



**BIOENERGY AND FOOD SECURITY  
RAPID APPRAISAL (BEFS RA)**

**User Manual**

**WOODFUEL PLANTATION BUDGET**



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BEFS Rapid Appraisal

# Natural Resources Module

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Woodfuel and Wood Residues Component

## **Section 2: Woodfuel Plantation Budget**

User Manual

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# BEFS RA User Manual Volumes

- I. Introduction to the Approach and the Manuals
- II. Country Status Module
- III. Natural Resources Module
  - 1. Crops
    - Section 1: Crop Production Tool
    - Section 2: Crop Budget Tool
  - 2. Agricultural Residues
    - Crop Residues and Livestock Residues
  - 3. Woodfuel and Wood Residues
    - Section 1: Forest Harvesting and Wood Processing Residues
    - Section 2: Woodfuel Plantation Budget**
- IV. Energy End Use Options Module
  - 1. Intermediate or Final Products
    - Section 1: Briquettes
    - Section 2: Pellets
    - Section 3: Charcoal
  - 2. Heating and Cooking
    - Biogas Community
  - 3. Rural Electrification
    - Section 1: Gasification
    - Section 2: SVO
    - Section 3: Combustion
  - 4. Heat and Power
    - Section 1: CHP (cogeneration)
    - Section 2: Biogas Industrial
  - 5. Transport
    - Ethanol and Biodiesel

## Table of Contents

1	Overview of the Natural Resources Module .....	3
2	Terms and Definitions in the <i>Woodfuel Plantation Budget Tool</i> .....	4
3	Scope and Objective of the <i>Woodfuel Plantation Budget Tool</i> .....	7
4	Running the <i>Woodfuel Plantation Budget Tool</i> .....	8
4.1	Step 1: Starting the analysis .....	8
4.2	Step 2: Entering growth characteristics and production data.....	11
4.3	Step 3: Entering country general data.....	12
4.4	Step 4: Entering planting and management costs.....	13
4.5	Step 5: Analysing the results .....	15
5	Assumptions and Limitations of <i>Woodfuel Plantation Budget Tool</i> .....	18
6	The Results of the <i>Woodfuel Plantation Budget</i> .....	19
7	Annex.....	20
7.1	Methodology .....	20
7.2	Data requirements for running the <i>Woodfuel Plantation Budget</i> .....	20
8	References .....	22

## List of Figures

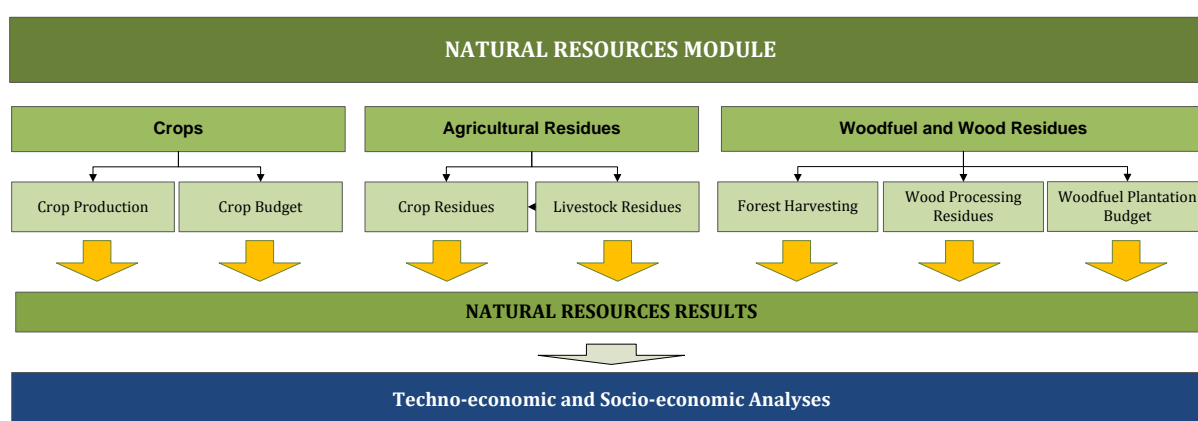
Figure 1: The Structure of the <i>Natural Resources</i> Module.....	3
Figure 2: Forest Types (Source: FAO, 2006b) .....	5
Figure 3: Types of Woodfuels and End Users (Source: FAO, 1995) .....	6
Figure 4: Opening the <i>Woodfuel and Wood Residues Component</i> File.....	9
Figure 5: Language Selection .....	10
Figure 6: Layout of the <i>Woodfuel and Wood Residues Component</i> Introductory Sheet .....	10
Figure 7: Layout for the Selection of Tree Species Sheet .....	11
Figure 8: Layout of the Growth Characteristics and Production Sheet.....	12
Figure 9: General Data Entry .....	13
Figure 10: Layout of the Tree Species-Specific Data for User-Defined and Default Values .....	15
Figure 11: Layout of the “User-Defined” and “Default Values” Profiles .....	15
Figure 12: Layout of the Analysis of Woodfuel Plantation Results Sheet – Numerical.....	16
Figure 13: Layout of the NPV Profile for <i>Acacia mangium</i> – Comparison between “User-Defined” Profile and “Default Values” Profile.....	17
Figure 14: Comparing the NPV Profile between Two Forest Plantation Species .....	17
Figure 15: Layout of the Wood Energy Content among the Selected Tree Species.....	18

## 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<sup>4</sup> that are suitable for the production of liquid biofuels and were generated using the Global Agro-Ecological Zoning<sup>5</sup> 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.

<sup>4</sup> The 10 crops are: cassava, maize, sorghum, sugarbeet, sugarcane, jatropha, oil palm, rapeseed, soybean and sunflower.

<sup>5</sup> *Agro-ecological suitability and productivity – Total production capacity maps*



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 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.

