BIOENERGY AND FOOD SECURITY RAPID APPRAISAL (BEFS RA)

User Manual

CROP PRODUCTION

BEFS Rapid Appraisal

Natural Resources Module

Crops Component

Section 1: Crop Production

User Manual

Acknowledgements

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3 The National Biofuels Board is chaired by the Secretary of Department of Energy and includes the following members: Department of Trade and Industry, Department of Science and Technology, Department of Agriculture, Department of Finance, Department of Labour and Employment, Philippine Coconut Authority, Sugar Regulatory Administration.

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1 Overview of the *Natural Resources* Module

Biofuels can be produced from different types and forms of biomass: fuelwood, crops, biodegradable residues and waste of different origins (e.g. municipal, industrial, agriculture and fisheries), etc. Biofuels come in liquid, gaseous and solid forms and can be used for heating and cooking, electricity production and as transport fuels.

The *Natural Resources* module of the BEFS Rapid Appraisal is used to assess the availability of bioenergy feedstock originating from crop production, agricultural residues and forestry. The module is divided into three components, based on the biomass type. The three components are: *Crops, Agricultural Residues, Woodfuel and Wood Residues.*

Figure 1 graphically depicts the structure of the NR Module.

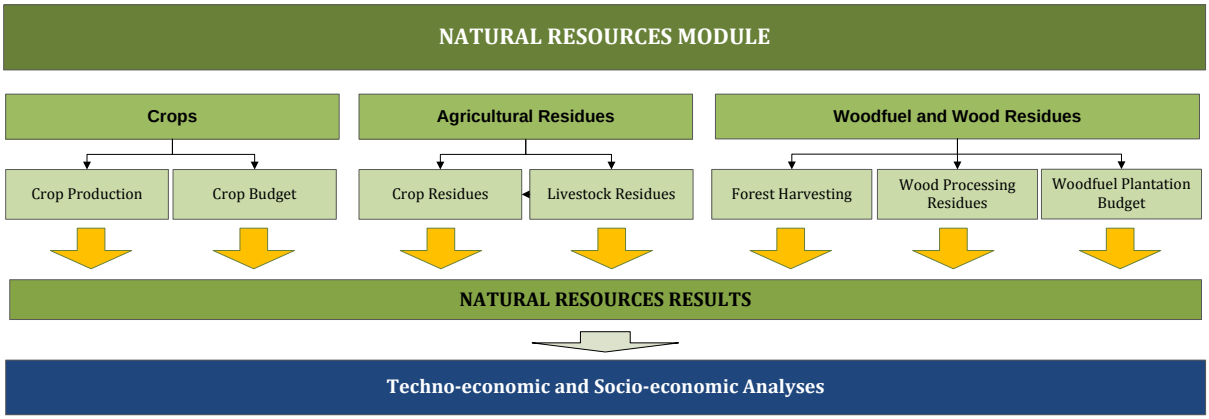

Figure 1: The Structure of the *Natural Resources* Module

Each component is an Excel file and within each file, there are one or more tools. Every Excel file starts with an introductory sheet explaining the structure and purpose of *Natural Resource* module.

The *Crops Component* includes the *Crop Production Tool* and *Crop Budget Tool*. The *Crop Production Tool* is used to assess the potential for additional production of oilseed, sugar and starch crops. The approach used to estimate the amount of these crops that could be available for bioenergy production, takes into account the countries needs for food, feed and other non-bioenergy purposes. Thus, food security measures are integrated into the analysis. These additional crops can then be used as feedstock for straight vegetable oil (SVO), biodiesel and ethanol.

The BEFS Rapid Appraisal land suitability maps are also included in the *Crops Component*. These country level maps were developed for 10 crops[4] that are suitable for the production of liquid biofuels and were generated using the Global Agro-Ecological Zoning[5] layers on land suitability and productivity (FAO, IIASA, 2012), the global land cover map GlobCover 2009 (ESA, 2012) and the World Database on Protected Areas (IUCN and UNEP, 2009). They serve to support the *Crops Production* and *Crops Budget* analyses.

The *Crop Budget Tool* provides an overview of input and labour requirements, in addition to crop production costs, profitability and labour demand. The *Crop Budget Tool* mirrors the set-up of the *Crop Production Tool*, allowing for the two tools to be used collectively or individually, depending on the nature of the analysis and

[4] The 10 crops are: cassava, maize, sorghum, sugarbeet, sugarcane, jatropha, oil palm, rapeseed, soybean and sunflower.
[5] *Agro-ecological suitability and productivity – Total production capacity* maps

the requirements needed. Crop budgeting requirements are differentiated by three input levels (i.e. low, medium, high), as in the *Crop Production Tool*.

The *Agricultural Residues Component* encompasses tools to assess the availability of crop and livestock residues. Crop residues are suitable feedstock for the production of briquettes and pellets (solid biofuels), while manure is suitable for the production of biogas. These biofuels can be used for heating and cooking or for electricity generation through gasification or combustion.

The *Woodfuel and Wood Residues Component* includes three tools: *Forest Harvesting, Wood Processing Residues* and *Forest Plantations*. These tools facilitate the assessment of the potential for additional harvesting of fuelwood from production forests and the availability of forest harvesting residues and wood processing residues. The *Forest Plantation Tool* is used to assess the potential harvestable volume of wood from dedicated fuelwood plantations and the costs and benefits of establishing these plantations.

The foreseen flow and options of the analysis within each component are described in the respective manuals. The module can be used for the analysis of all or only selected biomass resources. Which tools will be used will depend on the aim of analysis. For example, if the user is interested to screen which biomass resources are available in the area of analysis (the country), then all of the tools will be used. Whereas, if the user is interested in a specific biofuel chain then only those relevant for the chain will be used. For example, if the user is interested in the production of briquettes from crop residues, then he/she will use the *Crop Residues Tool* of the *Agricultural Residues Component.*

All of the tools in the *Crops Component* have a results sheet that summarizes the outcomes of the analysis. Since one biomass type can be converted into final energy using different technological pathways, the user is asked to allocate the amount of available biomass among the various bioenergy supply chains.

For example, upon assessing the potential for additional production of soybean and sunflower in the results sheet, the user will need to define the percentage of the available crops for the production of straight vegetable oil (SVO) and for biodiesel. These feedstock amounts are then fed into the *SVO and Transport Tools* of the *Energy End Use Options* module. Therefore, the results from the *Natural Resources* module serve as a threshold for defining the appropriate size(s) and number of processing plants in the *SVO and Transport Tools*.

The user manual for the *Natural Resources* module is divided into four sections: *Crop Production, Crop Budget, Agricultural Residues, Woodfuel and Wood Residues*. Each section includes a detailed description of the tool, terms and definitions used, data required to run the analysis and the steps of analysis.

2 Terms and Definitions in the *Crop Production Tool*

The terms and definitions below refer to all of the options which can be analysed in this tool, along with the methodological approaches and concepts, agricultural production systems considered and databases incorporated within the tool. It is important for the user to anticipate these definitions and consider them throughout the analysis, in order to interpret the results correctly. Some of the terms are also used in other tools and components of the *Natural Resources* module, especially in the *Crop Budget Tool*.

2.1 Options for the additional production of crops

- **Intensification:** The increase in annual production due to an increase in crop yield, which is achieved through the improvements in agricultural practices and/or increase in inputs (e.g. fertilizers, pesticides, machinery).
- **Change of crops:** The increase of annual production due to an increase in the production area of the analysed crop. This occurs due to the expansion of the land that is currently used for the production of another crop. Consequently, the production area of the current crop decreases.
- **Extensification:** The increase of annual production due to an increase in the production area of the analysed crop. This occurs due to the expansion of arable land, which includes land use change. Land use change can involve bringing idle arable land into production or the conversion of other land use classes into arable land (e.g. conversion of land classified as permanent crops, grasslands, meadows and pastures, forests, other land into arable land).

2.2 The agricultural production types and land suitability

The methodology integrated in the *Crop Production Tool* builds upon the Agro-ecological Zoning (AEZ) methodology (FAO, 1996) and relies on the data from the Global Agro-ecological Zones - GAEZ ver. 3.0 (IIASA/FAO, 2012a). Therefore, the approach and definitions from GAEZ (IIASA/FAO, 2012b) also apply here.

Input level of agricultural production

GAEZ defines three generic input levels for agricultural production: low, intermediate and high. In GAEZ, this variety in management and input levels is translated into yield differences (IIASA/FAO, 2012b)[6].

- **Low input:** Under a low input level, the farming system is mainly subsistence-based. Production is based on the use of local cultivars (if improved cultivars are used, they are treated in the same way as local cultivars) and labour intensive techniques. Under this level, chemicals for pests and disease control, along with nutrients, are not utilized. There are minimum conservation measures.
- **Intermediate input:** Under an intermediate input level, the farming system is partly subsistence-based and partly market-oriented. Production is based on improved varieties, on manual labour with hand tools and/or animal traction and some mechanization. Under this level, the labour is medium intensive, and some fertilizer and chemicals for pests, disease and weed control are applied. Additionally, the fallow planting strategy is implemented, as well as other conservation measures.
- **High input:** Under a high input level, the farming system is mainly market-oriented. Production is based on improved or high yielding varieties and is fully mechanized with low labour intensity. Under

[6] Definitions for input levels described here are adopted/simplified from those in the GAEZ Model Documentation, thus for detailed description please see: IIASA/FAO, 2012b.

this level, there are optimum applications of nutrients and chemicals for pests, disease, and weed control.

Land suitability

The AEZ methodology is used to assess the suitability of land for the production of crops, while considering the factors that affect the yield. These factors include the prevailing climatologic conditions, soil characteristics and landform of the assessed area, on the one hand, and the eco-physiological requirements of the analysed crop, on the other. The eco-physiological requirements of the crop regard thermal conditions, length of growing period and soil and terrain characteristics. The characteristics of agricultural practice[7] (input level) are also considered. By incorporating them into the AEZ, it is possible to determine potentially attainable yields under different input levels. The final outcome of the land suitability assessment is a land suitability map for the analysed crop/input level.

A land suitability map for a specific crop visualizes the suitability level for each grid cell of the map. GAEZ distinguishes between eight suitability classes: very high, high, good, medium, moderate, marginal, very marginal and not suitable. The distribution among the classes is based on the percentage of the maximal attainable yield that can be achieved in the given conditions. Consequently, for each suitability class a potential yield can be assigned.

The BEFS Rapid Appraisal land suitability maps, which are a constituent part of the *Natural Resources* module, and the "GAEZ yields" database, which is integrated in the *Crop Component* (GAEZ_LIL, GAEZ_IIL, GAEZ_HIL) are based on the GAEZ *Agro-ecological suitability and productivity – Total production capacity* maps and the respective summary tables. The land suitability classes in BEFS Rapid Appraisal maps are presented in the same way as in the GAEZ. In addition to the suitability of land, the BEFS Rapid Appraisal maps show areas not suitable for agricultural production. The "masked" areas include forest land (the layers were extracted from the global land cover map GlobCover 2009 (ESA, 2012)) and the IUCN nature protected areas (the layers were extracted from the World Database on Protected Areas (IUCN and UNEP, 2009)). Note that the BEFS RA suitability maps are valid for rainfed conditions only.

The original GAEZ land suitability classes are adapted and aggregated for BEFS Rapid Appraisal purposes. Therefore the "GAEZ yields" database of the *Crop Component* includes three land suitability classes:

- **Country average (vs-s-MS-ms), [t/ha]:** This represents the weighted average of potential yields for: very suitable, suitable, moderately suitable and marginally suitable land. The country average is calculated based on the potential yields for each suitability class (according to the GAEZ land suitability classification) and the proportion of each suitability class in the country.
- **Very suitable and suitable land (vs-s), [t/ha]:** This represents the weighted average of the potential yields for very suitable and suitable land. It is calculated based on the potential yields for very suitable and suitable land classes (according to the GAEZ land suitability classification) and the proportion of each class in the sum of very suitable and suitable land areas.
- **Moderately suitable land (MS), [t/ha]:** This represents the potential yield for moderately suitable land (according to the GAEZ land suitability classification).

[7] For detailed description please see: IIASA/FAO, 2012b.

