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Energy from Biomass: Assessing Sustainability by Geoinformation Technology

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Abstract

Sustainable Development Goal (SDG) target 7.2 requests a substantial increase in the share of renewable energy in the global energy mix by 2030. Renewable energy production in all sectors has to be evaluated for its contribution to reach this target. Biomass for energy production has gained a bad reputation over the past years due to the "food versus fuel" debate or reported unsustainable practices. The BIOPLAT-EU project is employing geoinformation technologies combined with sustainability and economic expertise to more accurately evaluate the sustainability of bioenergy value chains. The project has three main parts: first, the generation of a pan-European map of marginal, underutilized, and contaminated (MUC) lands potentially usable for bioenergy production. This is realized by employing remote sensing time series, existing Copernicus, and other spatial data sets. Second, the generation of a web-based geographical information system (GIS) connecting the MUC lands with other important information sources necessary to assess sustainability. Thisrd, the sustainability assessment includes not only typical social and environmental sustainability indicators like soil, water, or greenhouse gas emissions, but also economic sustainability indicators like employment. Current financial barriers are addressed by integrating innovative financing solutions considering SDG target 12.A.

Keywords: energy, sustainable production, biomass supply, time series, webGIS

1 Background and Introduction

Target 7.2 of the Sustainable Development Goals (SDGs) requests a substantial increase in the share of renewable energy in the global energy mix by 2030. Nevertheless, energy demand is growing in virtually all industrialized and even more so, in emerging economies worldwide (Capuano, 2020). Renewable energy production in all sectors has to be evaluated for its contribution to reach target 7.2. Sustainable feedstock supply is expected to play a central and crucial role not only for the production of biofuels (EC 2018/2001), but also for the production of green hydrogen through innovative pre-treatment processes or pyrolysis oil production. However, the use of agricultural crops for energy production has gained a bad reputation over the past years due to the "food versus fuel" debate, and also due to reported unsustainable practices (Humpenöder et al, 2018; Robledo et al. 2017). This led to the adoption of the European Union (EU) Directive EC 2015/1513 to reduce indirect land use change for biofuels and bioliquids (EC 2015/1513).

In the last decade, many scientific studies have demonstrated how bioenergy crops have the potential to be grown profitably on surfaces of land which are currently marginal, underutilized, and/or contaminated (MUC). Additionally, studies also showed that MUC lands can be found in several EU and neighbouring countries (Alcantara et al. 2013, Estel et al. 2015, Lieskovský et al. 2015, Szatmári et al. 2018). Using these areas for bioenergy purposes could offer a source of income to local populations (Traverso et al, 2020) while contributing to achieving the targets of the new Renewable Energy Directive (RED II). Using MUC lands for bioenergy production contributes to SDG target 7.2 and, through the calculation of greenhouse gas (GHG) emissions within the sustainability assessment, also supports SDG 13.2. Intending to promote the market uptake of sustainable bioenergy in Europe using MUC lands, the BIOPLAT-EU project is employing geoinformation technologies combined with sustainability and economic expertise to more accurately evaluate the sustainability of bioenergy value chains. A database of MUC lands is compiled, which integrates different existing data sets, as well as results of a remote sensing mapping exercise based on satellite image time series. In parallel, a concept is developed, which permits the sustainability assessment of a selected bioenergy value chain from an economic, environmental, and social perspective. Both, the MUC land database and the sustainability assessment concept are integrated and implemented within a webGIS system.

2 Data and Workflow

A number of different data sets are used in this study in the various steps and for various purposes. Table 1 lists these data sets together with the source and usage in BIOPLAT-EU. The overall workflow is shown in Figure 1. It depicts how the individual data sets from Table 1 are being combined.

