INTEGRATING BIOTREATED WASTEWATER REUSE AND VALORIZATION WITH ENHANCED WATER USE EFFICIENCY TO SUPPORT THE GREEN ECONOMY IN EU AND INDIA

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Water4Crops - EU

Work Package 3
Efficient water use in Irrigated Agriculture

Deliverable D3.1
Decision Support System (DSS) to help farmers to select the most suitable irrigation system to suit their local crops and soils

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1. Introduction

Increasing worldwide water supply shortages or competition for water resources have caused many irrigators in the developed and emerging countries to investigate alternative, water and/or energy saving irrigation methods.

Relative advantages and requirement of the most common irrigation application methods are well known by experts, technicians and advanced farmers, whilst the capability of non-trained technicians and small farmers to correctly select an irrigation system it's not obvious.

The selection of an irrigation system it's a strategic decision, taken once in a long period or over an entire season, that will impact as well on cascading tactical and operational decisions. Thereby the selection of the most appropriate irrigation system must take into account all the specific constraints besides the more evident advantages of the offered technology. As an example the irrigation method used for a specific small acreage situation is largely determined by the size and shape of the site, rotating crops in the farm, water supply and water quality, labour availability, cost, return of investment (ROI) time and access to financing by the farmer.

The strict inter-connection existing between a well-chosen and designed irrigation system and the productive and economic success of the crop, it's clear. The selected irrigation system should be compatible with the local climatic and soil conditions, the crop (either single or rotating crops), the water quality and governance, achieving the highest water use efficiency and lowest possible operating and maintenance costs.

An improper selection of the irrigation system will result in wasting of opportunities, because for practical and economic reasons it will be not possible to change it during the subsequent cropping season, and of the money invested in designing it. Besides, it will lead easily to waste of water.

The main constraints to the selection of the irrigation system that fits best are, firstly, the large variety of irrigation systems available on shelf, especially pressurised systems, and the difficult access to information which allows comparing and contextualizing the offers.

An effective way for selecting a proper irrigation system is first to define the operational boundaries, obtaining information on water, weather, soil, cropping pattern and economic aspects from locally available sources. Hence, starting from this characterisation of the irrigation system surrounding environment, farmers will acquire a first understating of the available options which should be indeed useful to support their choice. From this point, with an increased awareness of the local physical, environmental and economic objectives, and on the other hand taking into account his own preferences and limitation, the farmer himself would be able to select the best irrigation system from a short list of options fulfilling given main constraints.

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2. SelSys: Irrigation system selection tool

Farmers and irrigation service providers are looking for information which can aid in selecting appropriate irrigation systems considering as much as possible the multi-facet aspects of irrigate agriculture management and the increasing management complexity of limited water resources.

The SelSys Decision Support System (DSS) is a web based tool to guide decision on selection of suitable irrigation systems, taking into account constraints as soil characteristics, water quality, climatic conditions. The selection criteria are considering as well the crop, single crop or rotation, and the investment required.

The SelSys DSS consists in a set of matrix developed by an expert panel on the ground of the available literature and know how. Therefore, part of the knowledge build into this tool is a mix of knowledge extracted from various sources: from scientific journal papers, empirical relations not yet published, and to some extent concepts developed from expert knowledge and experience.

SelSys is working on the basis of the Expert System concept. An Expert System is a program that imitate behaviour of a human expert, as an artificial intelligence aimed to process and think like an expert and then act like a human advisor in the application area. The Expert System query stored information (databases) and continues to ask questions until a solution that matches the satisfactory answer criteria is found. The main characteristic of an expert system is that it has been established mainly on field based experiences.

SelSys DSS has been developed by CER in the frame of the W4Cs project, in the period from 2012 to 2014 and will be continuously improved in a closed loop following the Demming's cycle: plan-do-check-action. CER intends disseminate the DSS or the criteria behind the tool at regional and national level, thus playing its role as leading stakeholder in irrigated agriculture.

SelSys has been made available to W4Cs partners, through the CER website and soon through a link in the W4Cs website.

The aim of this document is to describe the main functions of the SelSys web-application.

The tool is available at the following URL: http://servizi.consorziocer.it/W4Cs/

3. Access the selection tool

Cliking the URL address (http://servizi.consorziocer.it/W4Cs/) users will be redirected to the SelSys home page.

