CREFF Final Report

Project ERA-Net Bioenergy CREFF

“Cost reduction and efficiency improvement of Short Rotation Coppice”

on small field sizes and under unfavourable site conditions by focusing on high product quality and a product-oriented cooperative value chain

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1 Summary

Besides the large potentials and opportunities, the establishment and cultivation of SRC is connected with several constraints and barriers – especially in the economics of the plantations. While most of the research results available in the past have been obtained for medium to good sites and the presumptions of a large field size for the SRC-plantations, this project focuses on unfavorable sites and small field sizes at scattered locations.

The main objective was the successful implementation of cost-efficient and consumer-oriented SRC-value-chains in regions with unfavorable site conditions for SRC. The research project covered all process steps of the SRC-value chain and is structured in 5 work packages (WP):

- WP1: Cost optimization through an adapted matching between plant material characteristics, site conditions and plantation management.
- WP2: Improvement of harvesting systems and transport logistics with regard to specific site conditions (steep slopes, long rotation periods with large stem-diameters).
- WP3: Value added conditioning of SRC raw material (regarding end product key-properties, industrial experiences, pilot storage trails and storage simulation device design)
- WP4: The economics of SRC-value chains and optimization strategies with respect to site location and dimension.
- WP5: New business concepts for successful implementation of a product-oriented wood fuel value chain from SRC.

The development of strategies allowing a major cost reduction and a higher efficiency has been achieved by an innovative approach to initialize intensive and early cooperation between producers and consumers. Inside these co-operations, the SRC-production concentrated on the requirements of industrial consumers. Based on the known value chain structures all major processes like the production (species-site matching, spacing, rotation), harvest, logistics and conditioning of SRC-products were streamlined.

The consortium work highlighted that farmers in the project region see SRC plantations as a good option to valorize their most marginal sites, where there is no or lower profit at the moment. However, the results have shown that SRC is not an option, which can raise profits on these unfavorable or marginal sites, but has the advantage to offer income with a minimum of input. CREFF consortium has made a number of recommendations, based on the results of each work package in order to optimize the management of the plantation as a whole: Producer – consumer co-operations, products, plantation design, plant material, fertilization, harvest and logistic, fuel quality and conditioning methods.

Moreover, some tools have been developed by partners to help stakeholders in decision making. A technical guide (in French) has been developed for interested farmers to explain every step of a SRC plantation. Also an excel model, the “KUP Ernteplaner” (in German) was realized in order to allow farmers with a SRC to accurately plan their harvesting operations and related logistics.

2 Framework and Goals of the Project

2.1 Background

Besides the large potentials and opportunities, the establishment and cultivation of SRC is connected with several constraints and barriers – especially in the economics of the plantations. Economic competitiveness is one of the main obstacles for a wider use of biomass from SRC. Up to now profits from SRC-production are comparably low, especially on a per hectare base. Costs of plant material production are still too high, yield needs to be raised by plant breeding and optimization of species–site matching on a regional scale, harvesting and transport costs are high due to non-existence of SRC markets and low utilization ratios of machinery. At present, most of the research results available have been obtained for medium to good sites and the presumptions of a large field size for the SRC-plantations. There are several reasons, that these conditions can be rarely found in many regions of Central Europe, where South-West Germany and North-East France are examples. The project, therefore, will focus on less favourable conditions with small field sizes at scattered locations and on unfavourable sites and terrains.

2.2 Common goals

The main objective is the successful implementation of cost-efficient and consumer-oriented SRC-value-chains through new business concepts and in regions, where small field sizes and unfavourable sites and terrain prevail. Therefore, the overall hypothesis shall be tested that in the project region mostly SRC is established or potentially established on the above mentioned unfavourable sites.

The consumers of woody biomass from SRC are relying on a constant supply of large amounts of raw material, with defined properties and quality, and at a profitable price-level ("Consumer-oriented product design").

On the other side of the value chain, the potential SRC producers need established markets with clearly defined products, and prices allowing a profitable SRC-management even under the unfavorable site conditions of our pilot regions.

Requirements from both sides of the value-chain are fulfilled optimally, if the products comply exactly with the requirements of the consumers (quality, quantity).

- It was tested whether the establishment of **co-operations between consumers and producers** not only has important effects on improving the efficiency of SRC-value-chains, but as well is a precondition to overcome obstacles and constraints for implementation of any SRC-value-chains (**WP5)**.

  Thus, the specific goal of WP 5 is to detect the reasons and constraints for the low spread of SRC in the project region. We assumed that a lack of personal information, missing markets and lacking established regional producer-consumer co-operations are the main obstacles for SRC implementation. The effect of producer – consumer co-operations were tested within two case studies.