Table 1: Input data, source and usage in the study

Input data	Source	Usage
Sentinel-2 time series data	Copernicus/European Space Agency, GEE	Classification of underutilized lands
Landsat 8 time series data	NASA, GEE	
Copernicus High resolution layers (HRL)	Copernicus: land.copernicus.eu	Generation of training data for utilized land categories; Partly used for elimination of used land; Input for scenario projection
Corine land cover data (CLC)		
Ukrainian Landuse data (= national LCLU data)	Myroniuk (2020)	
Land Use/Cover Area frame statistical Survey (LUCAS) point data	LUCAS (2015)	Generation of training & validation data for underutilized land categories
Google Earth very high resolution (VHR) image data	Google Earth	
OpenStreetMap (OSM)	https://download.geofabrik.de/	Elimination settlements
Shuttle Radar Topography Mission digital elevation model (SRTM DTM) from NASA	www2.jpl.nasa.gov/srtm/	Elimination of steep slopes for identified MUC lands
Natura2000 layer of the European Envirnmental Agency	natura2000.eea.europa.eu/	Elimination of protected areas
Heavy metal concentrations in top soils	JRC, Toth et al. 2016	Input for the identification of contaminated lands
National contaminated land data sets	National sources	
Global Agricultural Ecological Zone (GAEZ) layers	Food and Agricultural Organization (FAO)	Sustainability assessment
Precipitation data	Copernicus: climate.copernicus.eu	Sustainability assessment
Local administrative units (LAU)	EUROSTAT, Ukrainian cadastre	Geometric extent of LAUs for scenario projections
Social and economic statistical data per administrative unit	EUROSTAT, Ukrainian statistical office	Input for scenario projections