Crop production

The following terms about crop production are used in the *Crops Component*:

- **Current yield (t/ha):** The yield of the selected crop obtained in the area of analysis, under the existing agricultural production practice (input level), expressed in tons per hectare.
- **Annual production (t/year):** The amount of the analysed crop produced in one calendar year in the area of analysis, under the existing agricultural production practice (input level), expressed in tons.
- **Number of harvests per year:** The number of harvests of the analysed crops in one calendar year.
- **Total production area (ha):** The land area used for the production of the analysed crop, expressed in hectares**.**
- **Water supply:** The source and delivery system of water used for agricultural production.
  - **Rainfed:** Farming practices that rely on rainfall for water.
  - **Irrigation:** Farming practices that use irrigation systems for water supply.
- **Potential yield (t/ha):** The yield of the analysed crop that can potentially be obtained, based on the selected input level, water supply and the land suitability of the analysed area. In this version of the tool, potential yields are available for low level and intermediate input levels under rainfed conditions, and intermediate and high input levels under irrigated agricultural production.
- **Intensified production:** The production of the selected crop that would achieved with the potential (anticipated) yield, i.e. anticipated production.
- **Planned production of crops for non-bioenergy purposes:** The production of the selected crop for a purpose different than for the production of liquid biofuels. It reflects the foreseen consumption of the analysed crops as food, feed, export, etc.

3 Scope and Objective of the *Crop Production Tool*

The *Crop Production Tool* is one of two tools that form part of the *Crops Component* (Figure 2).

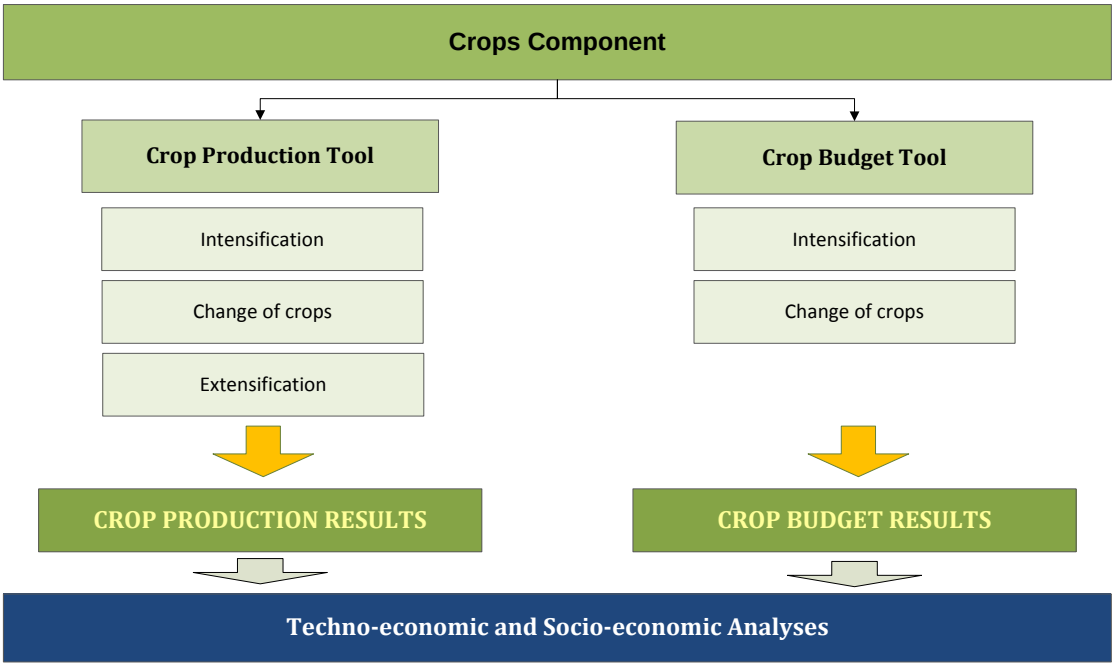

Figure 2: Structure of the *Crops Component*

The aim of the *Crop Production Tool* is to assess the potential for the sustainable production of crops, which can be used as bioenergy feedstock for the production of liquid biofuels, namely ethanol, biodiesel and straight vegetable oil (SVO). Ethanol is produced from sugar and starch crops such as sugarcane, wheat and cassava, while SVO and biodiesel are produced from oilseed crops such as sunflower, oil palm and soybean. Liquid biofuels are commonly used as substitution for diesel or gasoline in the transport sector, but can also be used for heating, cooking and lighting or electricity generation.

In order to minimize competition with food production and inputs, bioenergy feedstock production is always in addition to the existing or foreseen needs for food and other non-bioenergy uses. Therefore the safeguarding of food production and the sustainable use of natural resources are sought throughout the analysis. This is achieved through a defined flow of analysis, the underlying methodology and by using the information provided in the *Country Status* module throughout the *Crops Component*.

Three options for additional production can be analysed: intensification, extensification and change of crops.

First, the possibility for intensifying production is assessed. This option examines the comparison of current and potential yields, additional amounts that can be produced through a yield increase and how much of it could be used as bioenergy feedstock. It first takes into consideration the anticipated requirements for food and other non-bioenergy needs. If this option is feasible and economically viable[8], then it should be prioritized over expansion of arable land, which in this case is known as extensification. Improving current yields through intensification allows for the promotion of environmental sustainability in the initial stages of bioenergy policy planning.

The extensification option analysis gives an indication whether there is a possibility for the sustainable expansion of arable land. It is based on trends in land-use change in the evaluated area over the past 10 to 20 years. If this option is suitable, it is important to note that the results of BEFS Rapid Appraisal will not reveal the amount of land that is actually available or its location, but will only indicate the possibility of extensification and provide recommendations for further, more detailed analysis.

The change of crops option broadly analyses the implications of changing from a currently produced crop to a crop for bioenergy production on a defined land area.

The background methodology for the intensification, extensification and change of crops options is described in detail in the Annex.

[8] See manual for the *Crop Budget Tool.*

4 Running the *Crop Production Tool*

The *Crop Production Tool* is embedded in the Excel file named *Crops* and contains a total of seven sheets. The following figure shows the flow of analysis and the inter-linkages of the *Crops Component* with other tools and modules in the BEFS Rapid Appraisal (Figure 3).

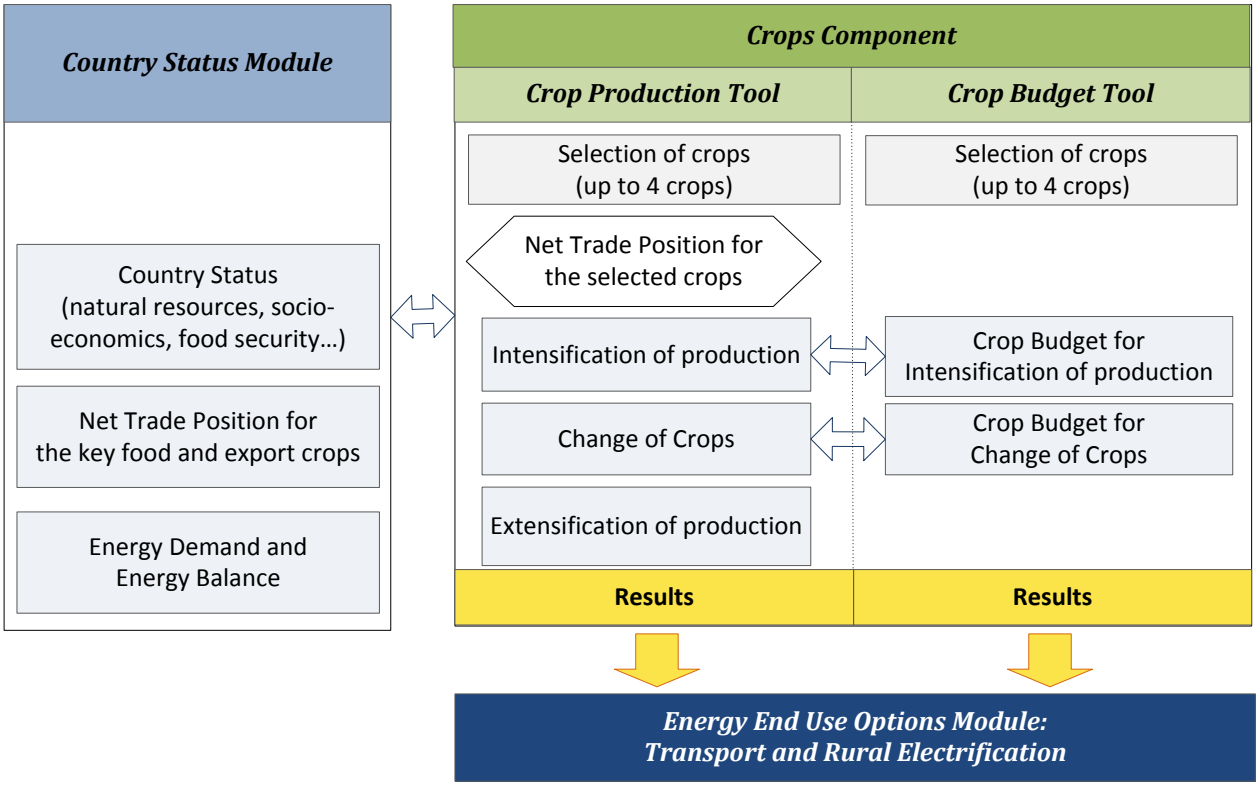

Figure 3: *Crops Component*: Flow of Analysis and Inter-linkages with BEFS RA Modules

The flow of crop production analysis is defined by the *Crop Production Tool.* During the analysis, the user is navigated step by step through each of the options and is asked to enter the data needed in order to obtain the final results. When the required data are limited or unavailable, then the default values provided by the tool can be used. The navigation buttons are placed on the top and bottom of each sheet, indicating the next step with the button "NEXT>>" and allowing the user to return to the previous section with the "<<BACK" button.

The following sub-chapters describe each step of the analysis, using Malawi as the example.

It is suggested to follow the order (priority) of the options examined as described below. Nevertheless, the user can evaluate the options in a different order or even omit some options and/or steps of the analysis (e.g. net trade position). Ultimately, the order of priorities and the complexity of analysis will depend on the aim, country context, etc. It has to be emphasized, though, that the comprehensiveness of the analysis will also depend on the expertise of the user.

When interpreting the results one should take into account all relevant factors, even when certain analytical steps were omitted. Some of the key issues that should be taken into account are the aspects related to food security, agricultural trade and future demands, sustainable use of natural resources, and so forth.

4.1 Step 1: Starting the analysis

The first step after opening the *Crops Component* file is to enable the use of ***Macros & ActiveX*** in the file, in order to use to tool (Figure 4).

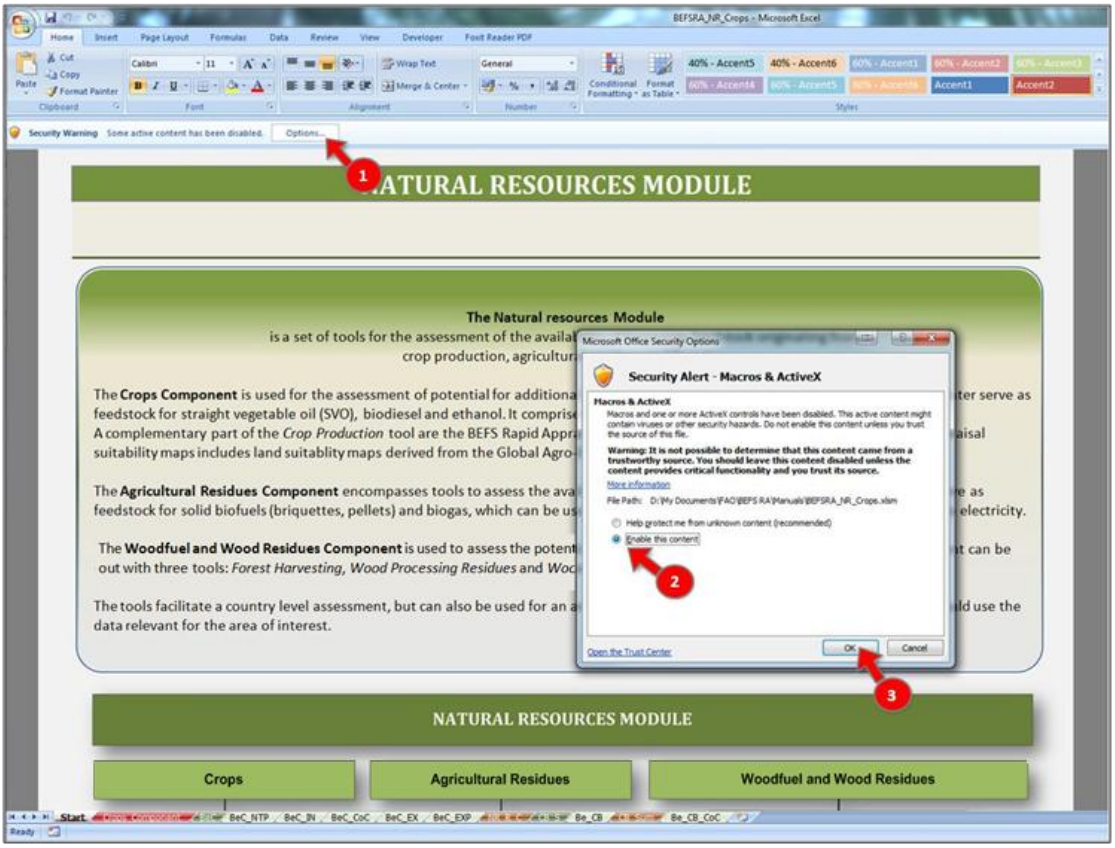

Figure 4: Opening the *Crops Component* File

Next, the user must select the language of preference in order to view the tool in that language (Figure 5, label 1). The language choices are: English (EN), French (FR) and Spanish (ES).