- Starting with **plantation management (WP1)**, costs and quality of the products can be influenced, e.g. by the choice of tree species, spacing, and rotation length. The relationships among plant characteristics (yield and efficiency to use resources for the different kind of plant material available for SRC), soil and climate conditions, and plantation management practices (planting density, fertilization, date of harvest, etc.) will be studied.
- Based on these parameters, the most suitable **harvesting- and logistics system (WP2)** needs to be selected, which also determines costs and properties of the product. For this purpose, about 40-50 different harvesting operations were to be documented in which different harvesting systems were used: a) fully mechanised systems using self-propelled cutter-chippers or tractor-mounted cutter chippers, b) fully mechanised harvests with forestry machinery like feller-bunchers and chippers used in forestry, and

c) semi-mechanized harvests using motor-manual techniques and mobile chippers. These harvesting methods were to be assessed with regard to their efficiency and cost performance under different site conditions in order to identify operational aspects that could be improved to reduce the costs. Similarly, the logistic strategies employed for the biomass transport were to be analysed with regard to their efficiency and costs. Based on the obtained results, we aimed at developing a tool which facilitates realistic estimations about the costs of the different harvesting strategies and transport systems, showing which system is most profitable.

- In the last stage of the value chain, the product undergoes the **conditioning (WP3)** according to defined quality demands, like moisture content, dimensions, and homogeneity.
- Obviously, all stages of the value chain need to be concerted and optimized to make it efficient, to reduce costs, and to maximise the revenues. These aspects will be subject of an **economic and socio-economic evaluation** of the recommended and tested SRC-value-chains **(WP4)**.

For the realization of the work packages 1, 2 and 3, it is essential to carry out a field data-collection on already established SRC-plantations. Especially, they will serve as study objects to survey the annual growth rate, the nutrient and water use efficiency (WP 1), and to carry out the scientific monitoring during harvesting and transport of SRC wood (WP 2). WP 3 will use raw material from harvest-operations for the research on conditioning and storage.

However, the involved institutions of the project have only small or no own SRC-plantations. Therefore, the consortium has invested time to find appropriate partners (farmers, industrial partners and contractors in the value chain) offering access to established SRC-plantations. This mix of selected areas offers a wide range of different SRC-plantations of poplar and willow in several European countries, but mainly in Germany and France. This reflects the particular research focus of this consortium, namely “product quality” on the one hand and “small field size and unfavourable site conditions” on the other hand.

2.3 Description of the consortium

The main objective of the consortium is the successful implementation of cost-efficient and consumer-oriented SRC-value-chains through new business concepts and in regions, where small field sizes and unfavourable sites and terrain prevail.

To reach the overall objective, the proposed research project covers all process steps of the SRC-value chain and is structured in 5 work packages defining 5 main research topics covering the whole SRC-value chain:

- WP1: Cost optimization through site adapted plantation management.
- WP2: Improvement of harvesting systems and transport logistics related to specific site conditions.
- WP3: Value added conditioning of SRC raw material regarding end product key-properties under consideration of different site conditions and field-sizes.
- WP4: The economics of SRC-value chains and optimization strategies with respect to site location and dimension.
- WP5: New business concepts for successful implementation of a product-oriented wood fuel value chain from SRC.

Each research partner is assigned to its work package. With the industrial partners, they form the CREFF consortium, presented in Figure 1.