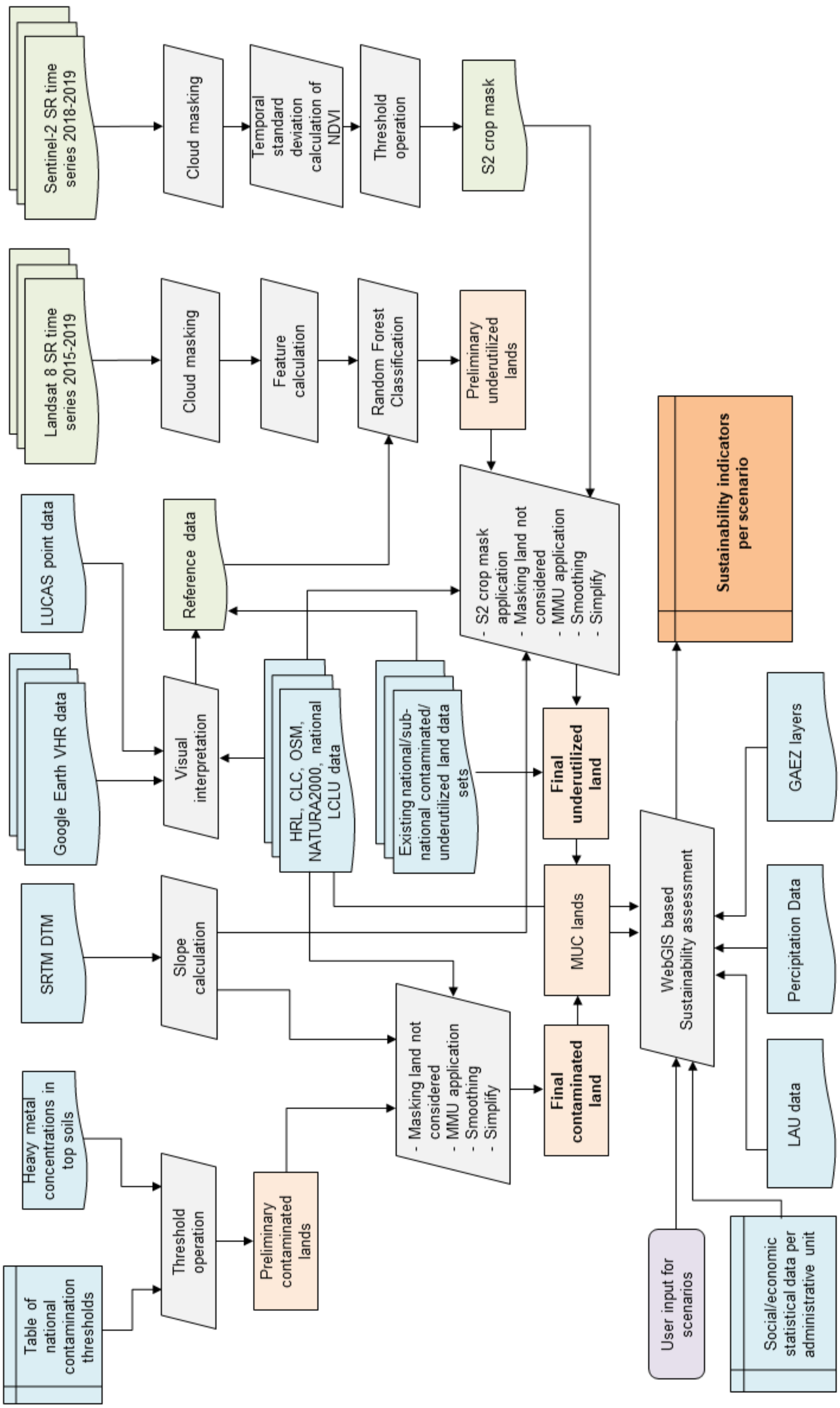

Figure 1: Overall workflow

3 The Spatial Solution

3.1 Generation of a pan-European data base of MUC lands

Marginal lands are difficult to define, as marginality can be understood in different ways: spatially, economically, or in terms of soil quality for example. Due to the "food versus fuel" debate, the project's precondition was set to consider only land which is currently not used or not usable (due to contamination) for food production. Analyses of existing databases of marginal lands (e.g. results from other projects such as SEEMLA or MAGIC) revealed that marginal lands are often being used for food production despite their marginality. Examples include traditional agricultural practices, of which areas of olive cultivation in Southern Italy are a significant example in terms of expanse. To avoid controversial discussions, it was decided to include only marginal lands, which are not cultivated. This characteristic of "no utility" would then make those lands fall in the underutilized lands category which are considered as lands that had no signs of human activity (including grazing) in the last five years.

For the identification of **underutilized land**, the envisaged wall-to-wall, continental-wide detection can only be achieved at reasonable effort by remote sensing approaches. Landsat 8 data for 2014 – 2019 was used to fulfil the five-year requirement and was complemented by Sentinel-2 data from 2018 and 2019. The analysis was carried out in a stratified manner by biogeographical region and country using Google Earth Engine (GEE). GEE is an online cloud-based processing engine for geospatial analyses, available free of charge for research projects (Gorelick et al, 2017). Separate assessments for each biogeographical region are needed, as underutilized lands show significantly different properties depending on their climatic, elevation, and soil properties. The employed random forest classifier requires training data of underutilized and utilized lands in each region. The utilized training data was generated from sampling within the Copernicus High-resolution layers (HRL) and Corine Land Cover data (CLC). The underutilized training data was generated based on a multitemporal assessment of areas within Google Earth using the LUCAS points to pinpoint possible locations. All details on the processing can be found in Hirschmugl et al (2021). The classification suggests that a total of 5.3 million ha of underutilized land in Europe are potentially available for agricultural bioenergy production. The results show an overall accuracy of more than 85 %, with a confidence interval of 1.55 % at the 95% confidence level.

For the identification of **contaminated land**, the initial attempt was to collect national data and aggregate them into a pan-European map. Although most member states report statistics on contaminated lands (shares of total land), many countries either do not have or do not share the underlying spatial data sets due to legal restrictions. In many cases (e.g. Hungary), only point-wise data is available. In other countries, such as Romania, the official contaminated land layer is still under evaluation and thus, not yet released. These limitations led us to the second option: a top-down approach using an EU-wide map of contaminations, which we derived from the Joint Research Centre (JRC) in the "Heavy metals in soils" product based on LUCAS 2009 heavy metal (HM) data (Toth et al., 2016). This map (available at https://esdac.jrc.ec.europa.eu/content/maps-heavy-metals-soils-eu-based-lucas-2009-hm-data-0) has a spatial resolution of 1x1 km and covers 27 EU member states (not including Croatia). Maps of nine different heavy metals are provided: Arsenic, Cadmium, Chromium, Cobalt, Copper, Mercury, Nickel, Lead, Manganese, and Antimony. For each of the heavy metals, thresholds had to be defined to separate contaminated from non-contaminated soils. If a threshold is exceeded, the use of this soil for food and fodder are not allowed/advisable. The relevant EU directive (Council of the European Union, 2002) gives only ranges of values rather than a specific threshold value. Previous studies (Toth et al., 2016) used Finnish thresholds for the whole of Europe, as these thresholds are well in line with the EU-directive. In our study, we collected national thresholds and applied them to the relevant country's territory completing with the above mentioned Finnish thresholds for countries without national thresholds. It is clear, that the resulting data set is not as accurate, nor as detailed as potential national maps, however, it was the only feasible option to produce a pan-European layer. In addition, for countries with available national maps, such as Italy, we included both layers. Figure 2 shows the resulting map of underutilized and contaminated lands for Europe. Please note, that no contaminated land information is available for Ukraine, as the above mentioned JRC data is not available for Ukraine. Further, contamination due to any other agents than the heavy metals mentioned above, like for example Cobalt-60 in Ukraine caused by the Chernobyl accident, was not included.