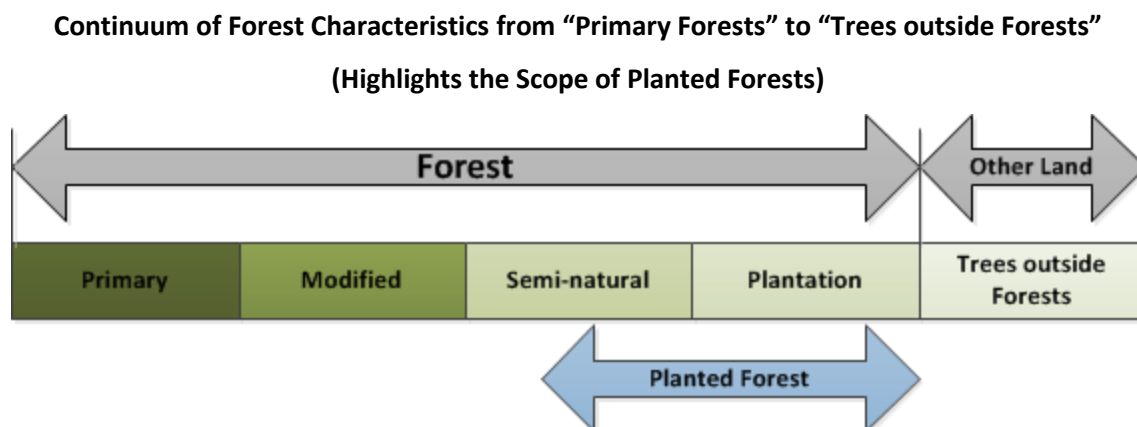
For example, upon assessing the potential for additional production of soybean and sunflower in the results sheet, the user will need to define the percentage of the available crops for the production of straight vegetable oil (SVO) and for biodiesel. These feedstock amounts are then fed into the *SVO 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 *Woodfuel Plantation Budget Tool*

Forest plantations constitute one category of planted forests together with semi-natural forests (Figure 2). Plantations can be further divided into either protective or productive plantations according to the function of the forest plantation. Protective forest plantations are forests of native or introduced species established through planting or seeding, and are mainly for the purpose of providing environmental services (FAO, 2006a). Productive plantation forests are forests of introduced or, in some cases, native species established

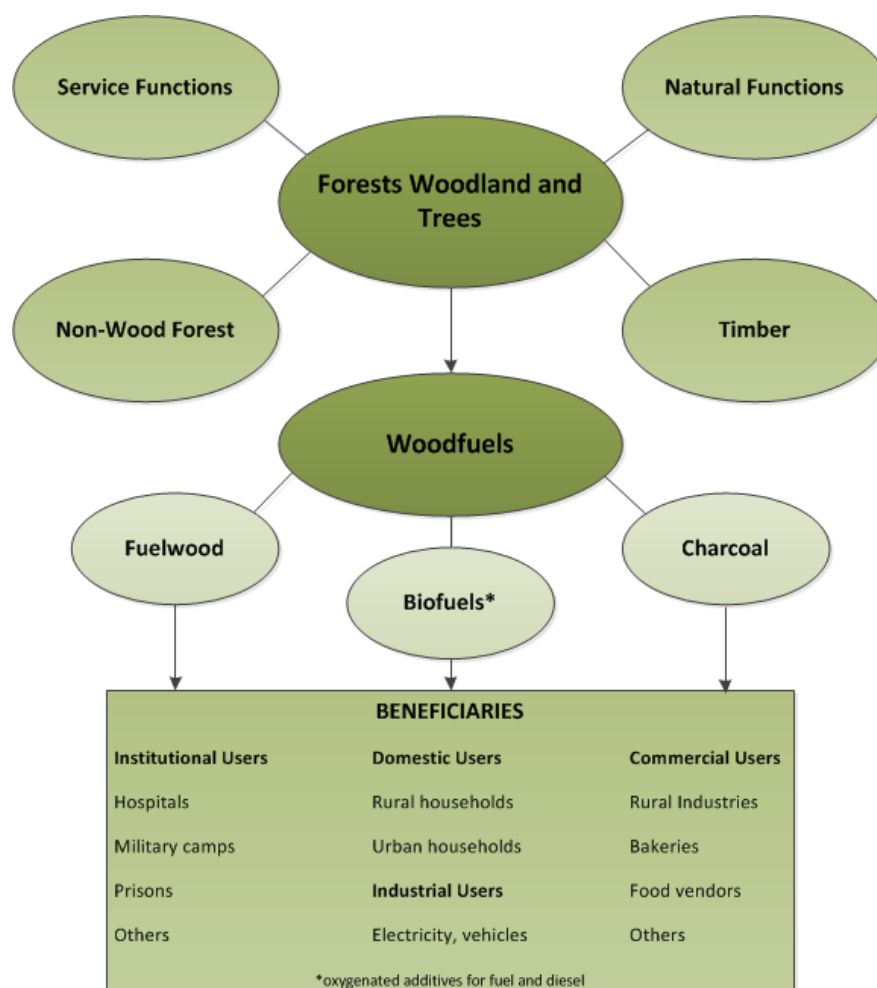
through planting or seeding, and are mainly for the production of wood or non-wood forest products (FAO, 2006a).



**Figure 2: Forest Types (Source: FAO, 2006b)**

This section includes terms and definitions used in the *Woodfuel Plantation Budget*. It is important to understand these definitions prior to running the tool and to consider them throughout the analysis, in order to interpret the results correctly.

- **Woodfuel** encompasses all types of biofuels derived directly and indirectly from trees and shrubs that grow on forest and non-forest land. This category also includes fuels derived from forest energy plantations (FAO, 2004). Three types of woodfuels and their associated end users are shown in Figure 3.



**Figure 3: Types of Woodfuels and End Users (Source: FAO, 1995)**

For the purpose of this tool, the analysis focuses only on woodfuel plantations since other BEFS RA tools examine the conversion of wood from forest plantations to charcoal and briquettes.

- The **Rotation Length** is the age of the stand of trees when harvested. The harvesting time depends on a number of factors including the species, management practices, profitability, growth rates, desired properties of the wood and fibre, site constraints and socio-economic factors (Rosengren, 2009, 13). The rotation length of plantations, used for the production of fuelwood, will be fairly short, especially if fast-growing species are used and the goal of the production is maximize the harvestable volume.
- The **Mean Annual Increment (MAI)** is the volume of wood growing on one hectare of forest plantation during one year, on average, since the establishment of the forest plantation. This is expressed in m<sup>3</sup>/ha/year. Default values are estimated using average values from existing literature at the global level. For calculation purposes, the MAI is defined as the merchantable stand volume at harvesting time divided by the rotation length.
- The **Planting Density** (or stocking) is defined as the number of trees, seedlings or cuttings planted per hectare. It is highly influenced by the end purpose of the wood being produced.

- The measurement of the profitability of forest plantations is carried out using two discounted cash flow techniques: the **Net Present Value (NPV)** and the **Internal Rate of Return (IRR)**. In order to calculate the profitability of an investment, it is necessary to calculate the total value of all future costs and revenues associated with a plantation as though they were all incurred immediately. This technique is based on the procedure of discounting, since the forestry investments have costs and revenues occurring at different times in the future and must be converted into a common present value. In the context of forest plantations, the NPV is calculated by the sum of these adjusted values over the course of a rotation length. If the NPV is negative, it implies that the investment is not profitable.

