BIOPLAT-EU

Promoting sustainable use of underutilized lands for bioenergy production through a web-based Platform for Europe

D3.1

Report on the harmonisation of methodologies and tools employed for bioenergy sustainability analyses in the EU

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Table of Contents

List of figures

List of tables

List of acronyms

BPP	Biomass Processing Plant
BPS	Biomass Processing Site
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GAEZ	Global Agro-Ecological Zones
GBEP	Global Bioenergy Partnership
GHG(s)	Green House Gases
GIS	Geographic Information System
GSI	GBEP Sustainability Indicators
IIASA	International Institute for Applied Systems Analysis
iLUC	Indirect Land Use Change
JR	Joanneum Research
JRC	Joint Research Centre EU
LUC	Land Use Change
MAGIC	Marginal lands for Growing Industrial Crops
MUC	Marginal, Underutilized and Contaminated
RED II	Renewable Energy Directive II
SQR	Soil Quality Ratio
SEEMLA	Sustainable exploitation of biomass for bioenergy from marginal lands in Europe
STEN	Sustainability Tool for Europe and Neighbouring Countries
TABL	Target Area Base Layer
UCLM	University of Castilla La Mancha

Executive Summary

Being at the same time one of the wealthiest regions of the world and one of the world's biggest consumer and trading blocs, the EU has a lot to give as well as a lot to answer for when it comes to sustainable development and in particular to the delivery of the SDGs[1]. In this context, the European Renewable Energy Directive II (RED II)[1] represents a good answer to pursuing the sustainability targets defined by the Paris agreement. Furthermore, by setting up new sustainable strategic targets through its own policies and mandates, the EU showed its willingness to seize the opportunity to become a leader in renewable energy and in the global fight against climate change. In this challenging environment, by representing the majority of the share of renewable energy supply of the EU, bioenergy in all its forms can take its chances and play the role of key actor in the achievement of the sustainability targets.

This document presents a review of the methodologies available in Europe for the sustainability assessment and their use within the context of the BIOPLAT-EU project. The work includes a list of well-known recognized institutions/organizations and their related bioenergy sustainability approaches and a series of bioenergy projects (mainly H2020 projects) and the harmonisation processes applied to incorporate them within the BIOPLAT-EU project.

The first part of the document describes the state of the art of methodologies and tools employed in bioenergy sustainability analyses in EU that have been selected and harmonized, with a detailed explanation about what has been taken and how the harmonization process has been done.

These are:

- Global Bioenergy Partnership (GBEP) Sustainability Indicators for Bioenergy
- Global Agro-Ecological Zoning (FAO)
- IPCC guidelines
- FORBIO Project
- BioGrace Project
- SEEMLA Project
- JRC database on bioenergy processing plant
- JRC Forest Information System for Europe (FISE)

The second part of the report provides with a discussion about the harmonization process, the contacts with the institutions and organizations involved and an overview of the BIOPLAT-EU sustainability tool (STEN).

Finally, the chapter 4 draws conclusions and a series of recommendations concerning the harmonisation process and its application in the context of the BIOPLAT-EU project.

[1]https://eur-lex.europa.eu/legalcontent/EN/TXT/?uri=uriserv:OJ.L_.2018.328.01.0082.01.ENG&toc=OJ:L:2018:328:TOC

1 Introduction

In the frame of the transition from linear to circular economy in Europe, marginal underutilized and contaminated (MUC) sites have been recognised as potential resources of raw materials for bioenergy production. The production of biomass from MUC lands depends on a number of values that have to be evaluated in a comprehensive manner through a holistic sustainability assessment. The European Commission has put substantial efforts and resources in the research of measures to increase the market uptake of bioenergy in recent and coming years and MUC lands clearly play a central role in this respect. This is supported by European policies like the RED II which takes a more targeted approach to reducing Direct and Indirect Land Use Change (LUC and iLUC respectively) impacts associated with conventional biofuels, bioliquids and biomass fuels. Since the risk of iLUC cannot be measured with the level of accuracy required to be included in the EU GHG emission calculation methodology, the RED II focuses on limiting the amount of crop-based biofuels, bioliquids, and biomass fuels consumed in transport that can be taken into account when calculating the national overall share of renewable energy and the sectoral share in transport. Using land that is currently unused, underutilized, because of its marginality or perhaps because it is contaminated and therefore not suitable for the production of conventional crops will reduce the risk for iLUC but it is a key that the assessments on various features of these value chains are made harmonically. In fact, for comparability of results, the methodology employed is often responsible for outcomes more than the dataset employed for such assessments. Hence, the need for this report. It is in fact considered crucial that the advancements of the research geared towards the market uptake of sustainable bioenergy from marginal lands is carried out in a way such that its results can be compared, examined and understood correctly and in order to meet this goal, harmonization of the various methodologies previously recognized and employed is carried out.

1.1 Problem statement

Differences in methodological approaches applied to define a common objective, e.g. mapping the amount of marginal, unused land in Europe for instance, can lead to broad variations of the results. Such variability of the outcome can take place even if identical datasets are used. In fact, every time an assessment is carried out, a number of assumptions and choices are inevitably made. Differing assumptions from the start can alter the final results significantly, and this is why the methodology (as well as the “materials and methods” section of scientific papers) has to be made explicit. The BIOPLAT-EU project takes stock of the excellent research and work done to date by other entities and projects over the years, predominantly those officially recognized by the European Commission through its Horizon 2020 funding programme or through other multilateral initiatives to which the Commission officially participates (e.g. the Global Bioenergy Partnership, etc.). One key issue for the advancement of science is that the results of previous studies and project used as data entries in a consequential study have a clearly defined set of assumptions and methodological approach that is consistent with that of further analyses being carried out, and in order to achieve this goal, harmonization of methodologies is fundamental.

2 State of the art in methodologies and tools employed for bioenergy sustainability analyses in EU

This chapter reports the main methodologies and tools available for the sustainability assessment of bioenergy productions. The first paragraph provides with a list of definitions that identify the goals of sustainability aspects when they are applied to the bioenergy sector. The following paragraphs are thought to provide an overview of the available tools and methodologies at both global and European level. In table 1 a list of global and European recognised approaches to bioenergy sustainability is provided. Their limits and constraints are introduced and shortly described in paragraph 2.3.