At the beginning of the analysis, the user is informed about the aim and structure of the *Natural Resources* module and the *Crops Component*.

In the *Crops Component* sheet, the user should:

1. Select the country of the analysis,
2. Select the area of analysis (if the analysis is conducted at a sub-national level, then enter the name of the analysed area) and
3. Press the *Crop Production Tool* button to start the analysis.

Figure 6 shows the layout of the *Crops Component* sheet with arrows signalling the steps previously described.

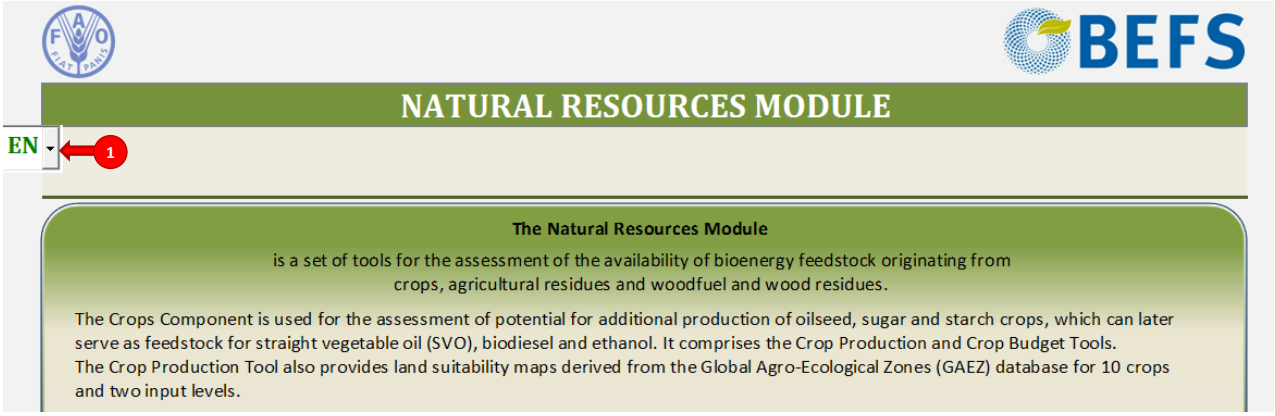

Figure 5: Language Selection

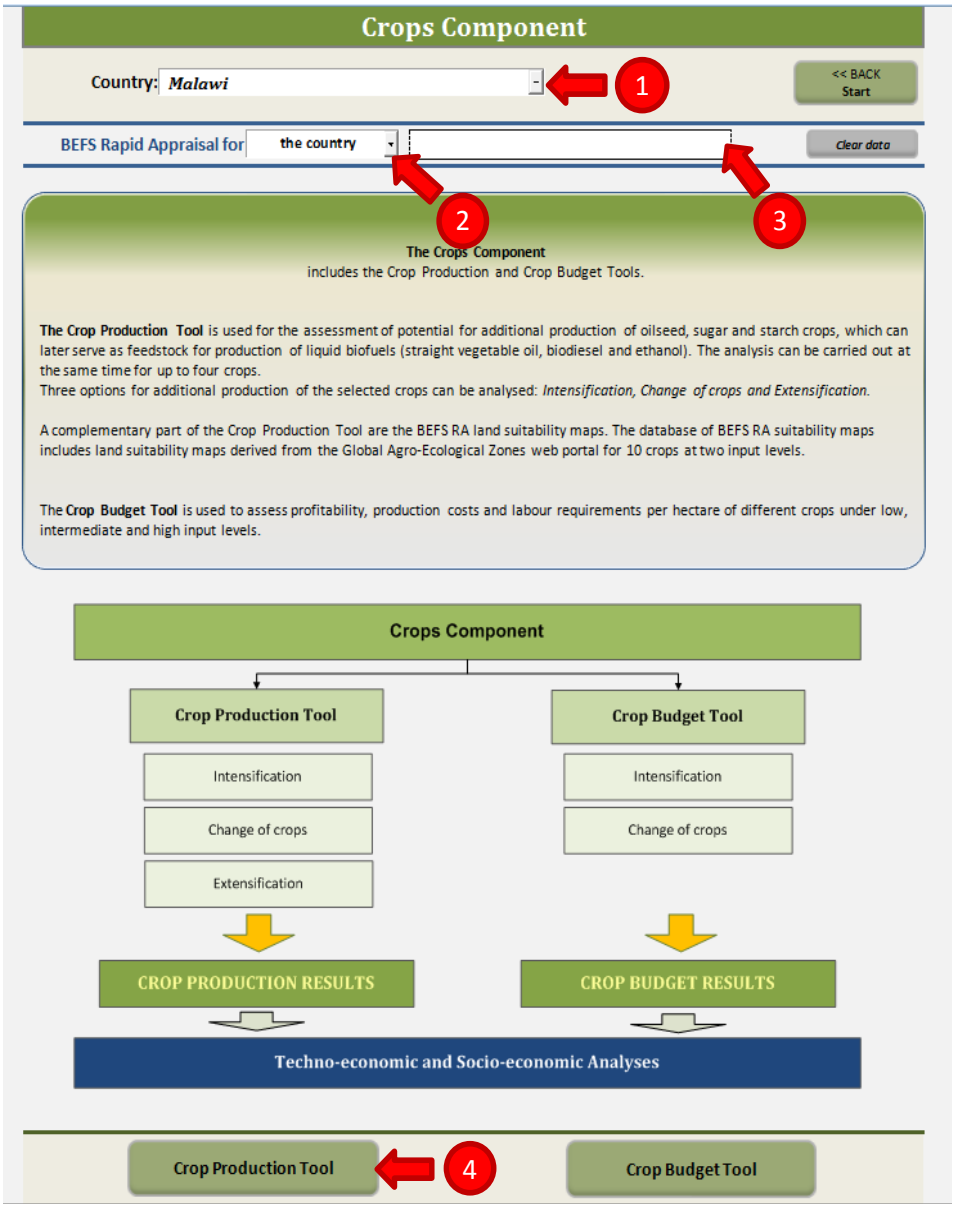

Figure 6: Layout of the *Crops Component* Introductory Sheet

4.2 Step 2: Selection of crops

The first step is to select crops that will be analysed as potential feedstock for the production of liquid biofuels. Up to four crops can be analysed at the same time and they are selected from a dropdown list (Figure 7). The list includes 25 key food and cash crops, among which thirteen crops are suitable for the production of liquid biofuels: coconut, jatropha, rapeseed, soybean, oil palm and sunflower for the production of straight vegetable oil and biodiesel, and barley, cassava, maize, sugar beet, sugarcane, sorghum and wheat for the production of ethanol.

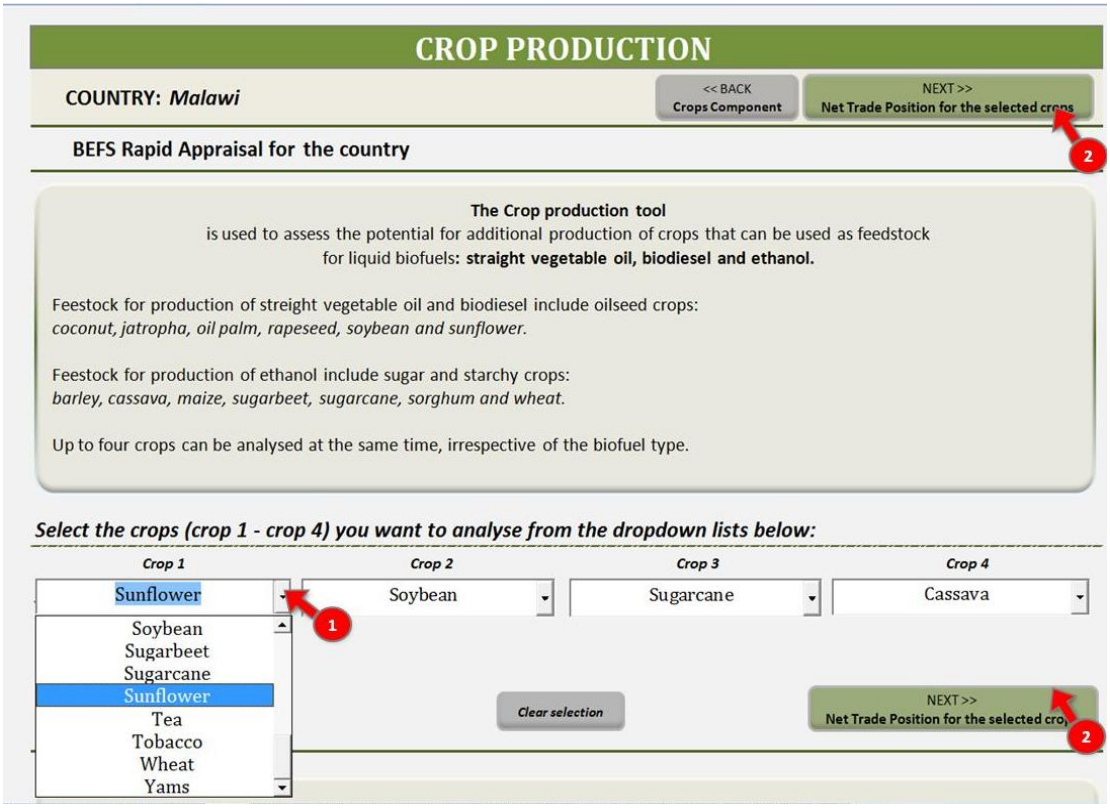

Figure 7: Layout of the Introductory Page of the *Crop Production Tool*

When selecting the crops, the country context has to be considered, especially the aspects of energy balance, agricultural production, technological and human capacity, etc. Following are some important questions the user must take into account (the list serves as a guidance and there are most likely other issues which should be considered within the specific country context):

- *Energy Balance*
  Is the country a net energy importer or exporter? What are the priorities in the energy supply – electrification, substitution of fossil fuels in transport sector, development of the sector for export purposes?
- *Food Production and Security*
  Is the country food secure? What are the key food crops in the country? What is the country's net trade position for these crops?
- *Agricultural Production*
  Which of the crops suitable for the production of liquid biofuels are already being produced in the country (area of analysis)? What is the level and type of production? What is the knowledge capacity of farmers?

- *Industry*
  What is the level of human and technological capacity for the establishment/further development of the biofuel industry?

The information from the *Country Status* module can help in the selection of the bioenergy crops.

4.3 Step 3: Defining the net trade position for the selected crops

After selecting the bioenergy crops, the country's net trade position for these crops should be defined. The net trade position is defined by entering information about the production, imports, stock variation, exports and domestic supply of the country over the past 10 years (Figure 8).

The steps to obtain the required data and enter them into the appropriate tables of the Net Trade Position sheet are the same as those applied in the *Country Status* module. Please refer to the respective chapter in the *Country Status Manual* for detailed instructions.

