DSS-Hortimed for on-line management of hydroponic systems

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Abstract

This paper describes the management of hydroponic systems that can be defined as open, semi-closed to completely closed or NFT (*i.e.* 0% to 100% recycling of the drain), which have several water sources with different water qualities. The methodology is based on:

- The quantitative response characteristics of the performance of the greenhouse cultivations to salinity
- The influence of the reduction of transpiration to the performance curve and the accumulation of salts in the recycling irrigation water in closed hydroponic systems.

A first effort to integrated management of the greenhouse environment and the root nutrient solution is described, where the optimization process takes into account the environmental as well as the root parameters to determine the management of irrigation (irrigation frequency, percentage of drain, water source) and that of fertilizers (proportions of elements from the tanks of stock fertilizers).

An on-line Decision Support System (DSS) was developed for the application of water and fertigation management, which operates as a supervisor system to other automatic systems for climate and hydroponics control. It communicates in a manner that the other systems have to adapt in order to cooperate.

1. It exchanges measurements with the supervised system for the usually measured variables (temperature, humidity, solar radiation, conductivity and pH of irrigation and drain solution, quantity of drain, etc.).
2. It uses simulation models when real on-line measurements are practically unfeasible.

More specifically, these models include plant (WU, NU) and root system parametric simulations for any type of substrate. The plant model accurately estimates water uptake (WU) and nutrient uptake (NU) at every moment (mass balance, per second) [*Pardossi et al*]:

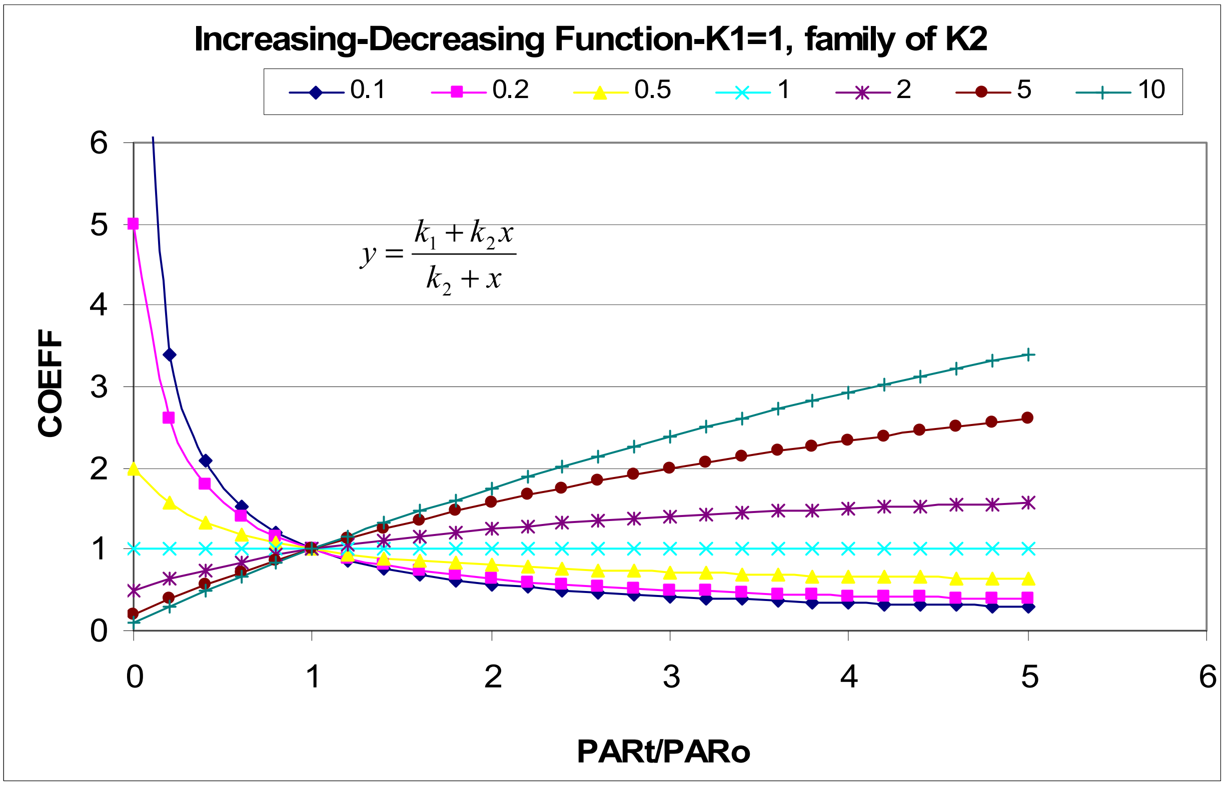
- It lets the user define the flow type from the mini sprinkler up to the drain from the substrate (from perfect mix to direct drain), so that it can accurately estimate the conductivity and the concentrations of the elements in the root.
- It lets the user regulate the water uptake model (WU), which is based on solar radiation (S_O) and vapor pressure deficit (VPD), with the capability of estimation of the leaf temperature [Fuchs *et al.*] and self-adaptation of the model [Sigrimis *et al.*] when some measurement (substrate's humidity, quantity of drainage, tank level in completely closed systems) is available.
- It lets the user regulate the uptake model (NU) of each major element (N, P, K, Ca, Mg, Na, Cl). The model of each element is parametric, of the following form:

$$NU_x = \left[k_x (1 + p_x \frac{C_1 - C_0}{C_0}) \right] \left[\frac{k_E + E_0}{k_E + E_t} \right] \left[\frac{k_p + PAR_t}{k_p + PAR_0} \right]$$

  where the user must define at least the uptake coefficient k_x for each element x (otherwise, there is a default value for each element). The other three parameters (p for the root concentration of the element, k_E for the intensity of transpiration and k_p for the intensity of photosynthetically active radiation – PAR) are set equal to zero if they are not known.
- It accepts periodic measurements and adjusts the uptake models. It integrates the absorbed elements and water, and adjusts the integrated elements to cover any losses as well as the

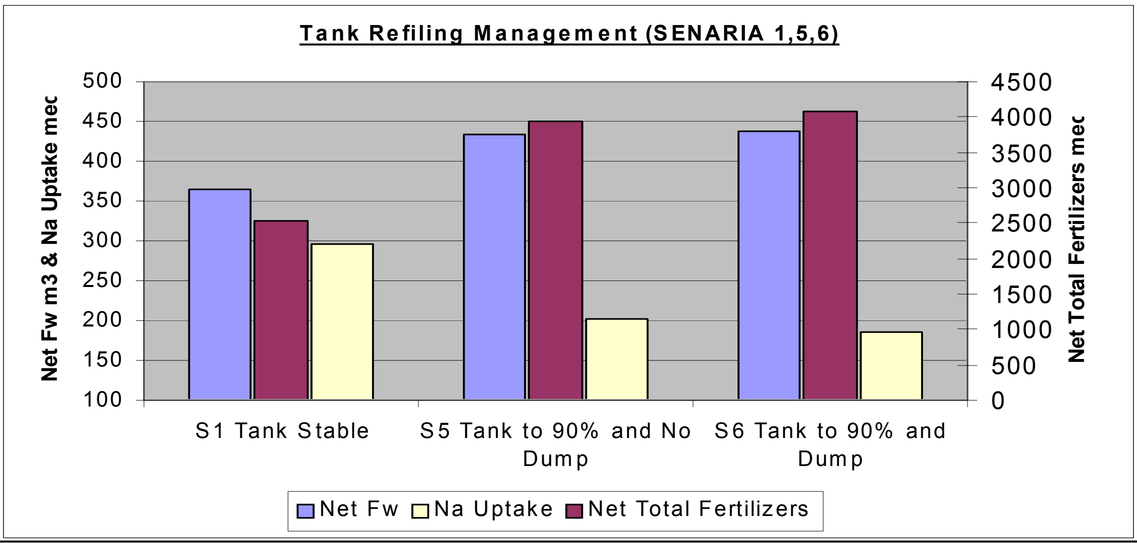
integrated salinity. In this way, it decides dynamically the proportion of usage of each water source, based on specific rules, which are user-defined and can be altered at any time.