2.1 Definitions

Bioenergy sustainability assessment: the BIOPLAT-EU's concept of bioenergy sustainability assessment refers to a state-of-the-art sustainability impact assessment and monitoring tools & methodologies. These will encompass all relevant environmental aspects (GHG emissions, soil, water & air quality, and land use change, etc.) but also social (job creation, wages, etc.) and techno-economic sustainability aspects (productivity, energy balance, gross value added, infrastructure and logistics, etc.). The concept behind BIOPLAT-EU contributes to reducing indirect impacts of bioenergy deployment by targeting underutilized and contaminated lands in the EU, thus minimizing the risk of indirect Land Use Change (iLUC).

Marginal and Underutilized land: According to the Food and Agriculture Organization of the United Nations (FAO), there are two different aspects for an area to be considered as marginal: 1) biophysical constraints: Soil constraints (low fertility, poor drainage, shallowness, salinity), steepness of terrain, unfavourable climatic conditions; or 2) socio-economic constraints: Absence of markets, difficult accessibility, restrictive land tenure, small holdings, poor infrastructure, unfavourable output/input ratios. In the context of BIOPLAT-EU, a surface of land is considered marginal only when satellite images time series show that such condition of marginality is supported by the lack of intensive utilization of the land for a period of more than 5 years. In the context of our project then, if an area is considered marginal because it has poor soil performances but there is some form of land use (e.g. agriculture, even if low productivity) this is not considered marginal. Similarly, if an area is classified as agricultural land but satellite images time series show no sign of utilization over the last 5+ years, the area is considered underutilized and therefore in a condition of having low or null impact on iLUC risk when turned into cultivation.

Contaminated land: According to the EU [2], contaminated land is defined by EU regulation as any land which appears to be in such a condition - by reasons of substances in, on or under the land - that significant harm is being caused or there is a significant possibility of such harm being caused; or pollution of controlled waters is being, or is likely to be caused.

iLUC: According to the EU[3], when biofuels are produced on existing agricultural land, the demand for food and feed crops remains, and may lead to someone producing more food and feed somewhere else. This can imply land use change (by changing e.g. forest into agricultural land), which implies that a substantial amount of GHGs are released into the atmosphere. The best available science indicates that iLUC is an issue that needs to be tackled and the BIOPLAT-EU project, through its webGIS platform is pursuing this objective aiming to prioritise the production of bioenergy which takes place on marginal and underutilized lands with low or null iLUC risk.

2.2 International and globally recognised approaches on bioenergy sustainability analyses

This paragraph reports the main methodologies, tools and research outcomes in the field of bioenergy sustainability, considering both European funded and international projects and initiatives, as reported in the table below:

Table 1. Overview of global and European recognised approaches to bioenergy sustainability

European context	International examples
- FORBIO Project - BioGrace Project - SEEMLA Project - JRC database on bioenergy processing plant - JRC Forest Information System for Europe (FISE)	- Global Bioenergy Partnership (GBEP) - GAEZ (FAO) - IPCC guidelines

2.2.1 The Global Bioenergy Partnership (GBEP) Indicators for bioenergy sustainability

The Global Bioenergy Partnership (GBEP) has defined the main aspects that affect the sustainability of bioenergy production worldwide. These include environmental, social and economic aspects, and are to be treated holistically as equally important. In the specific case of biomass production on underutilized lands, sustainability challenges include the actual greenhouse gas emission, to be calculated with a lifecycle analysis approach[4].

GBEP developed a set of 24 science-based and technically sound indicators for a national evaluation of the domestic production and use of modern bioenergy, selected according to their relevance (it must measure as closely as possible the trend of a theme or a component of a theme), practicality (which depends on data availability and the ability to collect the data) and scientific basis (therefore featuring well-established scientific relationship between the indicator and the aspect of sustainability meant to be measured or informed, as expressed by a theme or a component of a theme). The GBEP Sustainability Indicators (GSI) are not binding (i.e. there is no legislative obligation to comply with them), but they provide a straightforward and internationally accepted measurement of the sustainability of bioenergy[4]. The European

Commission is a Partner of the Global Bioenergy Partnership and has contributed to the development of the Sustainability Indicators.

FAO, one of the founding partners of GBEP, played a key role in the development of the GBEP sustainability indicators for bioenergy and has supported their implementation in various countries through technical assistance projects.

When it comes to the EU context, with the aim to develop and offer an ad-hoc sustainability assessment and monitoring tools and methodologies, FAO was able to bring into play its sustainability approach. That was the case of the FORBIO Project (described below in the following chapters), where the implementation of a country- and site-tailored set of sustainability indicators for bioenergy, starting from the GSI, allowed to assess the environmental, social and economic sustainability of a list of selected advanced bioenergy value chains in Italy, Germany and Ukraine. Practically, the GSI serves as a tool intended to guide nationwide policymaking by providing a broad spectrum of ex-post analyses at the national level. While in the context of FORBIO, this tool was adapted to better fit with the European policy environment (e.g. new sustainability targets) and to describe the sustainability performances of bioenergy planned (i.e. ex-ante) at the local level (i.e. sub-national)[5].

The GSIs cover all three pillars of sustainable development (environmental, social and economic), and include eight indicators under each pillar. The complete list of GSI is available in Figure 1.

1. Lifecycle GHG emissions	9. Allocation and tenure of land for new bioenergy production	17. Productivity
2. Soil quality	10. Price and supply of a national food basket	18. Net energy balance
3. Harvest levels of wood resources	11. Change in income	19. Gross value added
4. Emissions of non-GHG air pollutants, including air toxics	12. Jobs in the bioenergy sector	20. Change in consumption of fossil fuels and traditional use of biomass
5. Water use and efficiency	13. Change in unpaid time spent by women and children collecting biomass	21. Training and requalification of the workforce
6. Water quality	14. Bioenergy used to expand access to modern energy services	22. Energy diversity
7. Biological diversity in the landscape	15. Change in mortality and burden of disease attributable to indoor smoke	23. Infrastructure and logistics for distribution of bioenergy
8. Land use and land-use change related to bioenergy feedstock production	16. Incidence of occupational injury, illness and fatalities	24. Capacity and flexibility of use of bioenergy

Figure 1. The original set of 24 GBEP Sustainability Indicators (FAO, 2011)

The indicators, published by FAO in 2011[2], address all types of biofuels (e.g. liquid, solid, gaseous) for electricity, heat and transport. Each indicator was developed with three parts: a name, a short description, and a multi-page methodology sheet that provides in-depth information needed to evaluate the indicator. Each methodology sheet describes how the indicator relates to relevant themes of sustainability and how the indicator contributes towards assessing sustainability at the national level. The methodology sheets outline the approach for collecting and analysing the data needed to evaluate the indicator and for making relevant comparisons to other energy options or agricultural systems. The methodology sheet also provides information on data limitations and highlights potential bottlenecks to data acquisition.

