LABORATORY OF SUSTAINABLE WASTE MANAGEMENT TECHNOLOGIES

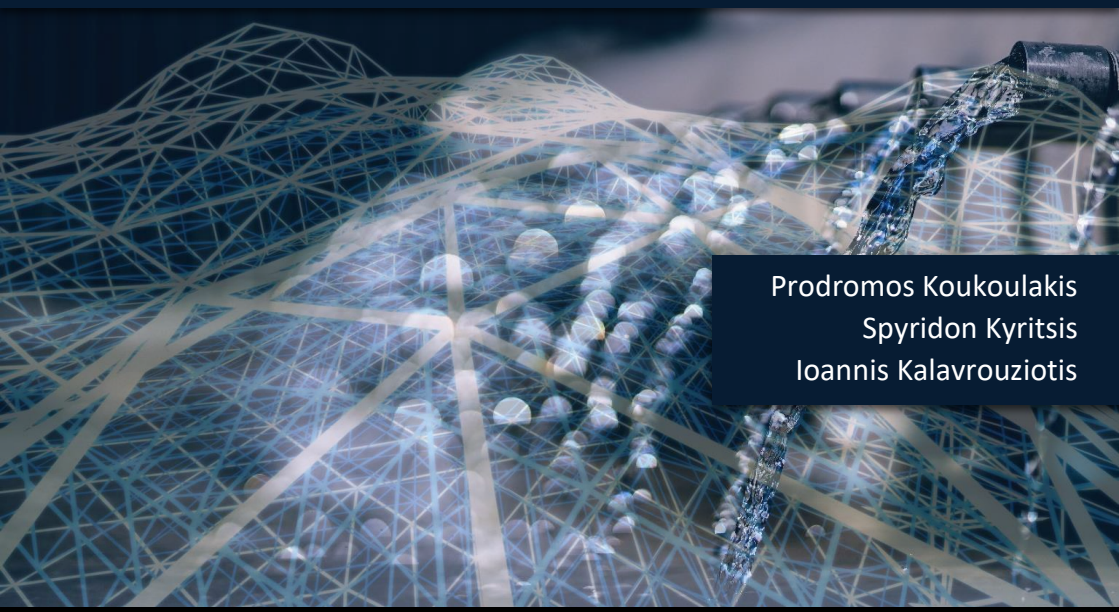
School of Science & Technology

HELLENIC OPEN UNIVERSITY

DECISION SUPPORT SYSTEM

FOR WASTEWATER AND BIOSOLIDS REUSE IN AGRICULTURAL APPLICATIONS

User Manual v1.5.1



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Decision Support System for Wastewater and Biosolids Reuse in Agricultural Applications

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(Self-financed project).

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DESCRIPTION

This Decision Support System (DSS) is an expert system (ES), containing a knowledge base with a plethora of multicriterial rules that analyses and evaluates input data of soil, treated municipal wastewaters (TMWW), and treated form of sludge (biosolids), and provides rational fertilization advice for crops and information for the determination of the optimum nutrient dose for N, P_2O_5, K_2O, MgO, Fe, Zn, Mn, Cu, and B.

GOALS

The present DSS is a special software solution with a multitude of goals. It is expected to contribute to the utilization of the wastewater and sludge

produced by the Wastewater Treatment Plants (WTPs), both alone or in combination with each other, and to supply plant nutrients and organic matter to soils many of which are depleted of these important constituents.

FEATURES

The DSS is capable of making decisions in relation to safe wastewater and sludge reuse, evaluating:

- The heavy metals soil pollution level due to long-term reuse of the above inputs and alerts the user to take promptly necessary measures to avoid the adverse consequences.
- The optimum fertilization of crops, in order to minimize the use of fertilizers and protect the agroecological environment from an unnecessary nutrient load, which otherwise could have unfavorable effects on the soil and life quality.

The current version processes analytical input data of soil, treated wastewater, and sludge, providing information about the elemental pollution index for the evaluation of soil heavy metal pollution level and the rational fertilization of crops by determining the optimum nutrient dose to be applied, contributing to the protection of the environment, especially of the soil from the accumulation of heavy metals and possibly of pharmaceuticals in the long run.

The system supports three operation modes:

- Reuse of only Treated Wastewater
- Reuse of only Sludge (Biosolids)
- Reuse of both Treated Wastewater & Sludge

The DSS is taking advantage of current web technologies for its user-friendly interface. It is

modular, flexible, and easily upgradeable in order to accommodate new features and functions.

The current version is built as a web application with PHP, MySQL, and JavaScript. It uses a simple, lightweight, and easy-to-use web interface even for a novice computer user. Its core engine is modular flexible, and customizable enough to accept and incorporate specific requirements, future changes, new technologies, or upgrades.

Upon request, custom configurations may be provided, in order to meet specific client requirements, i.e.:

- Language translations.
- Special crops.
- Specific guidelines suggested by national agencies.
- Interfacing with local weather stations[1] in order to take advantage of FAO 56 Evapotranspiration method, etc.

[1] If appropriate API is available

START THE SOFTWARE APPLICATION

The DSS is controlled, by the user, through a web User Interface (UI). Its web address is http://wdss.eap.gr/, and it can be opened in any major web browser running on a personal computer (Figure 1).

