Modeling and Control Issues on Growth of Crops Irrigated with Wastewater

Vladimir Vissikirsky

International Research and Training Center for Information Technologies and Systems of the National Academy of Sciences of Ukraine

dep195@irtc.org.ua

Abstract. *The paper considers the issues concerning the environmental modeling, control, and analysis of agricultural and forest plant species grown under different controlled and uncontrolled conditions, and irrigated with processed wastewater from Wastewater Treatment Plants (WWTP).*

Keywords

WWTP, control system, environmental modeling,
irrigation, wastewater, fuzzy sets, GMDH

1 Introduction

The reuse of reclaimed wastewater for agricultural irrigation provides economic and environmental benefits. Irrigation with processed wastewater can increase the available water supply, as well as prevent wastewater discharge into natural water bodies. In addition, wastewater contains chemical elements that are normally required for growth of crops. At the same time, the reuse of wastewater for irrigation implies comprehensive study of species' behavior, considering ecological chains with complex interactions, specific climate, cultivation, and other conditions. A Wastewater Treatment Plant (WWTP) is also a complex dynamic system with unknown mathematical descriptions of processes. Therefore, the integrated study and design of such complex engineering and environmental system requires the application of advanced AI and modeling methods. It is also important to provide coherent operation of a WWTP Control System and a Crops Growth Control System. General interface between the control systems is shown in Fig. 1.

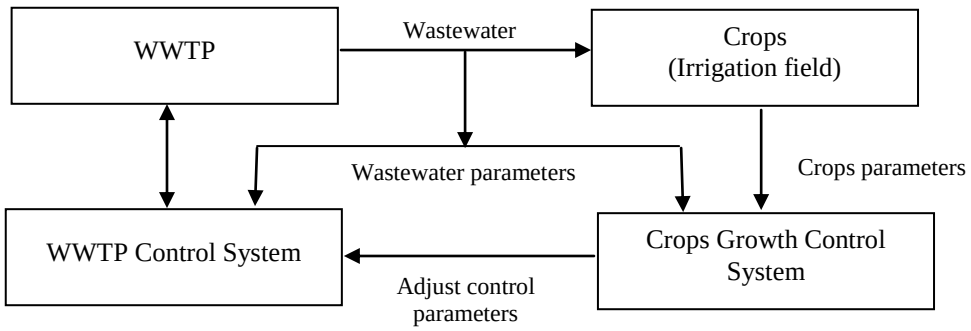

Figure 1. General interface between the WWTP Control System and the Crops Growth Control System

2 Problem statement

Here, we consider main features of the Crops Growth Control System. This system shall be developed for two stages: design and operation stage. At operation stage, the system shall provide real-time monitoring of the wastewater and crops parameters, and advise the WWTP control system on wastewater content, water supply mode, etc., to be met in order to observe the constraints and ensure criteria of optimum crops performance. Prior to operation stage, it is required to design a comprehensive study of crops behavior under different wastewater supply cases, obtain estimation models, include them into a knowledge base, develop control strategies proceed from constraints and performance criteria.

The tasks at design stage are shown in Fig. 2. The feature of environmental studies is that experiments aimed to identify effects of process wastewater on species' behavior are conducted by series, during long-term period, with the extension of number of investigated species and measured wastewater parameters. Therefore, measurement data are obtained by portions, and analyzed for both current set of experiments and the whole scope of all previously obtained results.