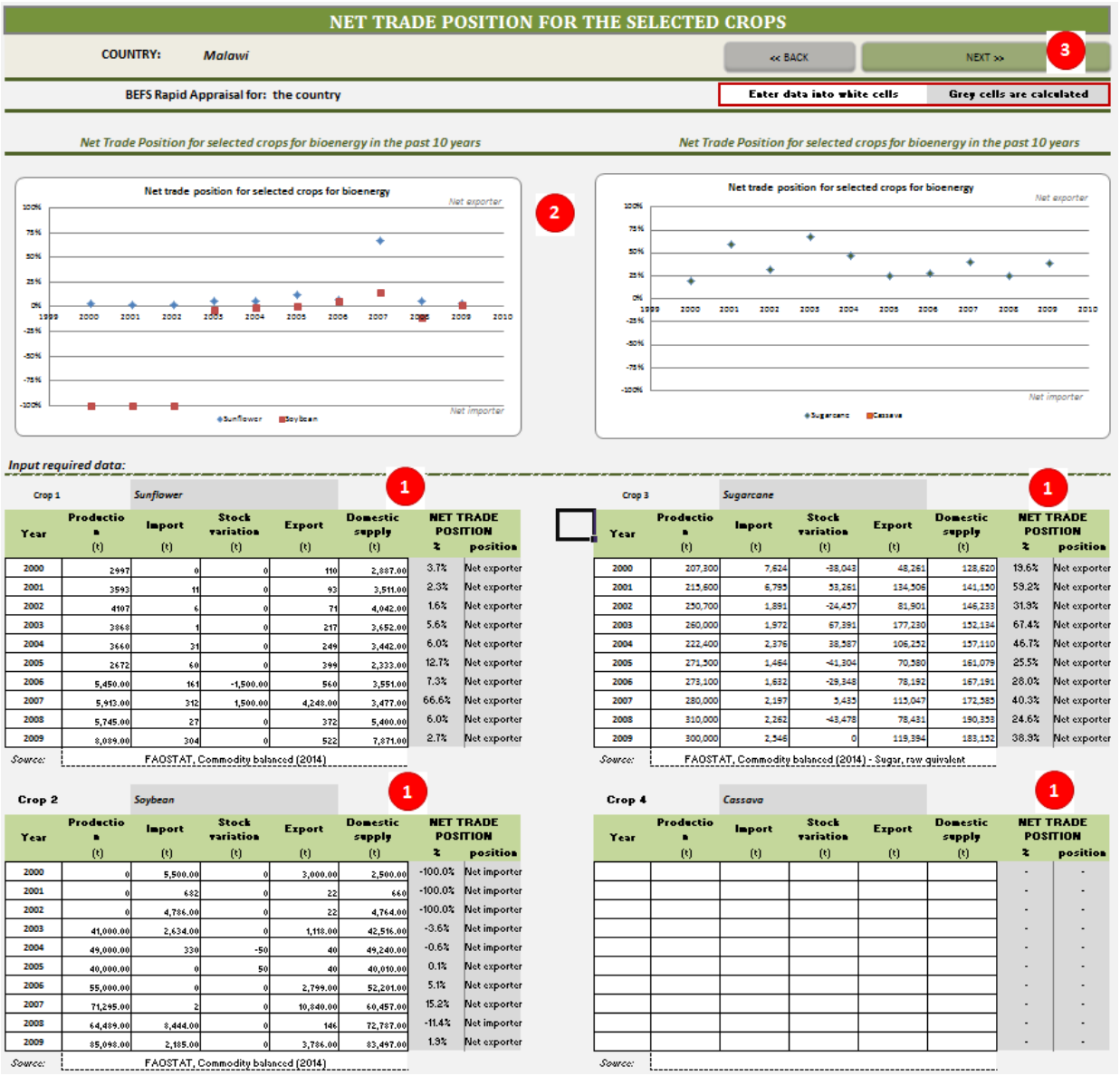

Figure 8: Layout of the Net Trade Position Sheet

When entering the data, the user must consider and understand the circumstances behind the net trade position of each crop examined. As described in the *Country Status Manual*, some crops are not internationally traded and therefore the country's net trade position for them is not assessed. In the case of sugar crops, such as sugarcane, the user should bear in mind that the crop itself is not traded. What is actually traded is raw sugar, due to the fact that the first stage of sugar processing takes place as close to the production field as possible. Therefore, the net trade position for raw sugar (not sugarcane) should be defined, i.e. data for raw sugar needs to be entered into the appropriate table.

The net trade position of the selected crops gives a structured overview of the production, consumption and trade at the country level over the past 10 years. The user should carefully analyse the net trade position for each crop, seek to understand the context and take it into consideration throughout the analysis.

Box 1: Interpreting the Net Trade Position of the Analysed Crops for Malawi

In the case of Malawi, four crops were selected: sunflower, soybean, sugarcane and cassava. Sunflower and soybean were chosen as potential feedstock for straight vegetable oil and biodiesel, while sugarcane and cassava were selected for ethanol production. Cassava is a non-tradable crop and was thus excluded from the net trade position analysis (Figure 8, Crop 4). For sugarcane, the net trade position for raw sugar was defined, for the reasons previously stated. Based on the data entered and the corresponding graphs (Figure 8, label 2), which demonstrate the net trade position for sunflower and soybean on the left and raw sugar on the right, the following can be concluded about each analysed crop:

- *Sunflower:* Throughout the past 10 years, Malawi was a net exporter of sunflower. In most years, the country had an exporting position rate of 1.6-7.3%, but had spikes of 12.7% and 66.6% in 2005 and 2007, respectively. The production level was more or less the same from 2000-2005, and then rose annually from 2006-2009. The consumption level stays steady with a slight rise starting in 2008.
- *Soybean*: In the period from 2000-2004, Malawi was a net importer of soybean, but this changed in 2005, when country became a net exporter. This occurred due to a change in production. In the early 2000s, the country did not produce any soybean. However, Malawi began soybean production in 2003 and increased production, more or less, since then. Simultaneously, domestic supply (consumption) also increased. In 2008, a drop in the production, which may have been caused by environmental or other disturbances, and an increase in consumption led the country to becoming a net importer once more.
- *Sugarcane (raw sugar):* Malawi is a net exporter of raw sugar, at a rate between 19.6% and 67.4%. The data shows an increasing trend in production and domestic consumption; however the latter occurs at a lower rate.
- *Cassava:* Since this crop is not traded internationally, it can be concluded that all production is consumed domestically. In the *Country Status* module, cassava was identified as one of the staple crops.

4.4 Step 4: Selecting the production option

After defining the country's net trade position for the selected crops, the user should select the option for additional production (Figure 8, label 3).

As described previously, three options for additional production can be analysed: intensification, change of crops and extensification of current production. It is recommended to start with the intensification option and then assess other options (Figure 9).

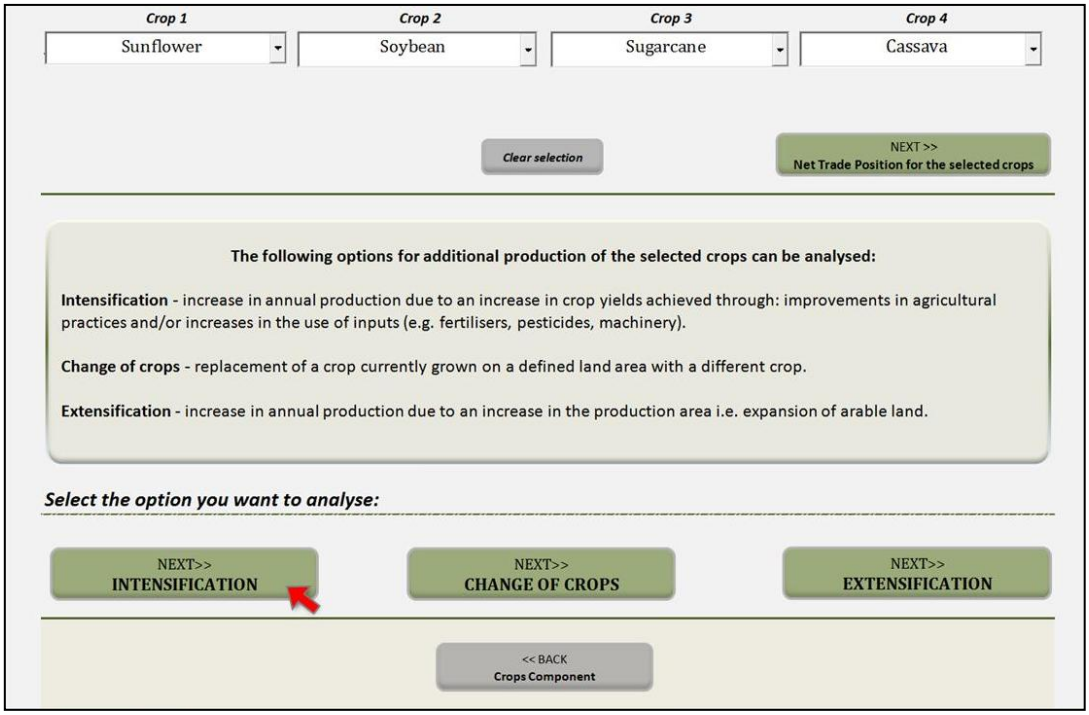

Figure 9: Layout of the Crop Production Sheet – Three Options for Additional Production

4.5 Step 5: Analysing the intensification option

In the Intensification sheet, the user has to enter data on:

1. Current production of the selected crops (Figure 10, label 1)
   - Current yield (t/ha)
   - Number of harvests per year
   - Annual production (t/year)

If the required data are available from national statistics or reports, they should be used. In case such data are unavailable, the default values from FAOSTAT can be used (Figure 10, label i). The tool includes a table on the 10-year average yield and total production at country level. These values reveal neither the level of production (e.g. smallholders or large-scale/market-oriented) nor if production comes from rain-fed or irrigated agriculture.

2. Intensified production of the selected crops (Figure 10, label 2)
   - Water supply (irrigation or rainfed)
   - Input level (high, intermediate or low)
   - Intensified yield (t/ha)
   - Number of harvests per year

If information on the potential yields in the analysed area is not available from a country specific agro-ecological zoning or from equivalent studies or research, the potential yields from GAEZ can be used. This

version of the tool includes the potential yields under rainfed or irrigated conditions based on the GAEZ database. Under rainfed conditions, GAEZ provides potential yields for low and intermediate input levels of agricultural production, whereas for irrigated conditions, the database provides potential yields for intermediate and high input levels. For each agricultural production input level, potential yields for three soil suitability classes are shown: country average, suitable-very suitable, moderately suitable (Figure 10, label ii). The country average represents a weighted average of potential yields for very suitable, suitable, moderately suitable and marginally suitable land. The country average is calculated based on the potential yield for each suitability class (according to the GAEZ land suitability classification) and the proportion of each suitability class in the country. For rainfed production systems, the user should consult the BEFS RA land suitability maps for the selected crops/input levels in addition to the data on potential yields shown in the Intensification sheet. The maps are stored in the database and can be downloaded from the BEFS Rapid Appraisal website. The database of BEFS Rapid Appraisal Suitability maps includes country level maps for 10 crops suitable for the production of liquid biofuels at two input levels (high and low) for each crop. At the moment, only maps for Africa, Asia and South America are available. An example of this type of map is given with Figure 11.

Based on the land suitability maps and potential yields under different input levels, the user can evaluate current production and identify if there is an existing yield gap, to then determine the "intensified yield" value that will be used in the analysis (Figure 10, label 2). When making this decision, the user should consider factors and circumstances relevant for agricultural intensification, such as: 1) the likelihood that there will be an increase in agricultural inputs and related costs, 2) the extent of improvements across the assessed area within a defined timeframe (e.g. long-term, medium, short-term planning) and 3) any other factors involving intensification. The information provided in the Summary of Results - Crop Budget for Intensification section in the *Crop Budget Tool* can serve as a guide for the user before making this decision[9].

[9] For further information and a detailed explanation see the *Crop Budget Manual*.