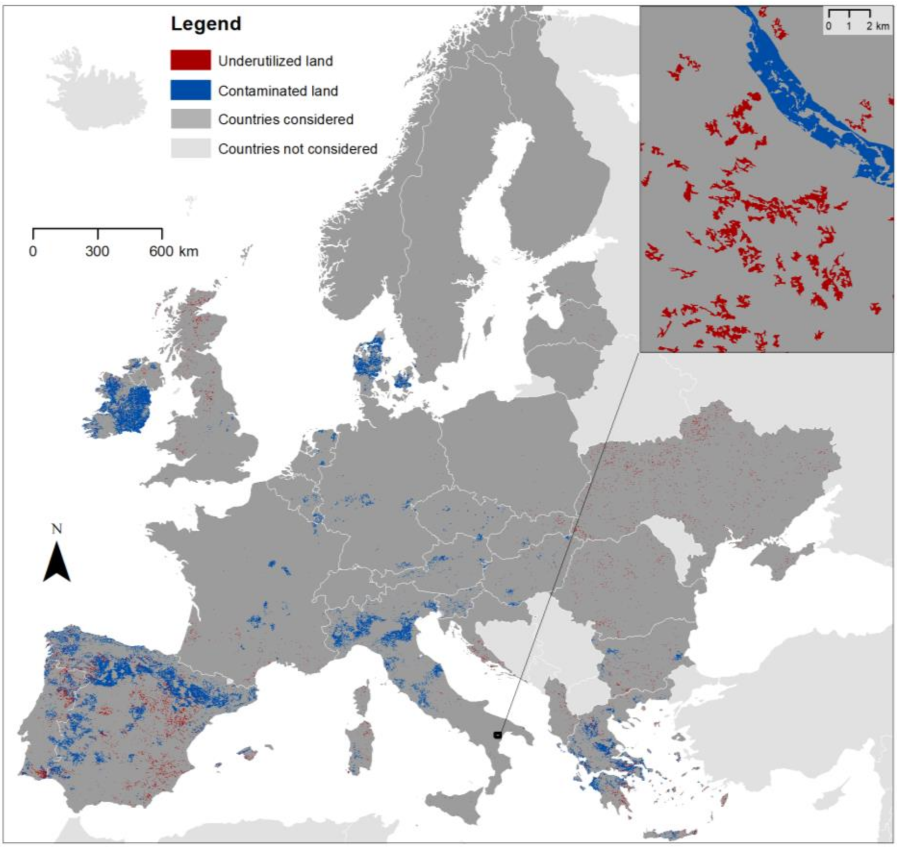

Figure 2: Pan-European map of underutilized and contaminated lands (country boundaries may be disputed)

3.2 Development of a webGIS platform for highly automated sustainability analysis

Sustainability assessment tools provide a better understanding of the three pillars of sustainability (economic, environmental and social) by conceptualizing and explaining the relationships and dependencies among them, aiming to help decision-makers to provide along more sustainable solutions. The methodology is described in detail in Traverso et al (2020). In these contexts, a suite of effective indicators and institutional frameworks were developed for assessing and measuring the sustainable production of bioenergy. They are intended to provide stakeholders with a set of analytical tools for policy decision making, management strategies' design, and alternative value chains comparative analyses. The most widely known and recognized tools for supporting the decision-making process include indicators proposed by the Global Bioenergy Partnership (GBEP, 2018), the Roundtable on Sustainable Biomaterials (2021), and others (Pulighe et al, 2019). The sustainability assessment is structured as the analysis of the difference in impacts caused by two (or more) projections: baseline vs target scenarios projections. A baseline scenario is projected into the future to present the foreseeable development of each selected sustainability indicator given the current circumstances and conditions, thus without the existence of the bioenergy value chain studied. This first projection, called "baseline", will consist of offsetting the current environmental, social and techno-economic features into the future for a reference period defined as relevant. For instance, the baseline scenario of the soil quality indicator is described as the trajectory that the specific soil quality parameter will have if no action is taken. The timeframe has to be explicitly set at the beginning of each analysis and it must be consistent for all scenario projections. The second projection, called "target", consists of the same indicators and their (different) behaviour and developmentif a new bioenergy value chain would be in place. More details can be found in Traverso et al (2020). These assessments are usually based on a lot of location-specific data, which is difficult to access. In order to move from such case-by-case assessment to an automated process, a webGIS system has been built including basic data available for the whole area of interest (i.e. Europe and Ukraine) either as fixed tables (such as the greenhouse gas emissions from the use of petrol versus other biomass sources), or as geospatial data sets. The latter included a layer of local administrative units including attributes on population, gross domestic product (GDP), different employment figures, etc. collected from various sources, mainly EUROSTAT and national statistics (see Table 1). Furthermore, several layers are needed to provide information on suitability for all feedstock types considered in the system. For this purpose, the Global Agricultural Ecological Zone (GAEZ) layers were employed (IIASA/FAO, 2012). This part is needed to assess the potential yield of different crops in a specific area.