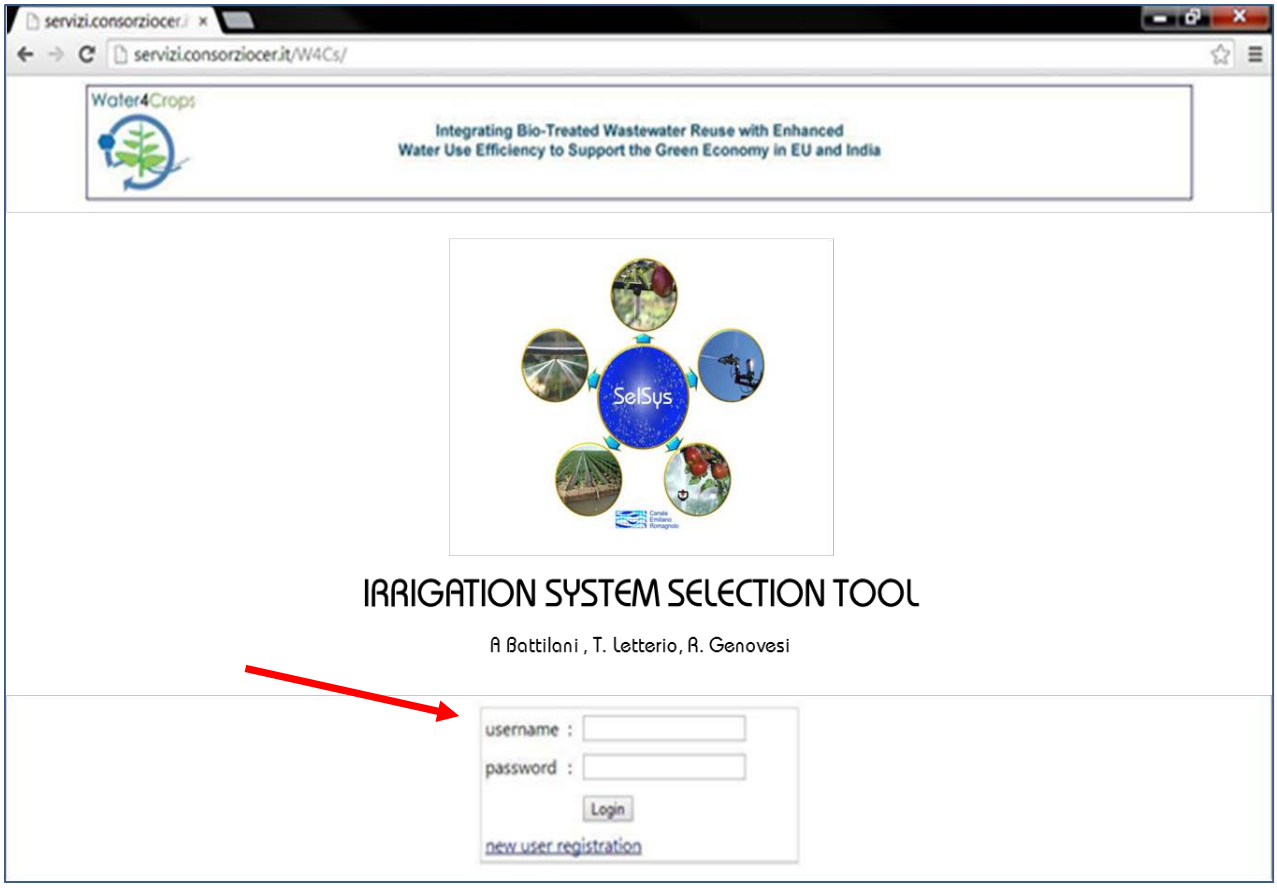


Figure 1 – Screenshot of the SelSys home page

In the home page users are requested to login, inserting the username and password already in their possession, or to register as new user clicking on “new user registration” link (Figure 1).

There are no limitations or rules users have to apply choosing username and password, however it must be noticed that the user’s profile and his accesses will be recorded. The information required registering and access the tool are shown in figure 2.