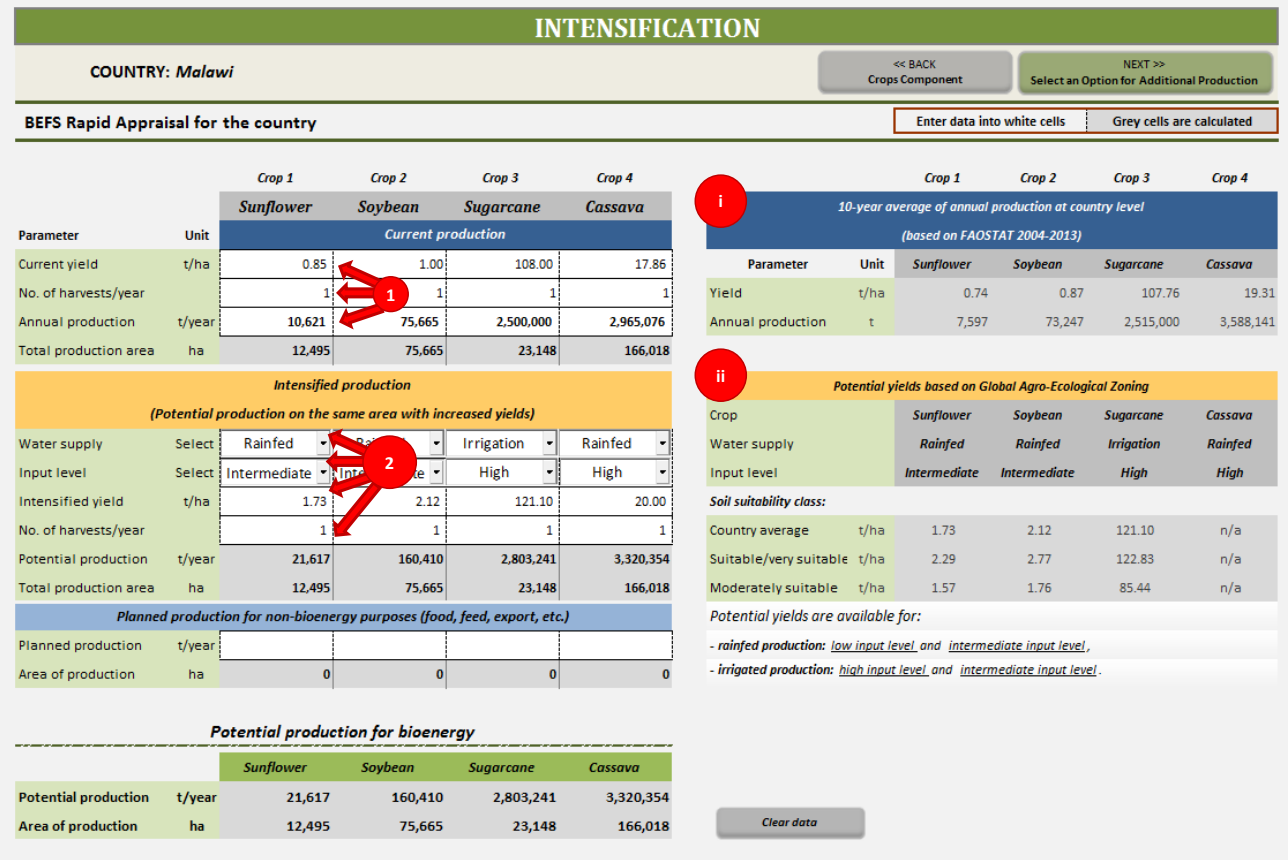

Figure 10: Layout of the Intensification Sheet – Part 1

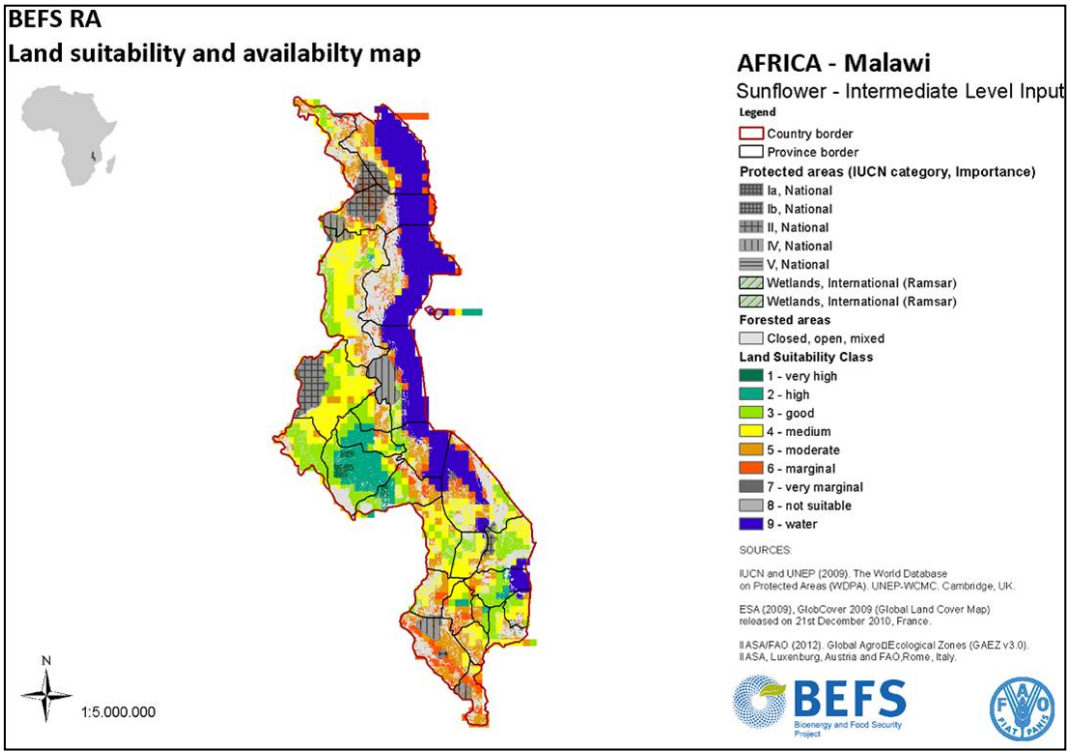

Figure 11: BEFS RA Land Suitability Map for Malawi: Sunflower at Intermediate Input Level

3. Planned production for non-bioenergy purposes (Figure 13, label 3).

The planned production for non-bioenergy purposes refers to the amount of selected crops that will be used as food, feed, production of other commodities and exports. When defining this amount, the user should take into account the timeframe of the analysis (e.g. long-term, medium, short-term planning), such as: the time expectations to achieve the expected increased yields, and the demand anticipated for non-bioenergy uses during that time. The user can consult trends in domestic consumption of the selected crops, country population, food supply, economic development trends, and national/subnational strategies and planning documents to help determine these values.

To ensure that food security if always safeguarded, a food security warning notice is integrated into the tool (Figure 12). So, if the entered value for planned production for non-bioenergy purposes is the same or lower than the current annual production, the following warning will pop-up:

> *"Food security warning: The entered value is lower or the same as current production. If the country is currently a net importer or expects an increase in consumption of this crop for food or feed, this may affect food security in the country. Continue?"*

Figure 12: Food Security Warning in the Intensification Option

The user can then decide if he/she wants to continue the analysis or revise the value entered. Upon making the decision, the warning system will remain in the form of "traffic light" within the respective cell. The warning does not have any effect on further analysis, but serves as a reminder for the user. The light will be orange if the value for planned production for non-bioenergy purposes equals the value entered in current production, red if it is lower and green if it is higher. The illustration of the warning system can be seen in the Figure 13, label 3.

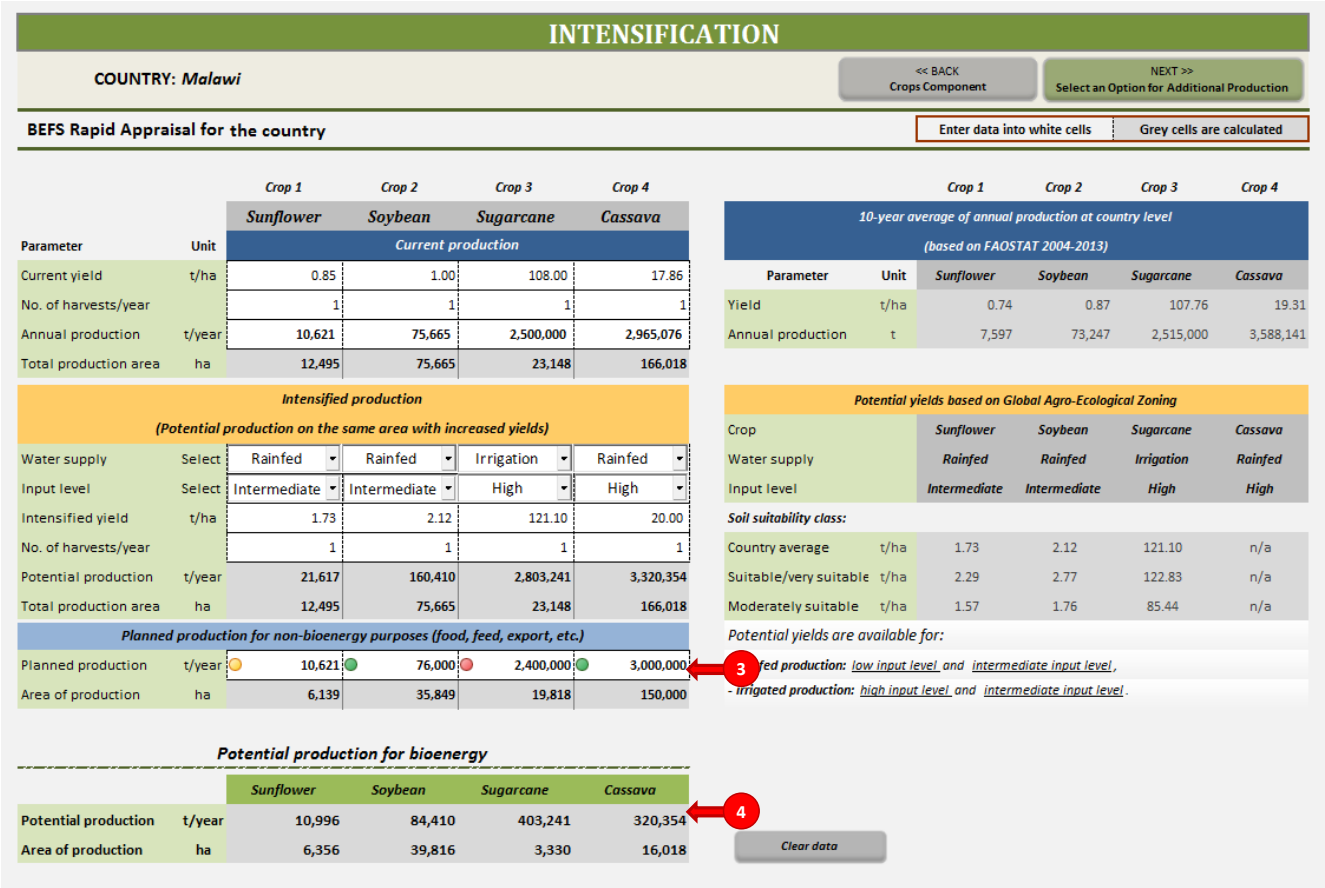

Figure 13: Layout of the Intensification Sheet – Part 2

Based on the data entered, intermediate and final outputs are calculated:

- **The intermediate outputs** include the *"Total production area"* (current production area for the selected crops) and the *"Potential production"* (annual production of the selected crops on the same area with increased yields).
- **The final result** is the *"Potential production available for bioenergy",* i.e. the amount (t) of the selected crops which could be available for production of liquid biofuels (Figure 13, label 4).

After finalizing the intensification option, the user must return to the introduction sheet of the *Crop Production Tool* to select the next option/step.

Box 2: Defining the Potential "Intensified Yield" of Sunflower in Malawi

To illustrate the flow of analysis and the rationale for decisions made during the analysis, the user can look at the example of sunflower in Malawi (Figure 13). According to the national statistics, the country average yield in 2012 was 0.85 t/ha. This is very close to the potential yield at low level inputs on the "country average" land suitability, which is estimated at 0.93 t/ha (GAEZ ver 3.0, IIASA/FAO, 2012). This indicates that average production of sunflower in Malawi is at a low input level. The potential yields for intermediate and high input levels are 1.73 and 3.21 t/ha, respectively (GAEZ ver 3.0, IIASA/FAO, 2012). The foreseen time frame of the analysis was 5-10 years, which is in agreement with national experts. Considering that sunflower is currently primarily produced in subsistence farming systems and that an increase of inputs is necessary for a yield increase, it was concluded that production could be intensified from the current (low) level to an intermediate input level. Therefore, "intermediate" was chosen as the input level under intensified production and a default value of 1.73 t/ha was used as the increased yield. Based on these assumptions, the results show that on the current production area of 12,495 hectares, an additional 10,996 tons of sunflower could be produced. This amount could then be used for production of liquid biofuels, if the consumption for non-bioenergy purposes remains constant at 10,621 tons.

4.6 Step 6: Analysing the change of crops option

In the context of the BEFS Rapid Appraisal, change of crops is seen as one of the options to increase the production of bioenergy crops. In this case, the production area of the selected bioenergy crop expands on the land which is currently used for the production of another crop. Consequently, the production area of the current crop decreases.

If implemented on a large-scale and/or if it involves a crop which is important from a trade or food security point of view, change of crops may have significant impacts on the overall agricultural sector in the country. It is a very complex exercise to forecast the ultimate direct and indirect effects of such a scenario. In line with the objectives of rapid appraisal, the aim of the change of crops option is not to perform this type of analysis, but only to provide an indication about the potential for the additional production of a bioenergy crop if produced on land that is currently under another crop.

For this option, only one of the previously selected bioenergy crops can be assessed against one of the 25 food or cash crops that are included in the tool's databases.