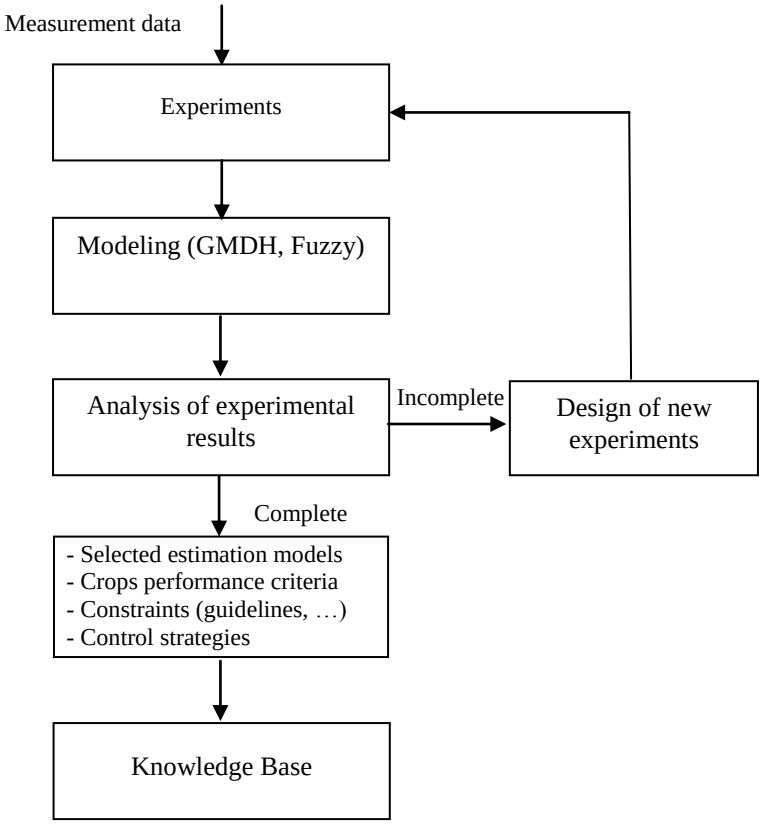

Figure 2. Flowchart of the Crops Growth Control System development at design stage

Analysis of experimental results is intended to determine behavior of species, find dominant factors, and to identify how good, safe, and reliable are the properties in order to utilize a species with wastewater supply, etc. Analysis is assisted with mathematical modeling of obtained measurement data. Behavior and properties of species grown with wastewater supply are the result of complex ecological interactions for which mathematical models of underlying processes are unknown. The purpose of a model is to adequately estimate data obtained and represent the results in the form suitable for further analysis. For this purpose, the Group Method of Data Handling (GMDH) method can be used, which is the application of inductive self-organizing approach to mathematical modeling of complex systems [1].

Design of new experiments is intended to fill up the lack of data or knowledge about species' behavior, involve new species in the study, etc. Design of new experiments implies making the decisions about whether to continue the experiments for some species and what kind of experiments shall be completed to reduce the uncertainty degree of knowledge available.

The knowledge base (KB) shall provide integral data and model storage and handling. It shall describe a set of estimation models obtained for different series of experiments. Each estimation model in the KB shall represent relationships among measurement data and other estimation models via variables and objects involved. The KB shall also provide grouping, amalgamation or other transformations of estimation models. Data and model handling is used for information and analysis purposes. For example, the investigator may want to retrieve details about what models and results have been obtained for a species or for a subset of species, thus analyzing similarity or difference between the results, comparing input variables; searching for a subset of species grown under specific water supply case, subsets of contained chemical elements, etc.

The KB shall include reasoning tools to facilitate the analysis of complex relationships, as well as to meaningfully advise how to maintain/change the WWTP control parameters. As the set of KB models extends, their common analysis becomes yet more complicated. One way to facilitate the analysis is to apply qualitative reasoning techniques.

A technique associated with qualitative simulation approach is described in [2]. For the purpose to represent, extract and manipulate qualitative knowledge proceed from obtained simulation results, a qualitative description of response function is considered as a string of signs of differences. This technique allows the investigator to find out regularities of changes, but it has some shortcomings, namely, a weak representation of functional dependencies between variables, which captures the sign information but has no measure of strength of dependencies. For this purpose it is reasonable to use fuzzy models capable of both capturing knowledge in qualitative form and reflect the strength of accumulated dependencies [1]. Thus, modeling results are represented in the form of fuzzy rules, e.g. "IF concentration of element Cu is low and pH is medium, THEN axial compression strength is medium".

3 Conclusion

The ultimate goal of experiments carried out in the field of wastewater irrigation is to obtain complete and reliable knowledge about behavior of irrigated plants, in order to provide further wastewater disposal control, maintain wastewater parameters within the limits ensuring the required characteristics of plant species, proceed from specific wastewater supply conditions and irrigated plant species. The purpose of the research was to obtain models describing the relationships between wastewater characteristics and various characteristics of crops: mechanical properties, height, mortality, concentrations of chemical elements in roots, leaves, etc. The models obtained shall provide the basis for the selection of crops most suitable for irrigation with wastewater under different irrigation modes, soil and climate conditions, etc., as well as for prediction of trees behavior and optimum wastewater control.

References

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