The equation used to calculate the NPV is (FAO 2000):

$$\text{Net Present Value} = \sum [C_0 + C_1/(1+r) + C_2/(1+r)^2 + \dots C_n/(1+r)^n]$$

Where:

$C$  = the projected net income in one period

$r$  = the discount rate

$n$  = the rotation length

- For forest plantation investments, the comparative financial indicator that is most commonly used is the **Internal Rate of Return (IRR)** analysis. The IRR is the level of profit expected from an investment project, expressed as an equivalent annual percentage rate of interest on all the financial capital invested in that project (FAO 2000). The IRR is further defined as that rate of interest (discount rate) which makes the NPV of an investment exactly zero. The equation used to calculate the IRR is:

$$NPV = \sum [C_0 + C_1/(1+r) + C_2/(1+r)^2 + \dots C_n/(1+r)^n] = 0$$

### 3 Scope and Objective of the *Woodfuel Plantation Budget Tool*

The aim of the *Woodfuel Plantation Budget* is to assess the potential harvestable volume of biomass from dedicated plantations for bioenergy that can be used in the form of fuelwood and/or as feedstock for charcoal, briquette and woodchip production. The analysis assesses the costs and benefits of forest plantation investments per hectare, provides a comparison of the profitability through two indicators (NPV and IRR) and estimates energy content in the wood harvested for each analysed tree species.

The *Woodfuel Plantation Budget* aims to answer to the following questions:

- How do the profitability and other economic results compare for different selected tree species (i.e. what are the relative costs and benefits of the investment)?
- How do different growth characteristics and input prices affect the profitability of the forest plantation?
- What is the potential energy content in the fuelwood harvested?

The methodology applied and limitations of the tool, as well as the list of required data and suggested data sources are described in the Annex.

## 4 Running the *Woodfuel Plantation Budget Tool*

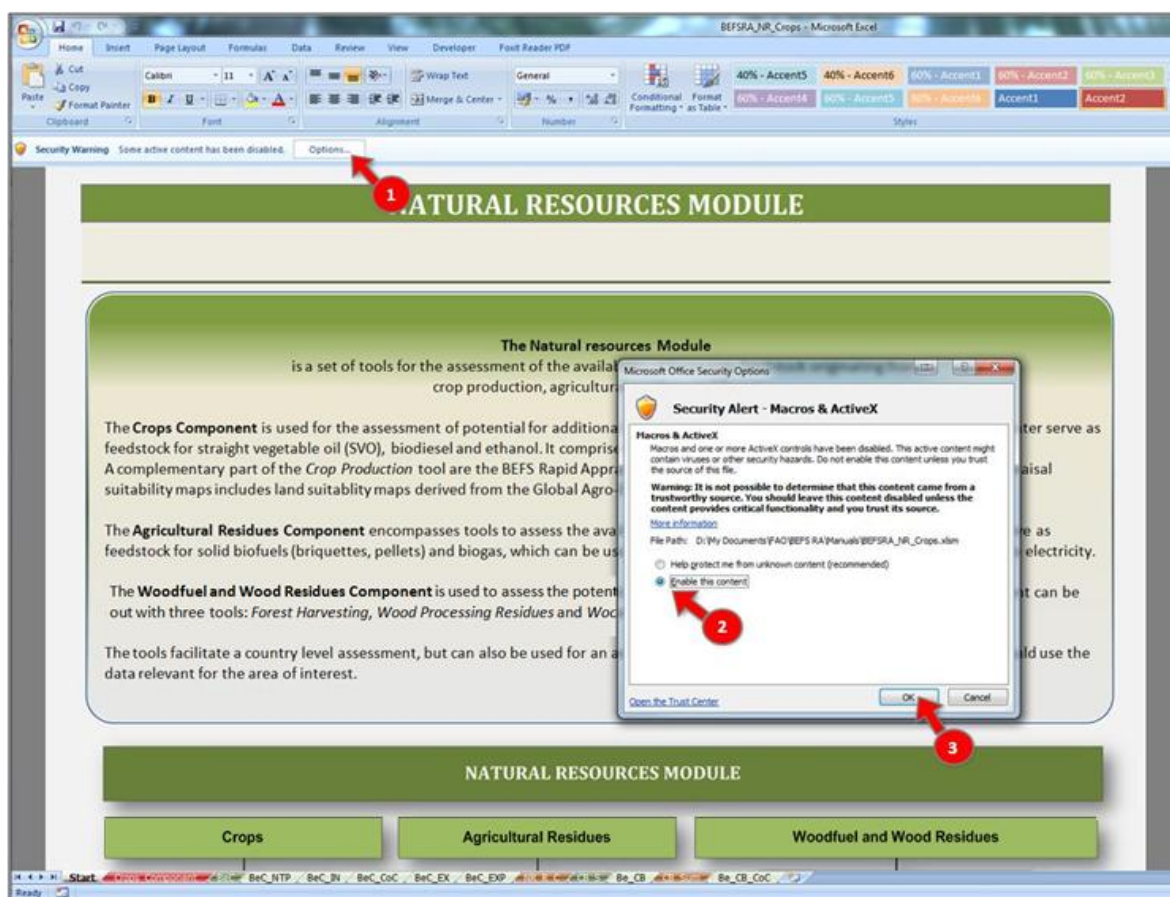
The *Forest Harvesting*, *Wood Processing Residues* and *Woodfuel Plantation Budget Tools* are embedded in the Excel file named *Woodfuel*. It contains eleven Excel sheets, of which the first two give information about the *Natural Resources* module and the *Woodfuel and Wood Residues Component*. The next four sheets are the *Forest Harvesting and Wood Processing Residues Tools* and their results. The last five sheets pertain to the *Woodfuel Plantation Budget Tool* and its results.

Depending on the aim of analysis, the user can decide whether he/she will use all of the tools or only those of his/her specific interest. The flow of analysis is pre-defined and the user is navigated step by step through the tools and asked to enter necessary data in order to obtain final results. When the required data are limited or unavailable, then the default values for a specific set of tree species are provided by the tool and can be utilised. The complexity of analysis depends on the aim, country context and other factors. It has to be emphasized that, due the comprehensiveness of analysis, when interpreting the results the user should take into account all relevant factors, even when certain analytical steps are omitted. 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 Philippines as an example.

### 4.1 Step 1: Starting the analysis

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



**Figure 4: Opening the *Woodfuel and Wood Residues 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 *Woodfuel and Wood Residues Component*.

In the *Woodfuel and Wood Residues 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. Select the *Woodfuel Plantation Budget Tool* button to start the analysis.

Figure 6 shows the layout of the *Woodfuel and Wood Residues Component* sheet with arrows signalling the steps previously described.