The GSIs and their sub-components are meant to describe all possible sustainability features of any bioenergy product globally and therefore several indicators are developed to address specific potential sustainability challenges found in developing countries in Africa or Latin America (e.g. the time spent by women and children collecting biomass or the assessment of indoor pollution attributable to bioenergy use, etc). Although these indicators are considered crucial in the bioenergy sustainability assessments of many developing countries, this is not the case for the BIOPLAT-EU context. In fact, being its predominant focus the European context (plus Ukraine), those indicators were considered not applicable and therefore discarded. Moreover, some indicators are expressively designed to work as ex-post (e.g. injuries and fatalities in the bioenergy sector) and it does not make sense to attempt to adapt them for an ex-ante assessment.

The same approach was adopted for the innovative set of sustainability indicators for bioenergy, developed in the context of the FORBIO project, to which a specific paragraph of this report is dedicated to explain its links with the GSIs and the BIOPLAT-EU project. Summarizing, it is safe to say that FORBIO represented the stepping stone in the evolution of the GSIs to reach a first degree of automatization with the BIOPLAT-EU Project.

Furthermore, a second important factor was considered in the screening of the GSIs. Indeed, the feasibility of the data collection represents an aspect not to be underestimated. Information needs are defined as the data from primary and secondary sources that must be collected and processed in order to satisfy assessment objectives. When referring to analyses that consider extensive surface of land, as in the case of the BIOPLAT-EU project, the information that is needed for the measurement of a hypothetical sustainability indicator (e.g. energy access indicator) can be not sufficiently detailed in the way it is available, and therefore not applicable to the indicator. For this reason, the indicators selected from the GSIs, for which their methodologies have been adapted to the BIOPLAT-EU project, were divided into two different groups following a simple approach. The ones for which secondary data is sufficient for their measurements were aggregated in a first group and defined as “core” indicators. These indicators are automatically calculated by the on-line tool thanks to the secondary data

[2] The full set of Sustainability Indicators for Bioenergy developed in the context of the Global Bioenergy Partnership is available on the GBEP website (http://www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/Indicators/The_GBEP_Sustainability_Indicators_for_Bioenergy_FINAL.pdf) and it contains the extensive methodological approach for each indicator of sustainability.

uploaded in the system. On the other hand, the remaining indicators, that can be measured only if primary data is entered, were enclosed in a second group and catalogued as "advanced" indicators. To measure this last type of indicators, the user who runs the analysis has to insert the primary data that could not be pre-uploaded in the indicator's database.

Table 2 (below) provides an overview of the core and advanced indicators developed in the context of the BIOPLAT-EU project.

Table 2. List of BIOPLAT-EU CORE and Advanced sustainability indicators

BIOPLAT-EU sustainability indicators	
CORE indicators	**Advanced Indicators**
Air Quality	Water Quality
Water Use	Biodiversity
Land Use Change	Land Tenure
Change in Income	Energy Access
Jobs in Bioenergy Sector	Capacity of Use of Bioenergy
Productivity	
Net Energy Balance	
Gross Value Added	
Infrastructure	

2.2.2 The Global Agro-Ecological Zones (GAEZ)

FAO and the International Institute for Applied Systems Analysis (IIASA) developed the Global Agro-Ecological Zones (GAEZ) for assessing globally agricultural resources and potential.

The GAEZ methodologies utilize the land resources inventory to assess all feasible agricultural land-use options and to quantify expected production of cropping activities, for a selected number of crops, relevant in a particular agro-ecological context, for specified management conditions and three levels of inputs (high, medium and low input level). The characterization of land resources includes all relevant components of climate, soils and landform, which are basic for the supply of water, energy, nutrients and physical support to plants. Under the low input regime in GAEZ, the farming system is largely subsistence based and not necessarily market oriented. Production is based on the use of traditional cultivars (if improved cultivars are used, they are treated in the same way as local cultivars), labour intensive techniques, and no application of nutrients, no use of chemicals for pest and disease control and minimum conservation measures. This scenario was considered not applicable to MUC lands in Europe as well as Ukraine, and therefore discarded.

Under the intermediate input level regime, improved management assumption, the farming system is partly market oriented. Production is based on improved varieties, on manual labor with hand tools and minimal mechanization. It is medium labor intensive, uses some fertilizer application and chemical pest, disease and weed control, adequate fallows and some conservation measures. This scenario was much more representative of a reduced farm management (inputs) regime in Europe and therefore was renamed as LOW scenario in the context of the BIOPLAT-EU project. Furthermore, the high input scenario of GAEZ was kept and applied as HIGH scenario to the BIOPLAT_EU project. Under this advanced management assumption, the farming system is mainly market oriented. Commercial production is a management objective. Production is based on improved high yielding varieties, is fully mechanized with low labor intensity and uses optimum applications of nutrients and chemical pest, disease and weed control. The harmonization of the various input levels has been necessary because it is clear how different management choices influence sustainability performances of the system, and as described by the indicators selected in BIOPLAT-EU.

To sum up, although three levels of agricultural inputs are defined in GAEZ, only the two most representative of biomass production on MUC lands in Europe have been considered for the BIOPLAT-EU project as applicable to the European context, and renamed HIGH and LOW level of input, where the two items represent the two farm management extremes most commonly encountered in Europe. These layers contain the necessary input information in terms of mechanization (tillage), nutrient, pesticides, irrigations activities, etc. that are used to run the sustainability analyses elaborated by the STEN tool. Figure 2 shows how the input levels have changed.

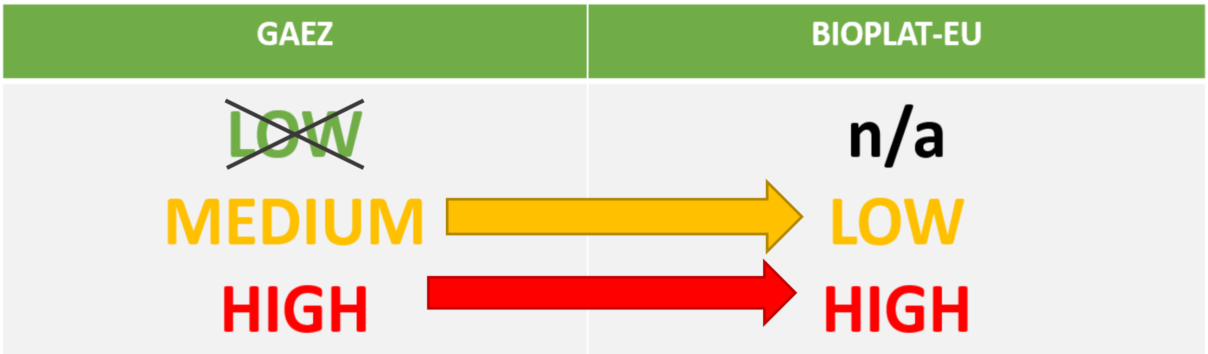

Figure 2. The adaptation of the GAEZ agriculture input level

The GAEZ's crop yield layers are essential inputs that were directly inserted into the STEN database. This allowed the system to obtain effective information of crop yield and suitability for a selected number of crops (Table 3) that have been considered for the BIOPLAT-EU project.