To run this analysis, the user has to enter data on the:

1. Current crop (the user must select the crop which would be replaced from the dropdown list) (Figure 14, label 1)
   - Current production
     - Yield (t/ha)
     - Number of harvests per year
     - Annual production (t/year)
   - Planned production
     - Annual production (t/year)
2. Bioenergy crop (the user must select one of the previously chosen bioenergy crops from the dropdown list) (Figure 14, label 2)
   - Planned production

- Expected yield (t/ha)
- Number of harvests per year

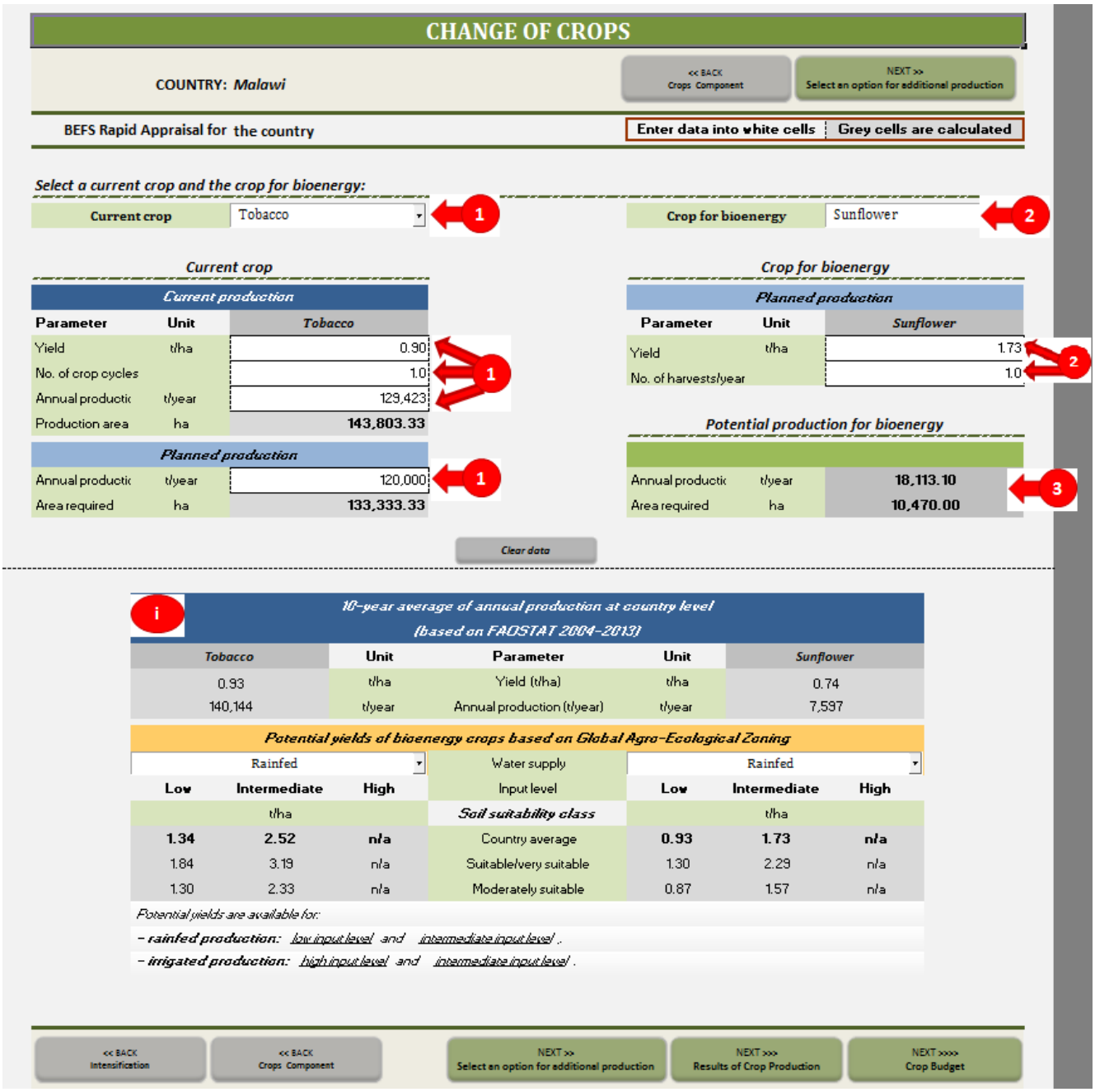

Figure 14: Layout of the Change of Crops Sheet

Utilising the BEFS Rapid Appraisal land suitability maps and information provided by the GAEZ portal, the user can determine which bioenergy crop and/or current crop to select for this option. Moreover, the results of the *Crop Budget Tool* can be of assistance[10].

[10] For further information and a detailed explanation see the *Crop Budget Manual*.

Similar to the other options, if the data needed are not available to the user, the default data on current and potential yields provided by the tool can be used (Figure 14, label i).

Based on the data entered, intermediate and final outputs are calculated:

- **The intermediate outputs** include the current production area and the area required for the planned production of the current crop.
- **The final results** include the *"Annual production"* (potential production) of the analysed bioenergy crop and the *"Area required"* for this production (Figure 14, label 3).

After finalizing the change of crops option, the user must return to the introduction sheet of the *Crop Production Tool* to select the next option/step.

Box 3: Reasons for Considering the Change of Crops as an Option in Malawi

The case of Malawi on the change of crops option is presented in Figure 14. Tobacco and sunflower were selected for this option due to country specific information that derives from the overview of country's agricultural sector:

"The agricultural sector employs nearly 90 percent of the total labour force and contributes about 35 percent to GDP (ILO, 2013). Malawi's economy has long been tied to tobacco production and export, accounting for over 50% export earnings over the last 30 years. Due to Malawi's heavy historical reliance on tobacco, and the threat of shrinking tobacco demand, there has been a recent push to diversify into other export crops" (FAO, 2013b).

Sunflower is considered as one of the potential crops that can contribute to diversification, due to several reasons: 1) the agro-ecological suitability of the land is moderate to very high throughout the country (Figure 11), 2) farmers have some experience in growing sunflower and 3) as an oilseed crop, it can serve both the food and bioenergy markets.

The numbers presented in the Figure 14 should be treated only as an example, as these values are not based on an examination of the sector nor official planning documents.

4.7 Step 7: Analysing the extensification option

Only the possibility for the extensification of crop production can be assessed with this tool. Once the Extensification sheet is activated, the country level information about trends in the land use change is shown. In line with FAO land-use classification, six land use classes are considered: forest area, arable land, permanent crops, permanent meadows and pastures and other land from FAOSTAT and FRA2010 databases. Depending on the changes in forest area and sub-classes of agricultural land (arable, permanent crops and meadows, pastures), the tool generates trend descriptions and gives recommendations for further analysis and/or bioenergy policy measures.

The segment of the Extensification sheet generated by the tool is presented in Figure 15:

- Label 1: FAOSTAT and FRA data on the land use change in the period 1990 – 2010
- Label 2: Graphic presentation of the data
- Label 3: Recommendations generated by the tool

Box 4: The Results of the Extensification Option Assessment for Malawi

Figure 15 shows the layout of the Extensification sheet with data for Malawi. In mid-2013, when the pilot analysis was conducted, the best available data on land use were those from FAOSTAT and FRA databases. Based on this data, the following conclusions and recommendations were deduced by the tool:

"The data on land use change during the period from 2000 to 2010 indicate that the expansion of agricultural land may be one of the key drivers for deforestation. Therefore, it is strongly recommended to implement policy measures and actions aiming at an increase of agricultural yields, without further expansion of arable land".

Considering this and the results of the intensification analysis (that there is substantial yield gap for some of the selected crops), the Malawian experts agreed that, at this point, the expansion of arable land for bioenergy would not be considered.

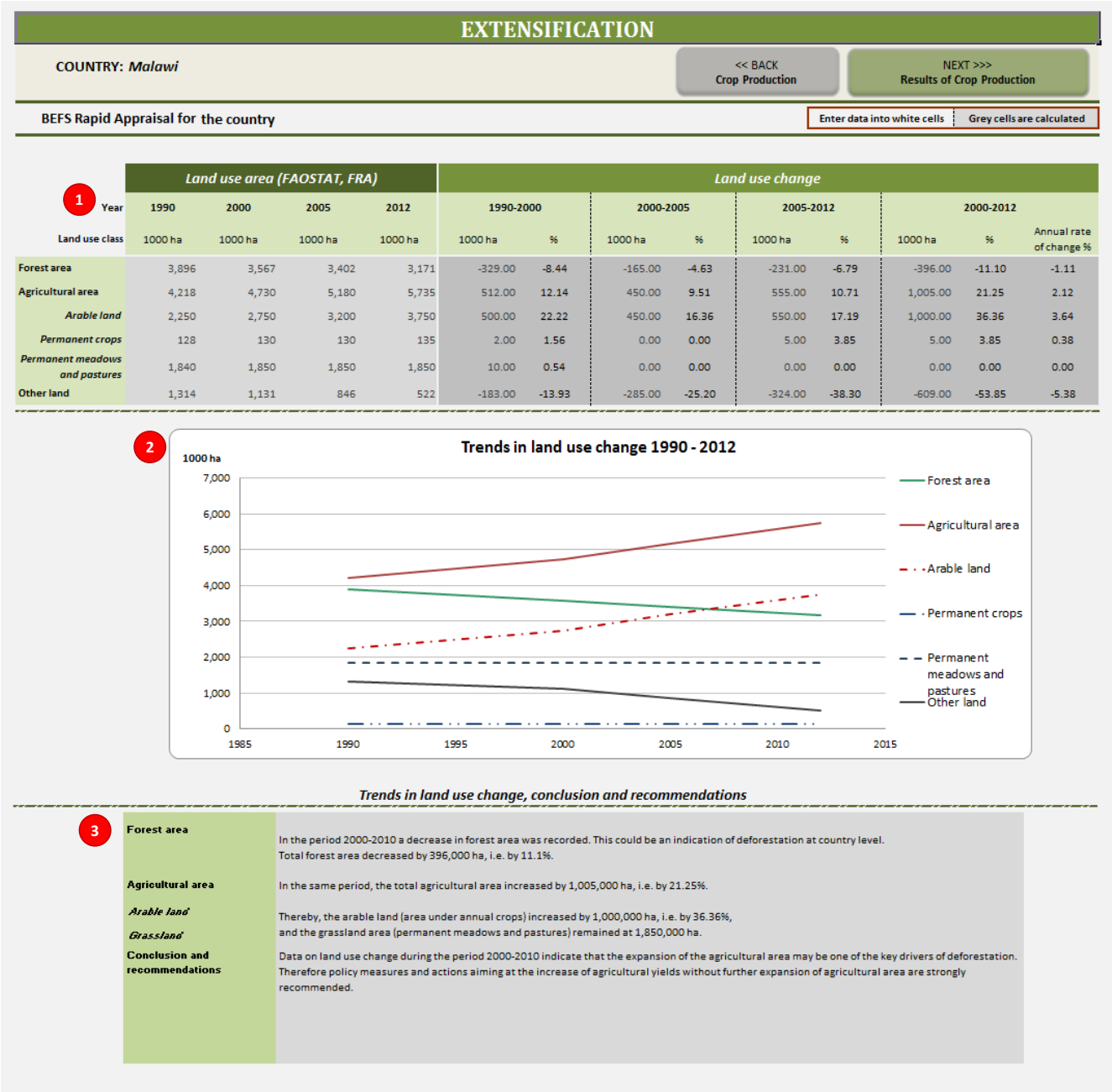

Figure 15: Layout of the Extensification Sheet – Part 1

If there are national/sub-national data available on the land use/land cover, then the user should enter them into the table titled Country Specific Data (User Defined Data). The tool will generate the same type of description and recommendations as described above. The user can then compare the results and decide on further actions.

The following data should be entered:

1. Years corresponding to the data provided on land-use classes (Figure 16, label 1)
2. Area of the forest land, agricultural land, arable land, permanent crops, permanent meadows and pastures, other land (expressed in 1000 ha for each year stated) (Figure 16, label 2)

Based on the data entered, outputs and recommendations are given:

- **The outputs** provided by the tool include numerical (Figure 16, label 3) and graphical (Figure 16, label 4) presentations of the trends in land use change during the defined period.
- **The conclusions and recommendations** are also generated, but this time based on the user defined data (Figure 16, label 5).