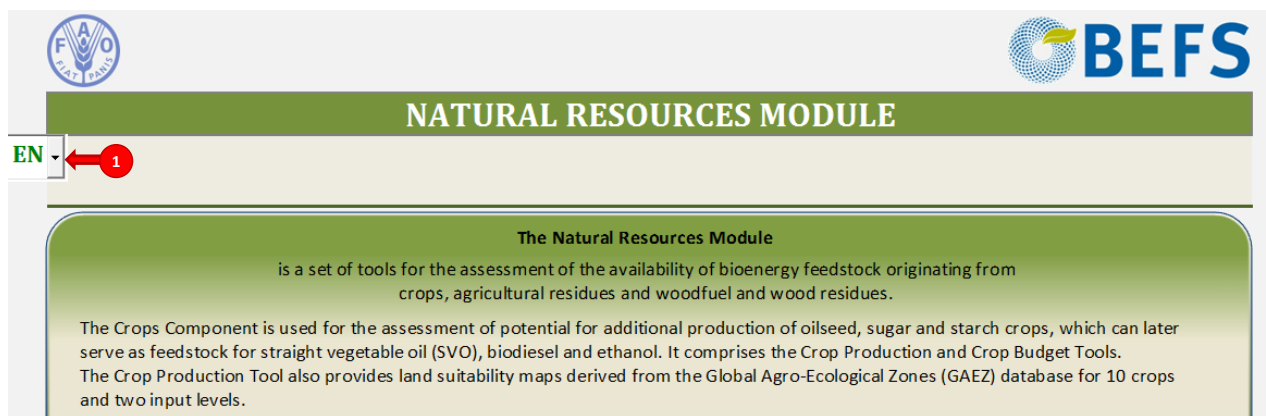
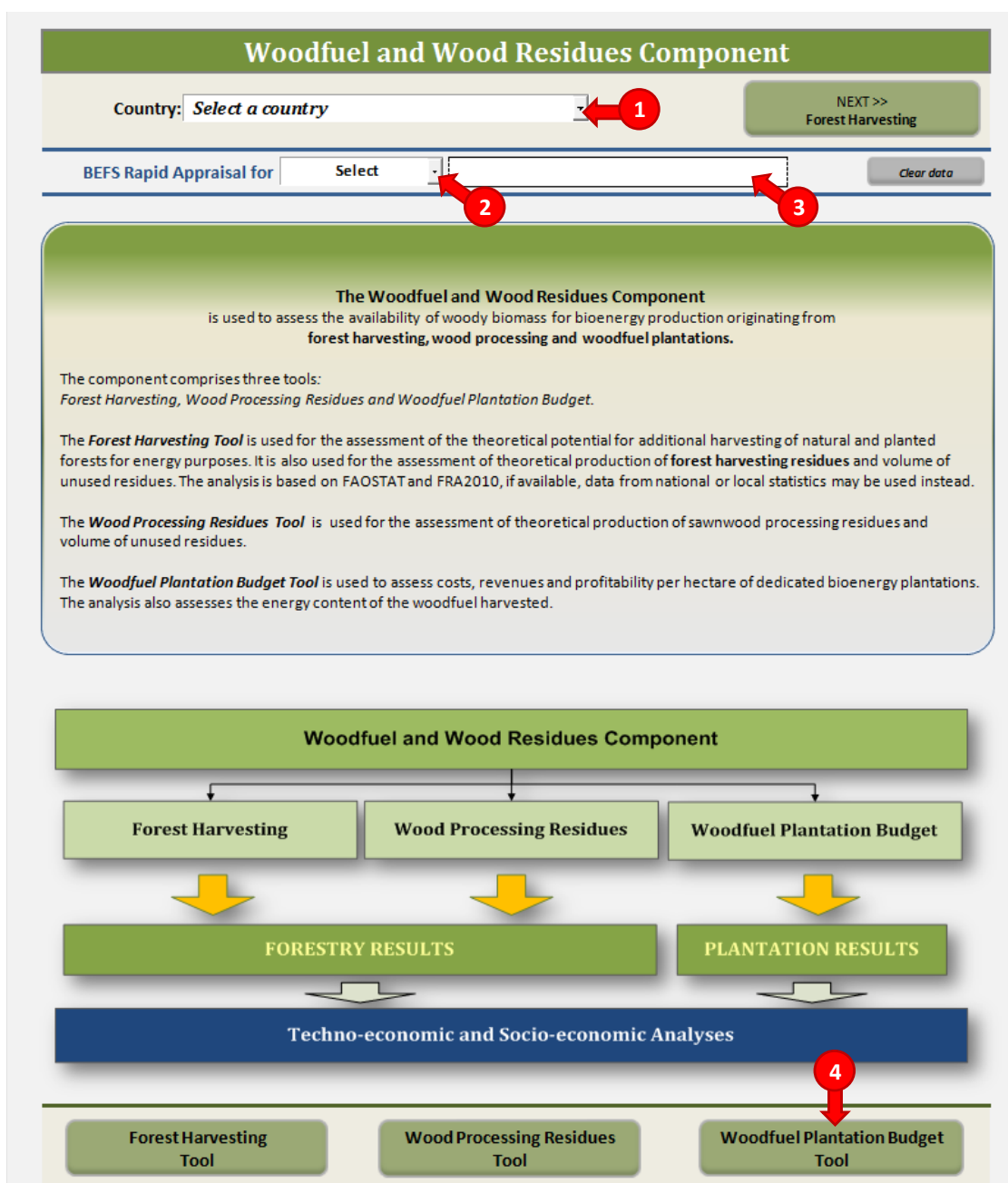


Figure 5: Language Selection

Figure 6: Layout of the *Woodfuel and Wood Residues Component* Introductory Sheet



In the first *Woodfuel Plantation Budget* sheet, the user will select the tree species to be analysed as potential feedstock for the production of wood. Up to two tree species can be analysed at the same time and they are selected from the list provided in the tool (Figure 7). The list includes *Acacia mangium*, *Acacia Senegal*, *Eucalyptus* spp., *Pinus patula*, *Pinus radiata*, *Populus* spp., and *Salix* spp. Furthermore, the user has the option to select a “user-defined” tree species for which he/she must enter the applicable name and data.

Figure 7: Layout for the Selection of Tree Species Sheet

## 4.2 Step 2: Entering growth characteristics and production data

After the user selects the tree species, the user must input the following data on the Growth Characteristics & Production sheet (Figure 8):

1. Growth Characteristics
  - Planting density (tress/ha)
  - Mean Annual Increment (MAI) (average) ( $\text{m}^3/\text{ha}/\text{year}$ )
  - Rotation Length (maximum 30 years) (years)
2. Production
  - Harvestable volume for bioenergy purposes ( $\text{m}^3/\text{ha}$ )
  - Low heating value (energy content) (MJ/kg)
  - Moisture (%)
  - Wood density ( $\text{kg}/\text{m}^3$ )

If country specific values are not available, then the default values provided by the tool can be used for growth characteristics and production. These default values represent global averages based on a literature review and are stored in the tool’s database.