An elaboration of proper functions for modeling NU is presented and a powerful function that can easily adapt to increasing/decreasing tendencies and fit NU data from the HORTIMED experiments [*Stangellini et al, Lorenzo et al*] and from the literature was investigated.
Results of different Hydroponic scenarios are presented as well as the field evaluation of the DSS in Real Time Management functionality and effectiveness with commercial operations.



CLOSED SYSTEM NFT

SENARIO	Leach	Net Fw	Net Fw/Net Fw S1	ELEMENTS meq/plant			
				Net Total/Net Total S1	Leached/Total	El. Error	Na Up
1	48.7	364.86	100.0%	100.0%	20.1%	7.52	296
5	139	433.65	118.9%	155.9%	45.4%	5.76	202
6	148	437.8	120.0%	161.4%	48.0%	5.46	186



Running the DSS off-line on different scenarios provides some insight with useful results

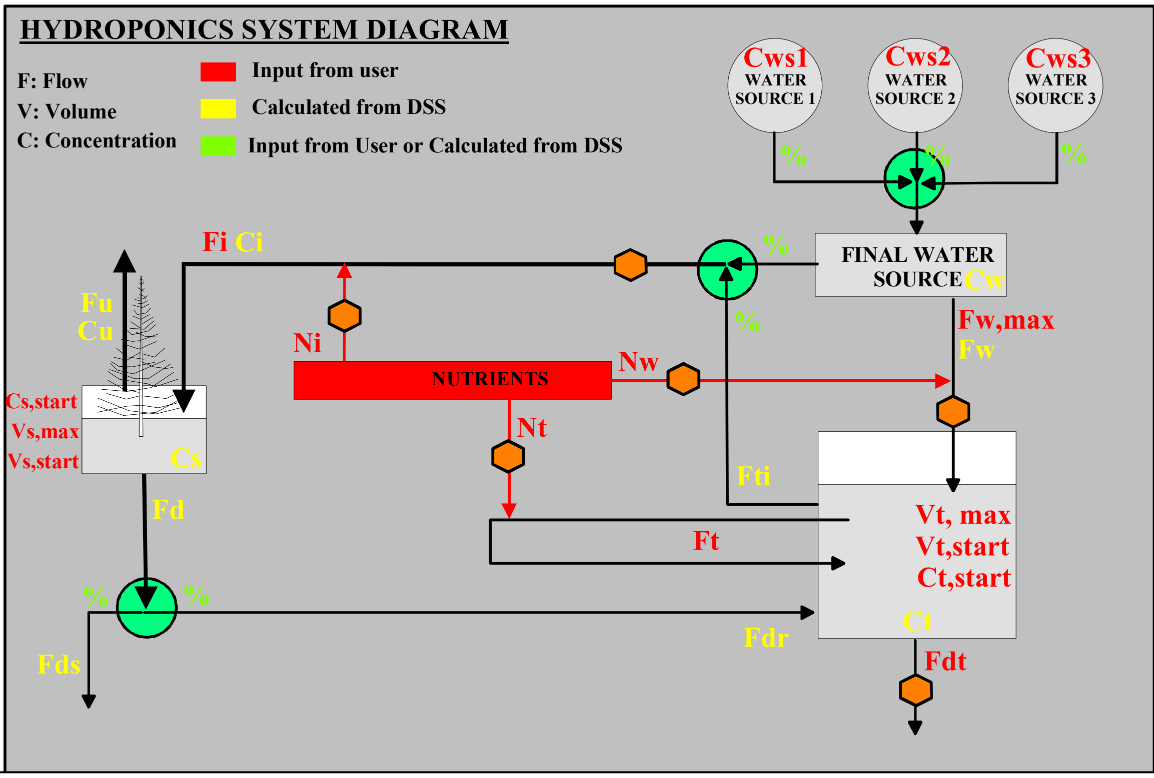
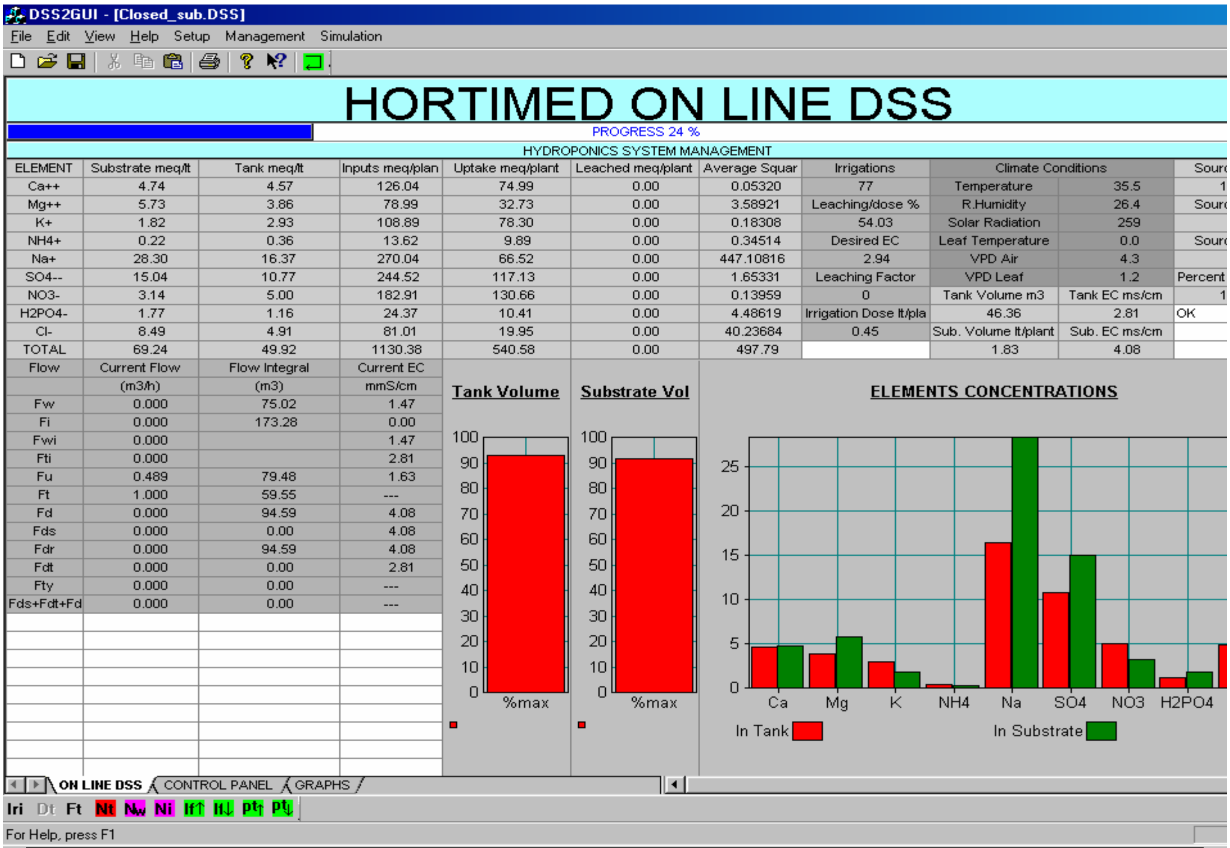
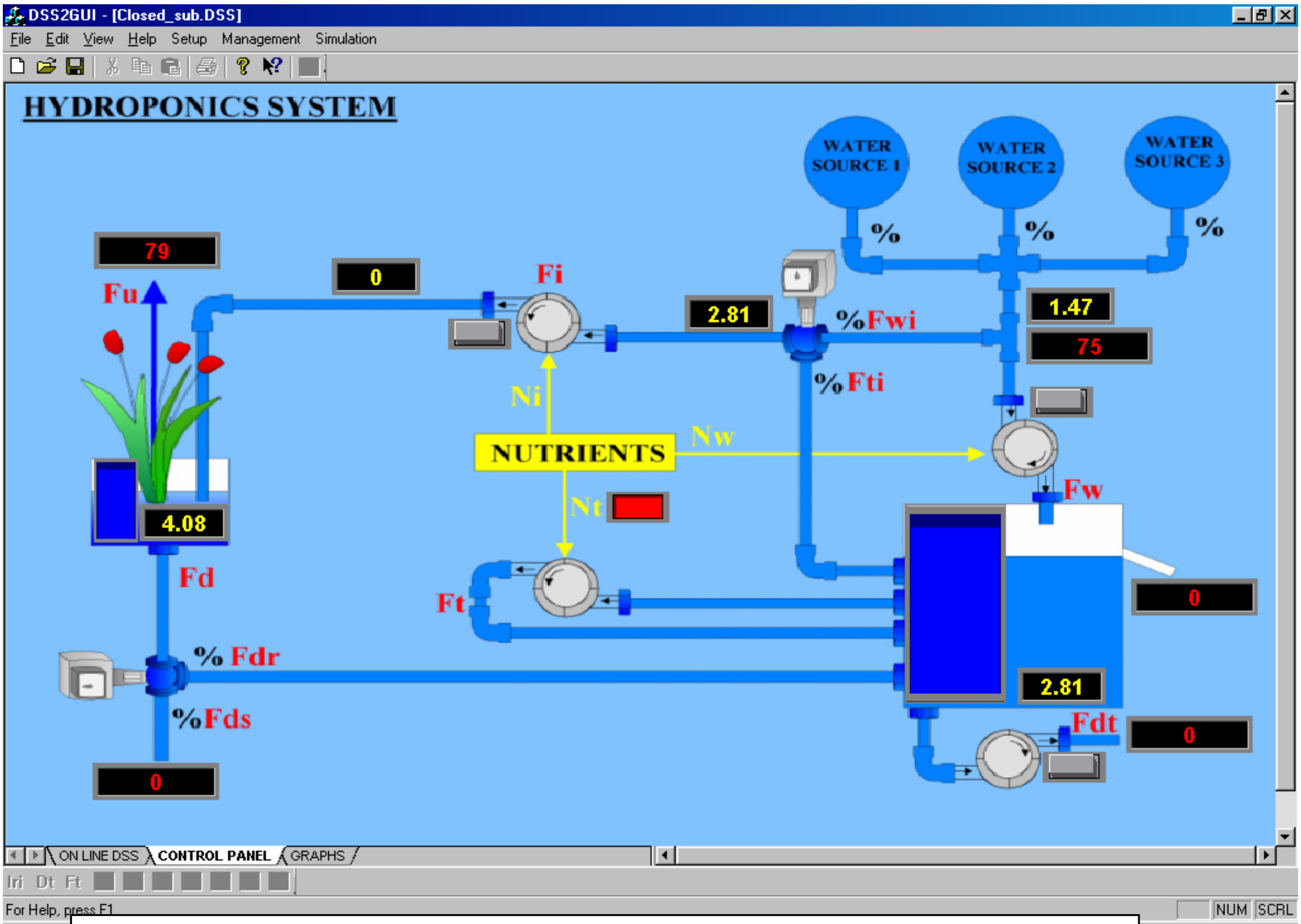