These layers were pre-processed in order to be inserted into the GIS-Platform. As for the crop layers, agro-climatic layers were also considered for the BIOPLAT-EU sustainability tool. These layers provide essential data on agro-climatic variables and constrains.

Table 3. List of crops relevant for bioenergy purposes in Europe contained in GAEZ

N°	GAEZ/BIOPLAT
1	Wheat
2	Maize
3	Sunflower
4	Soybean
5	Sugar beet
6	Rapeseed
7	Sorghum
8	Miscanthus
9	Switchgrass

The possibility to have the GAEZ methodology available is an important added value for the BIOPLAT-EU project. It represents an impressive source of data which, coming from a single FAO tool, are ready to be used in a purpose-built processing environment, like the STEN engine. On the other hand, due to the need to extrapolate a large amount of data, the further integration with a series of alternative variables (e.g. suitability maps from the Joint Research Centre EU - JRC) and the consequent transfer into the BIOPLAT-EU's system, collecting, categorizing, and harmonizing the wealth of information available from GAEZ and storing it into a single repository (i.e. physical server) has been a lengthy and complex task which required coordination among BIOPLAT-EU partners on one hand, and numerous staff from different teams in FAO.

Project name	Identified methodologies
GAEZ	- Land and Water resources, including soil resources, terrain resources, land cover, protected areas and selected socio economic and demographic data; - Agro-climatic resources, including a variety of climatic indicators; - Potential yields for several crops/land utilization types under alternative input levels (i.e. management levels);

2.2.3 Other EU and International relevant approaches

The following relevant approaches were considered for the development of the BIOPLAT-EU project methodologies.

2.2.3.1 Intergovernmental Panel on climate Change (IPCC)

By dealing with climate change and global warming issues, the IPCC offers several guidelines and methodologies that are essential to support the preparation and validation of international project reports and assessments. Particularly, when it comes to adaptation or mitigation actions supported by emission reduction assessments, IPCC provides a useful recognised scientific basis and guidance to structure all solid analysis that can be defined in specific bioenergy related projects. In the context of the BIOPLAT-EU project, the IPCC guidelines where useful to verify a list of internal calculation or directly applied for the development of the air quality indicators (e.g. GHGs and non-GHGs emissions). Other times, the IPCC references were present in and applied to the literature that has been used during the development phase of the BIOPLAT-EU project. In both cases, the IPCC's recognised approach proved useful for the validation and harmonisation of the BIOPLAT-EU structure. Specifically, the 2006 IPCC Guidelines for National Greenhouse Gas Inventories were directly consulted, and its methodologies and sources applied to the BIOPLAT-EU project. Useful clarifications and explanation came from the guide on the processes governing N_2O emissions from managed soils (direct and indirect) and CO_2 emissions from the agricultural activities. Furthermore, it is good to remind how the IPCC approach is widely used in the BioGrace analyses and calculation. The BioGrace project is better explained in the following paragraph and was more than once used to inspire the STEN tool methodologies of BIOPLAT-EU. This means that also indirectly the IPCC approaches were key for the STEN indicators when measuring the emission in agriculture. Especially when it comes to the processing phase of bioenergy feedstock, through the use of the BioGrace project a series of "ready-made" emission accounting (black-box) were developed in advance and introduced in the STEN tool to allow the indicators to run simplified calculations and be less loaded in term of variables. This harmonization has been necessary to allow an automated web-based system like the STEN to run the same analyses as BioGrace using the default values provided by the EU GHG calculator tool.

2.2.3.2 JRC Scientific Information System and Database

As contribution to the European Commission's Knowledge Centre for Bioeconomy, JRC developed the distribution of the bio-based industries database for Europe. The study provides an interactive map of the facilities and a transversal analysis based on the type of products and feedstock sources per facility and per country. FAO has been taking into consideration part of the information provided by the database. In the best scenario, this study will allow the BIOPLAT-EU team to develop a layer containing the locations of the different bioenergy plants at both European and neighbouring countries level (Ukraine). The layer is thought to provide information on plant processing capacity, typology (e.g. Boiler-CHP, Cellulosic ethanol production plant, etc.). The layer will also provide the location of the bioenergy plants, that will be used to calculate the distance from the biomass production sites.

2.2.3.3 JRC Forest Information System for Europe (JRC FISE)

JRC-FOREST research is at the basis of JRC's support to a range of forest-related policies, including EU Bioeconomy, Biodiversity, Forest Strategies and the Paris Climate Agreement. This website provides links to finalized research activities on Global and European forests that were carried out within the JRC. The JRC FISE was useful to integrate the information on perennial lignocellulosic bioenergy crops which were not provided by the GAEZ tool. Thanks to these maps, the list of crops assessed by the BIOPLAT-EU GIS-platform could include important perennial species (e.g. Black locust) that are an integral part of the current lignocellulosic feedstock utilised for bioenergy production. The black locust suitability and yield maps were therefore created starting from the JRC FISE databases following the same methodology used in GAEZ in order to provide two layers to the system that could be seamlessly inserted in the library present on the server. As in the case of any other crop modelled then, two management levels have been created (a "low" and a "high" input management type) and expected yields as well as a detailed list of inputs have been prepared.