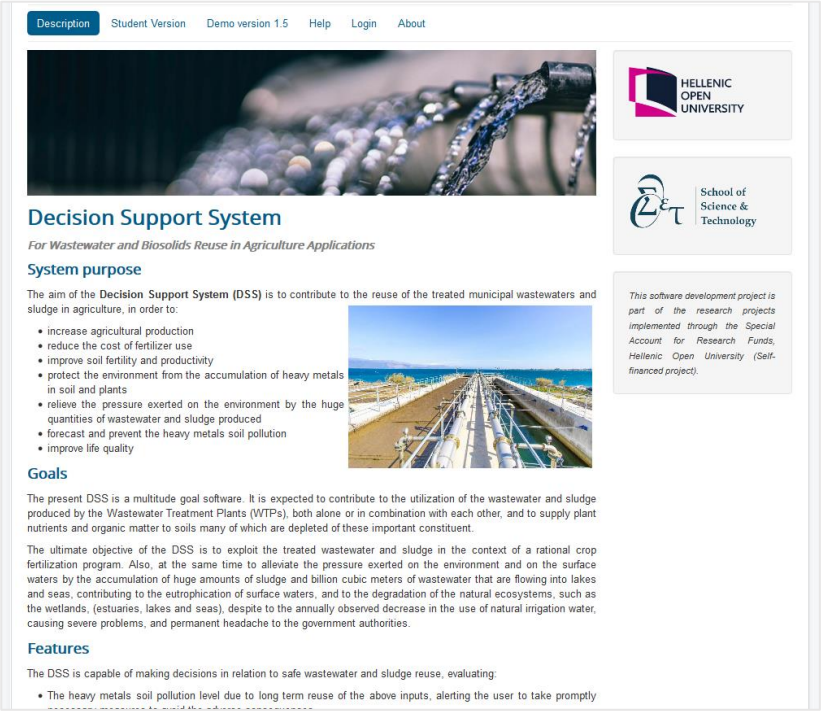


Figure 1. DSS homepage

The user can access the login screen by clicking on the Login button on the navigation bar (Figure 2).

Figure 2. Navigation bar

login[2] by entering a valid username and password at the login screen (Figure 3).

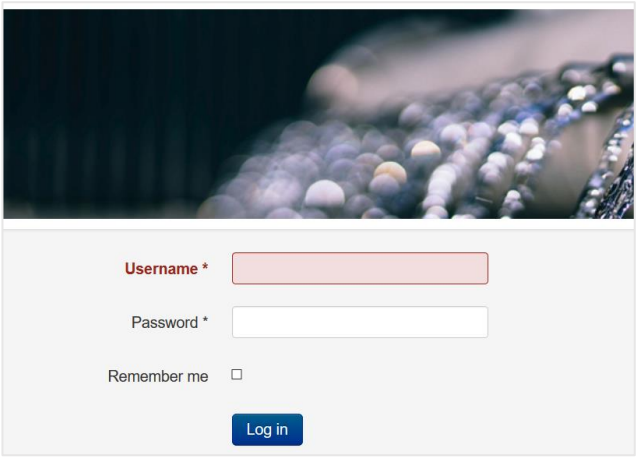


Figure 3. Login screen

[2] There is also a demo version accessible from the "Demo version 1.5" link without login where the user can load and run predefined examples.

After a successful login, the user can start the app by clicking on the DSS v1.5.1 button, and the data entry form (Figure 4) appears on the screen.

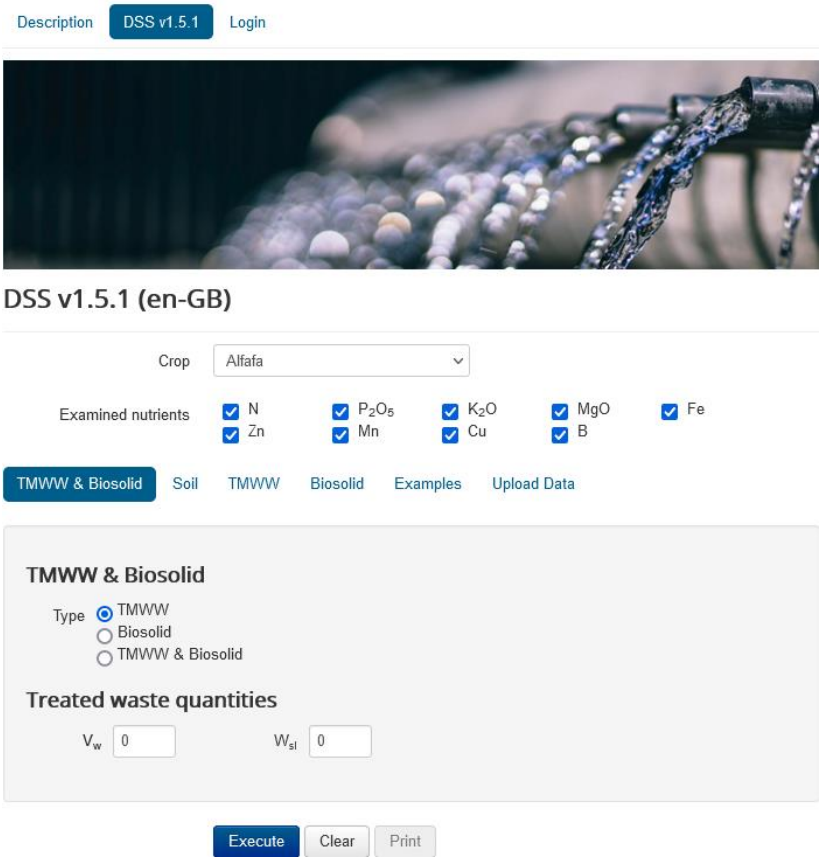


Figure 4. Data entry form

DATA ENTRY

At the input fields where we can enter our data, **the system accepts only numbers, integers, or decimals**. As a **decimal point,** the system accepts **the period symbol (.)**. i.e., 1.25

Note: The system does not accept symbols (i.e., measurement units) in the input fields. It accepts only numerical values that correspond to the measurement units described below in the tables with the input variables.

Input form fields accept values strictly starting with a numerical symbol. Values with only the decimal part must **always include zero (0)** before the decimal point. i.e.:

0.25 correct format

.25 wrong format (*missing leading 0*)

HOW TO ENTER DATA

1. Select the crop on which the treated waste is to be applied from the **"Crop"** dropdown menu (**Figure 5**).

Figure 5. Crop dropdown menu

2. Select or deselect macro-micro nutrients for which the fertilization advice is to be advised by clicking the corresponding checkboxes from the **"Examined nutrients"**. By default, the form has the fertilization advice enabled (checked) for all nutrients (Figure 6).

Figure 6. Examined nutrients checkboxes

3. On the tab **"TMWW & Biosolid"** (Figure 7), first, the waste type is selected, and second, the

corresponding numerical data are entered (Table 1).

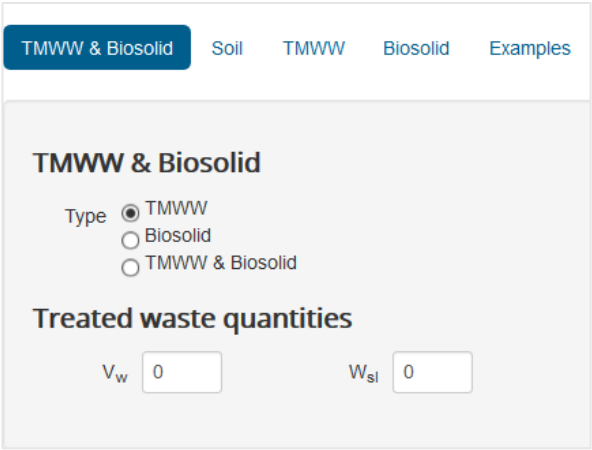


Figure 7. TMWW &Biosolid

Table 1. Treated waste quantities

Field	**Description**	**Units**
V_w	Treated wastewater volume	$m^3/10^3m^2$
W_{sl}	Biosolid (or sludge) mass	$kg/10^3m^2$

4. The **"Soil data"** tab opens by clicking the **"Soil"** button (Figure 8). The soil type is selected, and the

numerical data of soil values are entered in the corresponding fields as described in

5. Table 2 and Table 3.

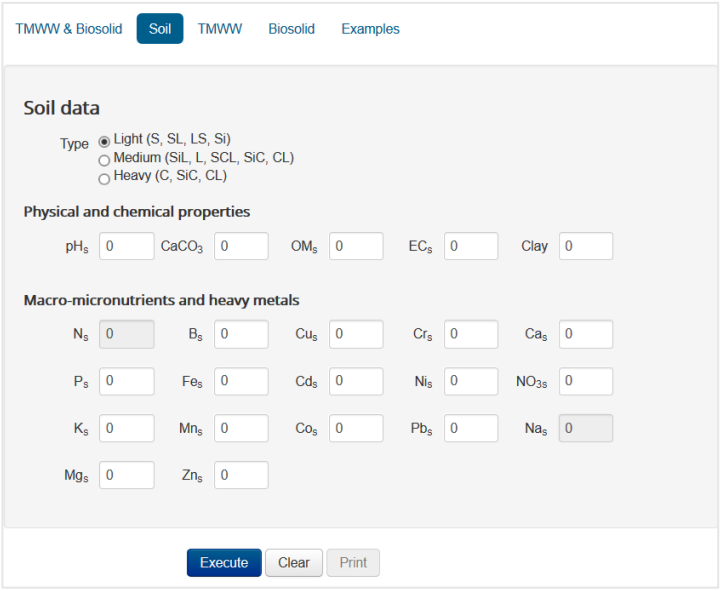


Figure 8. Soil Data

Note: Subscript (s) at the names of the input fields suggest that they correspond to soil characteristics, i.e., N_s or P_s.

Table 2. Soil physical and chemical properties

Field	**Description**	**Units**
pH_s	Soil's pH	
$CaCO_3$	Soil's calcium carbonate	%
OM_s	Soil's organic matter	%
EC_s	Soil's electrical conductivity	mS/cm
Clay	Soil's clay	%

Table 3. Macro-micronutrients and heavy metals

Field	Description	Units
N_s	Disabled[3]	
P_s	Soil available Olsen P	mg/kg
K_s	Soil available K	mg/kg
Mg_s	Soil exchangeable Mg	mg/kg
B_s	Soil available B	mg/kg
Fe_s	Soil DTPA[4] extractable Fe	mg/kg
Mn_s	Soil DTPA extractable Mn	mg/kg
Zn_s	Soil DTPA extractable Zn	mg/kg
Cu_s	Soil DTPA extractable Cu	mg/kg
Cd_s	Soil DTPA extractable Cd	mg/kg
Co_s	Soil DTPA extractable Co	mg/kg
Cr_s	Soil DTPA extractable Cr	mg/kg
Ni_s	Soil DTPA extractable Ni	mg/kg
Pb_s	Soil DTPA extractable Pb	mg/kg
Ca_s	Soil exchangeable Ca	mg/kg
NO_{3s}	Soil nitrate	mg/kg
Na_s	Disabled	

[3] Disabled fields are not used in current version.

[4] DTPA: diethylenetriaminepentaacetic

6. By clicking the button **"TMWW"** the **"TMWW data"** tab opens (Figure 9), and the treated wastewater data can be entered by the user as described in Table 4.

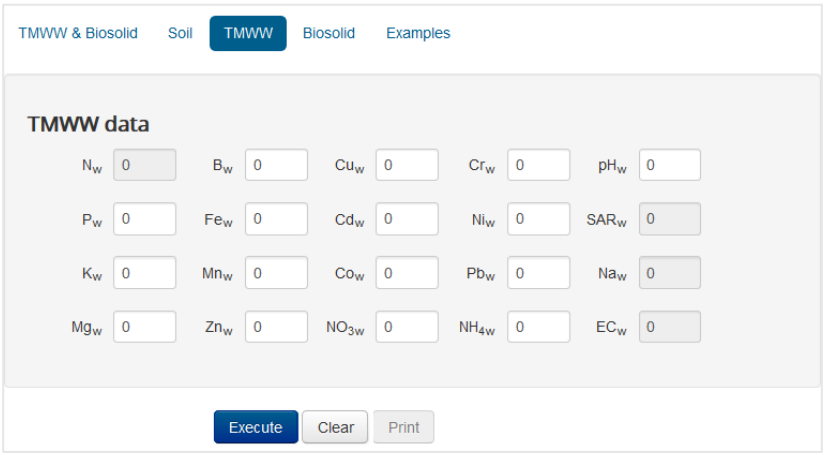


Figure 9. TMWW data

Note: Subscript (w) at the names of the input fields suggests that they correspond to the wastewater characteristics.

Table 4. TMWW data

Field	Description	Units
N_w	Disabled	
P_w	Treated wastewater P	mg/L
K_w	Treated wastewater K	mg/L
Mg_w	Treated wastewater Mg	mg/L
B_w	Treated wastewater B	mg/L
Fe_w	Treated wastewater Fe	mg/L
Mn_w	Treated wastewater Mn	mg/L
Zn_w	Treated wastewater Zn	mg/L
Cu_w	Treated wastewater Cu	mg/L
Cd_w	Treated wastewater Cd	mg/L
Co_w	Treated wastewater Co	mg/L
NO_{3w}	Treated wastewater nitrate	mg/L
Cr_w	Treated wastewater Cr	mg/L
Ni_w	Treated wastewater Ni	mg/L
Pb_w	Treated wastewater Pb	mg/L
NH_{4w}	Treated wastewater ammonium	mg/L
pH_w	Treated wastewater pH	
SAR_w	Disabled	
Na_w	Disabled	

7. By clicking the button **"Biosolid"** the tab **"Biosolid data"** opens (Figure 10), and there the data concerning the biosolids characteristics can be entered by the user, according to Table 5.

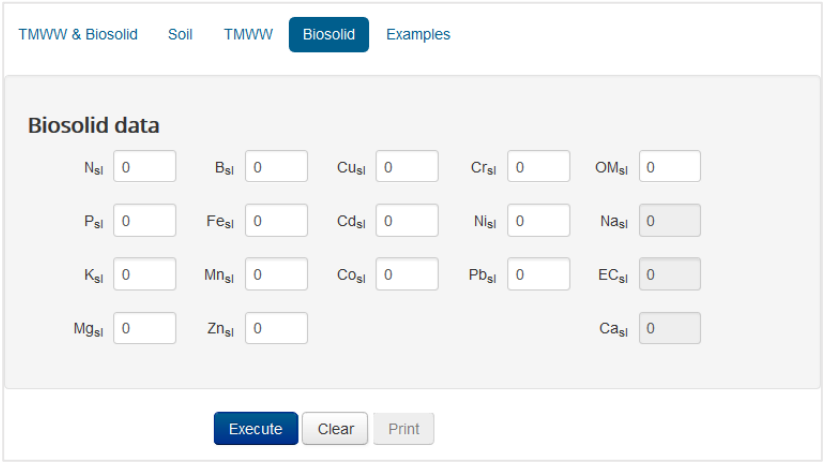


Figure 10. Biosolid data

Note: Subscript (sl) at the names of the input fields suggests that they correspond to biosolid characteristics.

Table 5. Biosolid data

Field	Description	Units
N_{sl}	Biosolid total N	%
P_{sl}	Biosolid extractable P	mg/kg
K_{sl}	Biosolid extractable K	mg/kg
Mg_{sl}	Biosolid extractable Mg	mg/kg
B_{sl}	Biosolid extractable B	mg/kg
Fe_{sl}	Biosolid extractable Fe	mg/kg
Mn_{sl}	Biosolid extractable Mn	mg/kg
Zn_{sl}	Biosolid extractable Zn	mg/kg
Cu_{sl}	Biosolid extractable Cu	mg/kg
Cd_{sl}	Biosolid extractable Cd	mg/kg
Co_{sl}	Biosolid extractable Co	mg/kg
Cr_{sl}	Biosolid extractable Cr	mg/kg
Ni_{sl}	Biosolid extractable Ni	mg/kg
Pb_{sl}	Biosolid extractable Pb	mg/kg
OM_{sl}	Biosolid orgranic matter	%

Warning: *The DSS in order to perform accurately, it must be fed with data in every enabled input field on the form. Despite the fact that some data may be missing the system will make a decision but in a negative case with many missing data, it will output error message/s,*

i.e.: Missing data for dosage estimation of a nutrient.

RUN CALCULATIONS

By clicking the **"Execute"** button (Figure 11) the system starts running and evaluates input data and outputs a detailed report with conclusions referring to the following:

- Soil physical and chemical properties.
- Soil macro – micronutrients and heavy metals.
- Treated wastewater chemical characteristics.
- Treated wastewater and biosolid macro–micronutrients and heavy metals.

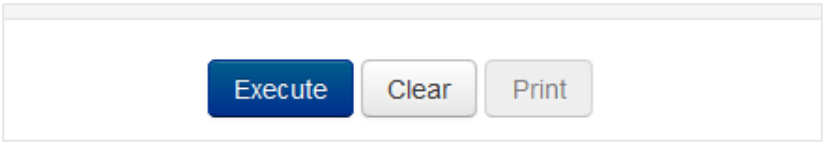


Figure 11. Execute calculations

The DSS checks whether the heavy metal concentrations of the treated wastewater are within the internationally recommended limits and presents with:

- Green color values within limits.
- Red color off-limits.

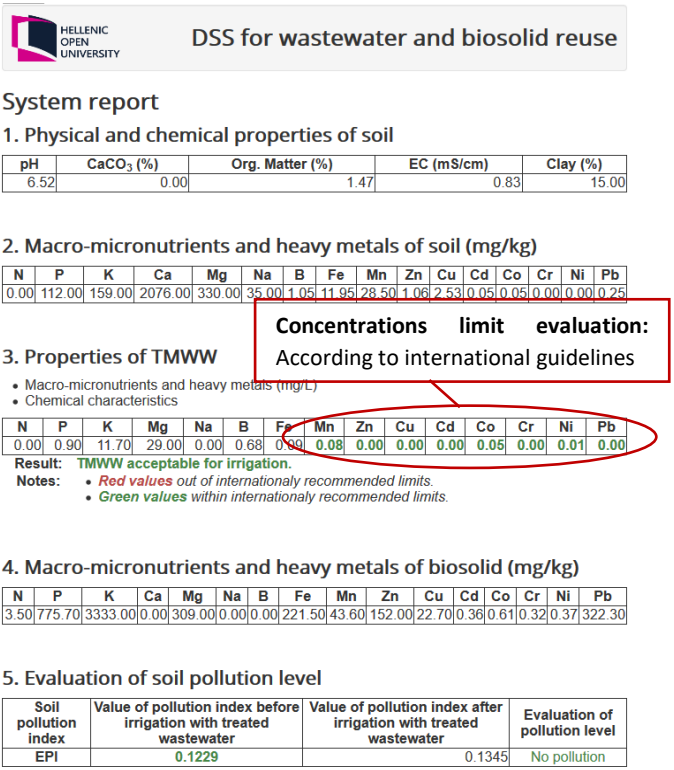
In a future upgrade, the system will also evaluate concentrations in biosolid.

Also, the system is able to evaluate soil pollution with the help of EPI (Elemental Pollution Index) before and after the wastewater and/or biosolids application.

Finally, the report contains the micro-macro nutrient dosages (kg/ha) for the rational fertilization of crops.

PRINTING

After the completion of the calculations, the button **"Print"** automatically is unlocked and by being pressed a printable form will be generated on a popup window, which can be printed by the user (Figure 12, Figure 13).



HELLENIC OPEN UNIVERSITY

DSS for wastewater and biosolid reuse

System report

1. Physical and chemical properties of soil

pH	$CaCO_3$ (%)	Org. Matter (%)	EC (mS/cm)	Clay (%)
6.52	0.00	1.47	0.83	15.00

2. Macro-micronutrients and heavy metals of soil (mg/kg)

N	P	K	Ca	Mg	Na	B	Fe	Mn	Zn	Cu	Cd	Co	Cr	Ni	Pb
0.00	112.00	159.00	2076.00	330.00	35.00	1.05	11.95	28.50	1.06	2.53	0.05	0.05	0.00	0.00	0.25

Concentrations limit evaluation:
According to international guidelines

3. Properties of TMWW

- Macro-micronutrients and heavy metals (mg/L)
- Chemical characteristics

N	P	K	Mg	Na	B	Fe	Mn	Zn	Cu	Cd	Co	Cr	Ni	Pb
0.00	0.90	11.70	29.00	0.00	0.68	0.99	0.08	0.00	0.00	0.00	0.05	0.00	0.01	0.00

Result: TMWW acceptable for irrigation.

Notes:
- *Red values out of internationaly recommended limits.*
- *Green values within internationaly recommended limits.*

4. Macro-micronutrients and heavy metals of biosolid (mg/kg)

N	P	K	Ca	Mg	Na	B	Fe	Mn	Zn	Cu	Cd	Co	Cr	Ni	Pb
3.50	775.70	3333.00	0.00	309.00	0.00	0.00	221.50	43.60	152.00	22.70	0.36	0.61	0.32	0.37	322.30

5. Evaluation of soil pollution level

Soil pollution index	Value of pollution index before irrigation with treated wastewater	Value of pollution index after irrigation with treated wastewater	Evaluation of pollution level
EPI	0.1229	0.1345	No pollution

Figure 12. Sample printed report (1st page)

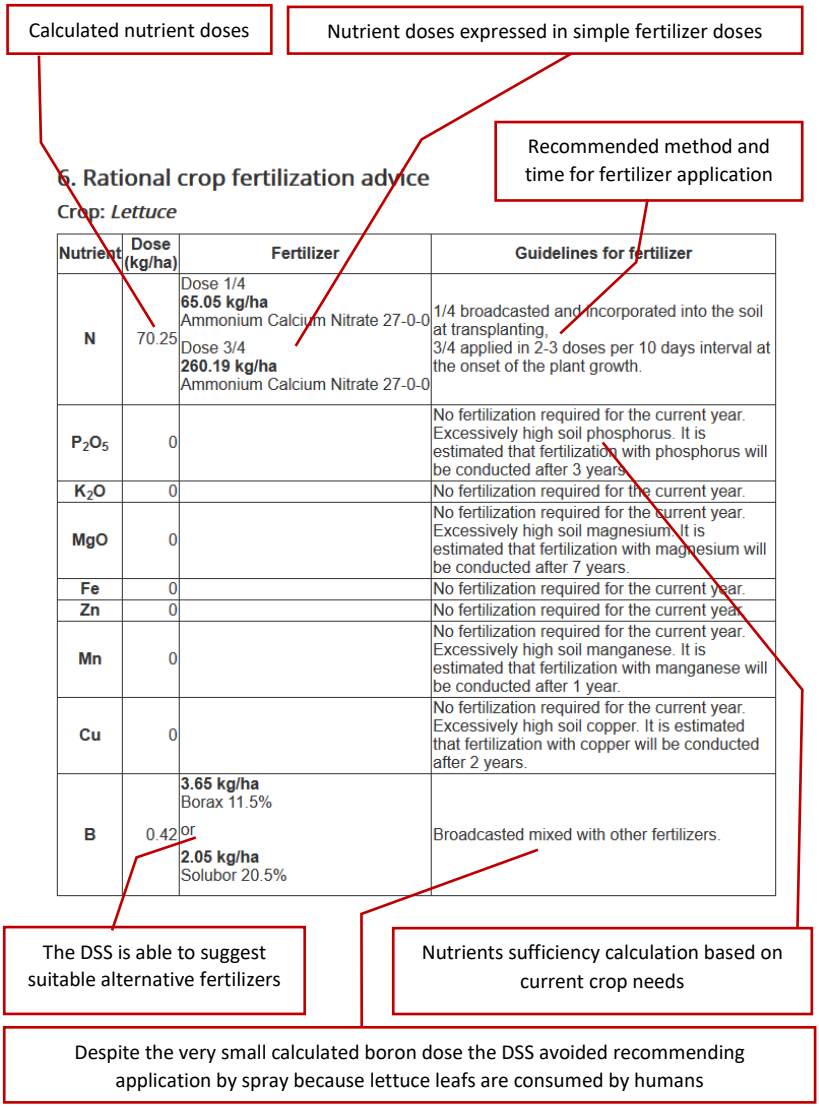


Figure 13. Sample printed report (2nd page)

FORM RESET

The input form can be reset by pressing the **"Clear"** button.

HIGHLY ACIDIC SOILS

The software can detect soils with highly acidic pH, and makes recommendations for lime requirements with $CaCO_3$ or CaO.

Figure 14. Highly acidic soil alert message

If during calculations low soil pH is detected the user will be redirected to the soil data section, where the desired pH value can be entered (Figure 15).

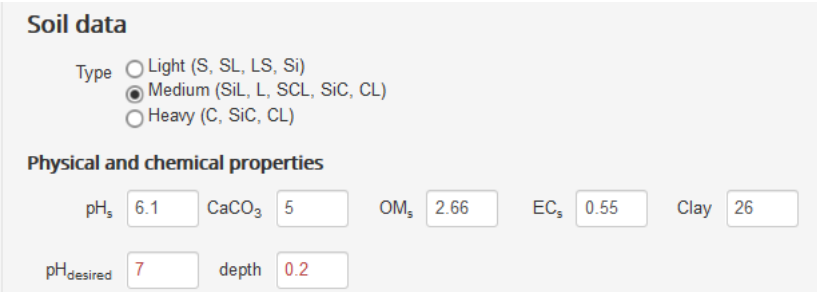


Figure 15. Desired soil pH

Two new input fields appear in **"Physical and chemical properties"** section. The **"$pH_{desired}$"** field for the desired soil pH with default value 7, and the **"depth"** field with default value 0.2m.

By pressing **"Execute"**, after entering desired values, the system includes in the report lime requirement with $CaCO_3$ or CaO in kg/ha (Figure 16).

Lime requirement with $CaCO_3$ or CaO in kg/ha	
$CaCO_3$	1151.04
CaO	644.58

Figure 16. Report section with lime requirements

EXAMPLES

The system includes some preloaded examples in the **"Examples"** tab (Figure 17). The user can load an example by clicking on it. The data entry forms will be populated automatically with the example's analytical data, and by clicking the **"Execute"** button, the system starts running and evaluates them and generates the report.

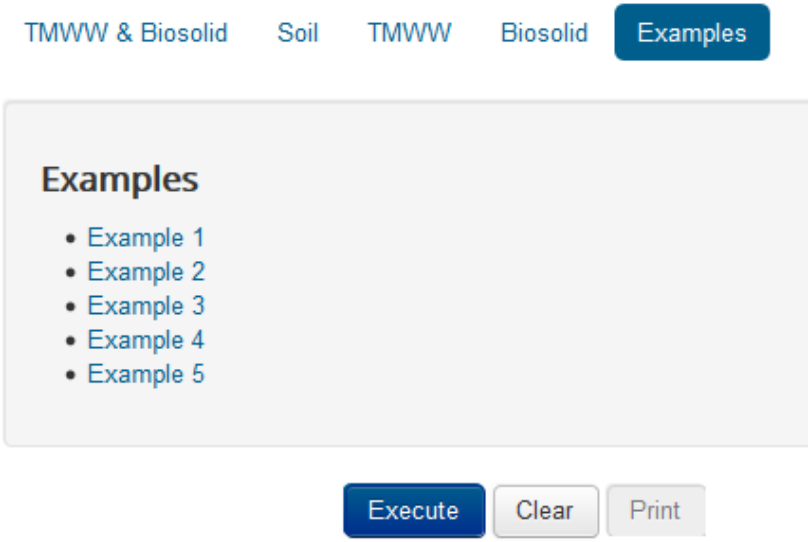


Figure 17. Examples tab

UPLOAD DATA

The user can load data from a CSV file through the **"Upload Data"** tab (Figure 18).

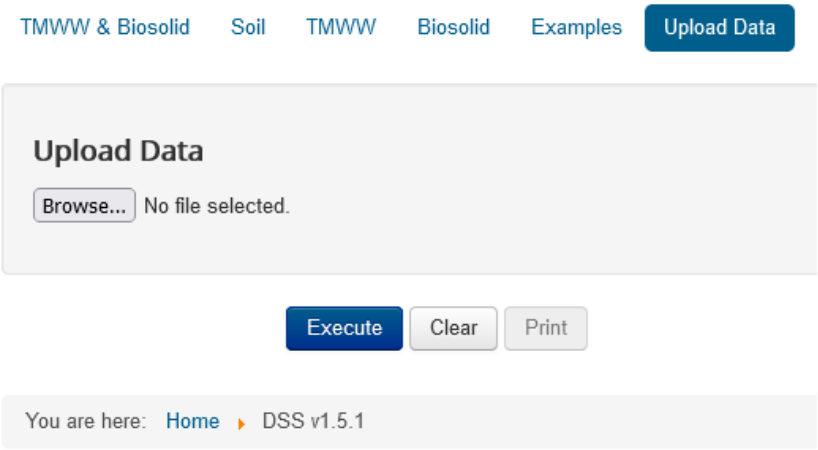


Figure 18. Upload Data tab

By clicking the Browse button, a file upload window opens. The user can select a **comma-separated values** (CSV) file and click on the Open button to load its data into the DSS (Figure 19).

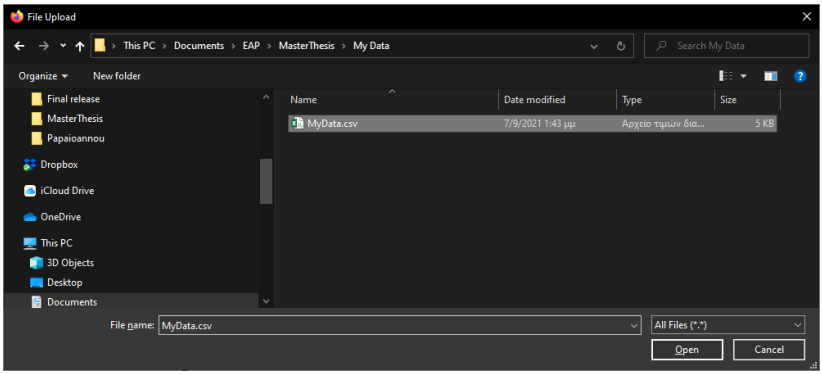


Figure 19. File Upload window

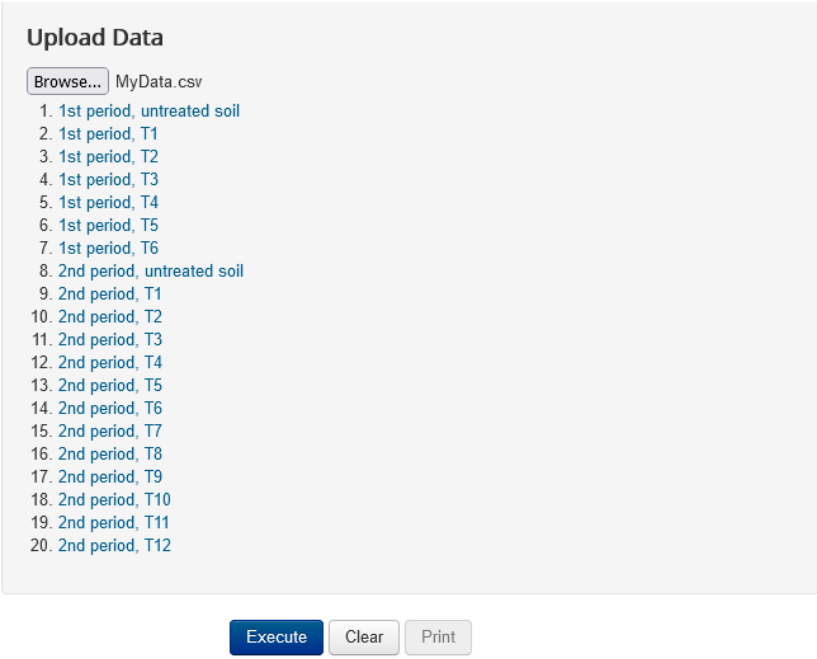


Figure 20. Uploaded data

By clicking on a list item, the user can populate the DSS forms with data, and by pressing the Execute button, the DSS can perform calculations (Figure 20).

CSV FILE SPECIFICATIONS

The user can load multiple cases to the DSS from a CSV file. The 1st row of the file contains the labels of the available fields. Each row (record) after the 1st line of the CSV represents a specific case, and each available field holds the value of a parameter. Table 6 contains all the available fields for the current version.

Table 6. CSV available fields

Field Label	Field Description	Field Type
comment	Small description or title for the case	String
crop	Crop ID. The user can find the ID of a specific crop from the crops list by pressing the Crops button.	Integer
Vw	Treated wastewater volume	Decimal
Wsl	Biosolid (or sludge) mass	Decimal
waste_type	Gets a value of 1, 2, or 3, where: 1 = TMWW, 2 = Biosolid, 3 = TMWW & Biosolid	Integer

Field Label	Field Description	Field Type
soil_type	Gets a value of L, M, or H where: L = Light (S, SL, LS, Si), M = Medium (SiL, L, SCL, SiC, CL) H = Heavy (C, SiC, CL)	Character
pH	Soil Data pH	Decimal
CaCO3	Soil Data calcium carbonate	Decimal
OM	Soil Data organic matter	Decimal
EC	Soil Data electrical conductivity	Decimal
C	Soil Data clay	Decimal
Ns	Soil Data N	Decimal
Ps	Soil Data P	Decimal
Ks	Soil Data K	Decimal
Mgs	Soil Data Mg	Decimal
Bs	Soil Data B	Decimal
Fes	Soil Data Fe	Decimal
Mns	Soil Data Mn	Decimal
Zns	Soil Data Zn	Decimal
Cus	Soil Data Cu	Decimal
Cds	Soil Data Cd	Decimal
Cos	Soil Data Co	Decimal
Crs	Soil Data Cr	Decimal
Nis	Soil Data Ni	Decimal
Pbs	Soil Data Pb	Decimal
Ca	Soil Data Ca	Decimal
NO3s	Soil Data NO_3	Decimal
Nas	Soil Data Na	Decimal
Pw	TMWW Data P	Decimal
Kw	TMWW Data K	Decimal
Mgw	TMWW Data Mg	Decimal
Bw	TMWW Data B	Decimal

Field Label	Field Description	Field Type
Few	TMWW Data Fe	Decimal
Mnw	TMWW Data Mn	Decimal
Znw	TMWW Data Zn	Decimal
Cuw	TMWW Data Cu	Decimal
Cdw	TMWW Data Cd	Decimal
Cow	TMWW Data Co	Decimal
NO3w	TMWW Data NO_3	Decimal
Crw	TMWW Data Cr	Decimal
Niw	TMWW Data Ni	Decimal
Pbw	TMWW Data Pb	Decimal
NH4w	TMWW Data NH_4	Decimal
pHw	TMWW Data pH	Decimal
Naw	TMWW Data Na	Decimal
ECw	TMWW Data EC	Decimal
Nsl	Biosolid Data N	Decimal
Psl	Biosolid Data P	Decimal
Ksl	Biosolid Data K	Decimal
Mgsl	Biosolid Data Mg	Decimal
Bsl	Biosolid Data B	Decimal
Fesl	Biosolid Data Fe	Decimal
Mnsl	Biosolid Data Mn	Decimal
Znsl	Biosolid Data Zn	Decimal
Cusl	Biosolid Data Cu	Decimal
Cdsl	Biosolid Data Cd	Decimal
Cosl	Biosolid Data Co	Decimal
Crsl	Biosolid Data Cr	Decimal
Nisl	Biosolid Data Ni	Decimal
Pbsl	Biosolid Data Pb	Decimal
OMsl	Biosolid Data OM	Decimal
ECsl	Biosolid Data EC	Decimal

Field Label	Field Description	Field Type
Casl	Biosolid Data Ca	Decimal

Description DSS v1.5.1 Login Crops

Crop	ID
Alfafa	1
Almond tree (1st year)	117
Almond tree (2nd year)	118
Almond tree (3rd year)	119
Almond tree (4th year)	120
Almond tree (5th year)	121
Almond tree (6th year)	122
Almond tree (7th year)	123
Almond tree (8th year)	124
Almond tree (>8th year)	125
Apple tree (1st year)	188
Apple tree (2nd year)	189
Apple tree (3rd year)	190
Apple tree (4th year)	191
Apple tree (5th year)	192
Apple tree (6th year)	193
Apple tree (>6th year)	194
Apricot tree (1st year)	133
Apricot tree (2nd year)	134

Figure 21. Crops IDs List