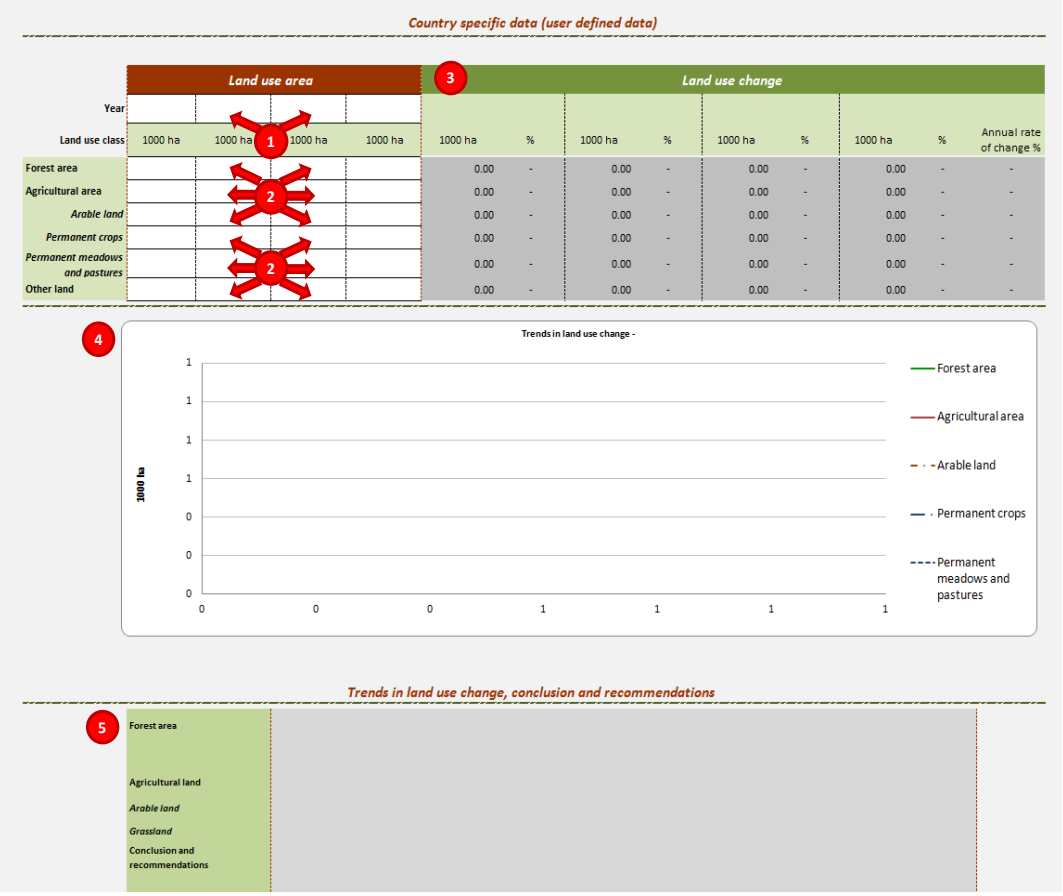

Figure 16: Layout of the Extensification Sheet – Part 2

If the possibility for the sustainable expansion of arable land exists, then the user can calculate the area needed for the production of a defined amount of analysed crops.

To enable calculation of the GHG emissions along the biofuel production chain, the user is asked to provide information about the foreseen land use change.

To run this analysis, the user should click the button labeled “Calculation of Expansion Area” on the bottom of the Extensification sheet.

To calculate the expansion, the following data are needed for each crop selected:

1. Planned production (Figure 17, label 1)
   - Annual production (t/year)
   - Water supply (irrigation or rainfed)
   - Input level (high, intermediate or low)
   - Expected yield (t/ha)
   - Number of harvests per year

Similar to the other options, if the data needed are not available to the user, the default data on current and potential yields provided by the tool can be used (Figure 17, label i). Based on planned production and the expected yields, the tool calculates the area required for the selected crop (Figure 17, label 2).

2. Percentage of each land use/cover class that would be converted into arable land (Figure 17, label 3)
    - Note that the initial land use class has to be defined for all land that will be used for the production of bioenergy crops, i.e. the total must be 100%.

It is important to emphasize that the tool can neither evaluate the sustainability of extensification nor determine where it could take place. Therefore, this section of the extensification option only provides analytical support, based on the data and information provided by the user.

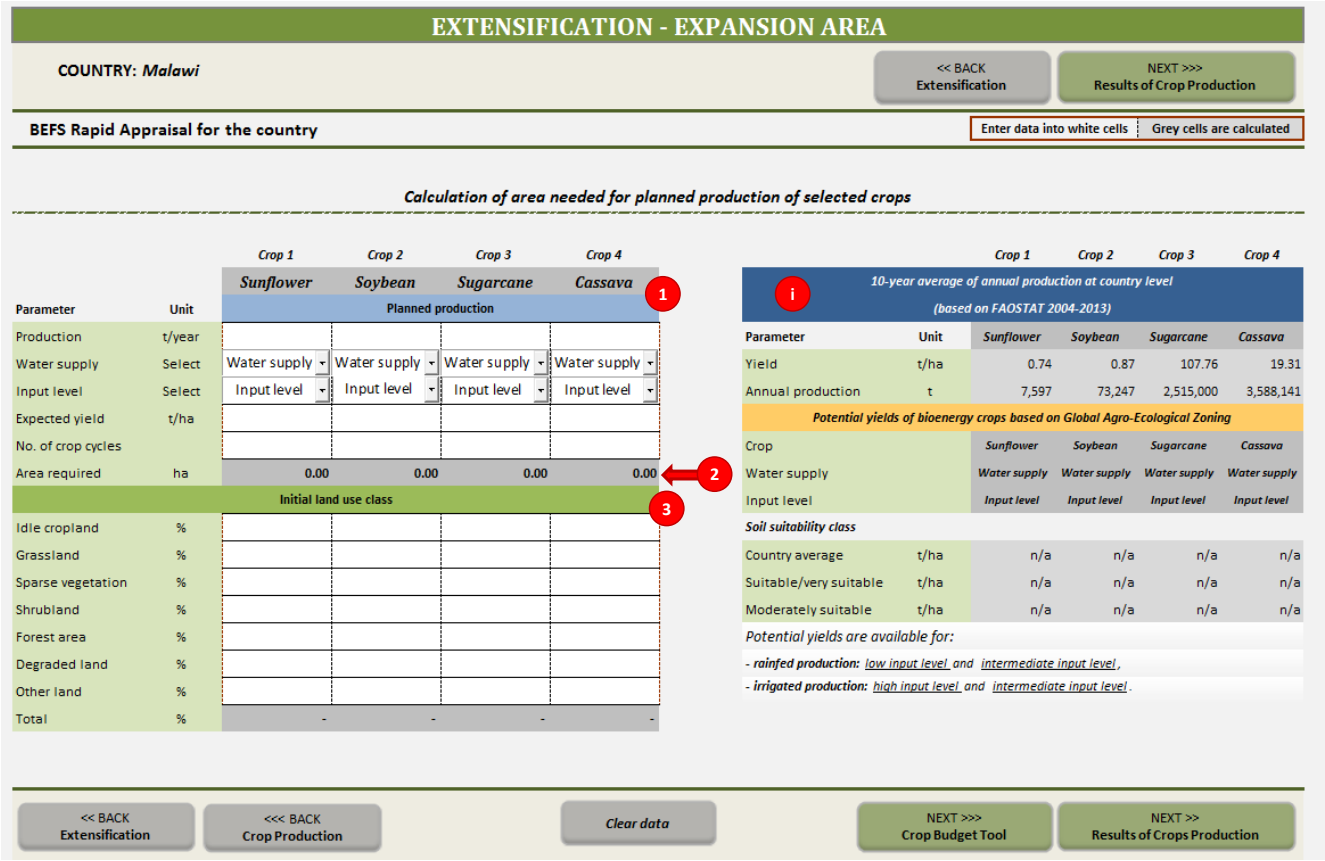

Figure 17: Layout of the Extensification Sheet – Expansion Area

5 The Results of the *Crop Production Tool*

Upon finalizing the analysis, for all or only some options, the results are summarized in the Crop Production Results sheet.

The final results show the potentially available amount of crops that can be used for the production of liquid biofuels. The results for each analysed option, with key information about the foreseen production (yield, number of harvests, area of production) of the selected crops, are displayed both numerically and graphically (Figure 18, labels 1 and 2).

In this sheet, the user can allocate the potentially available oil crops among transport sector and electricity and/or heat. For example, if the objective is to use the bioenergy crop for transportation, then it will be converted to biodiesel. If it is to be used for electricity and/or heat, then it will be converted to SVO (straight vegetable oil). This allocation of feedstock is important for the techno-economic analysis.

The user is asked to input (Figure 18, label 3):

1. The percentage of the available feedstock that will be used for transport (biodiesel and ethanol),
2. The percentage of the available feedstock that will be used for electricity and/or heat (SVO)

The amount (t) allocated to each end use is then calculated and the results depicted (Figure 18, label 4).

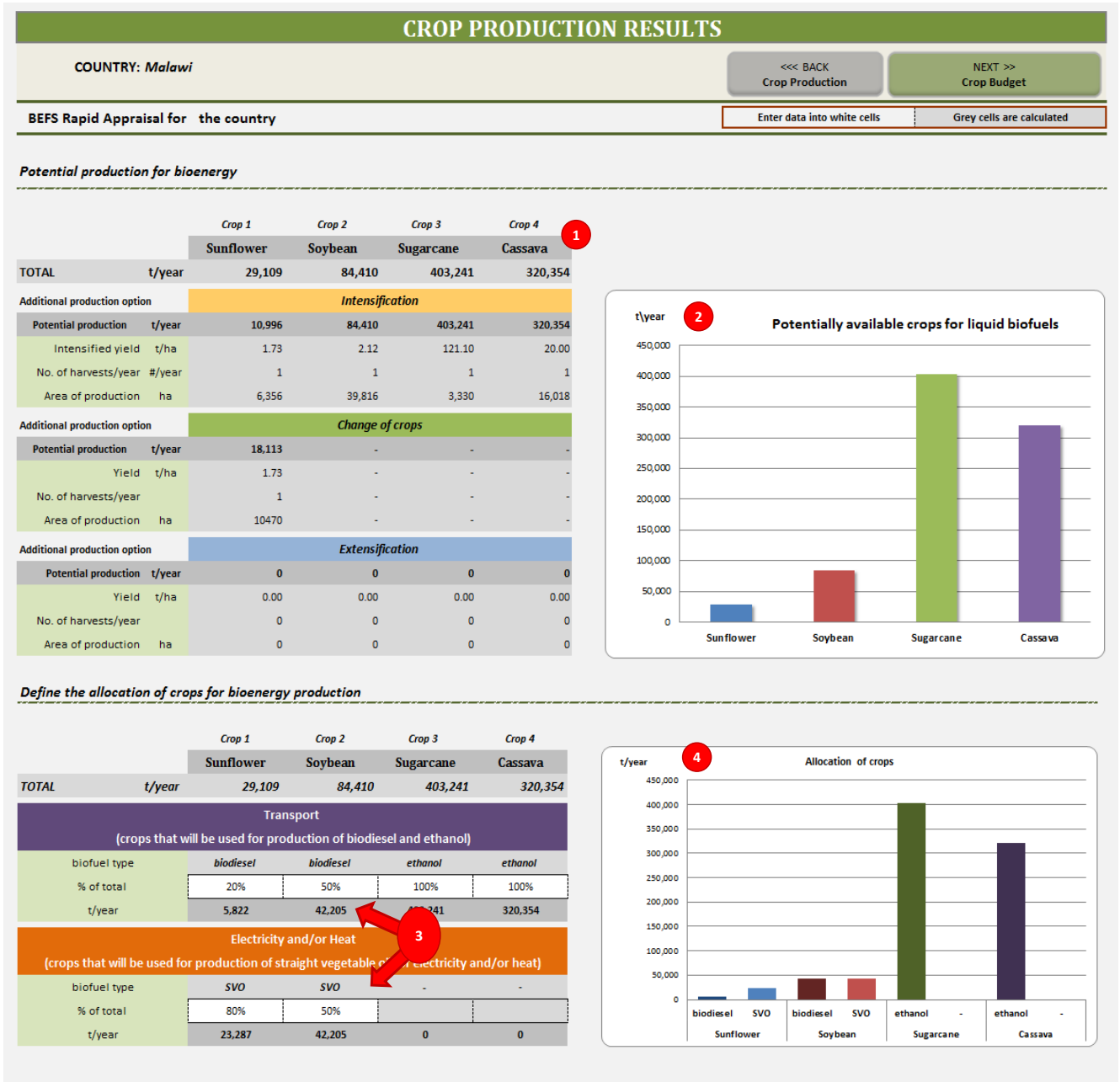

Figure 18: Layout of the Crop Production Results Sheet

6 Assumptions and Limitations of the *Crop Production Tool*

Before starting an analysis, the user should become familiar with the assumptions and limitations of the tools and take them into consideration during the analysis and most especially when interpreting the results. The limitations of the *Crop Production Tool* are twofold. On the one hand, they relate to the aim and objectives of rapid appraisal and on the other hand, to the in-built databases and the characteristics of their sources, namely the FAOSTAT and GAEZ.

The aim of the BEFS Rapid Appraisal is to provide easily applicable and user-friendly tools that can support an analysis even when the user has limited access/availability to the data necessary. Furthermore, the aim of the *Natural Resources* module of is to provide an indication of the potential for the production of bioenergy feedstock in a food-secure and sustainable way.

The first set of limitations is related to the:

- Form of analysis: The tool itself does not support spatial analysis, but provides only numerical results.
- Level of analysis: When using default values provided by the tool, the results represent a country level average, thus not revealing differences at the sub-national and local levels. For sub-national or spatially defined assessments, the user should provide spatially explicit data.