2.2.4 EU projects

2.2.4.1 FORBIO H2020 Project

The Fostering Sustainable Feedstock Production for Advanced Biofuels on Underutilized Land in Europe (FORBIO) H2020 project assessed the viability of using land in EU Member States for sustainable bioenergy feedstock production that does not affect the supply of food and feed, in addition to not interfering with land currently used for recreational and/or conservation purposes. The FORBIO Project represents an example of methodology harmonization with the GSIs and naturally its results were the launching pad for the setting-up of the BIOPLAT-EU Project. These three initiatives (i.e. the GBEP Sustainability Indicators, the FORBIO approach and the BIOPLAT-EU methodology) represent a natural evolution to adapt to emerging needs to stimulate the market uptake of modern bioenergy in Europe. The webGIS-Platform designed for the BIOPLAT-EU project, and particularly its Sustainability Tool for Europe and Neighbouring Countries (STEN), signed a significant progression in the harmonisation process from the work done in FORBIO for the development of a comprehensive, effective and above all automated sustainability assessment. FORBIO firstly introduced the concept of ***target area*** which is also at the heart of the delimitation of the reference system for the simulations in BIOPLAT-EU. This novel concept stepped away from the assessments performed using the GSIs before FORBIO and towards the analysis of a single value chain level at the sub-national level. The definition of the reference system in the sub-national realm was originally devised in FORBIO as the area delimited by those municipalities or watersheds touched upon the production of the biomass and its transport to the processing plant. In terms of area then, the ***target area*** of FORBIO was the minimum surface (delimited by existing physical or political borders) that was relevant to the bioenergy value chain simulated.

Linking the different parts of the platform such as GIS layer maps, various assessment tools, numerous EU- and national databases, and the possibility to connect this entire system to the European street network (via Google Open Street Map) was impossible in FORBIO. In fact, its more limited approach was to best characterize the environment before, during and after a given bioenergy production was planned and executed by simulating specific case studies. The second goal of the FORBIO approach was to learn lessons from the sustainability assessments performed and to employ those results to devise a strategy for the market uptake of advanced biofuels options in the case studies in the EU and Ukraine which maximised their sustainability. With BIOPLAT-EU, we are finally empowering the user to carry out a sustainability assessment of any MUC land of choice, with a comparable representativeness and credibility as FORBIO though without the lengthy data collection, and resource-intensive calculations required for each case study. Clearly, the second component of the FORBIO approach could not be retained in the BIOPLAT-EU project since to date an automated instrument to evaluate policies and develop strategies and ultimately roadmaps for the development of the value chains studied is not available. The FORBIO sustainability assessment approach, however, represents the root of the new STEN tool, and its methodologies have been adapted to cover a more detailed and wider scenario: the EU and the Neighbouring countries (Ukraine).

Project name	Identified methodologies
FORBIO	- Set of sustainability indicators for bioenergy - Data and information from case studies - Analysis of the economic and non-economic barriers to the market uptake in EU and Ukraine

2.2.4.2 BioGrace Project

The BioGrace project ran from 2010 to 2012 and was financed by the Intelligent Energy Europe programme. The overall objective of the project was to harmonise the European calculations of biofuel GHG emissions that have to be made to comply with the Renewable Energy Directive (RED, 2009/28/EC) and the Fuel Quality Directive (FQD, 2009/30/EC). As already discussed, the BioGrace tool was used to produce a series of black-box values that allow the air quality indicators of the STEN tool to measure the impact of bioenergy feedstock processing of different feedstocks and value chains (bioenergy pathways). Furthermore, the BioGrace tool was also used as direct source for a list of conversion factors that were applied to the STEN tool methodology (e.g. the emission from the production and application of the chemical or organic fertilizers, etc.).

Project name	Identified methodologies
BioGrace	- GHGs emission factors to be integrated with the relevant IPCC methodologies

2.2.4.3 *Sustainable exploitation of biomass for bioenergy from marginal lands in Europe (SEEMLA) H2020 Project*

The H2020 funded project SEEMLA was particularly considered for the BIOPLAT-EU context. SEEMLA's aim is the establishment of suitable innovative land-use strategies for a sustainable production of plant-based energy on marginal lands while improving general ecosystem services. The use of marginal lands could contribute to the mitigation of the fast-growing competition between traditional food production and production of renewable bio- resources on arable lands. The series of suitability maps for lignocellulosic crops (Poplar, willows, and switchgrass) developed by SEEMLA were used for the context of the BIOPLAT-EU project as integration to the suitability crop layers of GAEZ. In this case, from the relevant literature, the input levels and related crop performances have been used to derive the yield and attribute maps to measure all sustainability indicators selected in BIOPLAT-EU. This allowed the project to cover all the bioenergy crops that can be used for the considered bioenergy pathways on MUC lands in Europe and Ukraine.

Project name	Identified methodologies
SEEMLA	- Database on marginal lands - Catalogue of proposed policies at regional and EU level

2.3 Limits and constraints emerging from the identified approaches

Studies on bioenergy resources in Europe rely on an array of different assumptions, different calculation methodologies, different definitions of resource potential, different geographical scope and different assumptions regarding availability. Methodological differences lead to discrepancies in the results especially in the case of land and biomass availability potentials i.e. different potentials among different studies as to how much biomass of various fractions is available for energy[6]. Resource potentials can be categorised as theoretical, technical, economical or sustainable. Each step of the categorization introduces a degree of limitations so that the theoretical potential is expected to be higher than the technical potential, which in turn is higher than the economic potential and this latter is often higher than the sustainable potential for the same biomass resource.

Bentsen et al[6] have compared results from different assessments of the same biomass resource and found that the comparison does not return a clear picture of the hierarchical relation existing theoretical, technical, economical and especially sustainable potential. Therefore, the authors concluded that variability and methodological inconsistency are the responsible for the inversion of the logical hierarchical order expected and thus they seem to overrule the theory.

These limitations have to a certain degree been faced even in the context of BIOPLAT-EU. The SEEMLA[3] project quantified marginal lands for biomass production in Europe using soil-quality indicators disregarding to a certain extent the current land use of these surfaces. BIOPLAT-EU found that such a methodological approach could not be entirely lifted and employed without harmonization because several hectares considered marginal by the Soil Quality Ratio (SQR) analysis have been demonstrated to host agriculture of great relevance for local farmers and communities.

Another important aspect perceived as limiting was the definition of the level of detail applicable to the analysis. Indeed, many approaches that have been considered and discussed in this report make use of meticulous analyses which can only be done using trustworthy and detailed sources of primary and secondary data. As already discussed, this was the principal reason that led to the subdivision of the STEN indicators between ”core” and “advanced” indicators. In fact, in order to allow the STEN to keep a sufficient number of core indicators, FAO experts realised the need to ensure a fair and appropriate level of detail of the information required for running the analyses. Especially for the analyses that cover the whole European context, an excessive level of detail (intended both in terms of accuracy of the data and complexity of the analysis itself) would have often been improper or not attainable across the board. For these reasons, FAO dedicated relevant resources to the harmonization of the different methodologies employed in order to produce comparable levels of detail that were, by force of circumstances, provided by the several considered approaches/methodologies/ analyses.