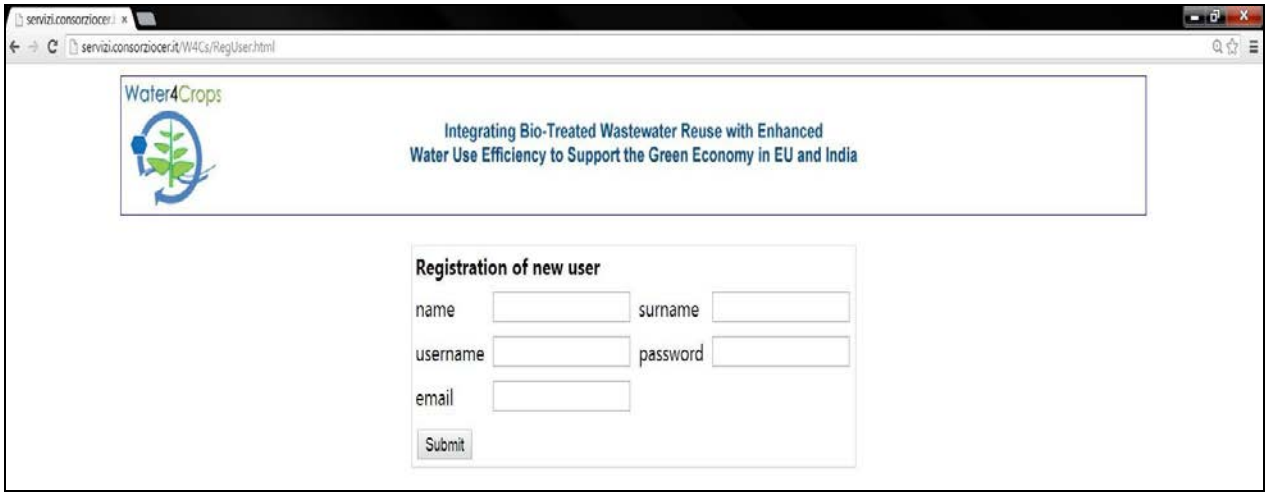


Figure 2 – New user registration page screenshot

4. Inputs

In order to give consideration to the circumstances in which the system must operate in terms of the physical and business environment, and how those factors relate to the advantages and disadvantages of the various system types the following inputs are required to let SelSys offer to the user a range of suitable options.

The SelSys database includes 44 irrigation methods, among the most diffused, which have been analysed and ranked with the help of 26 indicators, then normalised and grouped in 16 inputs categories. Each of these input categories has been divided into sub-groups according to the sensitivity thresholds indicated by the expert panel.

The input page is shown in Figure 3. The page heading reports the user name and the access date, that way each session is marked out. SelSys is not designed to store users queries and their outcomes, thus it's recommended to print out both the input and the output page.

For each parameter the user has to select an option from the drop-down menu. Only crop selection allows for multiple selections, in order to correctly take into account the farm rotation. When no selection is made the software will get the first option of the drop-down menu (default option).

