Qualitative Approach to Environmental Modeling Based on GMDH Models

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Abstract. *The paper considers the main aspects of the GMDH application together with deductive qualitative assessment techniques, which provides a consistent basis for the development of integrated tools intended to cover the modeling, analysis, and decision-making tasks in the field of environment and agriculture.*

Keywords

Environmental modeling, species irrigation, processed wastewater, qualitative approach, GMDH, decision making support.

1 Introduction

Wide utilization of wastewater and sludge for agricultural purposes requires a thorough investigation of the behavior of various species in biological, chemical, and physical aspects under different wastewater supply conditions. The problem involves many factors and parameters, such as the impacts of treatments on soil and flora, survival and mortality rates of species, their growth, silvicultural issues (roots and crown development, competition), wood properties, assimilation behavior for different chemical elements, etc.

The investigation process is virtually an iterative sequence of empirical procedures intended for the identification and selection of species with stable behavior and properties “good” enough to utilize them for agricultural purposes under cultivation with processed wastewater. These procedures involve the analysis of the problem at different degrees of knowledge detalization and certainty. The investigator may have a detailed look at a single direct effect of a chemical substance on a species, or consider a chain of interactions by trying to generalize and find out a similarity or distinctiveness in the behavior between different species.

Therefore, under uncertain multifactor conditions the search by using only conventional statistical methods becomes a trial-and-error procedure. Two main features of this process shall be emphasized: empirical estimation of complex nonlinear functional relationships between interacting objects in ecological network, and qualitative reasoning about such relationships to reveal stable characteristics of the objects and regularities of their behavior.

2 Peculiarities of the problem

More deep understanding of the behavior of species requires its investigation in different aspects and under different experimental plans, which at the same time substantially complicates the analysis of empirical results by using conventional statistical techniques. Important aspect of investigation is the analysis of how the concentrations in different species change and what would be the reaction of species when the concentrations in irrigated water increase up to the high toxic level.

The proposed solution to the development of computer-based intelligent tools is intended for the empirical modeling of species’ behavior and qualitative reasoning with imprecise information about this behavior.

The studies aimed to estimate characteristics of different plant species irrigated with processed wastewater, can be carried out with use of GMDH methods that allow us to analyze various aspects of plant species behavior: mechanical properties of trees (axial compression and bending) depending on concentrations of chemical elements contained in the wastewater [1], growth dynamics of trees irrigated with wastewater (development of tree height and mortality over time) [2, 3], etc. After that, qualitative analysis techniques can be applied to assess plant species behavior under different conditions: irrigation of forest species with wastewater and sludge [4].

3 Characterizing the approach

Here, the key approach to resolve the problem consists in the decomposition of a modeled system into subsystems, to provide the modeling and analysis of subsystem(s) that have subset(s) of input variables consistent with volume of sample available. The objective of the GMDH modeling is to obtain the regression models describing different relationships within the chain of interactions "soil - roots - leaves", as well as to provide further qualitative analysis of involved factors. Qualitative assessment provides initial generalization of regularities in change of heavy metals concentrations in soil, roots, and leaves, depending on distance from the road. It also allows us to determine the level of certainty / uncertainty of the models and to direct future experiments to obtain more detailed information.

The set of generated GMDH models gives the possibility to analyze the system from different viewpoints, according to the model accuracies and structures. In the decomposition of a modeled system into subsystems, the related sets of GMDH models can be analyzed to identify the most relevant structures and make assumptions about input of different factors, assess the uncertainty level regarding each factor input, as well as to make decision on how to design the next-stage experiments to obtain more information about system behavior. This also makes it possible to compare the sets of GMDH models describing different subsystems by their structural similarity / difference, hence, merge the models into a model that describes a higher-level subsystem.

In addition, this provides the basis to develop simple reasoning procedures for qualitative assessment of system behavior at different stages of long-term experiments.

4 Conclusions

Qualitative analysis gives the possibility, in terms convenient for the end user, to analyze behavior of individual subsystems as well as of the system in whole. It is intended to facilitate clear understanding of the experimental results, easily classify different irrigation/plant species cases and identify the best ones. In general, the application of GMDH methods together with deductive qualitative assessment techniques provides a consistent basis for the development of integrated tools intended to cover the modeling, analysis, and decision-making tasks in the field of environment and agriculture.

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