[3] https://www.seemla.eu/home-2/

3 Methodology for the harmonisation

3.1 BIOPLAT-EU approach

The main goal of the BIOPLAT-EU project is to deliver a user-friendly, yet scientifically profound aid to assess the sustainability of bioenergy value chains on MUC lands in Europe and Ukraine. There are, as we have seen, several excellent existing tools that however where not necessarily thought out and meant to work in synergy to tackle the myriad of aspects that constitute a full sustainability assessment, including environmental, social as well as techno-economic aspects. The webGIS platform intends to convert the existing methodologies and tools available into a single comprehensive instrument that users can exploit to assess the expected performances of bioenergy value chains through a *one-stop-shop* approach.

Two major action streams have been followed in order to harmonize the methodology of BIOPLAT-EU with those of other recognized instruments available. Because each of the tools/databases/instruments selected is highly specific, each methodology was lifted straight and used to build its counterpart in the BIOPLAT-EU webGIS platform. For instance, the overall skeleton of the STEN was derived from the concepts proven in the context of FORBIO and each Indicator was adapted to use the most appropriate reference tool. Along these lines the methodology for the calculation of the GHG emissions was lifted from the FORBIO Indicators (in turn the result of an adaptation of the GBEP Indicators) but instead of using the same algorithms, data and reference values from FORBIO, information on generic bioenergy pathways in Europe was instead lifted from BioGrace and reference values as well as calculation methodologies were cloned from IPCC methodologies in order to ensure maximum comparability with "stand-alone" simulations carried out using the aforementioned tools for the assessment of GHG emissions from bioenergy. For all other indicators the same approach was followed, when possible, mainly mirroring the work carried out in FORBIO. Alongside with the building of the webGIS using blocks from existing previous projects and initiatives, the harmonization work required that specific components were taken from sources other than those already listed. In this case though, standard values and algorithms were converted into usable formats as if these were fed to the stand-alone methodology blocks that compose BIOPLAT-EU's platform.

Figure 3 below shows the evolution of the GHG/air quality sustainability indicator, starting from the GBEP methodologies and getting to the STEN tool interface also passing through the FORBIO set of sustainability indicators.

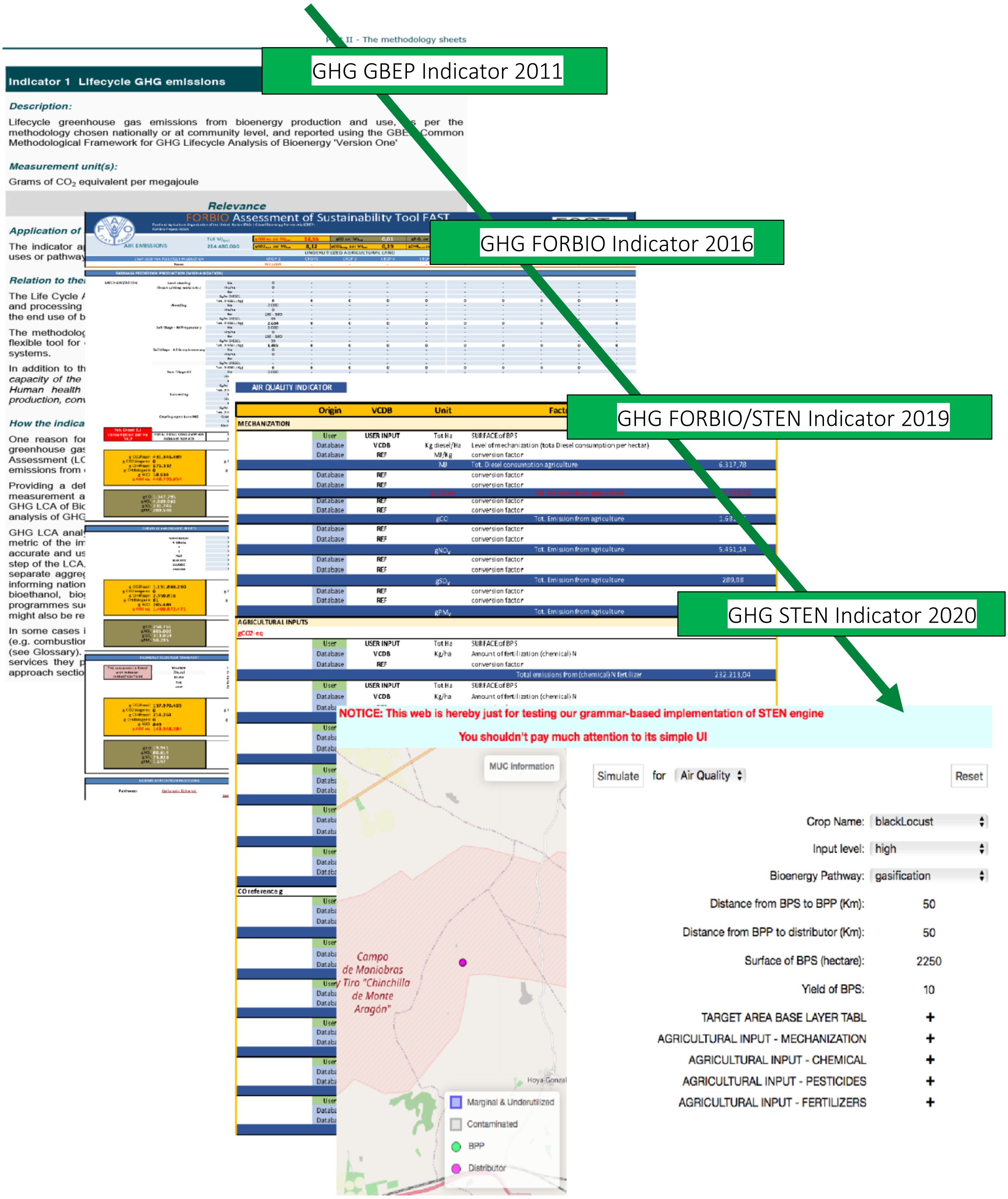

Figure 3. Evolution of GHG indicator

Figure 3 has been created to graphically represent and explain the evolution of the methodologies from the first GSIs tool to the BIOPLAT-EU sustainability tool (STEN).

In the first step (2016) the GSIs were screened and the ones selected were harmonized in order to fit with the FORBIO project requirements. This was a long process that started with and followed the FORBIO evolution. In fact, although the indicators were produced by FAO during the first part of the project (with the aim to assess the sustainability of the selected value chains in three case study sites), the real process of harmonization was mainly refined during their measurement and application to the real context.