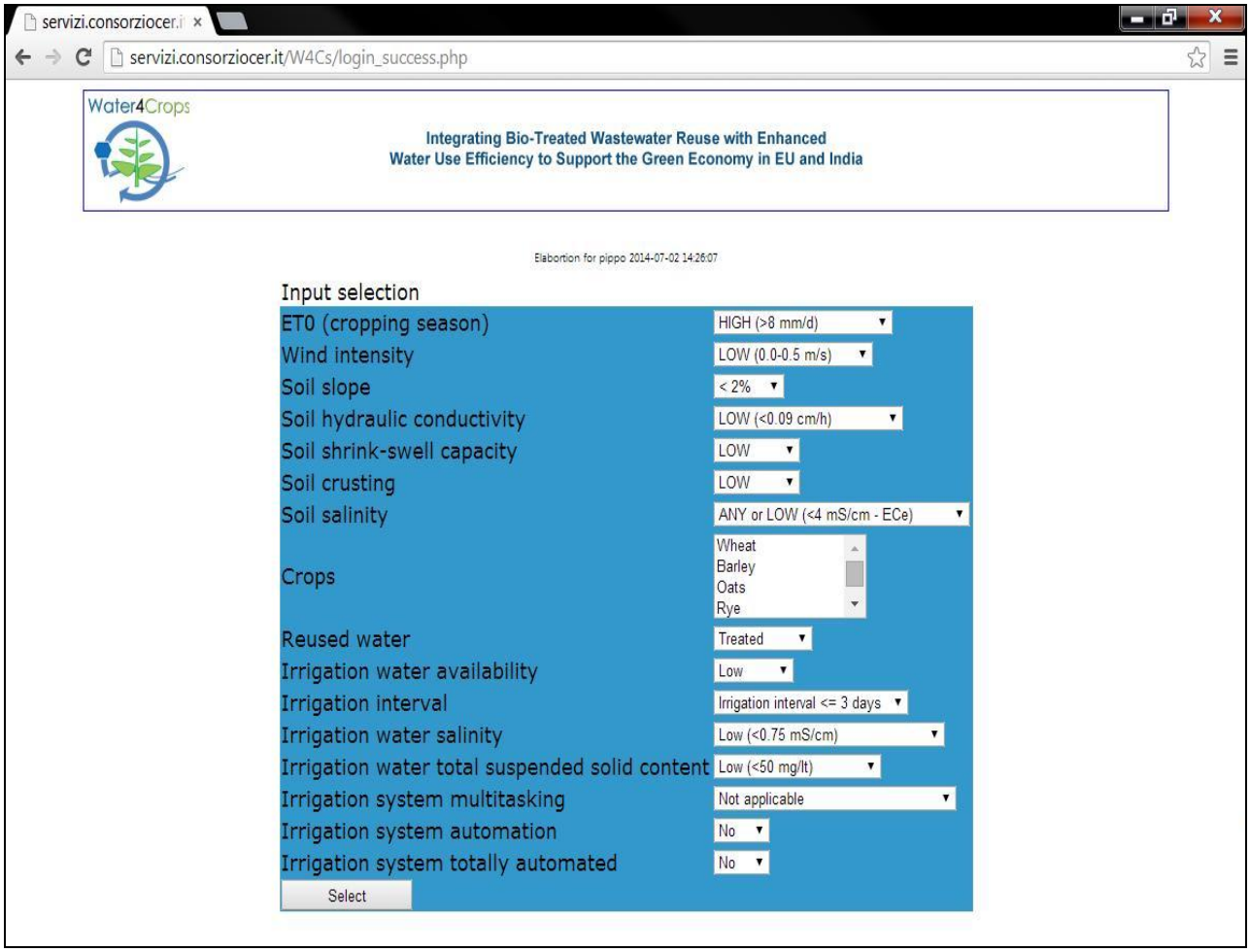


Figure 3 – Screenshot of input page of web-application

The inputs needed choosing the irrigation systems are as follows:

ET0

The reference evapotranspiration has been taken as the best representation of the climatic conditions driving irrigation requirements and management. ET0 has been ranked in 3 levels: HIGH (> 8.0 mm/d), MEDIUM (8.0-5.0 mm/d) and LOW (< 5.0mm/d). The considered ET0 is calculated as the average of cropping season.

Wind intensity

Wind intensity, as calculated over the entire growing season (average or peak) according to the local requirements, has been classified as follows: LOW (0.0-0.5 m/s), MEDIUM (0.5-2.0 m/s) and STRONG (>2.0 m/s). The wind intensity shall be measured at the height of 2 meters upon the ground level (international agro-meteorology standard).

Soil slope

Soil slope is considered as the steepest slope in the area served by the irrigation system. Soil slope ranks are as follows: < 2%, 2-5%, 5-15%, >15%.

Soil hydraulic conductivity

Soil hydraulic conductivity is utilised in combination with the following shrinking-swelling and crusting soil characteristics defining the soil type constraints affecting the irrigation system distribution efficiency. The considered soil hydraulic conductivity are LOW (<0.09 cm/h), MEDIUM (0.09-6.11 cm/h) and HIGH (>6.11 cm/h).

Soil shrinkage-swelling capacity

Soil shrink-swell capacity is classified on the ground of qualitative criteria, being impossible ask to normal users to define this particular aspect by the relation between the void ratio and the moisture ratio as for the soil shrinkage characteristic curve (SSCC). This parameter has three qualitative levels: LOW, MEDIUM, HIGH.

Soil crusting

As for the previous parameter the offered options are merely qualitative. As a matter of fact, it's difficult even for skilled technicians to measure in the field the soil crust strength in shear, rupture, and penetration. The three qualitative options are LOW, MEDIUM, HIGH.

Soil salinity

Soil salinity ranking is following the main crop sensitivity to saline stress. The thresholds have been prudentially set at the following levels: ANY or LOW (<4 mS/cm), MODERATE (4.0-16.0 mS/cm), HIGH (>16.0 mS/cm). The soil salinity value is expressed as saturated paste extract electrical conductivity (ECe).

