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Life Cycle Inventory Analysis in Horticulture

A conceptual framework for an environmental information management system

Agricultural and horticultural producers have been forced to include environmental aspects in their business strategies in recent years. This pressure, not only originating from consumers, but especially from the food industry, retailers and government authorities, expresses itself in an increased demand for information about "ecological quality" in agricultural and horticultural products. Here a computer-aided tool is presented, which should make it possible to collect and assess this information in a horticultural enterprise.

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Literature

Literature references can be called up under LT 04328 via internet http://www.landwirtschaftsverlag.com/landtech/local/literatur.htm.

A broad variety of different methods and instruments for environmental assessment is currently available. Besides the Life Cycle Assessment (LCA; [5]) there are methods like Environmental Performance Evaluation (EPE; [2, 6]), Ecological Bookkeeping [8] or Streamlined LCA [4] to name only a few. A common part of most of these methods is an information basis composed of comprehensive data on material and energy input, usage and output regarding the product or production system to be investigated. As collection and processing of data on material and energy flows is a resource intensive task, appropriate software tools could be used to assist in this part of environmental information management. The design and development of such a software tool for information management in horticultural production systems is the aim of the project "Environmental management in Horticulture" of the Technische Universität München.

Requirements of an environmental information management tool for horticulture

General requirements of an ideal environmental information system on the business-level can be summarised as follows [3, 7]:

- Data comprehensiveness: all relevant environmental aspects of the production system should be covered.
- Data aggregation: the vast amount of accumulated raw data has to be condensed to meaningful information
- Data relevance currency: data have to be collected and processed timely to allow timely integration of environmental information in operational and strategic management decisions
- Data traceability: the methods of data collection, aggregation and assessment have to be traceable.

For the practical usability of an environ-

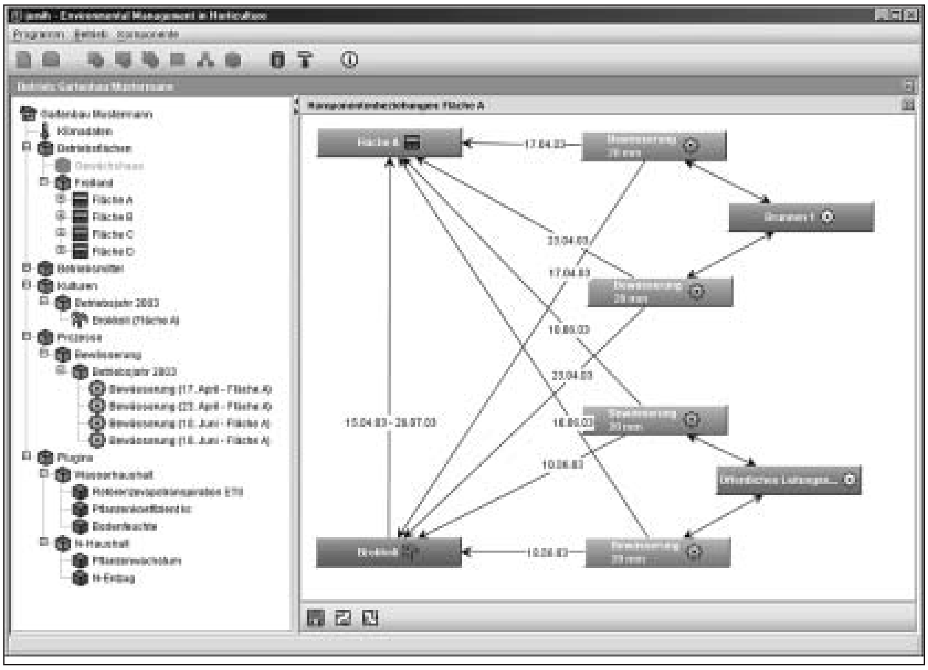

Fig. 1: Graphical presentation of the data model of a horticultural enterprise as a data tree (left) and as a graph (right)

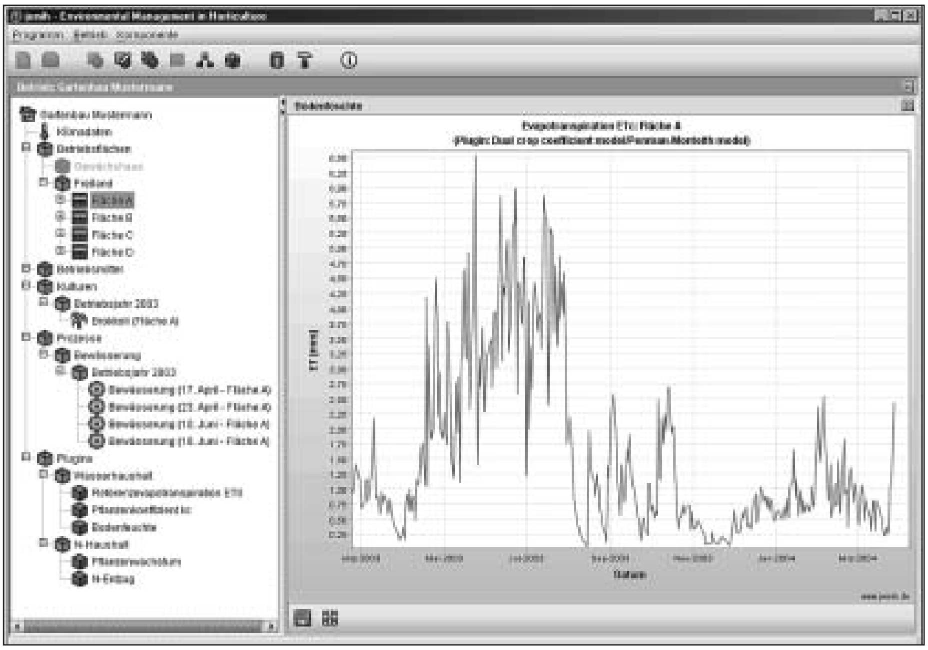

Fig. 2: Evapotranspiration for a special area of the exemplary business

mental information management tool in horticultural production, two further more specific requirements are important:

- Acquisition of specific material and energy flows: other than in most industrial production systems, there are different material and energy flows in outdoor horticultural production systems, that can hardly be monitored through measurement, e.g. evapotranspiration, soil water leakage or nitrogen uptake by plants. These flows are dependent on highly dynamic and/or site-specific parameters like climate data, soil properties, crop properties etc. Alternatively such values like evapotranspiration have to be estimated using appropriate models.
- Economic efficiency: as mentioned above the comprehensive collection and processing of relevant environmental data is a very resource intensive task. Therefore it is important that the financial input related to the implementation and maintenance of an information management system does not exceed its attainable financial benefits.

Conceptual framework and implementation

A fundamental task in developing a tool for information management concerns the representation and management of real-world information as abstract entities that can be handled by the computer. For this modelling purpose an object-oriented design approach was selected. In object-oriented programming so called "objects" are used as representations of real-life entities. Objects - as their corresponding real-life entities - share two characteristics: each object has a state and a behaviour. The representation of a real-world system in this modelling approach can be viewed as a population of interacting objects, each of which is an atomic bundle of data and functionality [9].

The aim of the conceptual framework of the information management system is the analysis of single horticultural companies. Therefore the main object type used in the model represents one company. Each single company object consists of an arbitrary combination of sub-objects. These sub-objects are classified to the following object types:

- Area objects: represent the fields that are available for crop cultivation within the company
- Crop objects: represent a plant species cultivated on a specific area object at a specific date
- Device objects: basically represent machine objects like tractors, tillage machinery, irrigation equipment etc.
- Process objects: an abstract object type defining the usage of one or more device objects on a crop or area object (e.g. a "ploughing process" could consist of a tractor object and a plough object which are used on a specific date for tillage of a specific area object)

Each of these basic objects may interact with other objects, e.g. each crop object is associated with exactly one area object, a process object is associated with zero to many device objects etc.

By choosing specific components from a database of predefined object templates, customisation of those objects and definition of associations between single objects it is possible to represent an individual horticultural company. *Figure 1* shows a hardcopy of the graphical user interface (GUI) of the information management software. On the left the object structure of the sample company is shown as an object tree, with each of the main tree branches holding objects of the same type (area, crop, device and process). Note that the real object structure rather equals a complex network of the single objects than the strongly hierarchic tree structure. A sample of a graphical view of the object structure as a graph is shown on the right of *Figure 1*.

For the assessment of each specific type of material or energy flow that occurs within the horticultural production system the program provides one individual interface. Each of these interfaces can be configured to use a specific interface implementation (plugin). A plugin can be implemented as a hardware driver (e.g. a direct connection to a climate station), a database connection or a mathematical model. The input data required by the different plugins is provided by the data model of the horticultural company as described above: the state of the individual objects in the model, the behaviour of the individual objects and the structure of the whole model. *Figure 2* shows the evapotranspiration occurring on a specific area object. In this example the Penman-Monteith model as proposed by the FAO [1] was used as the plugin for acquisition of evapotranspiration data. In a last step these single energy and material flows can be aggregated to a summary referencing the whole company ("gate-to-gate" summary), single area or crop objects. An example of such a flow summary for water is shown in *Figure 3*.

Fig. 3: Excerpt of an energy and material flow protocol for one business component