Subsequently in 2019, while applying the FORBIO indicators to the BIOPLAT-EU context, a new harmonisation process (described in chapter 2) was required. To do that, and to allow the University of Castilla La Mancha to have an easy-reading of the new methodologies, a new pre-set of indicators (STEN indicators) was developed. This excel pre-set of sustainability indicators is still in progress and will be completed in June 2020. The indicators will be then incorporated in the on-line tool by the Spanish colleagues of UCLM.

3.1.1 Contact and coordination with responsible institutions/ organisations

As a natural consequence of the identification of all the above-mentioned methodologies and approaches, and with the aim to grant them to the BIOPLAT-EU project, FAO corresponded with the respective institutions and organizations in different ways.

As already mentioned in this report, the results of the FORBIO project represented the backbone of the BIOPLAT-EU project proposal. The presence of many partners from the FORBIO project in the BIOPLAT-EU's consortium represented an added value for the development of the sustainability assessment methodology, as well as for several other aspects. On the other hand, for the other identified sustainability approaches, the FAO team had to trace back the authors and the representative people from a list of several institutions and organizations. Internally at FAO, staff members from the GAEZ team made themselves available to introduce the work behind the Agro-ecological zones tool, also inviting the BIOPLTAT-EU's experts to several meetings and internal workshops. The GAEZ team not only provided data and necessary literature, but also started a direct link with the BIOPLAT-EU consortium to provide assistance and share information about the harmonization between the GAEZ tool and the webGIS-Platform of BIOPLAT-EU project and, last but not least, shared several Gigabytes of data with the members of BIOPLAT-EU authorizing their full use in the webGIS platform.

Furthermore, for the development of the marginal, underutilized and contaminated land GIS map inventory, a core technical team of the BIOPLAT-EU project composed by FAO, the University of Castilla La Mancha (UCLM) and the Joanneum Research Institute (JR) established fundamental contacts with experts of the SEEMLA project. The exchange of information was essential to obtain GIS data resulted from the SEEMLA project and to allow the BIOPLAT-EU team to harmonize its methodology in the most appropriate way. The correspondence was mainly done by email and conference calls.

Last but not least, a strong connection was made between FAO and JRC for the development and harmonisation of a series of bioenergy related information and data. This required a continuous exchange of information between FAO and both the European Commission's Knowledge Centre for Bioeconomy and the FISE. In this context, a main topic was related to the confidentiality of the information provided by JRC on the location and characteristics of the biomass plants producing bioenergy products in Europe and their possible application for the BIOPLAT-EU project. In this respect, there is still an open discussion to obtain full disclosure rights. Both parties are in touch to define how to overcome the issue and go ahead with the inclusion of that information into the BIOPLAT-EU platform.

The work done so far showed how the interaction with different institutions and organizations was essential for the application and harmonization of different methodologies into the BIOPLAT-EU context. Although the technical data and information were often public and ready to be applied, the support received from the contacted authors/developers turned out to be an essential help for the development of the BIOPLAT-EU project and will probably continue until the end thereof.

3.2 The harmonized methodology of BIOPLAT-EU

The approach used to design the BIOPLAT-EU webGIS platform has taken into consideration two pivotal aspects:

- The reliance on existing, proven methodologies and tools recognized at EU-level; and
- A user-friendly experience constituted by a guided path with few, basic entries that in the meantime boasts a thorough and accurate workflow behind the scenes.

It has been clear already at project inception stage, that the tools used as reference needed considerable work to fulfil the needs of users-friendliness and be usable by a vast audience, as it is expected from BIOPLAT-EU.

In order to meet the first of the goals stated above, the project has been built around the methodologies presented in Paragraph 2 to realize the skeleton of its webGIS platform and its Sustainability Assessment Tool (STEN). The development of the STEN tool inherently started from the knowledge of datasets, reference default values, metrics and units of the BioGrace tool for bioenergy GHG accounting, and thus with the IPCC rules. The webGIS platform uses crop suitability and productivity maps from the Global Agro-Ecological Zoning produced by FAO and ad-hoc maps developed with the same methodology by JRC. The TABL is composed through the blending of images and shapefiles from the Corine Land Cover library and purpose-built time series based on Landsat and Sentinel Images to define the underutilization status of the land in Europe, EUROSTAT demographic and social datasets. The STEN tools stems from the Global Bioenergy Partnership Sustainability Indicators for Bioenergy, opportunely adapted in the FORBIO Project, to assess each indicator’s value. In addition, again from FORBIO, the BIOPLAT-EU project borrows much of the approach, including the inclusion of the ***target area*** concept to assess local impacts at the adequate scale within its reference system.

The user experience in BIOPLAT-EU has been the core of the development of its approach, culminated in a number of choices made to define the dataflow of the STEN engine. In fact, the approach chosen with BIOPLAT-EU will enable different types of users to carry out full sustainability assessments of the value chains selected in a given MUC area without necessarily setting high knowledge standards for the user itself, nor requiring users to enter vast and complex data entry sections. However, the BIOPLAT-EU project does not ignore the existence of much more advanced users who could use the tool, if opportunely developed, to accommodate far more accurate simulation which rely on site-specific, unpublished, or even forecasted data. This feature was strongly wanted by FAO who clearly sees not only its importance for the completeness and versatility of the tool but also considers it an obvious asset for the community of potential users of the webGIS platform in the future. Along these lines, two user profiles have been defined: a Standard User and an Advanced User (**Fehler! Verweisquelle konnte nicht gefunden werden.**). The Standard User in BIOPLAT-EU is conceived as a resource person who is concerned about the results of the analyses and to a lesser extent about its process, for a number of reasons. With this goal in mind the approach of BIOPLAT-EU encountered a sizeable obstacle, because the complexity of the science and tools employed (e.g. models, datasets, etc.), poses the risk to the user of being faced with a large amount of input data required by the system in order to perform its duty ultimately resulting into a cumbersome process. With this goal in mind the dataflow was defined in such a way to seek maximum simplification for the users while conserving a logical approach to building the simulation. The first action that a user, interested in simulating the production of biomass for energy purposes on marginal, underutilized or contaminated lands, is to locate a patch of land that has the MUC characteristics. The BIOPLAT-EU approach enables users to find the location of their interest through the most common set of instruments available on internet-based geographical applications (e.g. google maps, google Earth, etc.), thus a free navigation tool as well as the possibility to find the user's location or to type in coordinates.