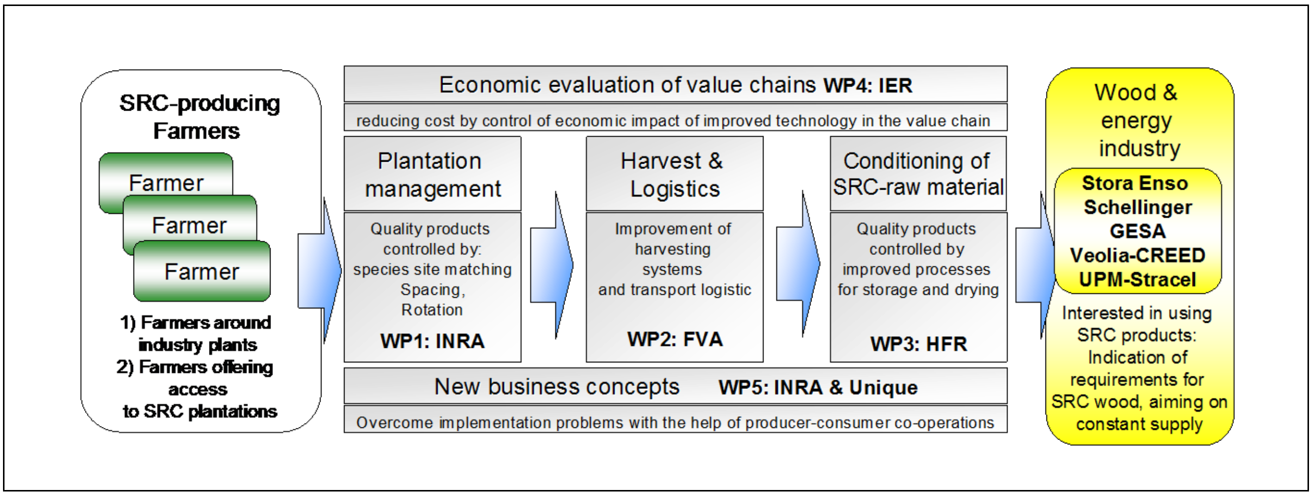


Figure 1: Description of the CREFF consortium

2.4 Expected outcomes

Main expected result is the development of successful strategies allowing a major cost reduction and a higher efficiency even for areas in Central Europe, which are characterized by less favourable conditions for SRC-production, fields with lower soil quality and unfavourable forms, small field sizes, at scattered locations and on unfavourable sites and terrains.

This should be achieved by an innovative approach to initialise intensive and early cooperation between producers and consumers – on the one hand – and to concentrate the SRC-production inside these co-operations to the requirements of industrial consumers. It will allow:

- To overcome the problems of small field size and scattered locations,
- To improve efficiency via a straight product-oriented quality production,
- To define the optimal production system for farmers to get the products, consumers are asking for (species, clones, spacing, rotation, harvest technique).
- To cooperate for better information between producers and consumers, better information upon product-oriented production systems among producers, for improved use of machinery for planting, but especially for harvesting and for establishment of efficient logistic system between partners.
- This in turn results in
  - adapted and efficient drying and storage processes and facilities,
  - low production risks for farmers and procurement risk for industrial consumers,
  - the implementation of a supply-chain management between partners, which can lower the costs of harvest, transport, storage and conditioning.
  - overall cost reduction for the SRC-production.

The new strategies are expected to allow the production of quality SRC-products for a known market based on new business concepts, via a trustful cooperation and a win-win situation for producers and consumers.

Through the combined use of the individual work packages results, the project will develop together with the industrial partners' local SRC cultivation and supply concepts (WP 3, 4+5), which will be practically implemented by the pilot-co-operations of SRC-producers and industrial consumers.

The pilot-co-operations will be used as show-cases for the new strategies to support the establishment of efficient SRC-Value chains.

The guidelines compiled from the project's results will be used to disseminate results among other interested initiatives for SRC-production.

Beside this the results will be as well used to support other activities fostering SRC implementation.

2.5 Time frame

The official starting date of the CREFF project was November 14, 2008 for a period of three years. In 2011, the project duration was extended to four additional months, until March 15, 2012. The CREFF project was framed by two ERA-Net meetings: an ERA-Net Bioenergy (SRC call) kick-off meeting took place in Potsdam, Germany, September 8 to 10, 2008, and a final ERA-Net meeting was held in Helsinki, Finland, February 7 and 8, 2012. Within CREFF, a kick-off meeting was held in Champenoux, France, February 4 to 6, 2009, in presence of all research and industrial partners. A second general meeting took place in Rottenburg, February 10 and 11, 2010. Additionally, two steering committee meetings per year (on an average) involving the five research partners only, were organized during the entire duration of CREFF.

Details about the time frame of each work package and the list of the meetings are presented in section 5.7 (WP0 – coordination). All documents related to the meetings (agendas, minutes, power-point presentations, etc.) can be found on the Silverpeas pages of the CREFF project.

3 Common State of the Art

In the last few years the demand for wood, both for energetic and for non-energetic use, has been constantly increasing. Against the background of climate change and CO2-reduction goals, new policies promote the use of renewable energies to substitute fossil fuels, and there is a clear expectation that the demand for woody biomass will increase further.

To satisfy the future demand for wood, additional sources need to be identified. One option is wood production in short rotation coppice (SRC). However its development in the majority of EU member countries has been slow up to recently. Even though there exist far more SRC plantations in Germany than in France, but in total they only account for about 5000 ha in 2011 which is about 0,02% of the total agricultural surface (FNR, 2011).

One of the main obstacles for a wider use of biomass from SRC is its economic competitive-ness. Up to now profits from SRC-production are comparable low, especially on per hec-tare base. Costs of plant material production is still too high, yield needs to be raised by plant breeding and optimization of species–site matching on a regional scale, harvesting and transport costs are high due to non-existence of SRC markets and low utilization ratios of ma-chinery. As an energy source, wood from SRC has to compete with fossil fuels, residues from agriculture (e.g. straw) and forestry as well as with other renewable energy sources. For a non-energetic use, wood from SRC has to compete with other agricultural products and with wood production from conventional forestry.

As there is a constant increase in the market price for wheat and corn, the potential for an in-creased SRC establishment lies in the usage of marginal, unsuitable for “conventional” agri-cultural crops. These sites are often transformed into grassland.