3. Wood harvested price (stack) (USD / $\text{m}^3$  or USD/ton)
  - The user must enter this data.



GROWTH CHARACTERISTICS & PRODUCTION

**COUNTRY:** Philippines

This sheet includes growth and production data for the selected tree species over a certain rotation length. Please note that some specific factors (e.g. site ecological conditions) are not considered in the default data. Thus, this data should be used as a general indication (further information is available in the section on "Assumptions and limitations" of the user-manual).

**NOTE:** Enter data only in white cells Grey cells are calculated

Species 1 selected: *Acacia mangium*

Species 2 selected: *Eucalyptus spp.*

Growth data	Unit	User-defined	Default values	User-defined	Default values
Planting density	trees/ha	1,500	1,111	2,225	2,500
Mean Annual Increment (average)	m <sup>3</sup> /ha/year	15.00	13.90	15.00	10.00
Rotation length (max 30 years)	year	5	8	3	7

Production	Unit	User-defined	Default values	User-defined	Default values
Harvestable volume for bioenergy purposes	m <sup>3</sup> /ha	75.00	134.31	36.00	79.52
Low heating value (energy content)	MJ/kg	20.10	20.00	18.50	18.00
Moisture	%	15%	15%	15%	15%
Wood density	kg/m <sup>3</sup>	780.00	780.00	650.00	650.00

Wood harvested price (stack) USD/m3

Species 1:	65.00
Species 2:	60.00

<< BACK  
Selection of Species

NEXT >>  
Planting and Management

Figure 8: Layout of the Growth Characteristics and Production Sheet

### 4.3 Step 3: Entering country general data

The General Data Entry section is a table included in the Planting and Management Costs sheet in which the user must provide data related to the input prices and labour costs that are specific to the country selected.

The following data must be entered ( Figure 9):

- Daily wage for agricultural labour (USD/day)
  - Note that the tool assumes that all operations are conducted by a paid labourer. Therefore, family labour is valued at the same rate.
- Machinery rental rate (USD/hour)
- Discount Rate (%)
  - Note that the discount rate is needed to run the financial analysis of the tool. Since the analysis uses constant, present day USD, the discount rate is above the inflation rate, which is also known as a real rate. The discount rate selected for the analysis should be based on the combined factors of expected return and risk. The higher the risk, the higher the associated discount rate. Selection of the discount rate might present a few difficulties, but if there is a well-developed capital market, the cost of borrowing money may be used (Dillon J.L. et al., 1993) or, as a second approach, the rate used in the returns that can be achieved from an alternative investment.
  - The user must also note that this value rarely exceeds 10%; therefore he/she should pick a value that is realistic for their area of analysis.
- Fertilizer price (USD/t)
  - Select the most common nitrogen, phosphate and potassium fertilizers used in the country and enter their respective prices in USD per tonne. In order to obtain actual production

costs, it is advised that the prices of fertilizers should be entered without subsidies. The fertilizers that can be selected from the dropdown list in the tool are provided in Table 1.

- Note that in the case of NPK complex, the N:P:K ratio has to be indicated.

<b>GENERAL DATA ENTRY</b>				<b>Unit</b>	
Daily wage for agricultural labour				USD/day	5.79
Cost per hour for machinery (average rental cost)				USD/hour	40.00
Discount rate				%	12%
<b>Fertilizers price</b>				<b>Unit</b>	
Nitrogen fertilizers	Urea			USD/t	458.65
Phosphate fertilizers	MAP			USD/t	448.37
Potassium fertilizers	Potassium chloride			USD/t	124.59
NPK complex fertilizers	14	14	14	USD/t	502.00
Plot size				ha	1.00

Figure 9: General Data Entry

Table 1: List of Fertilizers in the *Woodfuel Plantation Budget Tool*

Nitrogen Fertilizers	Phosphate Fertilizers	Potassium Fertilizers
Ammonia	MAP	Potassium chloride
Urea	DAP	Potassium sulphate
Ammonium nitrate	TSP	

#### 4.4 Step 4: Entering planting and management costs

The user is asked to provide specific data for each of the tree species selected (e.g. seedling price, input and labour costs), in order to assess the current plantation budget with the associated costs. The information should be entered in the “User-Defined” plantation budget section. This is the profile in which the user inputs his/her values per hectare to characterize the costs of current production. Unit price of items are automatically calculated in accordance with the values provided in the General Data Entry section (see Step 3, Figure 9).

On the same sheet, the plantation budgets for “Default Values” profiles are generated by the tool (Figure 11). These default values represent global averages based on a literature review and are stored in the tool’s database. If country specific values are not available to the user, then the default values provided by the tool can be used in this section. However, the user should be aware that if the default values are used, then he/she will not be able to make a comparison between a “User-defined” and “Default Values” plantation budgets for the specific tree species. It is also important to note that if the tree species selected in Step 1 was user-defined, then the tool will not provide a “Default Values” profile and the data needed must be entered in the “User-Defined” profile.

For the “User-Defined” profile, the following data must be entered (Figure 10):

1. Seedling unit price (USD/pc)
2. Years within the rotation length

- Note that this is the number of years the given input is provided or labour performed and must be entered under the labels “from” and “to”. For example, if the soil was fertilized before planting began and once within the next three years of the rotation length, then the user must enter ‘0’ in the “from” cell and ‘3’ in the “to” column. The user must note that the plantation is established at the beginning of the first year, i.e. year ‘0’. If any operation is done once during the overall rotation length, the user is required to enter the same year in the white cells “from” and “to” (e.g. for planting done only at the beginning the user should enter ‘0’ both in the “from” and “to” white cells). This is needed in order to carry out the financial analysis in the discounted cash flow calculations of the tool.
3. Total quantity per hectare
- Note that the total quantity takes into account the quantity of a specific input or labour requirement in the overall rotation length. It means that the total quantity per hectare (i.e. kg of fertilizers, man-days for application of fertilizers, etc.) refers to the total amount applied in the range “from” and “to” of the year(s) within the period of the rotation length.
  - For example, in Figure 10 under the “User-Defined” profile, nitrogen is applied at the establishment of plantation (year 0) and then up to the second year. The total amount of nitrogen applied is 70 kg per hectare as expressed in the column “Total quantity per hectare”. In this case, the tool automatically spreads the total amount in 3 equal applications among the years ‘0’, ‘1’ and ‘2’ and calculates the discounted cost at the present value.
4. Other inputs or other labour
- In this cell, the user can enter particular items that were not included in the other sections (e.g. herbicides as an input or other field operations as labour).

The “Discounted total costs” section is a financial calculation of the tool, which is expressed in USD/ha. It represents the discounted value of the input and labour requirements for the relevant year(s) within the rotation length. Since a future amount of money is worth less today, the tool automatically provides the financial calculation of future costs and gives it a present day value. The discounted value is dependent upon the discount rate entered in the General Data Entry table (see Step 3).

