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FATIMA

FArming Tools for external nutrient Inputs and water MAnagement

D4.1.1: Framework for Water-Energy- Food assessment in pilot areas

WP4.1 – Water-Energy-Food nexus

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Executive summary

Establishing the fundamental concepts and methods for setting up and implementing the framework for Water- Energy-Food assessment that will be carried out in pilot areas during FATIMA.

The starting point will be the integration of the nutrient-water efficiency management and sustainable soil management and cropping systems with energy efficiency use.

The framework includes the definition of different methodologies for energy and water management related to food production, capable of being used in different contexts/situations and a various stages. It regards the definition of basic set of data/information to be collected methodology & criteria to adopt; templates; questionnaires; procedures; and final detailed analysis. The framework will be proposed for both territorial and farm level, in selected pilot areas.

The framework will explicitly consider the options of full analysis (all required data either existing or to be collected) and reduced-size analysis (missing data). Draft framework was defined by small working group (on the Plenary meeting of FATIMA in October 2015, Albacete, Spain), and was approved by all Regional groups.

Definitions

Water-Energy-Food-Nexus – The Water-Energy-Food Nexus is a useful concept to describe and address the complex and interrelated nature of our global resource systems, on which we depend to achieve different social, economic and environmental goals. In practical terms, it presents a conceptual approach to better understand and systematically analyse the interactions between the natural environment and human activities, and to work towards a more coordinated management and use of natural resources across sectors and scales. This can help us to identify and manage trade-offs and to build synergies through our responses, allowing for more integrated and cost-effective planning, decision-making, implementation, monitoring and evaluation (FAO, 2014). In FATIMA it will be also declined WEF at farm level, showing linkages between inputs (water and energy) and output (yield) of farm's activity.to investigate through a set of indicators, farm's performance under environmental and economic point of view.

Farm Accountancy Data Network (FADN) - is an instrument for evaluating the income of agricultural holdings and the impacts of the Common Agricultural Policy. The services responsible in the Union for the operation of the FADN collect every year accountancy data from a sample of the agricultural holdings in the European Union. Derived from national surveys, the FADN is the only source of microeconomic data that is harmonised, i.e. the bookkeeping principles are the same in all countries.

Direct energy - Direct energy is represented by fuel oil, electricity and natural gas consumption

Indirect energy Other inputs constitute important indirect energy consumption posts, especially synthetic fertilizers, pesticides or seeds.

Energy Impact Matrix - a matrix showing the impact of total energy costs (direct and indirect) on main economic posts of farms' balance (mainly Total inputs and , Gross farm income etc.). It will allow the definition of that type and dimension of farms where energy has a high weight.

Energy Audit - An energy audit is an inspection, survey and analysis of energy flows for energy conservation in a building, process or system to reduce the amount of energy input into the system without negatively affecting the output(s). An energy audit is the first step in identifying opportunities to reduce energy expense and environmental impact.

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1 Introduction

The main objective of WP4.1 in FATIMA consists in developing and implementing a framework for Water-Energy-Food (WEF) assessment in pilot areas and integrate it into the central MDSS hub and the FATIMA prototypes. This includes energy audits of farm areas and energy footprints of rural areas.

The Workpackage is structured in the following way:

- D4.1.1: Framework for Water-Energy-Food assessment in pilot areas (M9)
- D4.1.2: Baseline Water-Energy-Food description of pilot areas (M13)
- D4.1.3: Guidelines for on-farm Water-Energy-Food audit, including training material [M12]
- D4.1.4: Summary report of on-farm audit results and impacts – baseline for promoting Sustainability measures in agriculture (such as Energy efficiency plans)[M36]

This report constitutes Deliverable 4.1.1 of the FATIMA project that aims to define a common analytical framework to assess WEF sustainability of FATIMA pilot areas (covering economic, environmental and social dimension). This includes the definition of the appropriate indicators and data needed to perform the assessment and the establishment of guidelines for roadmap development.

It regards both biophysical and socio-economic resources on which we depend to achieve social, environmental and economic goals pertaining to water, energy and food. Interactions take place within the context of external Drivers (Climate, Change, Globalization, Population growth, Market and price, Socio-economic development, Urbanisation etc.), Goal (Energy/Water/Food/security, Land productivity, Biodiversity etc.) and how the individual systems and their interlinkages can be managed (Governance, Economy, Technology, Ecosystem, Society). (FAO, 2014; Stigson, 2013).

According to the central goal of the FATIMA project "establish innovative and new farm tools and service capacities that help the intensive farm sector optimize its external input management (nutrients and water) and productivity, the framework aims to introduce two keys for quantum leaps in sustainable crop production: firstly, the integration of the WEF nexus into the current "water-only" management practice and secondly, the first-ever complete treatment of all energy sources and forms (electricity, fuel, indirect energy consumption in fertilizer/pesticide production)", the framework is mainly designed to tackle general context (as regional/river basin scale). But also to be applied at local level (pilot area) providing downlink to farm level (audit).

The framework will be developed, fine-tuned and implemented in each pilot sites jointly with WP1.1, Multi-actor community platform, WP 1.2 socio-economic analysis, and WP4.2 relating the framework with policy instruments for sustainable crop farming systems.

2 Overall framework for WEF assessment

The framework structure will consist of the following steps, described in the next paragraphs:

1. WEF logical framework;
2. set up the baseline conditions on WEF nexus in the pilot areas;
3. defining indicators for WEF assessment;
4. data collection and calculation methods;
5. on-farm WEF audit procedure.

2.1 WEF logical framework

Starting from an analysis of the regulatory framework, the FATIMA WEF Nexus involves all the three dimensions of sustainability, social, economic and environmental, looking also at the role played by stakeholders [Figure 1].

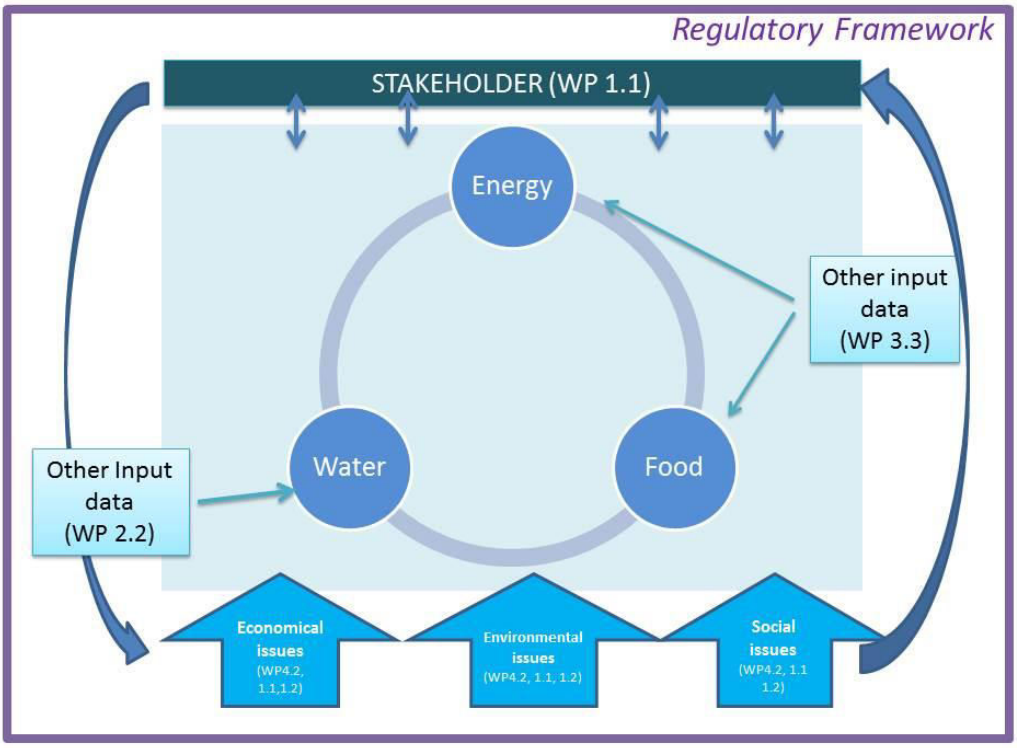


Figure 1 – WEF logical framework

We consider that the above relationships are also inverse, meaning that, for instance, changes in WEF can have effects on stakeholders under economic, social and environmental point of view.