In most cases, it is inferior under the given frame conditions. Consequently, to promote the use of biomass from SRC, costs for its production and supply have to be reduced.

At present, most of the research results available have been obtained for medium to good sites and the presumptions of a large field size for the SRC-plantations. There are several reasons, that these conditions can rarely be found in many regions of central Europe, where also South-West Germany and North-East France are examples.

The project, therefore, will focus particularly on these conditions, which can be characterized as follows:

- Good and optimal agricultural sites are rare, expensive and can be used for a wide range of food products or annual energy crops. Therefore, SRC might often only be established on less favourable site, fields with lower soil quality and unfavourable forms (e.g. small stripes along creeks and along forests).
- The average size of single fields as well as farms is much smaller compared for example to UK or South-Sweden (and many more regions in Europe), where SRC is far better established recently. Therefore, SRC in those regions will often be established in small field sizes, at scattered locations and on unfavourable sites and terrains.

These special frame-conditions for SRC production result in comparably low profits, especially on a per hectare base. Harvesting and transport costs are high due to a virtual non-existence of SRC markets and low utilization ratios of specialized machinery.

4 State of the Art, Activities and Results by Work Packages

4.1 Work Package 1 - Cost optimization through site adapted plantation management

4.1.1 State of the Art

Cost reduction necessary for the promotion of SRF to a larger scale can, among others, be attained by optimizing the biomass yield. In this perspective, the most striking difficulties concern the lack of knowledge in terms of productivity optimization and soil fertility maintenance. In other words, the questions asked by farmers and by the actors of the biomass network concerning biomass production and fertility are among the most deeply rooted limits to the full development of SRC plantations at a large scale in Europe. The major questions are:

1. how to take a maximum advantage of the soil / climate / site / productivity interactions?,
2. how to optimize the variety or species combination with the local conditions to maximize the yield?,
3. how to avoid or to slow down a rapid soil and whole system depletion in nutrients?

SRC plantations show several particularities as compared to a traditionally managed forest, notably concerning the fact that the quantity of carbon sequestered for a long time is inferior to the one of a classically managed forest or a long rotation plantation. Frequent wood exportations from the plantation imply a progressive depletion of the soil in mineral elements. However, **fertilization and irrigation of very large areas dedicated to SRF is not economically viable for farmers to the long term**. One solution to mitigate this problem is to improve the adequacy between the characteristics of the planted material in terms of water- and nutrient-use efficiencies (defined as the ratios between biomass production and water consumption or nutrient content, respectively) and the local edaphic and climatic conditions, plant material presenting higher water- and/or nutrient-use efficiencies being likely to be more adapted to poor and/or dry sites.

The values of energy crops water-use efficiency (WUE) collected so far have been shown to generally vary between 0.3 and 15 g biomass per kg water used. Besides varying definitions of WUE, the high variation is due to the strong impact of environmental conditions and to genotypic variations. On the other hand, the data on nutrient (N, P and K) use efficiency (NUE) often vary with a factor of about 20. The wide range of variation already observed for both traits, WUE and NUE, for various woody energy species highlights the possibility to optimize the adequacy between plant material and site conditions, and needs investigations. It is now well established that knowledge on energy crop water-use is crucial for local decisions and for technical optimizations. The selection of an energy crop for a specific region must be based on an evaluation of the crop water demand in comparison with local climatic and soil conditions. Water is often the main yield-limiting factor. Moreover, annual water use and WUE can be a key selection criteria in breeding programs to improve water restricted yield and to produce a range of varieties adapted to a range of precipitation regimes. The efficient use of nutrients in the production of energy crops is important as well to minimize the input need.

4.1.2 Specific goals

Intensive plantations of trees for bioenergy are often synonymous with soil depletion. To maintain productivity in the long term while reducing inputs (water, fertilizer) and their associated costs, an optimized match between (1) the characteristics of plant material (genera, species and genotypes, mixed or not) particularly in terms of efficiencies of resource use (Water-Use Efficiency, WUE; Nitrogen-Use Efficiency, NUE), (2) cultural practices (spraying, planting densities, pruning, etc.) and (3) the soil and climatic conditions must be found. The approach adopted to meet this objective was to study the effects of the three categories of above mentioned factors on productivity and its determinants in a network of plantations spread throughout the north of France.

Under the framework of CREFF, a network of collaboration was defined with most of the forest and agricultural institutions working on SRC in France (INRA Orléans, AILE, the Agricultural Chambers of Brittany and Vosges, FCBA, IDF, and LIMOS). Born from these collaborations, 10 experiments were set up in order to study the impact of various factors potentially influencing yield and plantation needs in water and nitrogen. The 10 factors can be summarized in the following practical questions:

1. **Clonal mixing**: Do we have to use monoclonal blocks or mixtures of clones / varieties?
2. **Cutting period during the year**: When should we harvest, spring *vs.* fall?
3. **Planting density**: Is there an optimal planting density?
4. **First year coppicing**: Do we have to coppice at the end of the first year?
5. **Chemical fertilization**: Is it relevant to fertilize SRC plantations?
6. **Pedoclimatic conditions**: To what degree the pedoclimatic context affects SRC?
7. **Species**: What are/is the "best" species for SRC?
8. **Sludge spreading**: Is sludge spreading a relevant practice?
9. **Cultural antecedent**: What is the best cultural antecedent, grassland *vs.* maize?
10. **Irrigation**: Is wastewater spreading a relevant practice?

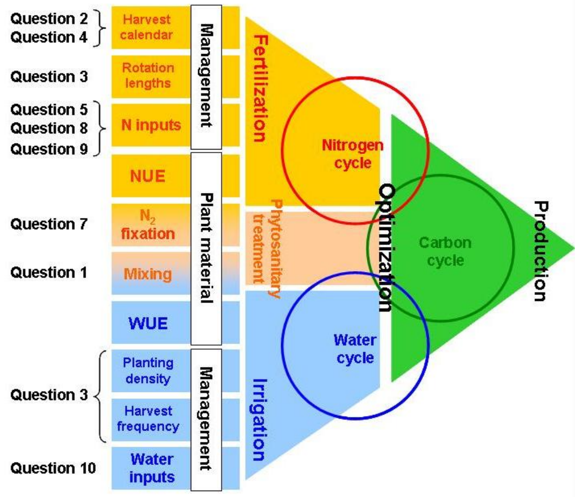


Figure 2: Summary of the different ways to maximize biomass production (green panel) while reducing water (blue panels) and nitrogen (orange panels) needs, in terms of the nature of used plant material and plantation management.

The positioning of the questions listed above in this general scheme is also indicated. water- (WUE) and nitrogen- (NUE) use efficiencies were studied in response to the 10 factors, in all experiments.

To answer the 10 questions, 20 plantations spread in the northern part of France, were used (tasks 1.1, 1.2 and 1.3: checking, selection and characterization of plantations). Refinements of the plantation list during the time course of CREFF were exposed in the first and second year reports of the project. Plantations were selected exclusively in France for practical reasons, but the questioning is valid irrespective of the country. For each of the 10 experiments, the situation, the objective, the involved partners, the description of the trial and protocol, and **the main results and conclusions of the site-specific study are exposed hereafter in the part 4.1.3.1**.

Additionally to the site-specific objectives listed above, the soil, climate and yield data collected for each of the 20 sites were gathered in a common database and used (1) to establish tentative yield models, predicting yields from site conditions, and (2) to get a general overview of the relationships among site conditions, tree growth, and tree efficiencies to use water and nitrogen. **This general study is presented in part 4.1.3.2.**

4.1.3 Activities and Results

For all experiments, wood and leaf samples were oven dried, ground to powder, and analyzed by mass spectrometry at INRA Nancy (Plateforme Technique d'Ecologie Fonctionnelle, PTEF) to get total nitrogen (N) contents and **carbon 13 isotope discrimination (Δ^{13}C, indicated as Δ hereafter), used as a surrogate of water-use efficiency** (usually **negatively** and linearly correlated to WUE; FARQUHAR & RICHARDS, 1984; FARQUHAR *et al.*, 1989). On all graphs presented hereafter, significance of the studied factors, and eventually their interaction, are represented by asterisks: * = $P \leq 5\%$, ** = $P \leq 1\%$, *** = $P \leq 0.1\%$, and ns = non significant. Different letters on the graphs indicate significant differences according to the post-hoc Scheffé test. Location, characteristics, and soil and climate data of the different plantations used in this WP are detailed in Annex 1.1. Detailed protocols, plantation maps, additional results, and pictures are presented in Annex 1.2.

Soil analyses were either obtained from the partners managing the different sites, or by samplings and analysis under the framework of CREFF. Climatic data were obtained from the national INRA database, at nearby weather stations. The staffs of the different partners contributing to the field measurements are summarized in Table 1 below.

Table 1: Staff of the different partners involved in the field measurements.

Unit / Institute		**Involved persons**
INRA Nancy	UMR Ecologie et Ecophysiologie Forestières (EEF)	Nicolas Marron, Julien Toillon (1/2), Bénédicte Rollin (1/2), Erwin Dallé, Laurent Roux (1/2), Romain Leray (1/2)
INRA Nancy	UE Foresière de Lorraine (UEFL)	Pierre Legroux, Fabrice Bonne, Thierry Paul, Vincent Rousselet
INRA Orléans	UE Génétique et Biomasse Forestière (GBFor)	Guillaume Bodineau, Jean Gauvin, Bénédicte Rollin (1/2)
FCBA	Forêt, Cellulose, Bois-construction, Ameublement	Alain Berthelot, Patrice Maine
AILE	Association d'Initiatives Locales pour l'Energie et l'Environnement	Aurélie Leplus, Laurent Roux (1/2)
CA88	Chambre d'Agriculture des Vosges	Flavien DiCintio, Eric Meurin
CRAB	Chambre d'Agriculture de Bretagne	Bertrand Decoopman, Aurélie Rio, Gilbert Le Stanc
CNBF	Conservatoire National de Biologie Forestière	Olivier Forestier, Romain Leray (1/2)
LIMOS Nancy	Laboratoire des Interactions Microorganismes - Minéraux - Matière Organique dans les Sols	Marie Stauffer
Orléans University	Laboratoire de Biologie des Ligneux et des Grandes Cultures (LBLGC)	Julien Toillon (1/2), Stéphane Maury, Clément Lafon-Placette, Alain Delaunay
IDF	Institut pour le Développement Forestier	François Charnet, Dominique Merzeau

As shown by the results to question 6, the site effect can be huge, and so, the conclusions of the experiments are often very dependent on site conditions. So, conclusions have to be interpreted with caution and with regards to the specific growth conditions. To try to make the conclusions as general as possible, some of them were replicated at several locations, but due to the heaviness of such experiments, it was not feasible to do it each time.

In the same way, most of the SRC plantations in France and Germany are young (many of the used plantations are only two year old), and results about a second or a third rotation are seldom. As a result, most of the results presented hereafter will have to be checked and tested again for longer periods of time, for successive rotations.

Contrarily to what was initially expected, it was not possible to calculate accurate values of NUE taking into account all nitrogen fluxes in the plantations (notably because of the difficulty to manage litter bags / boxes at each plantation). Only a stem NUE (roughly equals to the invert of stem N content per unit of wood dry weight, LACLAU *et al.*, 2000; JØRGENSEN & SCHELDE, 2001; THARAKAN *et al.*, 2005) was calculable. We have chosen to present the N results as mg of N per g of dry weight.

In France especially, short rotation plantations (TCR, with densities around 1500 trees/ha) are clearly differentiated from very short rotation plantations (TTCR, with densities between 7500 and 15,000 trees/ha). A large work has been carried out by FCBA and INRA in the past on TCR, but the TTCR are much less known in France and Germany. The following pages will mostly deal with very short rotation plantations (called vSRC).

Supplementary material and databases are on the Silverpeas pages of the project.

4.1.3.1 Site specific experiments

Question 1: Do we have to use monoclonal blocks or mixtures of clones?

Situation: Mixture of clones and varieties is a way to limit pathogen development, but what is the effect on biomass production due to more intense competition among clones with very different growth potentials?

Objective: The effect of a clonal mixing on biomass production, WUE and NUE was assessed.

Partners involved: The studied plantation has been installed and managed by INRA Orléans. The measurements and samplings were done in close collaboration with the INRA Unit GBFOr in Orléans.

Trial and protocol: The poplar plantation of Vatan, la Chesnaye (36) has been used to test the effect of clonal mixing on biomass production, wood N content and WUE. Nine poplar clones were present in this quite old plantation (the current rotation was 11 years long). Two of them were not used in the experiment because of very high mortality rate. The remaining clones were either from Italian (three clones) or Dutch (four clones) origins, and they were planted as monoclonal plots, completely mixed plots, or inter-origin mixed plots (three treatments). The 1.6 ha plantation was installed in 1991, with a density of 1900 trees per ha, and harvested a first time in 1998. Under the framework of CREFF, tree dimensions were measured for all trees during fall 2009, and a selection of tree was harvested in March 2010.

Some results: Figure 3 shows the Δ and N values for the main stem and the first co-dominant stem of the seven clones, irrespective of mixture treatment. No significant difference in terms of water use efficiency and nitrogen contents was observed among the different stems of the same plant.

Figure 4 shows the number of stems per stool, the clump biomass, and the yield (with and without mortality per clone taken into account) per clone and per treatment. When considered globally, clonal mixture has an effect on biomass production dependent on clone. When considered clone by clone, the biggest ones showed similar WUE in the pure and mixed treatments. The smallest ones are less efficient to use water in the mixed treatment because of competition / shading by the big clones.

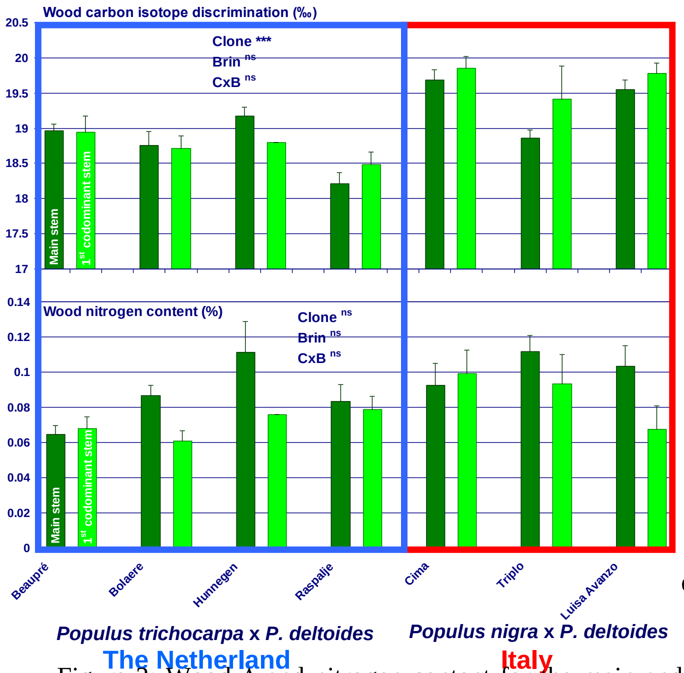


Figure 3: Wood Δ and nitrogen content for the main and co-dominant stems of the seven clones irrespective of mixture treatment.

Clone	Treatment	Potential productivity ($tons_{DW}$/ha/year)	Mortality (%)	Real productivity ($tons_{DW}$/ha/year)
Beaupré	Pure	7.37	12.8	6.43
	Origin mixture	4.18		3.65
	Total mixture	3.70		3.23
Boleare	Pure	6.86	12.2	6.02
	Origin mixture	6.72		5.90
	Total mixture	3.89		3.41
Hunnegen	Pure	6.98	18.8	5.67
	Origin mixture	4.11		3.34
	Total mixture	4.75		3.85
Raspalje	Pure	11.18	3.6	10.78
	Origin mixture	16.35		15.76
	Total mixture	13.94		13.44
Triplo	Pure	7.62	12	6.71
	Origin mixture	6.61		5.81
	Total mixture	12.88		11.34
Cima	Pure	7.36	2.9	7.14
	Origin mixture	6.34		6.16
	Total mixture	7.28		7.07
Luisa Avanzo	Pure	7.18	7.1	6.67
	Origin mixture	5.48		5.09
	Total mixture	9.45		8.78
Mean	Pure	7.79	9.9	6.86
	Origin mixture	7.11		6.26
	Total mixture	7.98		7.03

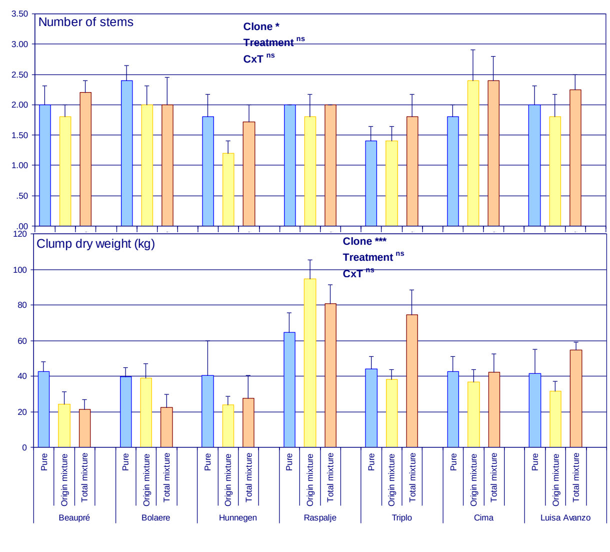


Figure 4: Number of stems, clump dry weight (histograms) and productivity (taking or not mortality into account, table) of the seven clones in the pure, origin and total mixture treatments.

At the end of the 2nd rotation (11 years), real mean biomass production was 6.9 $tons_{DW}$ / ha / year for the pure blocks (with clone 'Raspalje' reaching 10.8 $tons_{DW}$ / ha / year), 6.3 $tons_{DW}$ / ha / year in the origin mixture (with 'Raspalje' reaching 15.8 $tons_{DW}$ / ha / year), and 7 $tons_{DW}$ / ha / year in the total mixture (with 'Raspalje' reaching 13.4 $tons_{DW}$ / ha / year). Means are comparable in the three treatments, but the most productive clones are even more productive in the mixture and conversely for the least productive because of competition.