Diagram depicting the parameterized system capable to model any system in practical use.

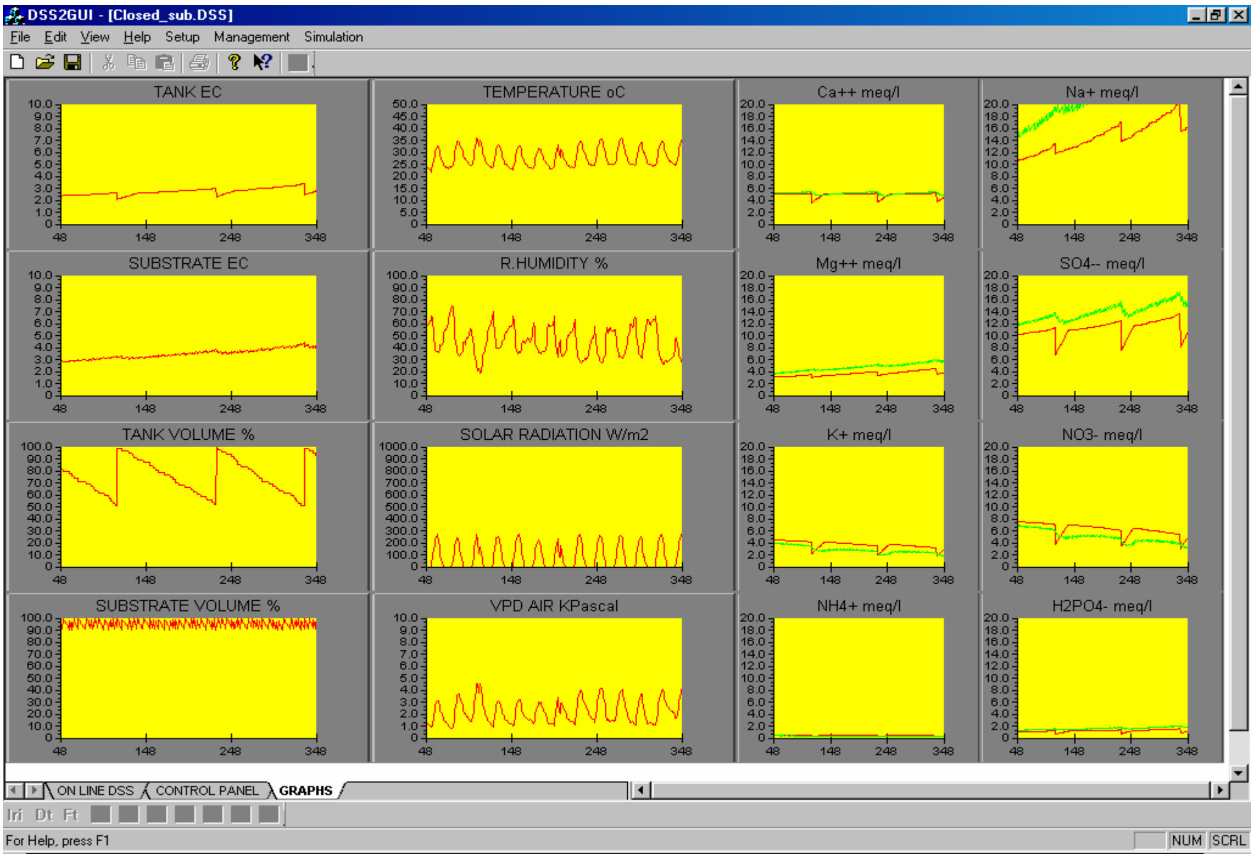
Some screenshots of the on-line program in operation are presented in the following figures:



Detailed presentation screen of real time hydroponic system simulator (screen1)



Pictorial screen view of simulated hydroponic system state variables (Screen2)



Graphics of the DSS showing historical details of variables using scroll charts (screen3)