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Modeling of supply chains for estimating logistic costs in energy wood industry

The supply chain needed for harvested wood in short rotation coppices accounts for up to 60 % of the total production costs. Therefore, logistics in agriculture industry faces a new challenge caused by an increasing number of short rotation coppices. The aim of the research project was the development of a model generating valid supply chains using quantified technological and infrastructural constraints. By this model estimations of total duration and costs can be automatically derived for each chain, independent of the particular cultivation area.

Keywords
Short rotation coppice, supply chain, energy sector, algorithm, prototype, database, model, parameter

Abstract
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In the field of agricultural economics, possible supply chains for energy wood are usually illustrated visually and verbally and their influential factors are often only described in a qualitative way. A parametric modeling of these chains has so far only been realized to a small extent.

One reason for that can be attributed back to the organizational and political marginal conditions for the cultivation of SRC (field-customer-relation, tenancy agreements versus residence time of the plantations, legal support modalities), which are difficult to be recorded in a quantitative way. The economic system, which supplies the energy wood, is momentarily only marginally differentiated from other fields of agriculture and with its special demands it is hardly ever taken into consideration as an essential component of a secure energy concept [1].

Besides that, important research on harvesting techniques, drying and chipping technologies as well as transportation and transshipment processes and their mutual dependencies has not been completed yet. These correlations, however, have a direct influence on the dimensioning of storage and transportation capacities as well as the application and order of certain manipulation processes. However, empirical values are still missing in Germany [2].

In order to make reliable statements about the structure, costs and duration of possible supply chains without a large effort, relevant influential factors were identified in a first step and their correlations were illustrated quantitatively. Afterwards, a process generator was developed which derives automatic valid supply variants based on the exemplarily illustrated correlations. With the aid of the developed calculation program/database surface, statements can now be made about each possible parameter constellation and decision support can be provided for the selection of optimal chains.

Model, Algorithm and Database

Subsequently, a model is introduced, which illustrates the parameters influencing the supply chains for energy wood (e.g. harvest size, water content, fraction, and place).

When the parameters of the wood are changed by technology, the term ‘process’ is used in the model. A sequence of processes, therefore, is a ‘process chain’. If the process chain is the connection between source (e.g. field) and terminal (e.g. consumer), it is called ‘supply chain’.

Product characteristics, process technologies and the topographic circumstances are the essential logistic influential factors on the supply chains for SRC-wood. If a spatial distance needs to be overcome between the processing processes, the topography of the cultivation area is included in the model calculation (**Figure 1**).

Product Characteristics

Energy wood is an end product with few characteristics relevant for the consumer. Among those are primarily water content and heating value, fraction size as well as bulk density, ash content and impurities [3]. The intrinsic good characteristics water content and fraction size are essential for the logistics, since they determine density, volume and therefore the mass of the goods. Apart from that, restrictions for the technology to-be-used are derived from them. Hence, fraction size and water content also have a direct influence on the reliable predecessor-successor-relation.

The current location as well as the according mass of the energy wood as non-intrinsic parameters has an essential influence on the supply process. These account for, among others, necessary transportation as well as the duration of processes. Finally, the abstract issues total time and costs are added to the product characteristics, which are changed after each performed process step by the applied technology.

Technology

Technology manipulates the defined product characteristics. Thereby, it is differentiated between property-changing technologies (manipulators) as well as transportation and transshipment technologies, which do not effect any changes of the non-intrinsic property characteristics. The parameterization of the technology was carried out on the basis of our own research and with data from respective publications, so that reliable statements about structure, duration and costs of the process chains to-be-determined can be made.

Topography

The illustration of different geographic and infrastructural dependencies was realized with sectors and a conjunctive path network. Sectors are hereby geographically connected places, at which property-changing processes can take place. Transportation processes within the sectors are not taken into consideration due to low distances but are attributed to the applied technology. These places are assigned to the available property-changing technologies. In case the process chain is disconnected due to the attribution of necessary process technologies to different sectors, a transportation process with at least two transshipment processes becomes necessary.

The individual sectors can be reached using different paths, which possibly show several road sections meaning a change of the road type. Should the transportation technology used until then not be suitable for the subsequent road type, transshipment processes might become necessary when the road type changes. Transshipment processes also take place when a sector is entered or left (loading and unloading)..

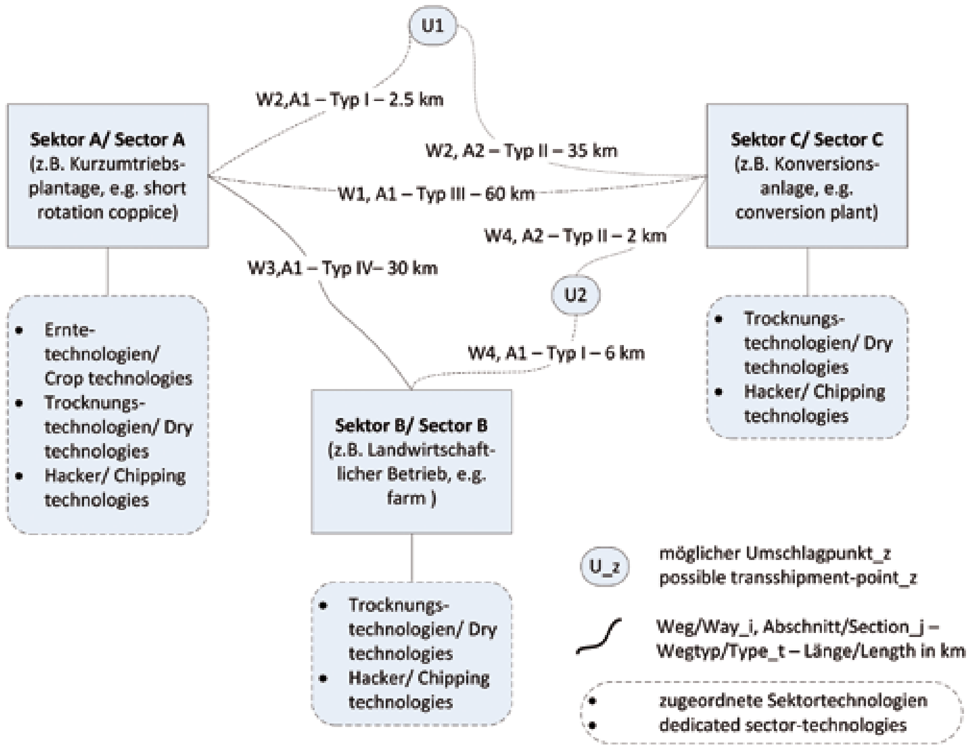
Database Concept

It could be determined that the bibliographical references regarding the costs and performance of the different technology vary extremely or are interpreted differently. This circumstance complicates realistic calculations with respect to duration and costs of the individual supply chains. In order to still make reliable statements for different scenarios, a database with standardized entries and user-friendly front-end is suggested additionally to the model.

This database generates average costs and performances from the stored data records. At the same time, it serves the structured recording and fast evaluation of the recorded own data about the parameters of machines, vehicles and cultivation areas. Furthermore, the authors aim at making the database freely accessible and therefore at animating the SRC-cultivators to add their own data.

A personalized access to the data insertion should be provided for the user in order to perform fast and meaningful analyses for their own cultivation area. In addition, the data of all users is

Fig. 1



Example of a SRC supply chain

anonymized and merged into average values (e.g. based on Federal States) so that these can be integrated into the calculations besides their personal database and comparative statements about the performance of their own supply chains can be made.

Algorithm

For an extensive comparison and the selection of an optimal process chain based on that, it is vital to determine all technologically possible chains. The calculations essential for that can hardly be carried out manually in a reasonable time due to the complex interaction of the marginal conditions and the large amount of possible chains.

Subsequently, an approach is suggested which is suitable for a software implementation in order to determine all supply chains in an automated way from the existing parameters including total duration and costs. The algorithm developed for that is similar to the principle of "depth-first search" (DFS) known from Computer Sciences [4].

Implementation

The described model and the algorithm were implemented into a software prototype taking the suggested database concept into consideration. On the one hand, this step aims at the validation of the developed model, on the other hand, information can be found fast about the structure, duration and cost of numerous different supply chains due to the automation. Due to the generally high availability of the programming environment, the prototype is programmed in VBA-Excel (**Figure 2**).

Results

The foci of the research project SRC-Logistics are put on the before-mentioned nonparametric models, which have described the cultivation of short-rotation coppices so far. At this, especially manipulation and logistics processes were taken into consideration and the development of an automated process chain generator for the locating of potential supply options was furthered.

A success could be achieved to design a parametric model, which illustrates all relevant technological and good-specific characteristics as well as their correlations and specifications for the supply of energy wood. Furthermore, transportation and transshipment processes can be regarded for any energy wood plantation using a sector model operating independent from the location. With the help of this, a way of describing process chains during the SRC-cultivation detached from the specific application was developed.

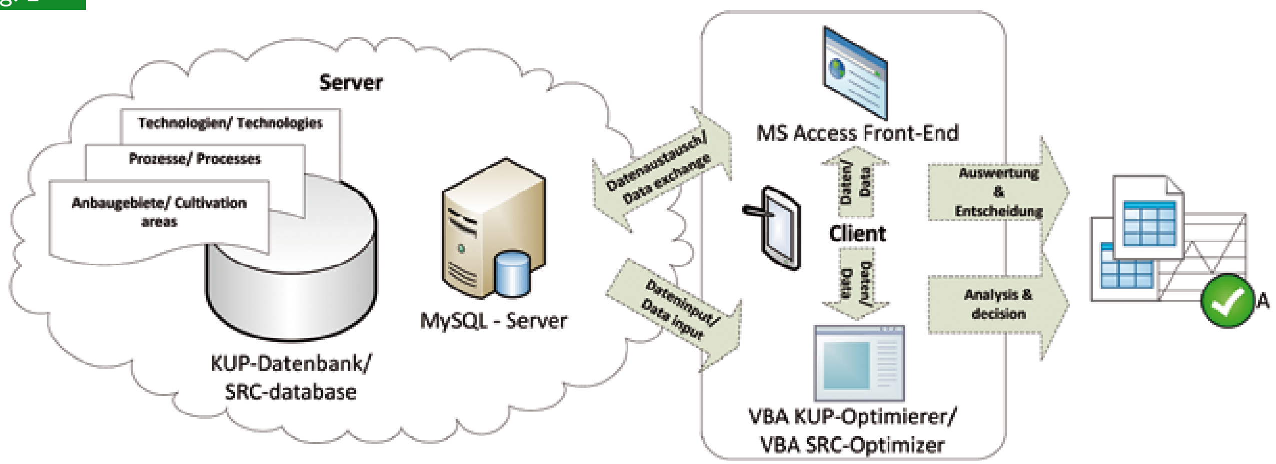
The model parameters are often subject to high regional variations due to their specific characteristics. However, in order to still generate realistic statements about the characteristics of the supply chains, a database concept for the supply of the consumer was developed with valid information such as harvesting capacity, process costs and process losses.

The suggested algorithm constitutes extensive statements about the number and structure of possible process chains. Numerous possible options can be calculated and evaluated fast. Therefore, a tool was created, which allows the client to choose an optimal process chain for the supply of the demanded energy wood with the help of simple insertion and filter options.

Conclusion

In the future, especially the problem of storage might have a great influence on the total costs, since the different degrees of ripeness of the trees on the fields of a cultivation area is crucial for the annual harvest size. A short-term high property occurrence in single harvest periods faces a year-long almost constant consumption. Under the premise that a perennial storage of wood is to be avoided, yet a high degree of security of supply is guaranteed, concepts are required which supply the right amount of energy wood at the right time. Especially the supply of the consumers with energy wood under minimal transportation expenses from the source (storage) to the terminal (conversion plant) is striven for. The areal enlargement of connected SRC economic territory is, therefore, going to be re-

Fig. 2



Components of a database assisted decision-making support for selecting an optimal supply chain for short rotation coppices stricted tremendously by the transportation expenses and the resulting costs. The logistics research can define and evaluate the concepts necessary for that.

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