Crops

Leveraging the know how acquired in previous EU projects and the experience done by the CER' Extension Service through the implementation of the water balance model IRRIFRAME, at local scale first and then all over Italy, crop requirements and related cropping systems characteristics have been cross checked with the considered 44 irrigation systems, seeking possible limitation to their application for each single crop listed. The list of crop considered for the irrigation system selection is reported in **Errore. L'origine riferimento non è stata trovata.Reused water**

The reused water topic has been solved making use of the GlobalGap standards classification: Treated, Not treated. It considers the application of not treated waste water to crops, which characteristics are extremely variable but in general not suitable for many irrigation systems. On the other hand treated waste water, as conceived in western countries and as permitted by EU regulations, has been assimilated to any other surface water for what concern its influence of irrigation system operability. Thus selecting the "Treated" option user indicates both the use of surface/ground water and properly treated waste water.

Irrigation water availability

The irrigation water availability parameter is intended to describe the user access to water in quantitative terms. The qualitative ranking it's in fact taking into account the amount of water available for the irrigation system. This parameter hasn't any defined value because of the large range of minimum discharge required by the different methods. Moreover, in general low tech irrigation systems are already fed by large amount of water, thus the modernisation process would have no constraints that respect. The parameter considers three levels: LOW, MEDIUM, HIGH.

Irrigation interval

Irrigation interval allows excluding a defined irrigation system according to its capacity to operate on demand or on shift. The discriminant for this parameter has been set as follows: <= 3 days and > 3 days.

Irrigation water salinity

Irrigation water salinity has been detailed more than needed when considering only limitations for the irrigation method. However, the five levels of water salinity taken into account allows to better discriminate between crops sensitivity to potential damages caused by water contact with leaves or crusting/sodicity effects on soil surface. The salinity of water has been ranked as LOW (<0.75 mS/cm), MEDIUM-LOW (0.75-1.5 mS/cm) , MEDIUM-HIGH (1.5-3 mS/cm), BRACKISH WATER (3.0-25.0 mS/cm), SALINE WATER (>25.0 mS/cm).

Irrigation water total suspended solid content

The total suspended solid content in irrigation water has clear effects on irrigation systems sensitive to clogging, as well as on maintenance and durability of pressurised equipment, The optimal thresholds it's normally deemed below 50 mg L^{-1}, the bearable limit it's set at 100 mg L^{-1} and over this threshold only very robust and simple methods can safely operate. The options are LOW (<50 mg/lt), MEDIUM (50-100 mg/lt), HIGH (>100 mg/lt).

Irrigation system multitasking

Nowadays, and more and more in the next future, irrigation systems will have to accomplish multiple tasks. In order to consider the limitations related to the most commons multitasking applications the DSS analysed and is taking into account uses for Frost protection, Cooling/ Micro-climate conditioning, Fertigation. The Not applicable option allows to exclude the multitasking use of the system. The irrigation methods are excluded according to the system capacity to provide other functioning requested.

Irrigation System Automation

Irrigation system automation takes into account whether the candidate irrigation systems are suited or not to be automated in order to control totally or part of the irrigation operation. The available options indicate either the willingness to install a method supporting automation at a certain degree or not (Yes/No).

Irrigation system Totally automated

Irrigation system totally automated, as the previous parameter, has only two options: Yes or No. This parameter considers the necessity to set up a system able to be fully automated.

Table 1 reports the list of parameters and related option as it is in the input menu and sub-menus.

PARAMETERS	ITEMS
ET0 (cropping season)	HIGH (>8 mm/d) MEDIUM (5.0-8.0 mm/d) LOW (<5 mm/d)
Wind intensity	LOW (0.0-0.5 m/s) MEDIUM (0.5-2 m/s) STRONG (> 2.0 m/s)
Soil slope	< 2% 2-5% 5-15% >15%
Soil hydraulic conductivity	LOW (<0.09 cm/h) MEDIUM (0.09-6.11 cm/h) HIGH (>6.11 cm/h)
Soil shrink-swell capacity	LOW MEDIUM HIGH
Soil crusting	LOW MEDIUM HIGH
Soil salinity	ANY or LOW (<4 mS/cm) MODERATE (4.0-16.0 mS/cm) HIGH (>16.0 mS/cm)
Crops	Wheat Barley
Reused water	Treated Not treated
Irrigation water availability	Low Medium High
Irrigation interval	Irrigation interval <= 3 days Irrigation interval > 3 days
Irrigation water salinity	Low (<0.75 mS/cm) Medium-Low (0.75-1.5 mS/cm) Medium-high (1.5-3 mS/cm) Brackish water (3.0-25.0 mS/cm) Saline water (>25.0 mS/cm)
Irrigation water total suspended solid content	Low (<50 mg/lt) Medium (50-100 mg/lt) High (>100 mg/lt)
Irrigation system multitasking	Frost protection Cooling/ Micro-climate conditioning Fertirrigation Not applicable
Irrigation System Automation	Yes No
Irrigation system Totally automated	Yes No

