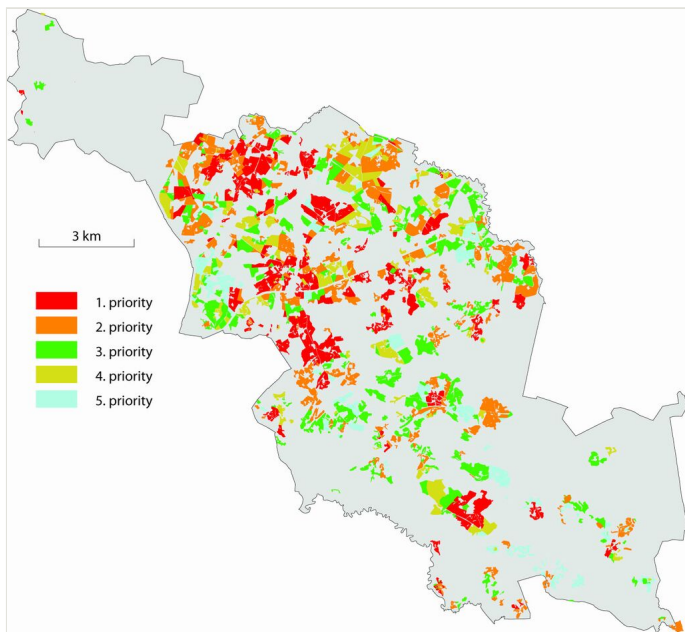
Figure 9.

The results of landscape management prioritizsation in the Cēsis Municipality showing spatial distribution farmland management priority classes. The highest priority class (1st priority) calls for intensive restoration management (removal of shrubs and Sosnowski's hogweed), 2nd priority class calls for medium restoration measures (i.e. removal of Sosnowski's hogweed from the neighbouring territories - ditches, forest edges), 3rd priority class calls for maintenance practices (i.e. cutting grass more than once a year), lowest categories (4th and 5th priorities) call for monitoring of maintenance actions (i.e. yearly monitoring of management practices in situ or tracking of IACS data).
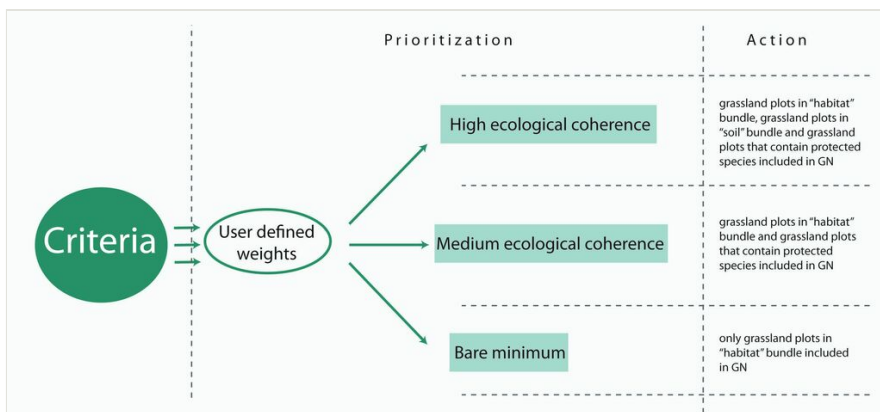

Figure 10.

GN planning scheme showing workflow (consecutive steps from left to right) for decision support: defining criteria, assigning weights, arranging weighting results and assigning selection for scenario building .
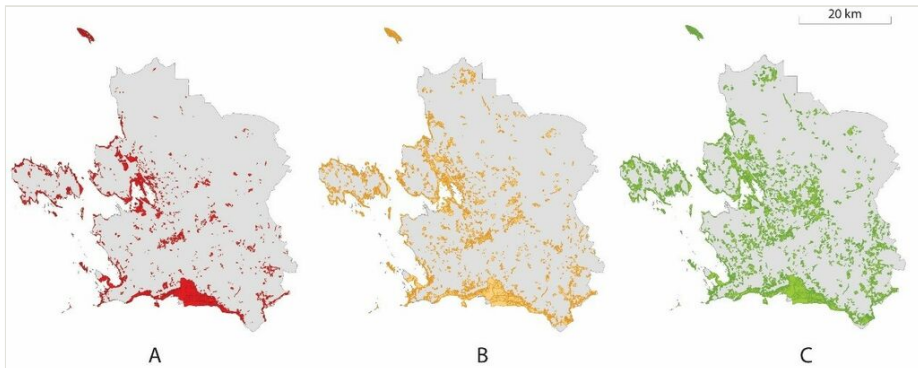
Figure 11.

Three consecutive scenarios of grassland inclusion in Green network of Lääne County, Estonia: (A) Scenario 1: bare minimum - only grasslands belonging to "habitats" bundle (i.e. displaying high or very high values for such ES as maintaining habitats for plant and animal nursery, pollination and seed dispersal, global climate regulations and herbs for medicine) are included in GN, (B) Scenario 2: medium ecological coherence - grasslands from "habitats bundle" and grasslands containing protected species are included in GN, (C) Scenario 3: High ecological coherence - grasslands from habitat bundle, grasslands containing protected species and grasslands form "soil" bundle (displaying high or very high values for such ES as bioremediation by micro-organisms, plants and animals, filtration/storage/accumulation by ecosystems, control of (water) erosion rates and chemical condition of freshwaters) are included in GN.

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Endnotes

[*1]   A database system set up in each EU member state to administer and control direct payments.

[*2]   An IT system based on aerial photographs of agricultural parcels used to check payments made under CAP.

[*3]   Habitats under protection by Habitats Directive (more formally known as Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora).