SHORT ROTATION PLANTATIONS IN SOUTH-WEST GERMANY ASSESSMENT OF THEIR ECONOMICAL AND ECOLOGICAL POTENTIAL

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Abstract: *The project "PROBIOPA" (Sustainable production of biomass with short rotation plantations of poplar on marginal sites) aims at optimizing the biomass-production of poplar in short rotation coppice (SRC).*
The primary objective of this work package, in which both institutes are involved, is the assessment of the technical and economical area potential for SRC in south-west Germany as well as the optimisation of utilization concepts for SRC. Additionally, life-cycle analyses and comparison of different supply chains are implemented to show the impacts of the selected utilization and transport systems.
One of the main results expected will be a detailed estimation and classification of which sites should be preferentially used for SRC cultivation and information about their technical, economical and ecological biomass potential. A model for a sustainable, site adapted supply chain as well as innovative and efficient harvesting and transport concepts will be developed and their impacts will be identified.

1. Introduction

Due to the shortage of fossil fuels and the climate change, the demand for renewable energies has increased in the last years. In all scenarios for the energy mix in the future, the energetic use of biomass plays an important role (WBGU, 2003). According to Germany's biomass action plan of the governance, the percentage of the bio energy in Germany should be redoubled until 2020 (BMELV, 2009). The intensified interest in bio energy also results in an increased demand for energy wood in form of wood chips or pellets. Studies even show a deficit up to 32 millions m³ of energy wood in Germany until 2020 (FUNK, 2010). The German Pellet Verband e.V. also assumes a demand of 10 millions tons of wood pellets in 2020 and relies to cover that requirement on the further establishment of short rotation plantations on agricultural sites in Germany (DEPV, 2008).

To what level the significant extension of SRC can be possible, depends on different factors like: availability of agricultural land, economic efficiency, sustainability and the ecological impact. Within the work package three of the project PROBIOPA (Sustainable production of biomass with short rotation plantations of poplar on marginal sites) it is analysed, how far the further establishment of SRC can be economical possible, without any negative ecological impacts or the causing of land use conflicts.

The detailed tasks of this work package are:
- Assessment of the biomass potential of SRC in Baden-Württemberg
- Modelling of utilisation concepts for SRC on community level

- Development and evaluation of harvesting- and logistic-systems as well as economical analysis
- Life cycle analysis of SRC with nutrition and water management

2. Materials and Methods

2.1 Assessment of the biomass potential of SRC in south-west Germany

The estimation of the biomass potential of SRC on crop- and grassland areas takes place on the basis of digital data for the Federal state of Baden-Württemberg. It will be subdivided into the assessment of the theoretical, technical, ecological and economical usable potential. Since for the Federal state the soil and climate data is only available on a small scale, there will be a detailed site assessment on parcel scale for five selected communities in different geographic regions.

The growth of short rotation plantations is essentially affected by the water supply (MURACH et al., 2008) and the temperature during the growing season. So called "SRC-site-classes" are formed on the basis of these two parameters. The water supply is described by the pedological humidity stages and is based on the work of HAUFFE & AUGENSTEIN (1996) and HAUFFE et al. (1998) (Tab. 1). These are made up from the relief-dependent (exposition, slope, relief position) climatic water balance from May to October and the available water capacity in the upper 10 dm of the ground (AWC).

Table 1. Classification of the pedological humidity stages of non-hydro morph grounds in dependence of the available water capacity of the soil and the climate area (modified after HAUFFE et al. 1998)

available water capacity	Climate area (relief dependent climatic water balance from May to Oct.)						
	0 - 1	2	3	4	5 - 6	7 - 9	> 9
< 50 mm	very dry	dry	dry	dry – mod. dry	moderate dry	moderate dry	moderate fresh
50 - 90 mm	dry – mod. dry	moderate dry	moderate dry	mod. dry – mod. fresh	mod. dry – mod. fresh	moderate fresh	moderate fresh - fresh
90 - 140 mm	mod. dry – mod. fresh	moderate fresh	moderate fresh	moderate fresh - fresh	fresh	fresh	fresh
140 - 200 mm	moderate fresh	moderate fresh	moderate fresh	moderate fresh - fresh	fresh	fresh	fresh
200 - 260 mm	moderate fresh - fresh	moderate fresh - fresh	fresh	fresh	fresh	fresh	fresh

On the basis of the soil data map 1:200.000 for Baden-Württemberg the waterlogged and wet sites have been selected separately, because they are only limited arable for the cultivation of short rotation plantations. With groundwater distance maps the areas with a middle ground water distance of max. 2 meter, were attached to the humidity stage "damp", because the roots from short rotation plants have the ability to reach this depth after two years and have therefore a continues water connection (MURN, 2008).

After the calculation of the pedologic humidity stages, the long-time mean air temperature during the growing season was classified in three interim classes (<12.5 °C, 12.5 – 13.5 °C and >13.5 °C). This equates in Baden-Württemberg the heights over 800 m, 600-800 m and under 600 m N.N.. With the pedologic humidity stages and the temperature classes a classification, analogue to table 2, of the agricultural land in five SRC-site-classes was done:

1. Excluded areas: These areas are either to dry or to wet and simultaneously to cold. Agricultural crop land is here almost not included

2. <u>Unfavourable areas</u>: These areas are either to dry, cold or to wet and therefore only conditionally usable for short rotation plantations. But with adequate species (e.g. locust, alder) they can be used.
3. <u>Medium areas</u>: These areas are suitable for short rotation plantations, but the growth is, because of the medium water availability and the cold climate, rather small.
4. <u>Favourable areas</u>: These areas are very suitable for the cultivation of short rotation plantations because of the good water availability and the temperature during the growing season.
5. <u>Very favourable areas</u>: These areas offer very good site conditions for the establishment of short rotation plantations concerning the water supply and the climate conditions.

Table 2. Interim classification of the site-classes for SRC cultivation dependent on the pedological humidity stages and the mean temperature during growing season

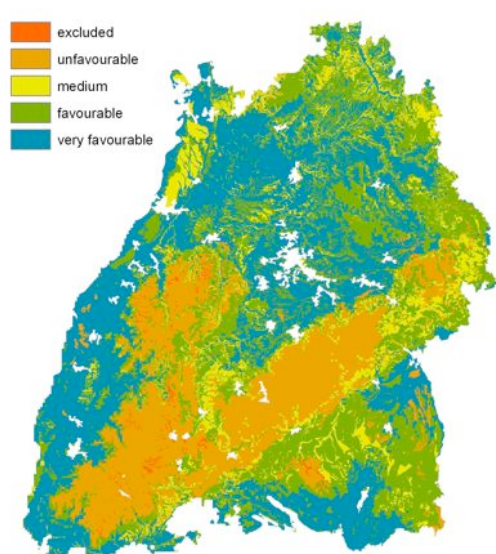| mean temperature during growing season	pedological humidity stages						
	very dry - dry	moderate dry	moderate fresh	fresh	damp	wet	water-logged
<12,5°C	excluded	un-favourable	un-favourable	un-favourable	un-favourable	excluded	excluded
12,5-13,5	un-favourable	un-favourable	medium	favourable	favourable	medium	un-favourable
> 13,5 °C	un-favourable	medium	favourable	very favourable	very favourable	favourable	un-favourable

Fig. 1: site conditions for the cultivation of SRC in Baden-Württemberg dependent of the pedological humidity stages and the mean temperature in the growing season
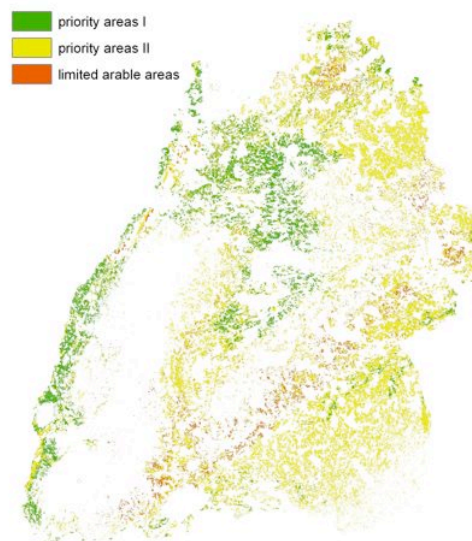

Fig. 2: priority and limited arable areas for the food production in Baden-Württemberg.

In Figure 1 the allocation of the site-classes for the cultivation of SRC in Baden-Württemberg can be seen. The next step will be the validation of the site-classes thru growth measurement on 20 short rotation plantations in Baden-Württemberg. In Addition with the measurement of the available water capacity and climatic data the site-classes will be verified and adapted. Furthermore these measurements are going to be supplemented with literature data.

Due to the fact that the establishment of SRC is standing in land competition to the common food production, there was a selection of sites, which are only limited arable for food production, because of their poor site conditions. This takes place through the use of the "Flurbilanz" of Baden-Württemberg. The Flurbilanz is classifying the sites, by the productivity value of the soil, the climatic conditions and their location, in priority areas I & II and limited arable areas for the food production.
The priority areas I & II should be preferentially used for the food production, whereas the limited arable areas can be used for other cultivations. The allocation of the "Flurbilanz" on crop land in Baden-Württemberg can be seen in Figure 2.

Because of the low nutrition requirements of short rotation clones and their extensive farming, the limited arable areas for food production can be very suitable for the cultivation of short rotation plantations, as long a sufficient water supply is given.

To asses this potential an overlay of the digital "Flurbilanz" with the "SRC-site-classes" was done, to select the sites which are useable for the SRC cultivation without affecting the food production.

Furthermore is the establishment of SRC in nature conservation areas, for example Natura 2000 or landscape protection areas, only possible in a limited way, and in some areas like nature-reserves even impossible. Therefore the protected areas will be selected in a digital map and classified as "limited usable" and "excluded areas" for the cultivation of SRC.

To asses the technical potential, the slope and sizes of aligned field and grassland plots will be calculated by a digital terrain model. On the basis of these two parameters, the classification of the plots into three technical-classes: „full-mechanized usable", „semi-mechanized usable" and „technical not usable" takes place.

On the basis of the technical-classes and the estimated growth by the site-classes, the expected yields per plot will be compared to the operating costs per technical-class. With the help of this step it will be possible to assess and illustrate the economical potential of SRC cultivation on agricultural land in Baden-Württemberg.

2.2 Modelling of utilization concepts for SRC on community level

In order to be able to optimize the management of short rotation plantations on community level, there has to be, next to the calculation of the economical potential, a model of an efficient supply chain. For that purpose in two chosen communities all possible consumers for SRC energy wood are identified, as well as their requirements to the product (quantity, delivery periods, water content, etc.). For every consumer a supply radius will be specified, within those the demand can be covered.

With the help of the potential computations, a model for an efficient supply chain on community level will be computed. The calculated costs of transport, storage and drying will also be included into the computations for the economic efficiency. In that way, the optimal rotation length for each plot, as well as the further operational steps of the wood chips supply, can be defined and illustrated in the model.

2.3 Development and evaluation of harvesting- and logistic-systems as well as economical analysis

It is aimed to evaluate and - if possible- to improve the overall harvesting and logistic concepts for specific products which are made out of SRC, as it is assumed that an optimised supply chain leads to an improved sustainability.

Accoding to Nagurney (2006), a supply chain is a "system of organizations, people, technology, activities, information and resources involved in moving a product or service from supplier to customer". Supply chains consist of manufacturers and suppliers, distributors, retailers and consumers in the demand markets which means they are linking value chains by transforming natural resources, raw materials and components into finished products. Supply chains and supply chain management was discovered very

much in the 1980s when companies developed new manufacturing technologies and strategies that allowed them to reduce costs and better compete in different markets (Simchi-Levi et al. 2003). An increase in demand for a product, entirely new demand markets (such as from SRC) also provides new opportunities for actors who are part of the supply chain by identifying possibilities in reducing costs, saving resources, using more efficient processes, machines or other materials etc.

To be able to advance and optimise the supply chain, it is necessary to identify and know system relevant processes according to Best and Weth (2003). In this study, those harvesting- and logistic-systems are analysed which differ a lot especially in the level of mechanisation (motormanual felling/ harvester-thresher) and the location of chipping the biomass (at the field, edge or at the purchaser). Common, in practise used systems are analysed and assessed in cooperation with the involved industry partners. The cost-benefit-analysis is done either with time studies according to REFA (1998) or, if possible, specific values from the literature are used to discover the required input-data for the modelling of the supply chains.

The modelling is done by using the software "Umberto" which is a tool for modelling, calculation and evaluation of material and energy flows. This software was chosen for the modelling of harvesting- and logistic-systems, although there are other comprehensive software tools as for example the concept of the event-driven process chains under the use of the software ARIS Business Architect and Aris Business Optimizer. The reason was that another aim of the work package is to do a life-cycle-analysis of the overall system and therefore, the chosen software was the best option. In Umberto, production networks of up to any complexity can be modularly built up of individual processes with material flow network. The calculation is done sequentially and locally, independent of the calculation direction. Period costing as well as product costing can be calculated by using material flow networks. Recycling loops can be displayed and included as well.

2.4 Development Life cycle analysis of SRC with nutrition and water management

In this methodological approach, the impact of a specific supply chain towards ecological impacts is measured. Therefore, a life-cycle-analysis is undertaken with the use of the software "Umberto".
Life cycle thinking is a way of addressing environmental issues and opportunities from a system or holistic perspective (UNEP 2003). It implies the linking of individual processes to organized chains. The technical framework for the Life Cycle Assessment (LCA) methodology has been standardized by the International Standards Organization (ISO). According to ISO 14040, LCA consists of four iterative phases: Defining the goal and scope of the study; making a model of the product life cycle with all the environmental inflows and outflows (life cycle inventory); understanding the environmental relevance of all the inflows and outflows (life cycle impact assessment) and the interpretation of the study.

Existing life-cycle-analyses claim positive effects of an increased use of biomass from cultivation of SRC on agricultural cropland compared to extensive agriculture and use of fossil energy. Decentralised energy production, the use of local energy sources, increased security of energy supply, shorter transport distances and reduced energy transmission losses can be seen as benefits.
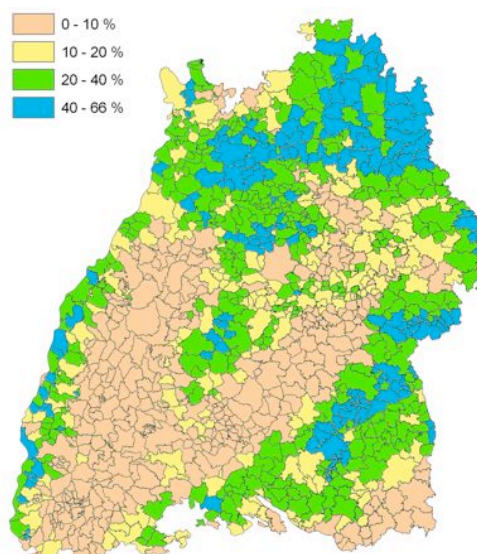

Fig. 3: percentage of the community area which has medium to very favourable site conditions for the SRC cultivation on cropland

Legend:
0 - 10 %
10 - 20 %
20 - 40 %
40 - 66 %

3. Preliminary Results

3.1 Assessment of the biomass potential of SRC in

south-west Germany

After summarizing the SRC site-class "very favourable", as shown in table 2, 43 % of the cropland seems to be very suitable for the cultivation of SRC in matter of the involved site conditions. Favourable and medium site-conditions are found on 35 %, respectively 10 % of the cropland. In Contrast, the unfavourable and excluded sites only cover 12 % and 0.1 %. Therefore, around 90 % of the cropland in Baden-Württemberg would be suitable for the cultivation of SRC in matter of water availability and the mean air-temperature during the vegetation season. The calculated percentage of these SRC-site-classes "medium to very favourable" on the community's areas, is illustrated in figure 3.

Overlaying the SRC site-classes map with the digital "Flurbilanz" clearly changes the situation. Because around 80 % of the cropland is assigned to the Flurbilanz classes "priority areas I&II" and
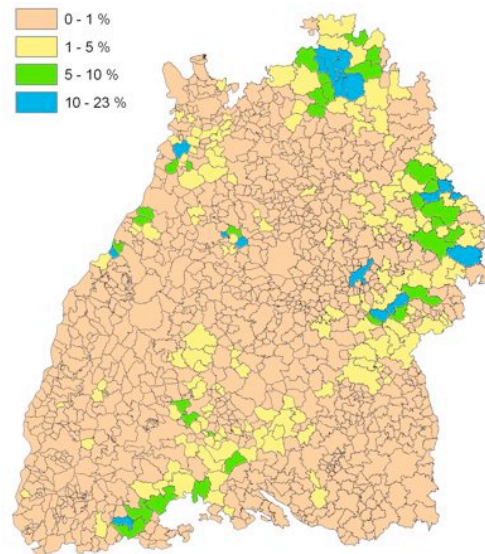

Fig. 4: percentage of the community area which is preferential useabel for the cultivation of SRC on cropland, in matter of site conditions and land competion for food production

should be therefore preferentially used for food production. The distribution of the area percentages, after the overlay, is shown in the following table 3.

Table 3. Overlay of the SRC-site-classes with the "Flurbilanz" of Baden-Württemberg

classes of the "Flurbilanz" in B-W	SRC site-classes				
	excluded	unfavourable	medium	favourable	very favourable
priority areas I	0,0 %	0,2 %	0,4 %	3,3 %	21,2 %
priority areas II	0,1 %	8,0 %	6,3 %	29,4 %	21,4 %
limited arable areas	0,0 %	3,6 %	2,0 %	2,8 %	0,9 %

To illustrate the results, the classes of table 3 have been reclassified in three SRC-suitability-classes:

1. not suitable areas for the SRC cultivation, either because of the poor site conditions (excluded areas) and/or they are priority areas I for food production - orange marked
2. limited suitable areas for the SRC cultivation, either because of the unfavourable site conditions and/or they are priority areas II for food production – yellow marked
3. preferential suitable areas for the SRC cultivation, because of the medium to very favourable site conditions and they are limited arable areas for food production – green marked

Summarizing the percentages of the suitability-class "preferential suitable areas" it is visible that only 5.7 % of the cropland is preferred usable in matter of the site conditions and without affecting the food production. In figure 4 the percentages of the SRC-suitability-classes on the community areas are illustrated. Implicating the SRC-site-classes "medium to very favourable" on the priority areas II would give further 57 % of the cropland, which are limited usable for the establishment of SRC. Other restrictions like technical constraints, for example because of step slopes, are not yet considered. The same calculation for the site and technical potential will be done for the grassland in Baden-Württemberg. In addition the restriction through protected areas will be implicated and illustrated.

3.2 Development and evaluation of harvesting- and logistic-systems as well as economical analysis

Heinrich (2006) gathers the harvesting systems into different categories, as for instance depending on the level of mechanisation, the age of the plantations, according to the assortments or segments in the partial work steps. In this study, mainly rotations from 3-5 years under conditions in Baden-Württemberg are considered and different products should be analysed. Therefore, it seems to be useful to divide the harvesting and logistic systems into their partial working steps.

As described in chapter 2.3, the first step of the process analysis is to identify system relevant processes. One possible harvesting and logistic system is to use well-developed harvesters, which are mainly used for traditional crops such as corn or sugar cane, and involve minor developments like headers specifically designed for harvesting small diameter hardwoods. Combined cut and chip, followed by on-site storage and delivery, or delivery direct to plant. The advantage of this system is, that all harvesting and logistic is in one step, which makes it cost efficient (<30€/t dry according to Burger, 2010). Material should be used directly in a heating plant; otherwise it needs to be stored. Chipped material from combined machines (for example from the companies "Claas" or "New Holland") is fine cutted and studies show big losses of mass while storage up to 20% if the material is very fine (Scholz 2010). To get more detailed information about the loss of mass detailed analysis are planned within the project.

Another possible harvesting and logistic system is the harvest with a "stick harvester" like for example the machine "Stempster MK III" developed by the company "Nordic Biomass" and the use of a mobile chipper after a temporal break (4-10 weeks) which lets the material dry. The machine cuts the crops, but chips the material not yet. Roods are laid down at the field and it takes 2-3 months weeks until the roots have a moisture content less than 25-30% which means they are suitable for storage (according to DIN CEN/TS 14961). This system causes on the one hand more costs as a mobile chipper has to chip the material in a second step after some weeks of drying. Then, it will be transported to the place where it is used. On the other hand is the heating value of dry material significantly higher: poplar with a moisture content of 25% offers a heating value of 3.5kwh/kg (lowest value) while material with 50% moisture content offers a heating value of 2.107kwh/kg. Additionally, the quality of chipped material which is already dry is higher than the quality of material which is cut-and-chipped by one machine. With the possibility to storage the material, demanders can be supplied in the whole year.

Figure 5 shows the supply chains describing the two presented harvesting- and logistic systems. The next steps will be to analyse data about costs and other drivers as f.e. fuel consumption or distance of transport km in order to be able to optimise the supply chain. Afterwards, other possible systems will be analysed, too.
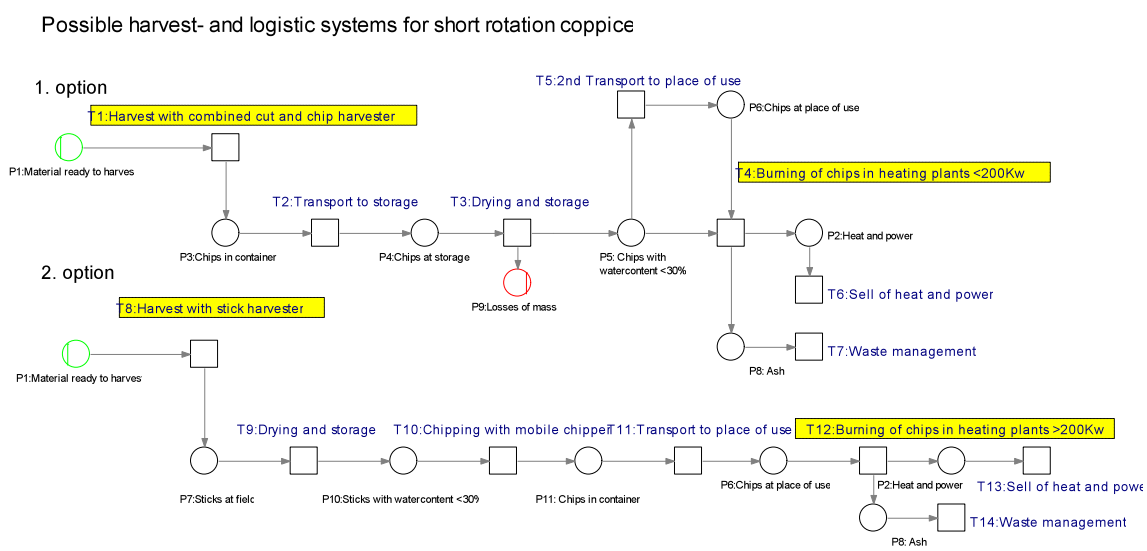

Possible harvest- and logistic systems for short rotation coppice

Figure 5. Possible harvest- and logistic systems for products from short rotation coppice. The figure shows the process chains for (1) a harvest with a combined cut and chip harvester which means for the

subsequent processes that the material hast eventually to be dried before the use. This is dependent from the purpose of use. The other possibility (2) is to cut the roods and lay them down at the field so that the material can dry until it's chipped and delivered to the plant.

3.3 Life cycle analysis of SRC with nutrition and water management

In this study, the full life-cycle, including all impacts between the changes of cropland to the conversion of the product into energy is taken into account while the main focus is lying on the impact of different harvesting operations, which were defined in the previous task of the work package. Questions like "does a higher heating value caused by a moisture content less than 25% (and approximately also less transportation) saves more emissions as caused by a not-combined harvesting and chipping, e.g. with the stick harvester?" will be analysed with the help of the results from the LCA.

4. Discussion

The results of the calculated potential for the short rotation plantations can only be used as a reference value. The real potential depends on many ascertainable factors and all of them can not be considered. Especially in a study where the evaluation is based on digital surface data, the results depend on the quality, topicality and the dissolution of the basic data. For example it's not possible to consider the small differences and local varieties of the soil and climate from the data on a scale from 1:200.000 to 1:1000.000. The results can deliver thereby only an overview over the adequate sites, as well as an estimation of the attainable biomass thru SRC on land level.

For the verification of the assessment on Land level and the modelling of the utilization concepts, a detailed assessment is accomplished on five selected communities. Since for these communities ground maps on a scale 1:50.000 exist, the local conditions of the soil can be better covered. This is particularly relevant for the determination of the water supply. Because of an overlap of the computations on land level, the results can be compared and discussed to point out the weak points of the assessment of the area potential on land level.

The assessment of the theoretical biomass production can also be seen as a reference value only. The actual producible biomass on a certain cropland depends on many not coverable factors like e.g. type of land use before establishing a plantation, care, rotation length, nutrition availability and type of species planted. That is why the estimation is accomplished with standard values for certain factors like plant spacing, rotation time and species choice depending on the site-class. The same applies for the economic estimation. It is likewise based on standard values for cultivation cost and revenues after harvesting. In Contrast the real achievable revenues in the practice are dependent to the surface management, availability of planting and harvesting machines and as well of the regional prices.

The analysis of the harvesting and logistic systems is not yet finished but there seems to be a significant correlation between costs for harvesting and logistics, dimension of the field to harvest and intended purpose of use. Landowners need to calculate in an up-streaming way to optimise their harvesting and logistic systems: the intended use of a product appoints the required properties as e.g. the length or moisture content of material. Qualities are the results of the one or other harvesting system and the harvesting system as such is depended from the size of the field (cost-effectiveness) or the availability of harvesting machines. At the same time is often the demanding market the driving force, e.g. when deciding whether a product needs to be stored or delivered.

The results of the life cycle analysis will also support to decide which harvesting and logistic systems the best option is; not only regarding costs but also for environmental aspects.

5. Conclusion

The potential assessment on land level gives a good demonstration if an increased establishment of short rotation plantation in Baden-Württemberg is realizable. It will be visible how restrictions the establishment of SRC on crop land constrain or even exclude. The illustration of preferential areas for SRC, offers a planning aid for the establishment of pellet or biomass power stations, which rely on agricultural wood. Therefore, a first estimation can take place whether and within which radius a permanent supply for the consumer would be possible.

By using the model on community level it is shown, how far the energy requirement of a community can be covered and how the supply can be sustainable improved. On this basis and in addition of further studies, the use of renewable energy sources can be further planned and developed.

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