PARAMETERS	ITEMS
Crops	Wheat Barley Oats Rye Maize Rice Sorghum Millet Bean Pea Chickpea Soybean Bean Alfalfa Italian sainfoin Clover Ryegrass Vetch Vicia faba var. minor Rape Sunflower Peanut Flax Kale Castor-oil plant Sugar beet Potato Tomato (Processing) Tobacco Hemp Cotton Flax Liliaceae (onion, ...) Brassica Apiaceae Cucurbitacee Solanaceae Fresh Tomato Asteraceae Fabaceae Horticolture leaf Cucurbitaceae Solanacee Apiacee Strawberry Laefy vegetable Asteracee Apple Pear Quince Nashi Pear Peach Plum Apricot Cherry Hazel Olive oil Table oil Grapevine Table Grapes Kiwi Orange Lemon Grapefruit Almond

Table 1. Input menus and sub-menus

5. Outputs

As far input selection is completed, user has to click on the “Select” button to start selection and move to the Outputs page.

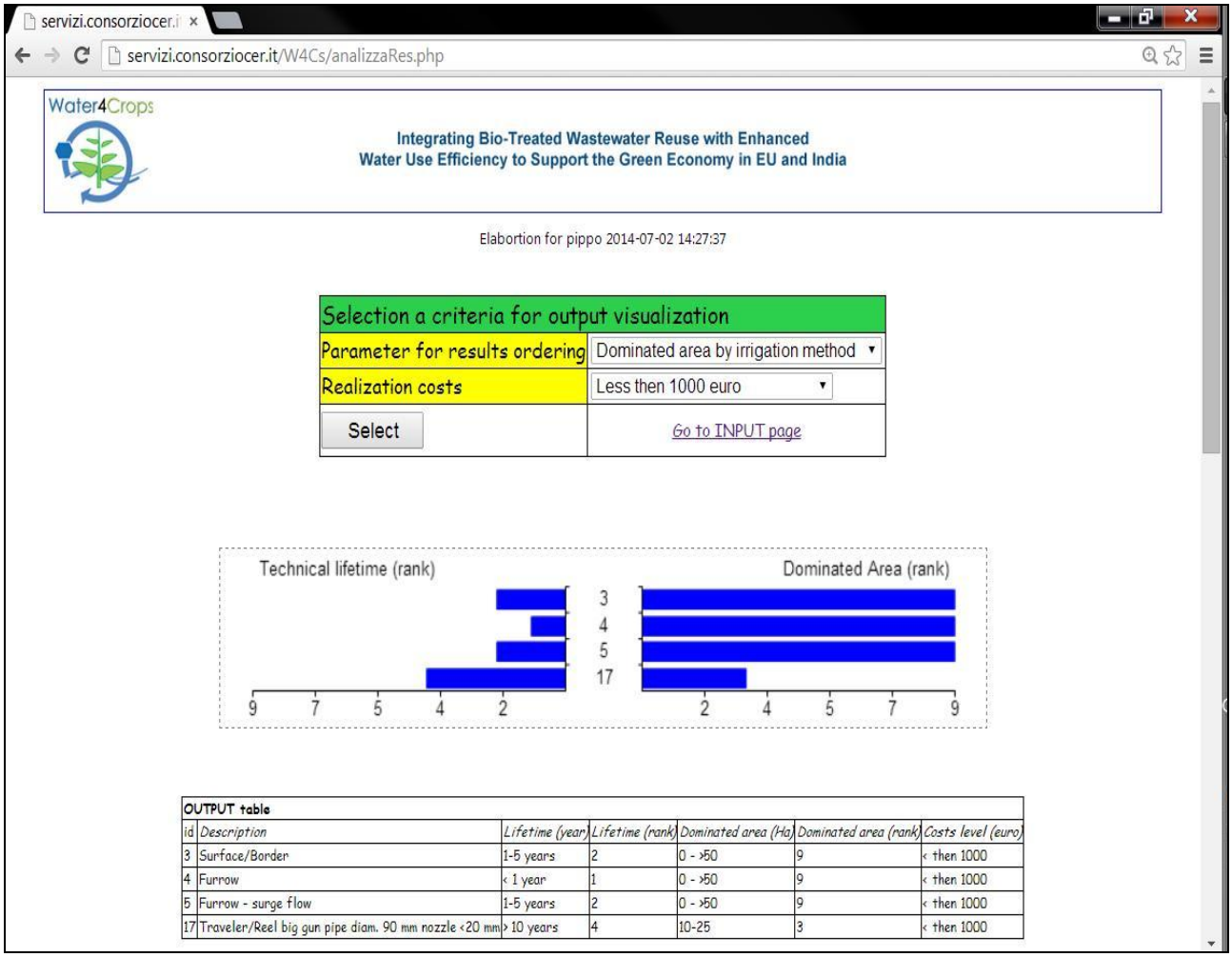


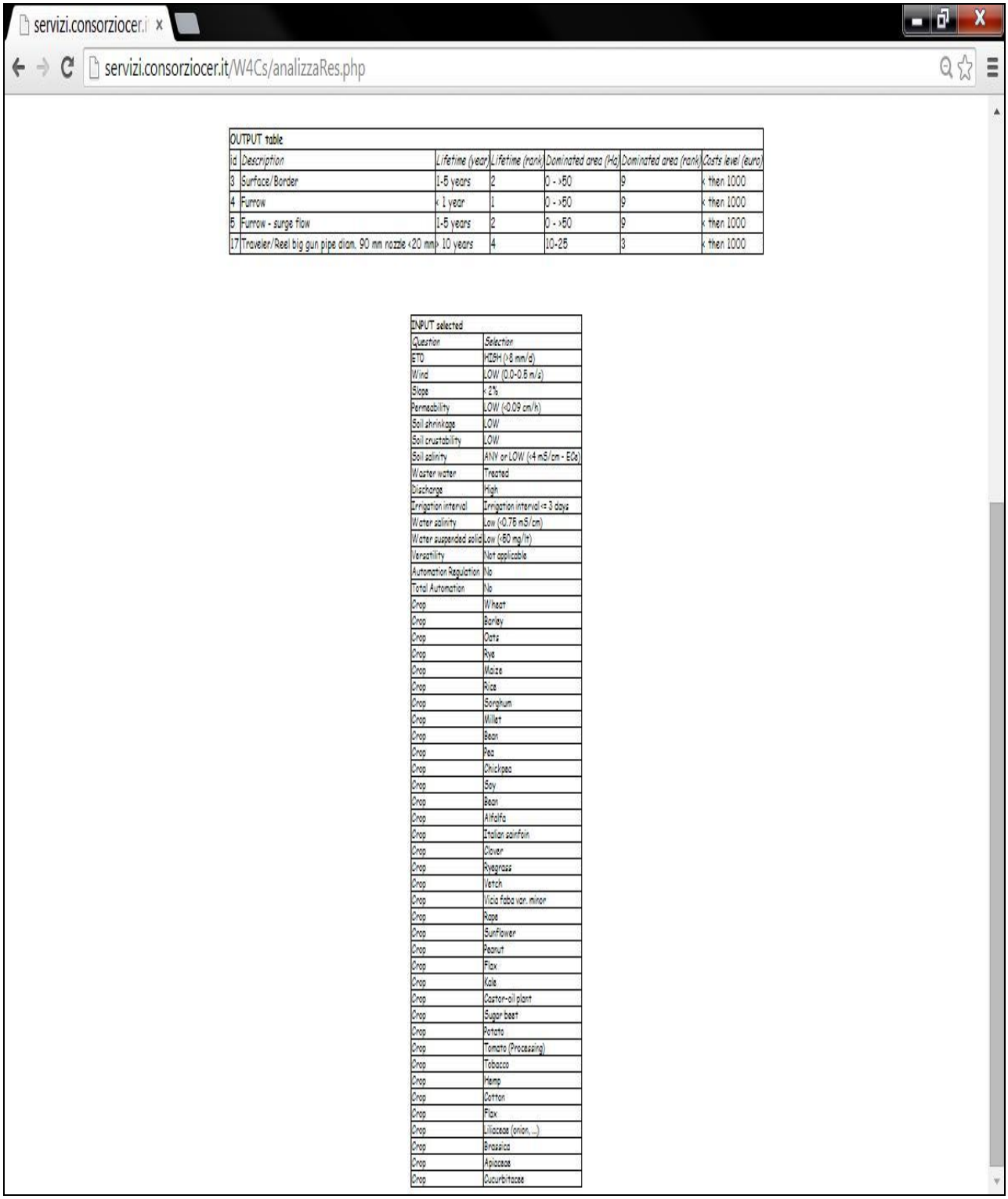
Figure 4 – Screenshot of output page

The output page consists in two selection menus in the upper part, a twin graph in the middle and a table at the bottom.

The dropdown-menus allow selecting the output visualization criteria. The output table can be sorted out by “Dominated area by irrigation method” or “ Technical lifetime of irrigation method”.

The last selection option allows users to choose the investment cost in a range below 1000 € ha^{-1}, between 1000 and 2000 € ha^{-1} or more than 2000 € ha^{-1}.

At the bottom of the output page can be found a table summarising the input selected by the user (Figure 5).