Species 1 selected: <i>Acacia mangium</i>			
<div> <div>Rotation length</div> <div>years</div> <div>User-defined: 5</div> <div>Default: 8</div> </div>			
Inputs		Unit	Unit Price (USD)
Seedling		pc.	0.15
Fertilizer nutrients			
- Nitrogen	kg	0.97	
- Phosphorus	kg	0.95	
- Potassium	kg	0.70	
Other inputs:	insecticide	oz	5.00
Total inputs costs			
Labour		Unit	Unit Price (USD)
Land clearing and planting			
- Manual	man-day	5.79	
- Machinery	hour	40.00	
Application of fertilizers			
- Manual	man-day	5.79	
- Machinery	hour	40.00	
Application of other agrochemicals			
- Manual	man-day	5.79	
- Machinery	hour	40.00	
Harvesting			
- Manual	man-day	5.79	
- Machinery	hour	40.00	
Other labour:	weeding	man-day	5.8
Total labour costs			

User-defined			
Years within the Rotation Length		Total quantity per hectare	Discounted total costs (USD/ha)
from	to		
0	0	1,500	225.00
0	2	70.0	60.76
0	2	70.0	59.85
0	2	70.0	44.03
0	2	15.0	67.25
			456.89

Default values			
Years within the Rotation Length		Total quantity per hectare	Discounted total costs (USD/ha)
from	to		
0	0	1,111	166.65
0	3	140.0	115.25
0	3	64.0	51.90
0	3	100.0	59.65
			393.46

User-defined			
Years within the Rotation Length		Total quantity per hectare	Discounted total costs (USD/ha)
from	to		
0	0	35.0	202.65
0	0	6.0	240.00
0	2	3.0	15.58
			0.00
0	2	18.0	93.45
			0.00
5	5	30.0	98.56
			0.00
0	2	6.0	31.20
			681.44

Default values			
Years within the Rotation Length		Total quantity per hectare	Discounted total costs (USD/ha)
from	to		
0	0	65.0	376.35
0	0	5.7	228.00
0	3	8.0	39.39
0	3	6.0	204.11
0	3	8.0	39.39
0	0	0.0	0.00
8	8	20.0	46.77
8	8	8.0	129.24
			1,063.26

Figure 10: Layout of the Tree Species-Specific Data for User-Defined and Default Values

User-defined			
Years within the Rotation Length		Total quantity per hectare	Discounted total costs (USD/ha)
from	to		
0	0	1,500	225.00
0	2	70.0	60.76
0	2	70.0	59.85
0	2	70.0	44.03
0	2	15.0	67.25
			456.89

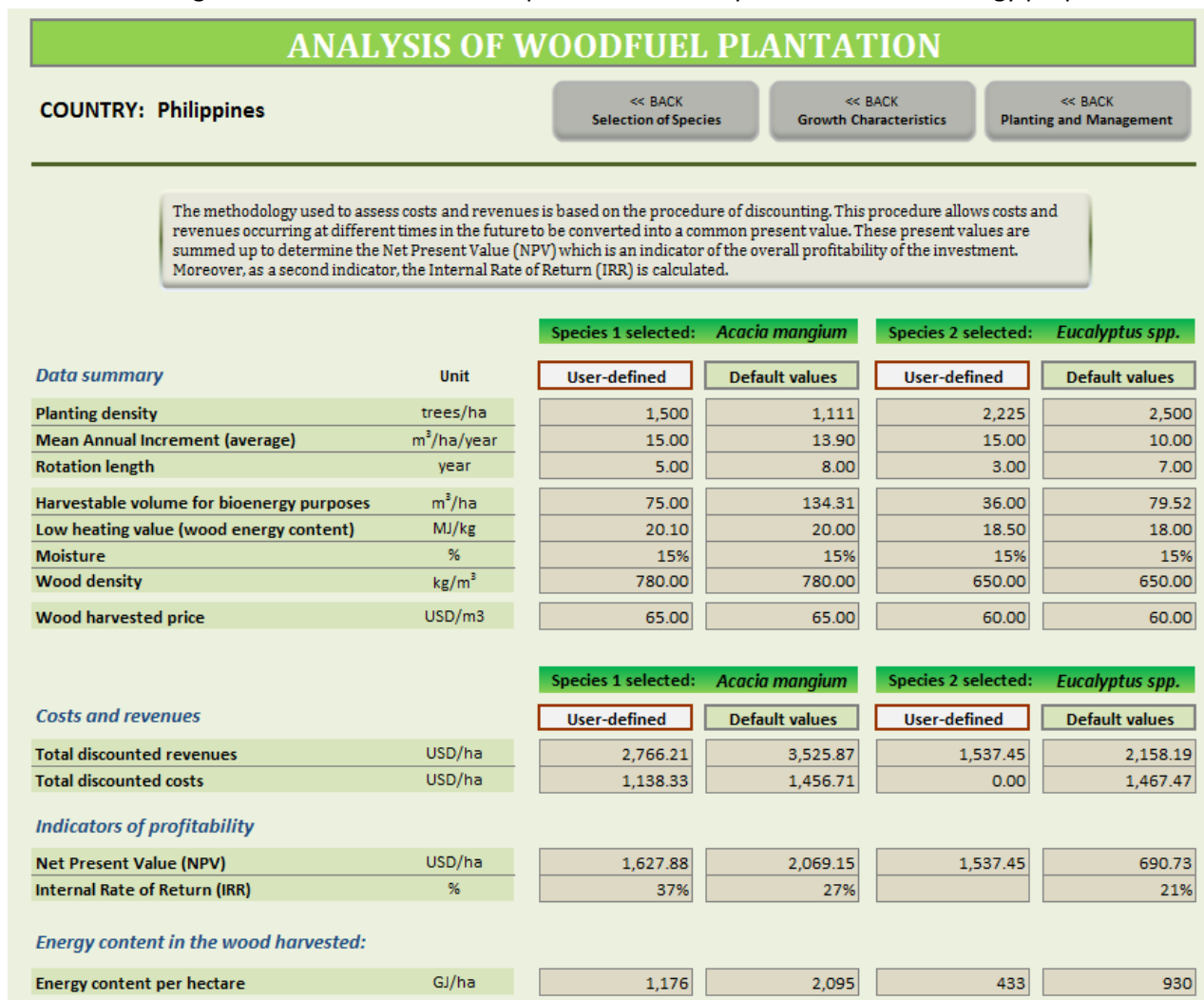
Default values			
Years within the Rotation Length		Total quantity per hectare	Discounted total costs (USD/ha)
from	to		
0	0	1,111	166.65
0	3	140.0	115.25
0	3	64.0	51.90
0	3	100.0	59.65
			393.46

Figure 11: Layout of the “User-Defined” and “Default Values” Profiles

## 4.5 Step 5: Analysing the results

The next step of the *Woodfuel Plantation Budget* is to analyse the results that include numerical (Figure 12) and graphical (Figure 13, Figure 14, Figure 15) comparisons of costs, revenues, profitability indicators and energy content in the fuelwood harvested for each analysed tree species.