In finding linkages between external factors, and their impacts on the nexus and stakeholders (and vice versa), different methodologies of WEF nexus assessment will be applied for energy, water and food.

We propose downscale approach starting from regional dimension, passing through pilot area and reaching farm level [Figure 2]. The results of farm level analysis and experimental field activities will be once again reported to spatial level to find general sustainability measures capable to be adopted in different environmental and socio economic scenario.

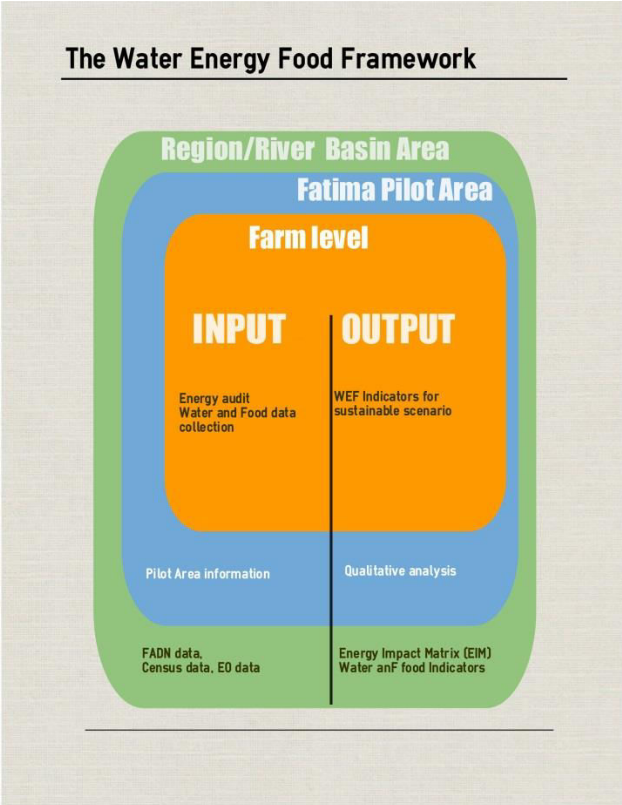


Figure 2 - WEF level of analysis

ENERGY

The proposed methodology is expected to tackle both economic and environmental dimensions affecting social perspective in the sense that a better knowledge of energy uses and costs is a basic step also for the stakeholders to find measures to improve energy efficiency at all levels[1].

<u>1st level (Regional).</u> Agriculture represents a very small part of direct energy consumption[2] but energy, direct and indirect, is an important part of farm's costs. As a matter of fact the considerable increase of energy prices in the past years, due to constant growth in oil prices from January 2009, affected considerably farmers, generating disturbing effects on production costs. To estimate the impact of energy costs of farms, "Energy Impact Matrices" (EIM) at regional level will be defined through the analysis of national Farm Accountancy Data Network (FADN). FADN collects data concerning "direct energy" (for electricity, fuel, gas) and "indirect energy" (which includes costs seed, crop protection and fertilizers) costs for each Type of Farming (TF) and Economic Size Class (ESC) of farms[3].

Direct and indirect energy and their sum "Global Energy" costs, correlated with financial data such as "Total Inputs" and "Gross Farm Income" will be reported in different EIM for each type and economic size of regional farms.

[1] Energy efficiency is now recognized as the main field of action to achieve international target of reduction of CO_2 emissions.
[2] In Italy agriculture is responsible of 2% of national energy consumption and food industry of 9%.
[3] The FADN considers 8 general Type of Farming and 6 Economic Size Classes.

The EIM's obtained, shows the differences for each intersection TF/ESC, referred to the weight of energy expenditures on the financial indicators used in the analysis, highlighting those cases with percentage above regional average value. This kind of analysis will allow to find where to adopt measures at regulatory level, addressing public funding and investments in specific sectors, as well as at private level, promoting actions to reduce energy costs through management approaches or tools such as energy audits to improve energy efficiency of farms.

2nd level (Pilot area). Furthermore once defined the size and type of farm with higher weight of energy costs, we'll move down to pilot area level, performing a qualitative analysis using available data and finding how many farms of EIM's realized are located in the area. This step will show the "sensitiveness" of the pilot area to energy costs and then consumption.

3rd level (Farm). Acknowledgements of regulatory framework and technical approaches in use, such as ISO 50001 certifications systems (adoption of EMS – Energy Management System) allow us to consider Energy Audit as the right tools to set farm's base line scenario on energy consumption.

Basing on the concept that you can't manage what you don't know (Colonna, 2014), we focus the attention on farm level adopting "Energy audit" tool for those kind of farms with the appearances shown in the EIM analysis. Based on Deming Cycle approach (Shewhart, 1939), energy audits represent the basic step to build pathways of efficiency and sustainability through actions and ad hoc measures. According to the methodology defined by American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE, 2004), energy audit can be performed at the first level of analysis, which through an energy bill analysis can give an idea of farm's model of consumption. The total virtual energy consumed at farm level related to quantitative (Yield) or physical (hectare) dimensions, gives also a proxy of energy productivity.

WATER

Evaluating and managing the water resources is a key pathway to enhance sustainability of the agricultural sector in Europe, especially in the Mediterranean countries. Water sustainability indicators matching supply and demand of water are influenced by irrigation and type of crops. A common measure to characterize water sustainability is the ratio of water use to water availability (looking at Water footprint approach).

Also for water the 3 levels approach will be adopted (regional, pilot area, farm), finding specific indicators of irrigation efficiency considering crop evapotranspiration data and volume of water applied in the area. In the first two steps data coming from various sources, statistic, EO, stakeholders, etc., will be gathered, while concerning farm level, data will be collected directly in pilot farms if equipped with measure instruments or from local knowledge (farmers, research and local institutions, other, etc.).

FOOD

From WP 3.3 and WP 2.2 data, a qualitative and/or quantitative analysis at farm level and area test level will show how to reduce input (nutrients, water and energy) without a decrease in yield production and farm's income.

To achieve food security goals, the WEF approach must be defined looking not at the amount of yield but at the input used in production processes. Regarding food production, the global sustainability of agriculture can be well represented from the paradigm: "reducing inputs while maintaining (hopefully increasing..) food production". The results of the analysis will allow to find where we should adopt measures both at regulatory level, addressing public funding and investments in specific sectors, or at private level, promoting actions to reduce costs through management approaches or tools such as energy audits, different agronomic practices to improve farm efficiency and agriculture sustainability.

2.2 Setting up the baseline

The baseline setting up will provide an overview of the current nexus status in the different pilot sites, in terms of natural resources and their uses, through the identification and quantification of key nexus interlinkages, taking into account that these systems are interconnected and that these linkages need to be analysed to identify trade-offs and goal conflicts (barriers) as well as synergies (opportunities) (Hoff, 2011), and that all linkages may not be important in all cases – thus different approach will be suggested for the different FATIMA pilots, in the close cooperation with Regional team.