OUTPUT table

id	Description	Lifetime (year)	Lifetime (rank)	Dominated area (Ha)	Dominated area (rank)	Costs level (euro)
3	Surface/Border	1-5 years	2	0 - >50	9	< then 1000
4	Furrow	< 1 year	1	0 - >50	9	< then 1000
6	Furrow - surge flow	1-5 years	2	0 - >50	9	< then 1000
17	Traveler/Reel big gun pipe diam. 90 mm nozzle <20 mm	10 years	4	10-25	3	< then 1000

INPUT selected

Question	Selection
ET0	HIGH (>8 mm/d)
Wind	LOW (0.0-0.5 m/s)
Slope	< 2%
Permeability	LOW (<0.09 cm/h)
Soil shrinkage	LOW
Soil crustability	LOW
Soil salinity	ANY or LOW (<4 mS/cm - ECe)
Wastew water	Treated
Discharge	High
Irrigation interval	Irrigation interval <= 3 days
Water salinity	Low (<0.75 mS/cm)
Water suspended solid	Low (<60 mg/l)
Versatility	Not applicable
Automation Regulation	No
Total Automation	No
Crop	Wheat
Crop	Barley
Crop	Oats
Crop	Rye
Crop	Maize
Crop	Rice
Crop	Sorghum
Crop	Millet
Crop	Bean
Crop	Pea
Crop	Chickpea
Crop	Soy
Crop	Bean
Crop	Alfalfa
Crop	Italian sainfoin
Crop	Clover
Crop	Ryegrass
Crop	Vetch
Crop	Vicia faba var. minor
Crop	Rape
Crop	Sunflower
Crop	Peanut
Crop	Flax
Crop	Kale
Crop	Castor-oil plant
Crop	Sugar beet
Crop	Potato
Crop	Tomato (Processing)
Crop	Tobacco
Crop	Hemp
Crop	Cotton
Crop	Flax
Crop	Liliaceae (onion, ...)
Crop	Brassica
Crop	Apiaceae
Crop	Cucurbitaceae

Figure 5 – Screenshot of the bottom of output page

6. Conclusions

It should be evident from the issues briefly described in this report that the choice of an irrigation system is not a simple matter.

In selecting an irrigation system, it would be great if an expert or a decision support system could be designed that met all of the user requirements ending with precise indication of the method best fitting user' specific conditions.

However, there is no perfect irrigation system, thus the choice of system always requires compromise. The final choice can be done only by the farmer himself, on the ground of factors that cannot be codified into a decision support tool. As an example, when selecting an irrigation system the cost of the system is usually uppermost in farmers' minds, but skilled farmers are not simply looking at up-front capital costs but also at operational and maintenance costs, at their own capability to install, recover and repair the equipment, and so on.

There are a few key messages that must be kept in mind: many factors need to be considered when choosing a system and many information are required to make a wise choice; there is not necessarily a single "best" choice for a particular user, choice depends on individual farm circumstances and compromise is always needed.

The last suggestion is to consider all costs, not just up-front capital costs, and to consult an independent expert when the investment is significant and/or there too many irrigation system matching the boundary condition set for your selection scenarios.