In line with the objectives of the BEFS RA, the aim of the *Woodfuel Plantation Budget* is to provide an assessment that gives an indication about the potential biomass production for bioenergy purposes.



**Figure 12: Layout of the Analysis of Woodfuel Plantation Results Sheet – Numerical**

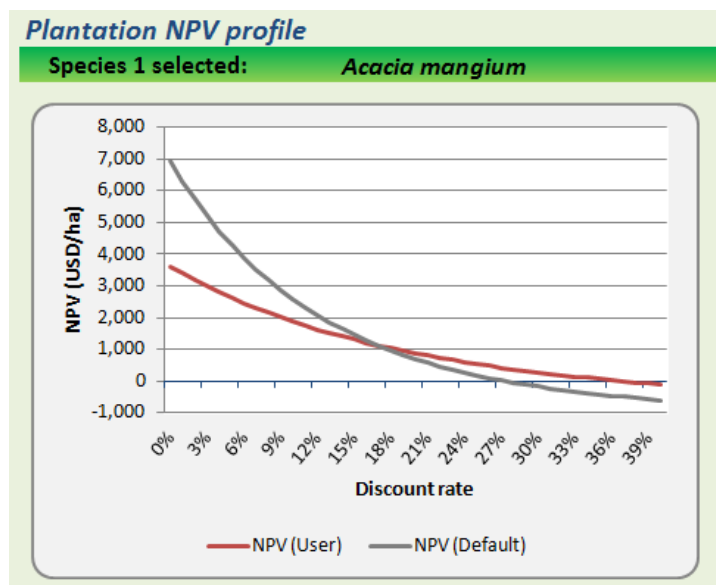
Tree species can be compared using the NPV and IRR, even when they have two different rotation lengths.

If the NPV is positive the investment may be said to be profitable, while if the NPV is negative it is not profitable. When comparing investment alternatives, the one with the highest NPV is usually regarded as the best option in terms of profitability. This is due to the fact that the NPV calculates the total value of all future costs and revenues into a common present value.

Using the IRR indicator, an investment is usually said to be profitable if it yields a rate of return greater than the discount rate. In comparing investment alternatives, the one with the highest IRR is normally regarded as the best option in terms of profitability. The user must keep in mind that the IRR can be determined by examining when the NPV is 0 on the graph, i.e. where the NPV line crosses the x-axis.

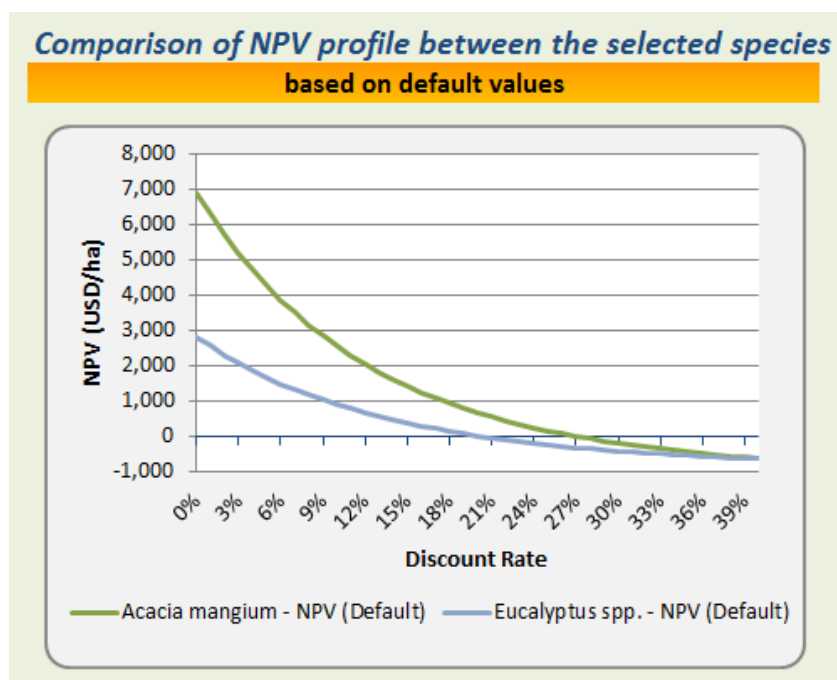
However, it is important for the user to note that the NPV and IRR values must be taken into consideration in conjunction with the discount rate available for the investor in the area under examination. This will help the user determine if an investment is favourable.

The following charts plot the net present value at different discount rate levels. From these NPV profiles, the user can see the relationship between the NPV, the IRR and the discount rate used in the analysis.



**Figure 13: Layout of the NPV Profile for *Acacia mangium* – Comparison between “User-Defined” Profile and “Default Values” Profile**

In Figure 14 the user can determine from the default values that the tree species, *Acacia mangium*, has a higher NPV than the tree species *Eucalyptus* spp. Moreover, since the NPV crosses the x-axis at about 27% for *Acacia mangium* and 20% for *Eucalyptus* spp., the IRR for the former is higher and therefore more profitable. However, as previously stated, the user must determine if this is a favourable investment after determining the discount rate available to him/her among other factors.



**Figure 14: Comparing the NPV Profile between Two Forest Plantation Species**

It is vital that the user also consider the energy content of harvested wood species in addition to profitability prior to investing in a woodfuel plantation. When choosing wood for fuel utilisation purposes, there are three factors which have an effect on the amount of available heat per unit of fuel, also known as the calorific value (CV): species choice, wood density, and moisture content.

Species may be either hardwoods or softwoods. The general differences are that hardwoods (deciduous, broadleaved tree species) tend to be denser, and softwoods (evergreen, coniferous species) tend to contain more resins. Species with dense wood will burn for longer than less dense woods. This means there will be a need for fewer ‘top ups’ to keep a log stove burning, for example. If wood is measured by volume, then generally there will be the ability to use more kilowatt hours (kWh) of heat from a cubic metre (m<sup>3</sup>) of hardwood than softwood. On the other hand, softwoods are often cheaper and easier to source than hardwoods.

There often is little variation in the CV between two or more different species, if they are tested at the same moisture content. The main differences between species are: moisture content when the timber is green, moisture content at the time of felling, and the rate at which this moisture is lost during seasoning.

The following chart presents energy content of the wood harvested at the end of the rotation length, expressed in GJ/ha. It provides the user with a comparison among the “User-Defined” values and “Default Values”, for each analysed tree species. In this example, the user can determine that the overall energy content is higher for *Acacia mangium* for both default and user-defined values than for *Eucalyptus* spp. This information, together with the IRR, NPV and discount rate, can give the user an indication on which tree species is a better investment.

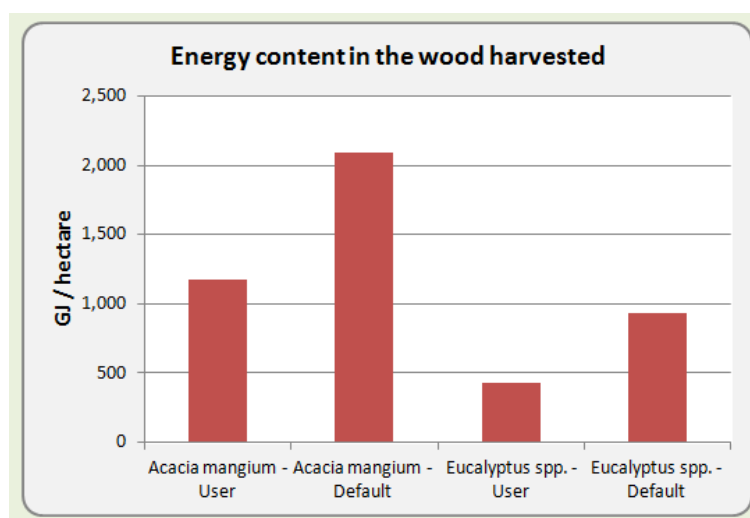


Figure 15: Layout of the Wood Energy Content among the Selected Tree Species

## 5 Assumptions and Limitations of Woodfuel Plantation Budget Tool

Before starting the analysis the user should be aware of the basic assumptions and main limitations of the tool, as summarised in the following:

- Estimated costs and revenues in the “Default values” profiles are calculated based on average conditions. Therefore, the values do not reflect diverse environmental conditions and it is recommended to provide user-defined data for a more detailed analysis.

- The management systems included in the analysis have been chosen as the most common systems in forest plantation for bioenergy purposes. Moreover, it is assumed that trees are not thinned or pruned in the default profiles.
- The tool focuses exclusively on productive plantations and excludes protective plantations and semi-natural planted forests.
- It is assumed the harvestable volume of wood includes stems, branches and bark.
- The calculations are made before tax, without including land values.
- The *Woodfuel Plantation Budget* does not consider irrigation systems and their investment.

Finally, it is necessary to mention the importance of carrying out an initial and careful sustainability assessment of the establishment of forest plantations in the specific country context. The following should be considered when evaluating the sustainability of forest plantations for bioenergy (Evans, 2009):

1. Nutrients may be removed from the site as trees are harvested.
2. Soil surface chemistry may change since the litter layer and organic matter are suddenly dominated by one species.
3. Site preparations including ploughing, draining and fertilization directly affect soil physical parameters and thus moisture and nutrient availability.
4. The size of nutrient losses depends on which components of the tree are removed (e.g. logs, bark, branches) since nutrients are unequally distributed in plant tissue.
5. If a plantation forest loses more moisture than what it receives through precipitation then on-site water reserves may be depleted.
6. Plantation forests may suppress ground vegetation that can indirectly cause an increase in soil erosion rates. Removal of the litter layer can also cause soil erosion. Minimal disturbance of the forest floor is important in order to prevent soil erosion, improve the infiltration of water and ensure the establishment of a nutrient store and nutrient cycling.
7. The harvesting of logs can cause compaction of soil and soil erosion. The method of extraction coupled with climate and soil conditions greatly influences the extent of damage.
8. It is widely accepted that even-aged monoculture plantations have lower resilience and increased risk of exposure to tree pests and pathogens than native forests.
9. Uniform stands of trees monoculture plantations have lower resilience to droughts, storms and hurricanes than native forests.

Those in charge of decision-making should consider these points and proceed carefully when establishing forest plantations. An alternative management system, which can be used to produce wood, is an agro-forestry-based Integrated Food Energy Systems which – if managed properly – can be highly resilient in terms of food and energy security, resource efficiency and adaptation to climate change (Bogdanski et al., 2010).

## 6 The Results of the *Woodfuel Plantation Budget*

The main results of the *Woodfuel Plantation Budget* are presented in specific numerical tables (Figure 12) and graphical charts (Figure 13, Figure 14, Figure 15) giving the following outputs:

1. Comparison of profitability, costs and revenues among various alternatives of tree species.
2. Comparison of energy content in the wood harvested (GJ/ha).



## 7 Annex

### 7.1 Methodology

This section describes the methodology integrated in the *Woodfuel Plantation Budget*. In order to assess the profitability, the costs and revenues calculated as part of the analysis are based on the procedure of discounting, since forestry investments cover several years. This procedure allows costs and revenues occurring at different times in the future to be converted into a common present value. Using annual estimated costs and revenues, the cash flow of the forest plantation investment is calculated. The estimated cash flow indicates when payments are due and when revenues are accrued over the rotation length of the forest plantation. Once the yearly costs are entered (Step 4) the tool automatically provides discounted cash flow calculations with total costs and revenues. They are summed in order to determine the Net Present Value (NPV), which is an indicator of the overall profitability of the investment. Moreover, as a second indicator, the Internal Rate of Return (IRR) is calculated.

The default values used in the *Woodfuel Plantation Budget* are derived from existing literature at the global level and some specific factors (e.g. site ecological conditions) are not considered in such data. Thus, this data should be used as a general indication (further information is available in the relevant section on "Assumptions and Limitations").

### 7.2 Data requirements for running the *Woodfuel Plantation Budget*

The tables below include data requirements for running the *Woodfuel Plantation Budget* for each selected tree species:

Country Data Entry	
Daily wage for agricultural/forestry labour	USD/day
Cost per hour for forestry machinery (average rental cost including fuel consumption)	USD/hour
Discount rate	%
Unit prices of the selected chemical fertilizers	USD/ton

Tree Species Dataset	
Planting density	trees/ha
Mean Annual Increment (average)	m <sup>3</sup> /ha/year
Rotation length	years
Harvestable volume for bioenergy purposes	m <sup>3</sup> /ha
Low heating value (energy content) of wood	MJ/kg
Moisture of wood	%
Market price of wood harvested (stack)	USD/m <sup>3</sup> or USD/ton

Input Requirements	
<b>Fertilizer nutrients:</b>	
- Nitrogen	Kg/ha
- Phosphorus	Kg/ha
- Potassium	Kg/ha
<b>Other agrochemicals</b>	

Labour Requirements	
<b>Land clearing and planting</b>	
- Manual	man-days/ha
- Machinery	hours/ha
<b>Application of fertilizers</b>	
- Manual	man-days/ha
- Machinery	hours/ha
<b>Application of other agrochemicals</b>	
- Manual	man-days/ha
- Machinery	hours/ha
<b>Harvesting</b>	
- Manual	man-days/ha
<b>Other labour</b>	

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