On setting up the baseline conditions, will be utilized available information coming from WP 1-5 data integration, which provide some basic information of the main crops present in each pilot areas, as surface, yield, fertilizer input, irrigation type and water, nutrient requirements, etc. (in Figure 3 is shown an example of the main crops), and other available dataset on agronomic/economic input-output (i.e Farm Accountancy Data Network (FADN), Eurostat, FAO, Census data, Statistical data , etc), in order to provide information on the nexus status:

- The current state and pressures on natural and human resources systems;
- Expected demands, trends and drivers on resources systems;
- Interactions between water, energy and food systems;
- Different sectoral goals, policies and strategies in regard to water, energy and food.

Some indications on the first point are already available based on the main challenges (as reported in D.1.1.2), for the pilot site.

Table 1– First indications on the current state and pressures on natural resources systems in pilot site

Pilot Area	Main challenges
France	Water and nutrient efficiency, nitrate lixiviation
Greece	Low soil organic matter content reduces soil fertility, high soil clay content in many cases limits crop yields, excessive fertilizer and pesticide inputs, limited availability of irrigation water during the summer growing season
Austria	Diminishing water levels in aquifer by groundwater abstraction, low groundwater quality
Turkey	Increasing population pressure on water allocation & demand & increasing pollution. Frequent droughts. Risk of water and soil contamination. Ground water level problems due to intensive agriculture.
Italy	Groundwater pollution problems (nitrate lixiviation). Reduction of high costs (electricity) of water pumping on irrigation network
Czech Republic	Groundwater pollution problems - drinking water reservoir catchment for Prague - soil erosion, no irrigation
Spain	Diminishing water levels in aquifer by groundwater abstraction. Frequent drought conditions. Risk of water & soil contamination.

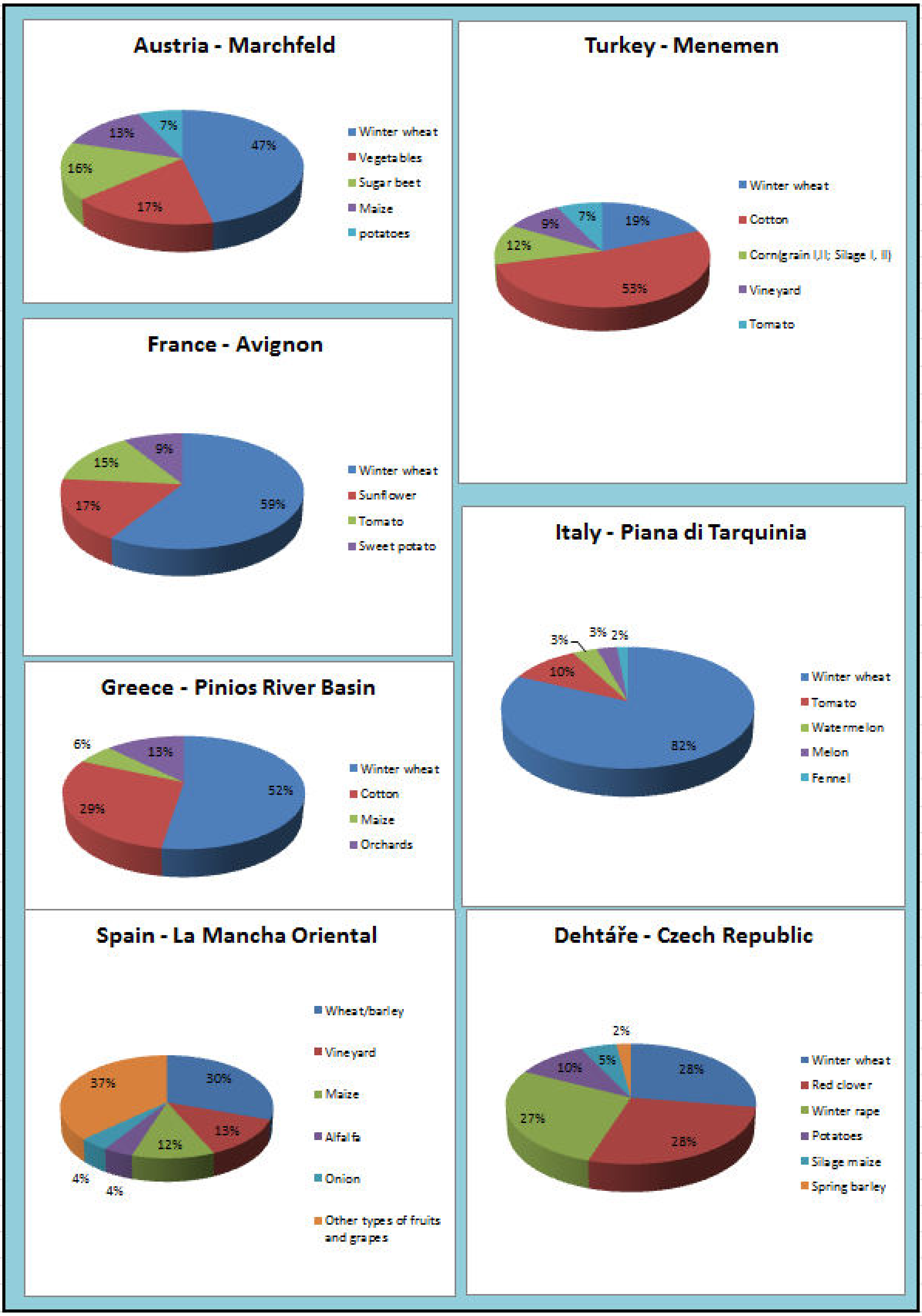
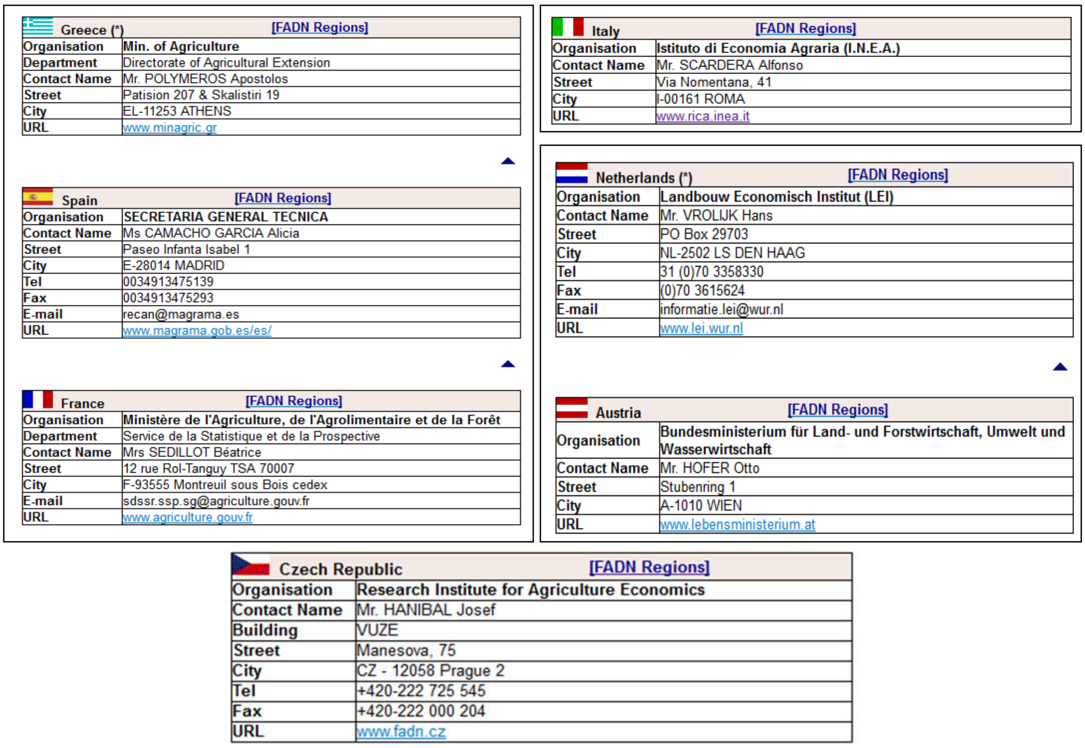


Figure 3- Main crops in pilot areas.

2.3 Data collection

2.3.1 Baseline data

For instance the use of FADN dataset will be particularly useful regarding the economic input/output of agricultural activities: national survey derived from EU countries are the only source of microeconomic data that is harmonised, i.e. the bookkeeping principles are the same in all countries. For Turkey pilot area where FADN data aren't available, key informant interviews will be carried out with relevant stakeholders (farmers, technicians, managers of agribusiness companies etc.). The European Commission does not directly collect data itself. This is the responsibility of a Liaison Agency in each Member State [*Figure 4*].



Greece (*)	[FADN Regions]
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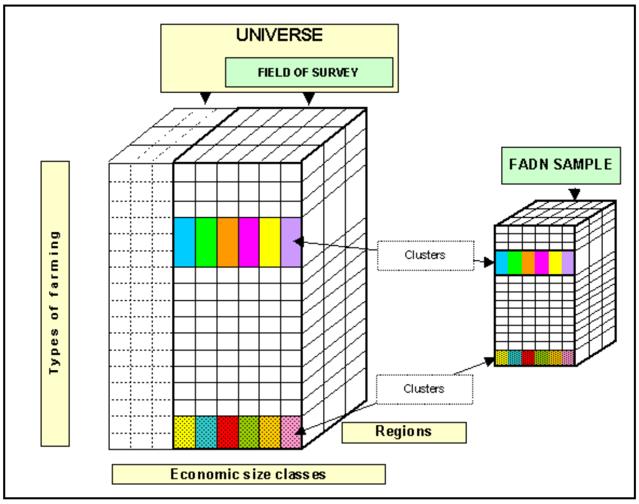
URL	www.fadn.cz

Figure 4 - FADN liaison agency. (Source: FADN website)

FADN is representative at Regional levels. The FADN field of survey is a subset of the EUROSTAT Farm Structure Survey (FSS). Holdings in the sample and in the field of survey are stratified according to the same three criteria: FADN region, type of farming and economic size class [Figure 5].



Type of Farming (TF): A farm is classified as Specialist if the Standard Output ***(SO = value of final output – specific costs)*** of one of the farms productive activities (or more than one if the activities are related) represents over two thirds of the total SGM of the farm

Economic Size Class (ESC): Total farm standard output (€)

Figure 5 - Stratification of holdings sample (source FADN website).

The data described in Figure 1 should be checked (Last update of the website is: 25 January 2010). In fact observing the figure we notice at least two changes in the Liaison agencies:

For Greece: Ministry of Rural Development and Food.

For Italy: Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria

A selection of variables, which are useful for the pilot site baseline description, will be prepared by the WP4.1 leader and sent to the Regional manager, who will check the availability of those variables in their respective Liaison Agency, with the respect of the data confidence, (i.e in Italy FADN data must be used exclusively for statistical purposes and cannot be granted to any other person, public or private, foreign to the National Statistical System (SISTAN), and may not be disclosed except in aggregate form so that it is not possible to identify the person to whom the information relates. The FADN data can be disseminated only through elaborate on the analysis groups composed of at least five (5) observations).

In the main time a questionnaire will be developed (in strictly cooperation with Regional manager) to identify data not available inside the FADN database needed to compile the baseline description.

Result of this activity will be described in Deliverable D4.1.2: Baseline WEF description of pilot areas (M13).

2.3.2 On-farm Water-Energy-Food data

The audit technique is referred to the traditional procedures adopted for quality and/or environmental management systems derived from ISO 19011:2003 "Guidelines for quality and/or environmental management systems auditing".

The general audit procedure, is based on the Deming Cycle or Plan-Do-Check-Act, which represent a systematic series of steps for gaining valuable learning and knowledge for the continual improvement of a product or process (Figure 6)

The cycle begins with the Plan step. This involves identifying a goal or purpose, formulating a theory, defining success metrics and putting a plan into action. These activities are followed by the Do step, in which the components of the plan are implemented, such as making a product. Next comes the Study step, where outcomes are monitored to test the validity of the plan for signs of progress and success, or problems and areas for improvement. The Act step closes the cycle, integrating the learning generated by the entire process, which can be used to adjust the goal, change methods or even reformulate a theory altogether. These four steps are repeated over and over as part of a never-ending cycle of continual improvement (W. Edwards Deming Institute, 2015).

As mentioned audit technique will be applied at farm level mainly concerning energy. Water and food assessment will follow different methodologies.

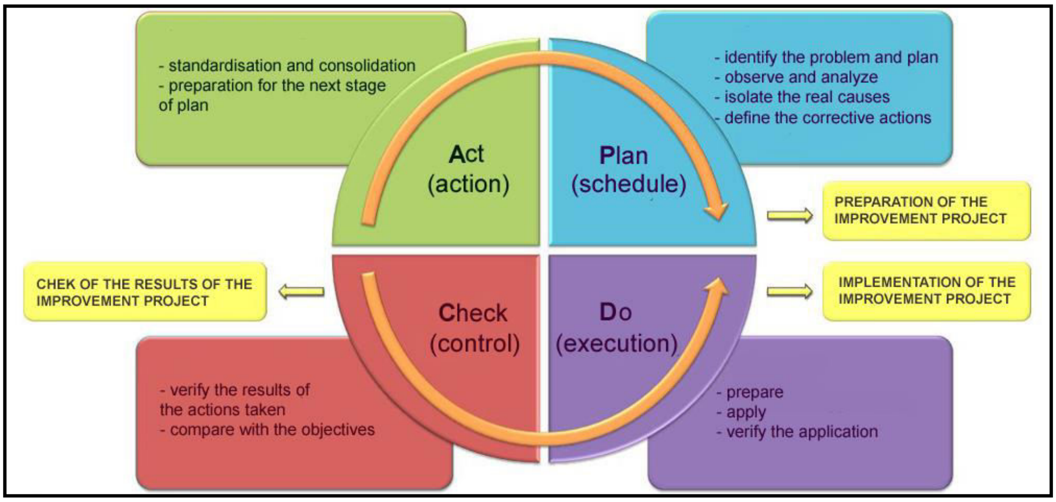


Figure 6 - Plan-Do-Check-Act flow chart.

To find water and food indicators specific information will be obtained through ad hoc surveys in pilot areas.

2.4 Calculation method and indicators for Water-Energy-Food assessment

2.4.1 Calculation method.

With a view to organize the data and information needed for the calculation of the indicators in a common way, a simple tools (Sustainability Indicators Calculator Tool - SICT), based on the template provided by Camargo, et al. (2013) will be prepared by the WP Leader with input from all regional team (CREA-INEA). The v.01 of Tool has been presented (for review & comment) during the Plenary meeting of FATIMA in October 2015, Albacete, Spain.

The tools currently includes the following indicators, related to energy and food production:

Table 2 - Example of energy-food indicators

Indicator	Unit	Description
Energy use efficiency (EUE)	ratio	energy output/energy input: energy embedded in product/energy used to produce it. The output-input energy ratio is and index that show the energy efficiency of production. An increase in the ratio indicates improvement in energy efficiency, and vice versa
Energy Productivity (EP)	kg/MJ	yield/energy input, energy input to produce 1 unit of yield
Specific energy (SE)	MJ/kg	energy input/yield, reversal of energy productivity
Net energy (NE)	MJ	energy Output (MJ) - Energy Input (MJ)

Once fully developed the Tool will allow to:

- evaluate the energy required to grow a crop by accounting for energy (both direct and indirect) associated with required inputs and then converting inputs to a same unit of energy (MJ), which creates an analytical coherence and flexibility that is very practical for evaluating systems (Farrell et al., 2006; Pimentel & Patzek, 2005)
- evaluate the greenhouse gas (GHG) emissions for different agricultural systems, converting all inputs and outputs to one mass unit of carbon equivalent or carbon dioxide equivalent (CO2e) (Farrell, et al., 2006; Lal, 2004).
- calculate the indicators for sustainable WEF assessment
- evaluate cropping systems sustainability (i.e. associated with current intensive farming practices versus more sustainable alternatives as proposed by the FATIMA project)
- present the results in form of different graphs

Sustainable Indicators Calculator Tool (SICT), will be an excel Workbook organised in different worksheet (Table 3):

Table 3– Main input/output of SICT Tool

Worksheet	Description
Main input	
Energy	Energy parameters for agricultural inputs and outputs conversion into unit of energy (MJ), an example is given in Table 4.
GHG	Greenhouse gas (GHG) emissions parameters for agricultural inputs and outputs conversion into unit of CO2e an example is given in Table 5.
Default agronomic/economic input/output	Will consist of a database which will store information about agronomic inputs (human labor, machinery, diesel fuel, electricity, fertilizer, pesticides, water, yield…), and related economic value, from all available sources and literature. (Table 6). This database aims at characterizing the energy consumption and WEF nexus indicators calculation in a given area (aquifer, irrigation scheme, river-basin, or regional administrative unit).
User defined agronomic/economic input/output	The same as below but collected in the project pilot areas at farm level (Table 7)
Indicators calculation: (Fig. 6)	
Main output	
• Indicators for WEF assessment (Figure 7 depicts an example of energy food indicators, (based not to real data but only to give a picture of the indicators) • Energy input: Crop system energy analysis, total (figure 6) and per crop (Figure 8) • Energy forms: direct/indirect (Figure 9), renewable/not renewable (Figure 10) • Greenhouse gas emissions analysis	
References: give all the references cited in the Energy, CHG and Default agronomic/economic input/output worksheet, and the link to the source where available	

The following scheme summarizes the content of the tools.

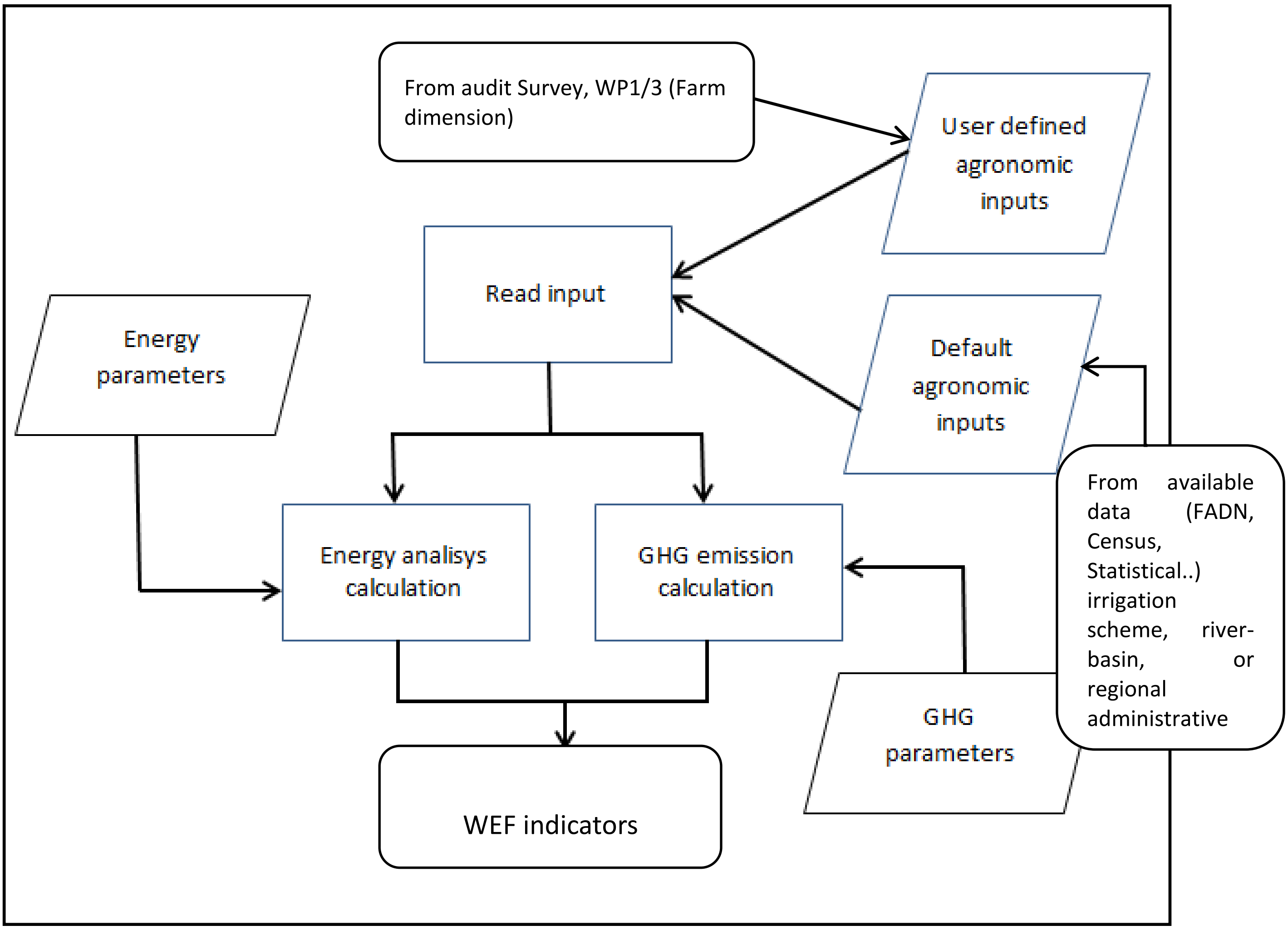


Figure 7 - Schematic representation of the SICT content, adapted from Camargo, et al. (2013)

The following tables are organised as following:

1. The first row indicated the input/output parameters (i.e. human labour, fertiliser, etc.)
2. The second row the average of the value present in the database
3. The database item report the number of observation for the parameters (i.e. in table 5 for human labour there are 3 observations with the same value 1.96, retrieved in the references [1-3], and another value 0.27 retrieved in references [4]

Table 4 - Example of inputs and outputs conversion into unit of energy equivalent (MJ)

1. Human labor	Average value	Database item	Unit	Energy equivalent MJ/unit	References
Human labor stats	1.12				
No. estimates in the population	4	3	h	1.96	*Yilmaz et al. (2005), Ozkan et al. (2004), Mohammadi et al. (2008), Heidari et al. (2012) References [1-3]*
Standard Deviation	1	1	h	0.27	Kitani (1999) *[4]*
Mean	1.12				
95% confidence region	1				
4. Chemical fertilizer					
Nitrogen energy stats	62.00				
No. estimates in the population	18	13	kg	54.80	*From FEAT database (see references from ..to..)*
Standard Deviation	5	2	kg	60.60	*Singh JM. (2002), Gündoğmuş (2006)*
Mean	62.00	3	kg	66.14	*Esengun et al. (2007), Yilmaz et al. (2005), Mohammadi and Omid (2010)*
95% confidence region	3	1	kg	66.44	*Taki et al., 2012*

Table 5- Example of inputs and outputs conversion into unit CO2 equivalent (CO2e)

Chemical fertilizer		Database item	Unit	kg CO2e/Unit	References
Nitrogen GHG	3.9				
No. estimates in the population	6	1	kg	4.38	*Kaltschmitt, M., G.A. Reinhardt. 1997.*
Standard Deviation	0.8	1	kg	4.51	*Robertson, G. P., E. A. Paul, and R. R. Harwood. 2000*
Mean	3.9	1	kg	4.00	*Wang, M. 2001*
95% confidence region	0.7	1	kg	3.14	*West, T. O., and G. Marland. 2002*
		1	kg	4.77	*Lal, R. 2004*
		1	kg	2.65	*Snyder, C.S., T.W. Bruulsema, and T.L. Jensen. 2007*

Table 6- Example of default Agronomic input/output

Province	ID	Crop parameters	1. Human labor	Average value	Database item	Unit	Value	Ref.	2. Machinery	Average value	Database item	Unit	Value	Ref.
			Labor stats	44					Machinery stats	43.18				
		Durum wheat	No. Estimates	4	3	h	50	*[1-3]*	No. Estimates	9	1	h	62.70	*[1-3]*
	01		Standard Deviation	1	1	h	34	*[4]*	Standard Deviation	16	3	h	25	*[4]*
			Mean	44					Mean	43.18	5	h	38	
			95% confidence region	1					95% confidence region	10	2	h	47	
			Labor stats	44					Machinery stats	43.18				
		Barley	No. Estimates	4	3	h	50	*[1-3]*	No. Estimates	9	1	h	62.70	*[1-3]*
Viterbo	01		Standard Deviation	1	1	h	34	*[4]*	Standard Deviation	16	3	h	25	*[4]*
			Mean	44					Mean	43.18	5	h	38	
			95% confidence region	1					95% confidence region	10	2	h	47	
			Labor stats	400					Machinery stats	48				
			No. Estimates	1	1	h	400	*[6]*	No. Estimates	1	1	h	48	
	01	Tomato	Standard Deviation						Standard Deviation					
			Mean	400					Mean	48				
			95% confidence region						95% confidence region					

Table 7 - Example of user Agronomic input/outuput

	Country:	Italy			
	Pilot:	Piana di Tarquinia			
	Municipality:	Tarquinia			
	ID_farm	1			
Crop	Unit	Wheat	Barley	Tomato	Corn
Human labor	[h/ha]	50.00	50.00	400.00	64.00
Machinery	[h/ha]	40.53	34.00	48.00	50.00
Diesel fuel	[l/ha]	167.20	134.00	880.00	204.00
N	[kg/ha]	115.00	116.00	150.00	220.00
P_2O_5	[kg/ha]	63.00	47.00	100.00	120.00
K_2O	[kg/ha]	50.00		120.00	110.00
Farmyard manure	[kg/ha]			17,000.00	
Commercial compost	[kg/ha]				
Green manure; vetch	[kg seed/ha]				
Herbicides	[kg/ha]	2.08		3.50	
Fungicides	[kg/ha]	0.33		2.50	
Coppers and sulfurs	[kg/ha]				
Insecticides	[kg/ha]	1.50		3.20	
Water for irrigation	[m3/ha]			4,150.00	3,500.00
Seed	[kg/ha]	295.00	235.40	5.00	
Yield	[kg/ha]	1,825.41	1,694.53	70,000.00	800.00
Staw yield	[kg/ha]	2,387.60	2,145.80		
Area	[ha]	5	3.00	2.00	7.00

Once the agronomic inputs table (Table 7) has been completed, the energy and GHG calculations are performed. The calculations embedded in each cell are available allowing the user to track back the source of parameters.

Sustainable Indicators Calculator Tools

FArming Tools for external nutrient Inputs and water Management

crea

Energy Analysis

Unit	Crop energy input/output	Farm	Wheat	Barley	Tomato	Corn	0	0	0	0	0	0	0	0	Total per input MJ/yr	Total per input (MJ/ha/yr)
	Crops yield area		5.00	3.00	2.00	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	Total area 17	
(MJ/yr)	Human labor		362.60	294.00	11,191.60	125.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11,973.64	704.33
(MJ/yr)	Machinery		5,329.50	6,395.40	3,009.60	3,135.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	17,869.50	1,051.15
(MJ/yr)	Diesel fuel		9,929.00	19,957.29	49,645.00	10,127.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	89,658.87	5,274.05
(MJ/yr)	N		9,299.25	21,574.26	20,458.35	13,638.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	64,970.76	3,821.81
(MJ/yr)	P_2O_5		1,932.90	1,603.17	3,411.00	1,364.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8,311.47	488.91
(MJ/yr)	K_2O		334.50	0.00	3,345.00	1,226.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4,906.00	288.59
(MJ/yr)	Farmyard manure		0.00	0.00	5,100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5,100.00	300.00
(MJ/yr)	Commercial compost		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
(MJ/yr)	Green manure; vetch (kg seed)		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
(MJ/yr)	Herbicides		4,760.00	0.00	833.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5,593.00	329.00
(MJ/yr)	Fungicides		0.00	0.00	230.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	230.00	13.53
(MJ/yr)	Coppers and sulfurs		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
(MJ/yr)	Insecticides		0.00	0.00	636.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	636.80	37.46
(MJ/yr)	Water for irrigation		0.00	0.00	4,233.00	3,570.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7,803.00	459.00
(MJ/yr)	Electricity				13,958.10										13,958.10	821.06
(MJ/yr)	Seeds		5,427.00	2,499.00	0.10	2,184.00									10,110.10	594.71
(MJ/ha/yr)	Total input energy	241,121.24	37,375	52,323	116,052	35,372	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
(MJ/yr)	Total input energy	823,548.95	186,874	156,969	232,103	247,603										
(MJ/ha/yr)	Total output energy	271,276.00	53,576	44,100	56,000	117,600										
(MJ/yr)	Total output energy	1,335,380.00	267,880	132,300	112,000	823,200										
kg	Total yield	223,500.00	18,500	9,000	140,000	56,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		

Indicators

Energy Indicators	Wheat	Barley	Tomato	Corn
Energy ratio	1.43	0.84	0.48	3.32
Energy productivity	0.10	0.06	0.60	0.23
Specific energy	0.40	1.94	0.41	0.09
Net energy	16,201	-8,223	-60,052	82,228

Water Indicators

Food indicators

Energy forms	Wheat	Barley	Tomato	Corn
Direct energy [a]	10,291.60	20,251.29	79,027.70	13,823.02
Indirect energy [b]	27,083.15	32,071.83	37,023.85	21,548.80
Renewable energy [c]	5,789.60	2,793.00	20,524.70	5,879.44
Non- renewable energy [d]	31,585.15	49,530.12	95,526.85	29,492.38

[a] include human power, fuel, water for irrigation and electricity power

[b] include the Chemical poisons, fertilizers, seeds and machinery,

[c] include human power, seeds, manure & compost fertilizers, water for irrigation

[d] include fuel, electricity, Chemical, poisons, fertilizers and machinery.

Intelink Matrix

	WATER	ENERGY	FOOD/LAND	LABOUR
WATER				
ENERGY				
FOOD/LAND				
LABOUR				
COSTS				

Table 8- Example of calculation sheet

2.4.2 Indicators for energy-water-food assessment

From the above calculator a set of data and parameters referred to for example crops or type of energy can be obtained, as reported in the following figures:

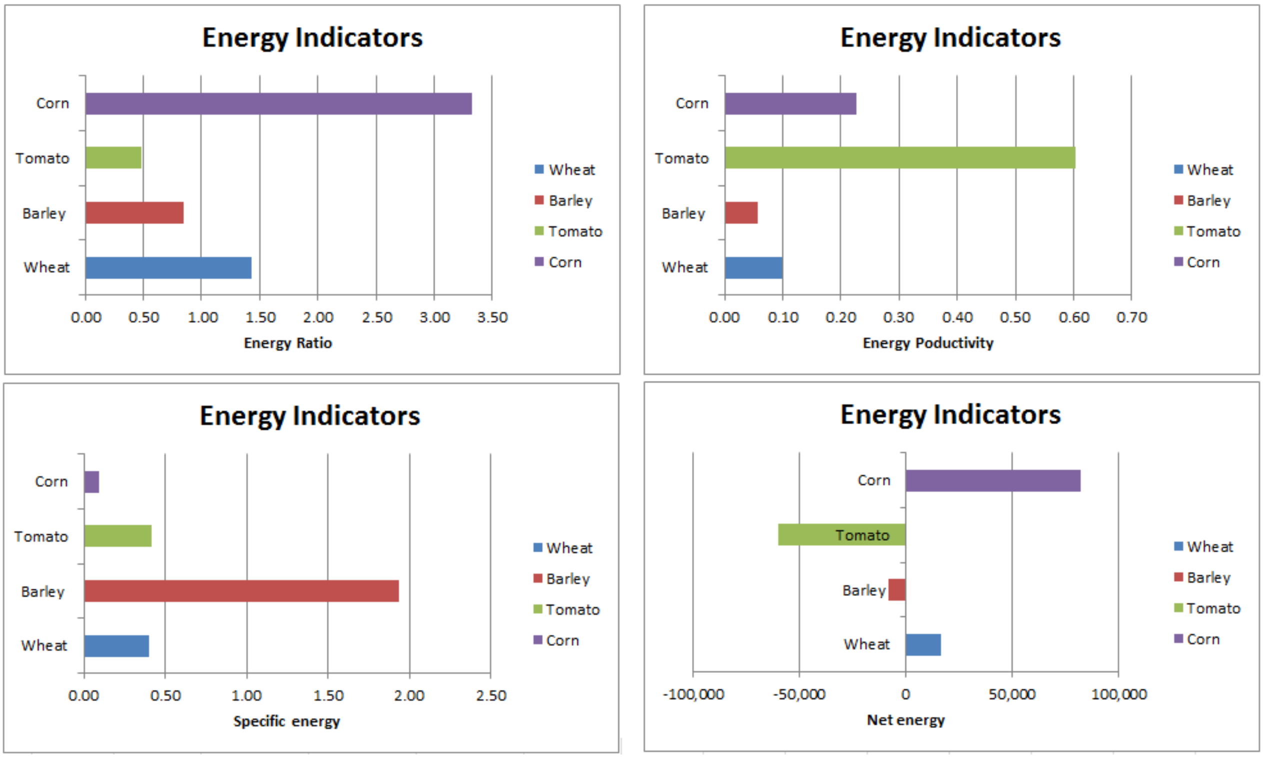


Figure 8 – Examples of Energy indicators

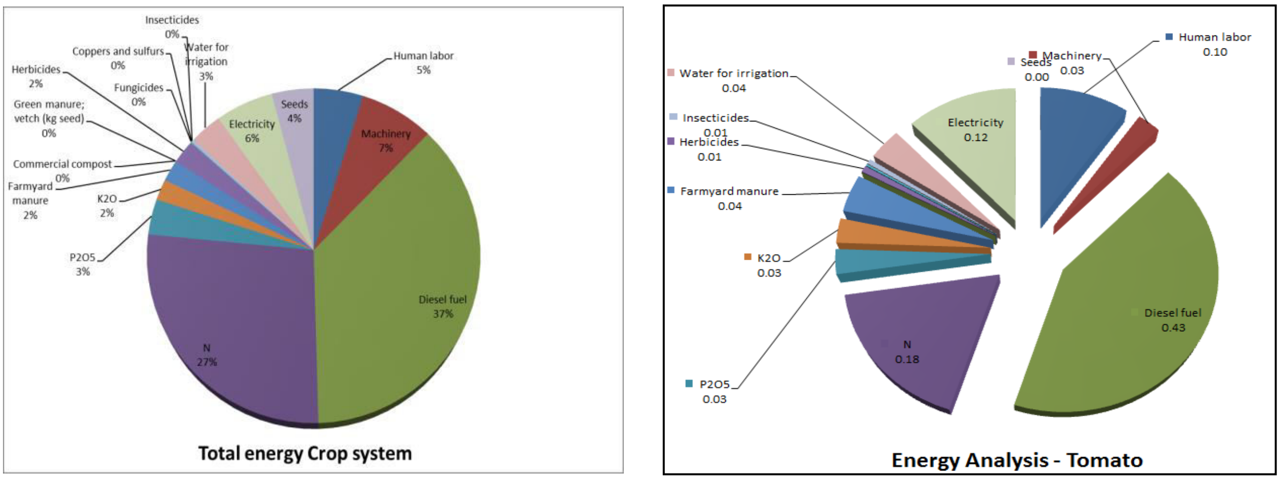


Figure 9 - Crop system energy analysis, total (left) and per crops (right)