Figure 3 shows the overall scheme of the sustainability assessment in the webGIS solution with the backend covering the MUC maps and all other geospatial and tabular data mentioned above, and the frontend with the user interaction. The user interaction includes inputs for location and scenarios selection and output of the final results, which are the assessments of the sustainability indicators for the selected scenarios. There are two levels of users: the standard user, and the advanced user. For advanced users (upon registration), the tool will even allow an in-depth analysis by adjusting pre-defined settings and integrating own values and results in the sustainability assessment. The webGIS tool is currently under finalization and will be made available through the BIOPLAT-EU website (www.bioplat.eu) in July 2021 with fine-tuning until the end of the project in October 2021.

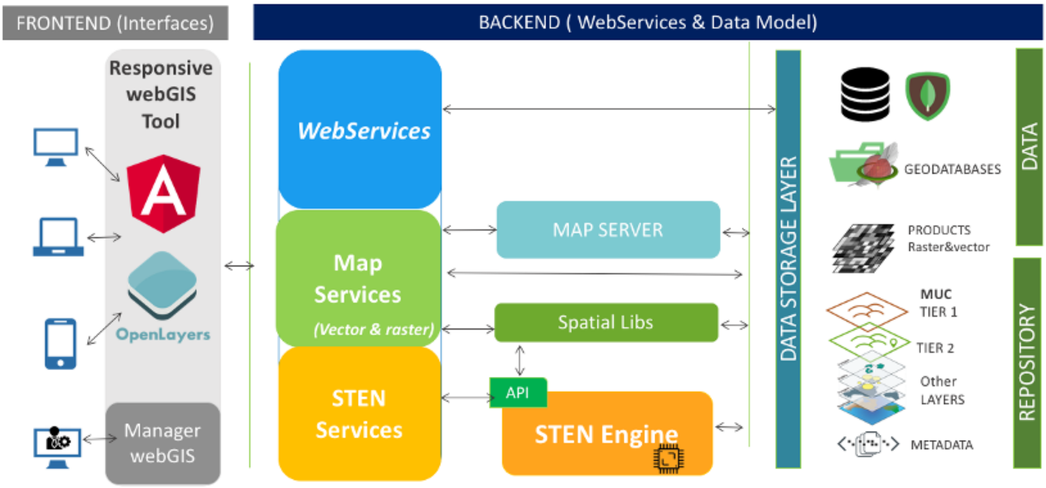

Figure 3: Set-up of the webGIS tool for automated sustainability assessment (STEN stands for the sustainability assessment tool used)

4 Conclusion & Outlook

This study employed geoinformation technologies combined with sustainability and economic expertise to more accurately evaluate the sustainability of bioenergy value chains. The proposed solution facilitates access to sustainability assessment tools by providing necessary input data and algorithms. The presented webGIS tool, which assesses the sustainability of different bioenergy value chains on selected MUC lands in an automated manner, represents a major step forward towards supporting data-based decisions. It also improves the overall understanding of existing dependencies among different indicators in an easily accessible way. Further, it will clearly help to improve indicator 7.2.1: "share of renewable energy in the total final energy consumption" by providing this tool for sustainability assessment together with measures to remove existing barriers in bioenergy production. By providing free access to this webGIS tool BIOPLAT-EU also fosters SDG target 12.2: "By 2030, achieve the sustainable management and efficient use of natural resources". In order to potentially roll out the solution to areas outside Europe in future, existing barriers, such as lack of appropriate financing options, must be addressed. Based on the webGIS solution described above, innovative financing solutions can be developed supporting SDG indicator 12.a.2: "International financial flows to developing countries in support of clean energy research and development and renewable energy production, including in hybrid systems". Sustainable energy, including research and development, challenges in many aspects of finance theory following capital asset pricing models (Sharpe, 1964) and the role development finance institutions play in including the private sector in the energy transition in developing countries. New business models will emerge with a more balanced approach between public and private sectors with often the public sector as initial mover in making grants available in breakthrough innovations in the biofuels and biorefineries sector as witnessed in the launch of the Innovation Fund, and through recent calls for proposals for sustainable energy projects at early technology readiness levels between EU and Africa (26th Jan 2021), and between EU and India (Dec 2020).

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