As already stated, the second set of limitations arises from the characteristics of the FAOSTAT and GAEZ databases:

- FAOSTAT is a global database on the world agricultural statistics, managed by the UN FAO. The statistical data stored in FAOSTAT originate from the respective countries, which send their data to the FAO Statistics Division. The FAOSTAT data integrated into the *Crop Production Tool* refer to the whole country, i.e. the yields are averaged at the country level. This means that differences among agricultural practices and technologies, (e.g. subsistence-market oriented, small holder-commercial, rainfed-irrigated) are not revealed.
- GAEZ is a spatially explicit global database. Land suitability and associated potential yields are modelled and presented with at the resolution of 5 arc-minutes[11]. On the country level, this is a rather course resolution, especially in the case of small countries, and therefore provides only an indication. The information included in the *Crop Production Tool* includes aggregated information about potential yields for rainfed agricultural production under low and intermediate input levels, and irrigated production under intermediate and high input level of 25 crops for three types of suitability classes (country average, very high/high and medium).

An overview of the assumptions and limitations for each production option is given in the table below. They are included as part of the methodology description.

[11] Each cell (for which the suitability class is presented) represents approximately land area of 10x10 km.

Table 1: Overview of Assumptions and Limitations for each Crop Production Option

Assumptions	Limitations
Intensification	
- The maximal attainable yield of a crop depends on the prevailing agro-ecological characteristics of the production area and eco-physiological requirements of the crop. - Improved agricultural practices and/or increased use of inputs (fertilizers, agro-chemicals, mechanization, etc.) can result in increased crop yields. The potential for yield increase is positively correlated with the difference between current and potential yield (yield gap).	- The tool provides information about the existing production of selected crops at a country level. These include 10-year average annual yields and country level production, based on statistical data (FAOSTAT, 2013). - Information about potential yields is derived from GAEZ database, which includes modelling results (IIASA/FAO, 2012). - Results represent a country level average, thus not revealing differences at the sub-national and local levels.
Change of Crops	
- The agricultural area subject to change of crops is defined by the user, based on the planned production of the crop currently produced on that land. - The selected bioenergy crop will be grown on the "freed" land.	- The results show only the potential production of bioenergy crop on an area which is currently used for the production of another crop, without providing information on the potential economic and social effects of the change.
Extensification	
- In order to ensure sustainable land use and avoid GHG emissions, forest land, grasslands, wetlands and other biodiversity rich areas, as well as areas important for ecosystem services, are not considered suitable for conversion into agricultural land. - Areas that are suitable for conversion include idle agricultural land, degraded land and areas currently classified as "Other land".	- Accurate country level land cover/land use data and information on past land use changes are often limited or/and hard to access. - Data available in the global databases (FAOSTAT and GlobCover) are either not spatially explicit or not accurate enough to estimate the area available for the sustainable expansion of arable land. Therefore, the tool provides only an indication of the possibility for the expansion at the national level and generic recommendations for policy measures suitable to promote sustainable bioenergy production.

7 Annex

7.1 Methodology and outputs

This section describes the methodologies used in the *Crop Production Tool*. It also includes a description of the databases integrated in the tool. The databases are not visible to the user, but their structure and content are important for interpretation of the results and for those who will update them and/or work on the improvement of the tool.

7.1.1 Intensification option

Intensification of agricultural production means an increase in annual production due to an increase in crop yield, which is achieved through improvements in agricultural practices and/or increase in inputs (e.g. fertilizers, pesticides, machinery).

The assessment is based on the assumptions that:

- The potential for additional production is positively correlated with the difference between the current and potential yield, i.e. yield gap.
- The potential yield of a crop depends on the land suitability, which is determined by the prevailing agro-ecological characteristics of the production area and eco-physiological requirements of the crop.
- Improvements in agricultural practices and/or increased use of inputs (fertilizers, agro-chemicals, mechanization, etc.) can result in increased crop yields.

Considering these assumptions, the potential additional production of selected crops is based on the difference of the potential and current yields. It is calculated as a product of yield difference (t/ha) and current production area of the selected crop (ha):

$$P_{add} = (Y_p - Y_c) \times A_c \qquad (1)$$

Where:

P_{add}, [t] = additional production (t)
Y_p, [t/ha] = potential yield (t/ha)
Y_c, [t/ha] = current yield (t/ha)
A_c, [ha] = current production area (ha)

The amount of crop potentially available for bioenergy is calculated as a difference between total potential production (based on the increased yields) and the amount planned to be used for non-bioenergy purposes.

$$LB_p = P_p - NB \qquad (2)$$

Where:

LB_p, [t] = amount potentially available for liquid biofuels (t)
P_p, [t] = potential production (t)
NB, [t] = amount planned for non-bioenergy purposes (t)

If the selected crop is also a key food crop and the amount foreseen for other uses is lower than the current national consumption, the tool will warn the users that such planning may have negative effects on food security and a respective traffic light sign will appear in the cell.

The final output is the amount (t) of the selected crop(s) that can be available for production of liquid biofuels.

7.1.2 Change of crops option

In the *Crops Production Tool,* change of crops is seen as an option to increase the production of bioenergy crops, in which the production area of the selected bioenergy crop expands on the land which is currently used for the production of another crop. Consequently, the production area of the current crop decreases. It does not refer to the rotation of crops.

The assessment is based on the assumption that:

- The agricultural area subject to change of crops is defined by the user, based on the reduced production of the crop currently produced on that land.
- The selected bioenergy crop will be grown on the "freed" land.

Considering these assumptions, the land area subject to change of crops is calculated as a difference between the current production area and the area required for the planned production of the current crop:

$$A_{CoC} = \frac{P_{cc}}{Y_c} - \frac{P_{pc}}{Y_c} \qquad (4)$$

Where:

A_{CoC}, [ha] = area (ha) subject to change of crops
P_{cc}, [t] = annual production of the current crop
P_{pc}, [t] = planned annual production of the current crop
Y_c, [t/ha] = yield (t/ha) of current crop

The production of bioenergy crop is calculated as a product of the area subject to change of crops (A_{CoC}) and expected yield of the bioenergy crop.

$$P_{CoC} = A_{CoC} * Y_e \qquad (5)$$

Where:

P_{CoC} , [t] = amount (t) the bioenergy crop potentially available for production of liquid biofuels
A_{CoC}, [ha] = area (ha) subject to change of crops/area of the bioenergy crop production
Y_e, [t/ha] = expected yield (t/ha) of the selected bioenergy crop

In the change of crops option, the potential production of one of the bioenergy crop versus one current crop can be analysed. Namely, the user can select one "current" crop from the list of 25 and one bioenergy crop from the list of four, which were selected at the beginning of the crop production analysis.

7.1.3 Extensification option

Extensification refers to an increase of annual production due to increased production area of the analysed crop. Additional production area is gained through the expansion of arable land, which includes land use change. Land use change can refer to bringing idle arable land back to agricultural production or conversion of other land use classes into arable land (permanent crops, grasslands, meadows and pastures, forests, etc.).

With this tool, only the possibility for the sustainable expansion of arable land and its use for production of bioenergy feedstock can be evaluated. The assessment is based on the historic trends in land use change in the country. Trends in land use change are determined according to the area under different land use classes in 1990, 2000, 2005 and 2010. The tool provides information on six land use classes: forest area, agricultural area (arable land, permanent crops, permanent meadows and pastures) and other land (FAOSTAT and FRA2010, FAO 2012). If national/sub-national data are available, the user can enter them in for that appropriate table and compare the results.

The information on the existing trends and recommendations for further analysis and/or bioenergy policy measures are generated by the tool, based on the changes in forest area and subclasses of agricultural land.

The assessment is based on the assumptions:

- That in order to ensure sustainable land use and avoid increase in GHG emissions, forestland, grasslands, wetlands and other biodiversity rich areas, as well as the areas important for ecosystem services should not be considered suitable for conversion to arable land.
- That simultaneous decrease in forestland and increase in agricultural land, indicate that expansion of agriculture may be one of the drivers for deforestation.
- That a decrease of agricultural land over time indicates a decline in agricultural activity and therefore points out a possibility for the expansion of arable land.

If a possibility for expansion of arable land exists, the user can calculate the area needed for production of a planned (user defined) amount of selected crop and document foreseen land use changes. This information data can later be used for the assessment of GHG emissions associated with production of liquid biofuels from the selected crop.

The area needed for the production of selected crop is calculated according to the planned production, expected yield and number of harvests per year:

$$A_{LUC} = \frac{P_{ex}}{Y_e \times H} \qquad (3)$$

Where:

A_{LUC}, [ha] = required production area (area that would be converted into arable land)
P_{ex}, [t] = planned production
Y_e, [t/ha] = expected yield (t/ha)
H = number of harvests per year

7.1.4 Databases

The databases incorporated into the tool support the analyses in the *Crops Component*. In cases when country specific data are not available, the data provided by the tool can be used for the analysis. They include information on country level agricultural production and the potential yields extracted from the global databases FAOSTAT and GAEZ:

1. **FAOSTAT production and yields**
   - **FAOSTAT_production:** includes data on the country level annual production of 25 key food and cash crops for the years 2001-2010. Source: FAOSTAT.
   - **Production:** includes data on the country level 10-years average (2002-2011) annual production of the 26 crops. Source: FAOSTAT_production database.
   - **FAOSTAT_yield:** includes data on the country level yields of 26 key food and cash crops for the years 2001-2010. Source: FAOSTAT.
   - **Yield:** includes data on the country level 10-years average (2002-2011) yields of 25 the crops. Source: FAOSTAT_yield database.
2. **GAEZ yields**
   - **GAEZ_LIL_Y:** includes potential yields for 25 key food and cash crops for rainfed, tillage based agriculture under the low level input, for three land suitability classes: country average, very suitable/suitable land and moderately suitable land. Source: GAEZ Portal, Summary tables.
   - **GAEZ_IIL_Y:** includes potential yields for 25 key food and cash crops for rainfed, tillage based agriculture at the intermediate level input, for three land suitability classes: country average, very suitable/suitable land and moderately suitable land. Source: GAEZ Portal, Summary tables.
   - **GAEZ_IIL_IR:** includes potential yields for 25 key food and cash crops for irrigated, tillage based agriculture at the intermediate level input, for three land suitability classes: country average, very suitable/suitable land and moderately suitable land. Source: GAEZ Portal, Summary tables.
   - **GAEZ_HIL_IR:** includes potential yields for 25 key food and cash crops for irrigated, tillage based agriculture at the high level input, for three land suitability classes: country average, very suitable/suitable land and moderately suitable land. Source: GAEZ Portal, Summary tables.

7.2 Data requirements for running the tool

The tables below include data requirements for running the *Crop Production Tool*. A suggested data source is provided.

Table 2: Data Requirements for Running the Intensification Analysis

Data	Data Source
Current production	
- Current yield (t/ha)	Agricultural statistics (national, sub-national), FAOSTAT. Information provided by the tool.
- Number of harvests/year	Agricultural statistics (national, sub-national), FAOSTAT. NR module *crop catalogue*.
- Annual production (t)	Agricultural statistics (national, sub-national), FAOSTAT. Information provided by the tool.
Intensified Production	
- Input level	Selected in the tool – based on the assessment of the level of current production, results of the crop budget analysis.
- Increased yield (t/ha)	National/sub-national research, national level AEZ, GAEZ For rainfed, tillage based agriculture information provided by the tool.
- Number of harvests per year	See above.

Table 3: Data Requirements for Running the Change of Crops Analysis

Data	Data Source
Current Crop Production	
- Annual yield (t/ha)	Decided by the user if it is current or expected yield. See above for intensification option.
- Number of harvests per year	See above for intensification option.
- Annual production (t)	See above for intensification option.
- Planned annual production (t)	Decided by the user.
Selected Bioenergy Crop Production	
- Input level	See above for intensification option.
- Expected yield (t/ha)	Decided by the user if the expected yield is the same as current or if it will be intensified. See above for intensification option.
- Number of harvests per year	See above for intensification option.

Table 4: Data Requirements for Running the Extensification Analysis

Data	Data Source
Assessment of possibility for expansion of arable land	
- Forest area (ha)	National land use/land cover maps, national statistics on the land use/natural resources management or agriculture, FAOSTAT. Information provided by the tool.
- Agricultural area: arable land, permanent crops, permanent meadows and pastures (ha)	
- Other land use classes (ha)	
Calculation of area needed for planned production of selected crops	
- Planned production (t)	Decided by the user.
- Expected annual yield (t/ha)	See "average annual yield" and "increased yield" for intensification option.
- Number of harvests per year	See for intensification option.
- Initial land cover/land use class	See above.
- Land use classes that will be converted to arable land	Decided by the user, based on the planned production area and current land use/land cover.

8 References

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