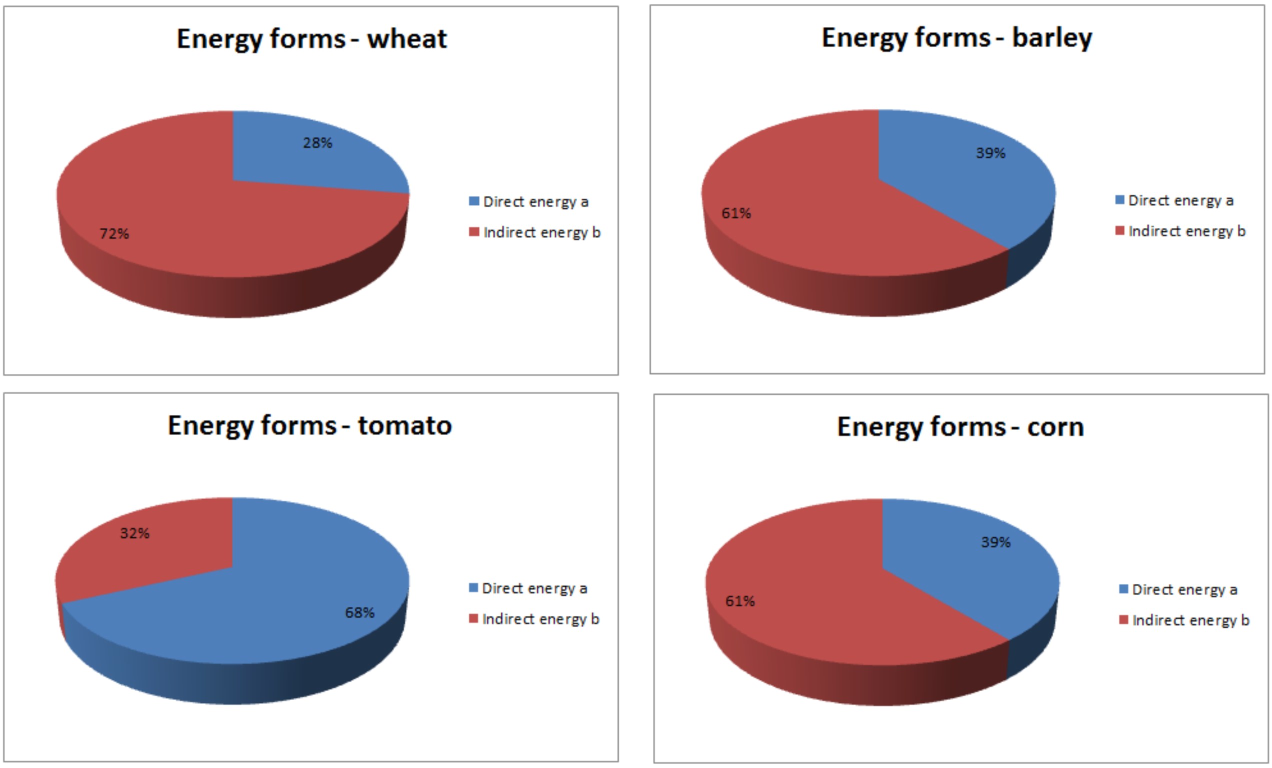


Figure 10 - Energy forms: direct/indirect

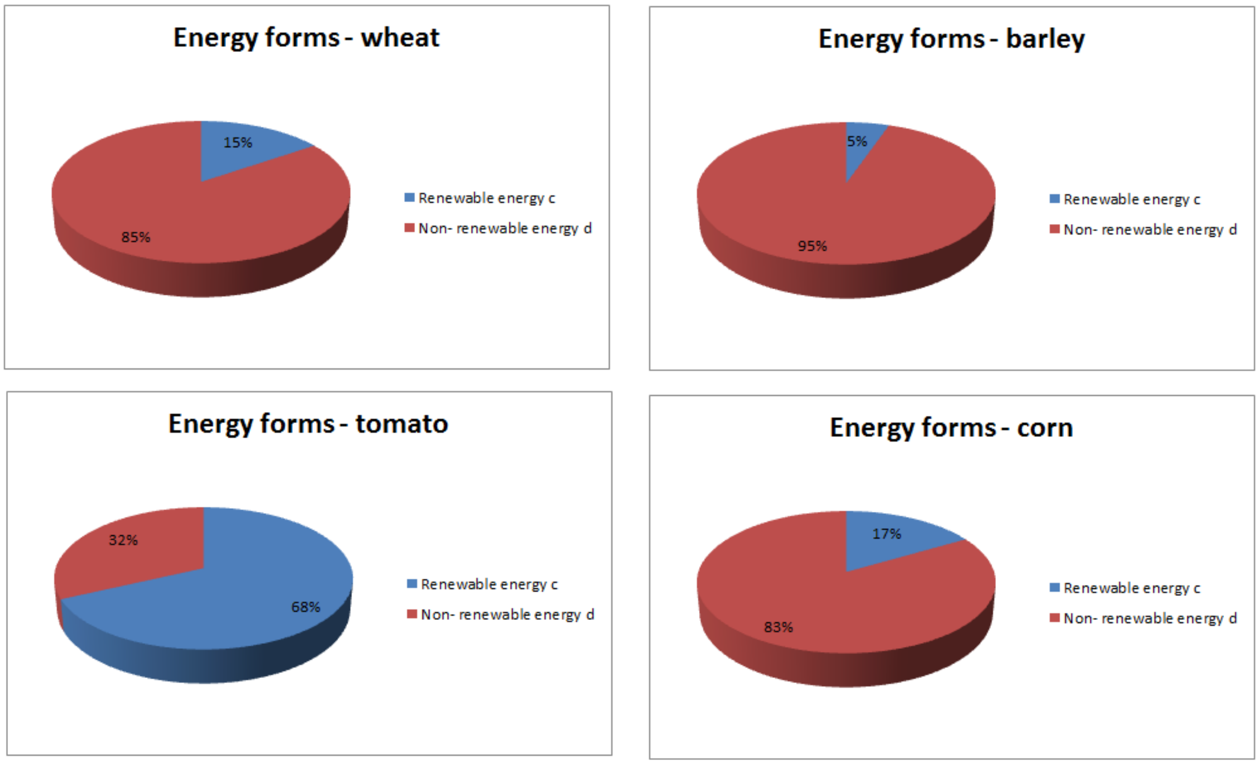


Figure 11 - Energy forms: renewable/not renewable

The aims of this activity is to provide a quick and simple way to better understand and quantify the interconnection of WEF nexus with the agricultural production, as derived from the baseline description, through the definition of linkages matrix and nexus sustainable indicators dealing with (FAO, 2014);

- Water for food
- Energy for food
- Water for energy
- Energy for water

Along with indicators directly relevant to water, energy and food, it could be useful to contextualize also the sustainability status in relation to human resources. These relate to i.e on labour intensity requirement, and capital intensity requirement, which can include information on capital availability as well as costs related to the agricultural production (including investments costs needed to improve sustainability).

The definition of indicators is of primary importance for the nexus assessment, and it will be implemented in a consultative process with Regional team and stakeholder, in order to establish which indicators fits context situation in each pilot site, and allows to build the interlinkages matrix.

Table 9 - Interlinkages matrix example

	WATER	ENERGY	FOOD/LAND	LABOUR
WATER				
ENERGY	Δ amount of water pumped/energy used Δ amount of water pumped/fossil energy used			
FOOD/LAND	Δ water pumped/land irrigated Δ yeld/water pumped	Δ energy used/irrigated land		
LABOUR			Δ Income per worker/yield	
COSTS	Δ Annual cost (capital, maintenance and operation)/amount of water pumped		Δ Value of agriculture produce/annual cost	

Table 9 is only an example of the interlink matrix. Based on the consideration that the understanding of the systems are interconnected and that these linkages need to be analysed to identify trade-offs and goal conflicts (barriers) as well as synergies (opportunities), and that all linkages may not be important in all cases, different indicators/approach will applied for the different FATIMA pilots, in the close cooperation with Regional managers.

The symbol Δ means "change in" allowing on evaluating and comparing the current status with the FATIMA tools proposed for better management of external inputs (energy, nutrient an water) for more sustainable alternatives cropping systems, in the intensive farm sector.

3 Conclusions

Following on the theoretical approach proposed in the above chapters, the WEF assessment will be implemented in each pilot area, in close cooperation with all regional team, based on the following steps:

- Step 1 – Setting a baseline scenario of WEF nexus at geographic level

A selection of variables concerning water and energy use and food production, useful for the pilot site baseline description, will be prepared by the WP4.1 leader and sent to the Regional manager, who will check the availability of the proposed variables in the reference area. This activity will be realized through questionnaire and completed within 31/12/2015. Data required will concern:

- The current state and pressures on natural and human resources systems;
- Expected demands, trends and drivers on resources systems;
- Interactions between water, energy and food systems;
- Different sectoral goals, policies and strategies regarding water, energy and food.

- Step 2 - Definition of WEF indicators

Indicators will be defined dealing with the three sustainability dimensions (FAO, 2014):

- Sustainable water (ex. Sustainable use and management);
- Sustainable energy (Efficiency, energy services and management, energy sources)
- Food (availability, stability and supply)

A specific focus will be dedicated to the economic analysis of the impact of energy costs in farm's balance. To estimate the impact of global energy costs of pilot area farms, "Energy Impact Matrices" (EIM) will be defined through an analysis of regional Farm Accountancy Data Network (FADN). Data collected will regard direct energy costs (electricity, fuel, gas) and indirect energy consumptions (seed, pesticides, fertilizers) for each Type of Farming (TF) and Economic Size Class (ESC) of farms[4].

- Step 3 – Acknowledgement and training on audit procedure

A lower level of WEF assessment will regard farm level. Guidelines on data gathering and, specifically on energy, audit procedure with identification and training of "auditors" will be realized. Water and food information will be collected directly (in close cooperation with WP 1.2) in pilot farms or from local knowledge (farmers, research and local institutions, other, etc.).

Conclusions from step 2 and 3 will be presented in 2nd project plenary meeting (march 2016)

- Step 4 – Execution of audit and Farm report

The WEF audit will be performed in different moments. Farm visit to collect data and create "consumption models". Reports containing analysis with dedicated tools (SICT) will be performed.

The aim of those documents is to highlight farm's performance making a comparison between new sustainable cropping systems and traditional ones, in terms of water and energy use, linked to food production and sustainability indicators showing their impacts on pilot sites, regional or river basin level.

[4] The FADN considers 8 general Type of Farming and 8 Economic Size Classes.

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