The scale at which the MUC lands are represented at screen is another key enabling factor for a user to perform a simulation of the sustainability of a theoretical bioenergy value chain. It is possible that on certain, relatively vast areas there is very little or no MUC land. However, unless the user zooms out to the point where a given MUC land appears, this would not be visualized at screen. Thus, depending upon the zoom level, if the MUC land has limited surface compared to the scale the user might find it difficult to locate it on screen. To solve this first issue the BIOPLAT-EU project aligned with one of the resources vastly employed for the production of the webGIS platform, the free-library of Google Maps tools. The Marker Cluster Utility is a tool produced and distributed by Google Maps that solves the issues of visualization of items at screen by helping with the management of multiple markers at different zoom levels, by clustering the items when appropriate and declustering when needed. The webGIS platform harmonized its "search MUC" section, the very first step of any simulation, with this clever and powerful utility produced by Google.

3.2.1 Structure of the web-GIS

The general structure of the webGIS dataflow is represented in **Fehler! Verweisquelle konnte nicht gefunden werden.** for both Standard and Advanced Users.

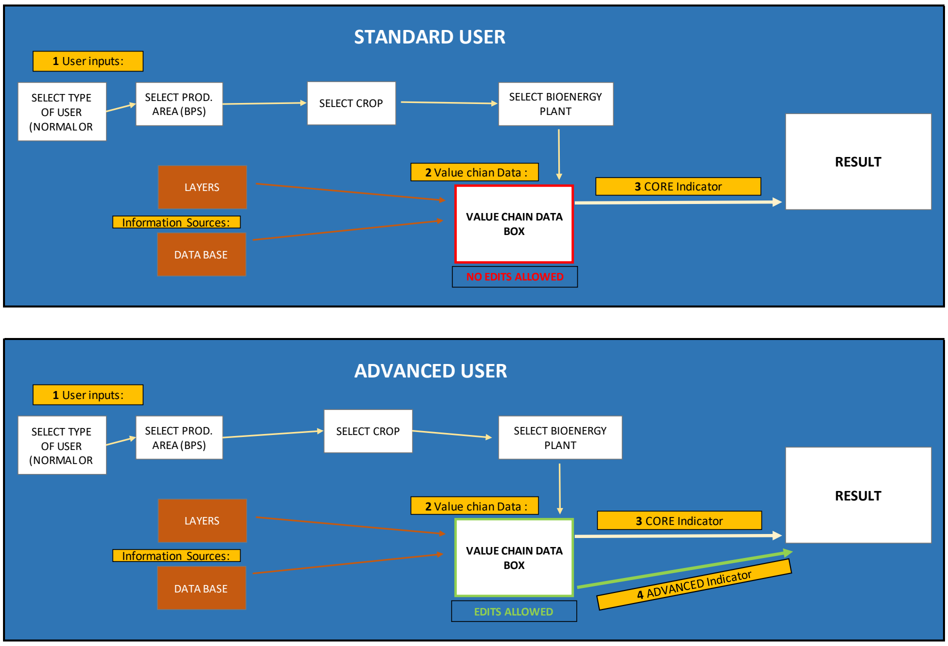

Figure 4. Data flow of the STEN tool

Once the user has located the MUC land of interest, she/he can select the entire MUC patch or free-hand draw the borders of a patch that is relevant to the user itself. This area is denominated "Biomass Production Site" or BPS. This apparently simple action (as per the concept explained above: simple data entry steps required, which entail great depth of work for the software) triggers a number of commands to the software which is now able to draw from its databases and GIS layers all relevant information linked to the specific area selected by the user. These include the list of suitable crops (from GAEZ and other harmonized resources, like SEEMLA and the JRC FISE) and the list of potential bioenergy pathways already existing in the area, thanks to the library of positions linked to various Biomass Processing Plants (BPPs) retrieved by FAO. The list of crops that will appear in the second message box to the user depend on the previous selection and thus on the location of the BPS because georeferenced areas have specific suitability for a set of crops. The system therefore pre-selects the list of suitable crops by searching inside its databases and present to the user only the selection of crops that are considered suitable according to same methodology employed in the GAEZ. Lastly, the user can select the bioenergy product which she/he is interested in simulating.

With these simple three steps, the webGIS platform is capable of retrieving attributes of each location (BPS), suitable crop, as well as biomass processing plant (BPP) in the given ***target area*** and populates a value chain data box which lists all raw data used by the system to assess the values of each of the sustainability indicators considered.

The Advanced users have the ability to change values listed by default in the value chain data box, whereas Standard users can use only default values for their simulations.

The specifics of the data flow will be discussed in detail in the dedicated Deliverable (D3.4), though this quick introduction to the structure of the webGIS platform explains how that was thought, planned and finally built to work seamlessly with the georeferenced datasets resources employed (GAEZ, Corine Land Cover, Google Maps, etc.) as well as the set of tools and indicators used (FORBIO, SEEMLA, GBEP Indicators, etc.). Each component of the BIOPLAT-EU software has been shaped in order to match with its reference, parent data or tool, and the filling of gaps was made by adapting to these existing methodologies any additional material coming for further sources. Finally, the BIOPLAT-EU webGIS platform incorporates in a harmonized manner the solid scientific background developed in and outside the context of EU projects and is capable of integrating these sometimes very different tools and databases to work seamlessly and interactively, since every sustainability indicator is inherently linked to several others, the methodologies have been adapted to reflect such synergies.

4 Conclusions and recommendations

In conclusion, the long process of methodologies harmonization that refers to bioenergy sustainability concepts and approaches in BIOPLAT-EU was a carefully-thought path that involved the responsible partners UCLM, FAO and JR in coordination with all other partners of the project and several members and experts of other EU and International initiatives and projects. This work has been key to deliver solid background of information and methodologies to the members of the BIOPLAT-EU project for their further development in the form of the webGIS platform. Without the harmonization of the various methodologies the interconnection among all sustainability indicators would have not been possible and results would have hardly been considered within a common reference system. Thanks to the work summarized in this report instead, the project can produce sustainability analyses using the most recognized methodologies available in Europe and show the potential that such an integration can have in terms of results and applicability.

It is expected that such a refined and comprehensive approach to sustainability will allow the project to deliver capable tools for the sustainability assessment of the studied value chains. It is also expected that the high level of accuracy reached with the harmonisation allows the project to work properly covering the large set of varied European scenarios and to prove to be effective in its sustainability analyses and ultimately provide its users with sound-science based instruments that have an unprecedented simplicity of use.

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