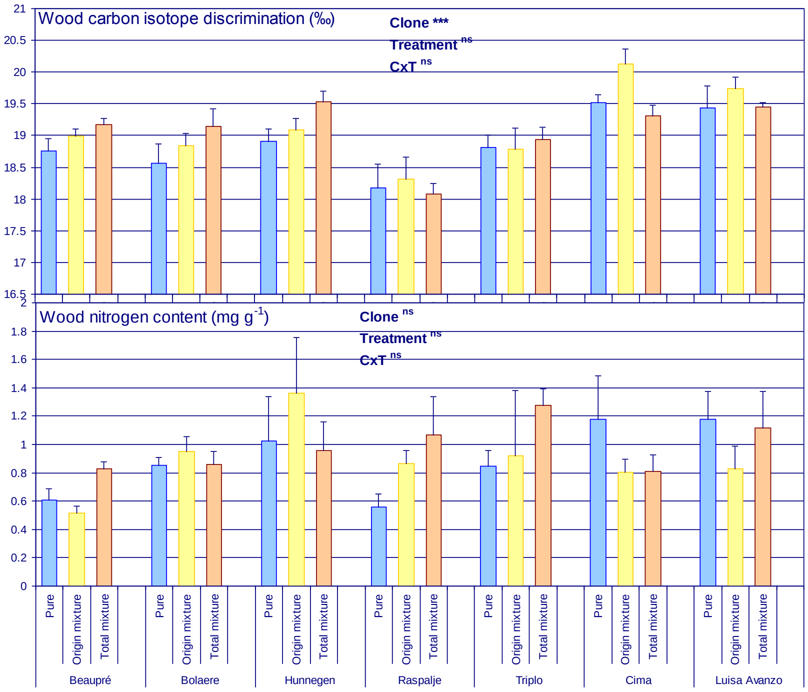


Figure 5: Wood Δ and nitrogen content of the seven clones in the pure, origin- and total mixture treatments.

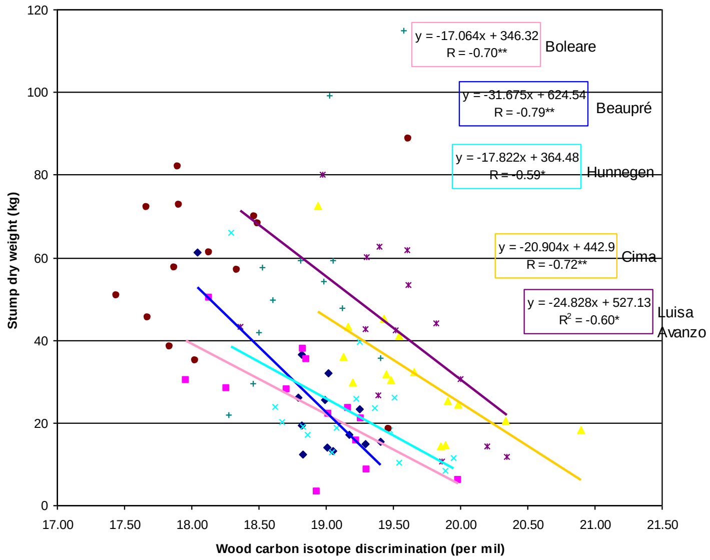


Figure 6: Relationship between yield and wood Δ for the five clones (without clones 'Raspalje' and 'Triplo' for which the relationships were not significant).

The clones are different for their wood nitrogen content, but this content is not affected by clonal mixture. Clones of this experiment established in 1991 are quite old and most of them are not used anymore in plantations… but it was one of the oldest SRC trials in France. The plantation has been removed after the last harvest.

In terms of the relationships between yield and WUE (Figure 6), except for 'Raspalje' and 'Triplo', the most productive clones, water use efficiency was positively correlated with main stem biomass production. The link between both characteristics is true for the weakest clones, the ones affected by competition.

In conclusion: Clonal mixture is recommended to prevent pest development.

At plantation level, there is no effect of mixture on yield, but at clonal level, differences among clones are emphasized in the mixture. Consequently, mixture has to be preferred.

<u>Question 2</u>: When should we harvest, spring *vs.* fall?

Situation: When harvest is only possible during the leafy period, leaf exportations are likely to alter soil fertility. It is notably the case in Brittany, where the soil is never frozen during winter.

Objective: The effect of harvest period during the year was estimated on re-growth, WUE and wood N content.

Partners involved: The plantation (previously used for weed control experimentations) belongs to the experimental domain of the Agricultural Chamber of Brittany (CRAB). Tree dimension measurements, biomass production estimations, and wood samplings were done in close collaboration with CRAB and the GBFOr Unit (INRA Orléans).

Trial and protocol: The willow plantation in Kerguéhennec (56) was used. It has been established in 2006 and never harvested before the beginning of the CREFF experiment. The plantation covers 0.7 ha, with a density of about 15,000 trees per ha, and clone 'Olof'. Biomass production, tree dimensions, evolution of mortality, resprouting, WUE and N content were estimated in fall 2009 and 2010, and spring 2010 and 2011.

Regrowth (stem height and circumference, number of resprouts) was monitored at the end of 2010 and 2011, and will be monitored again at the end of 2012.

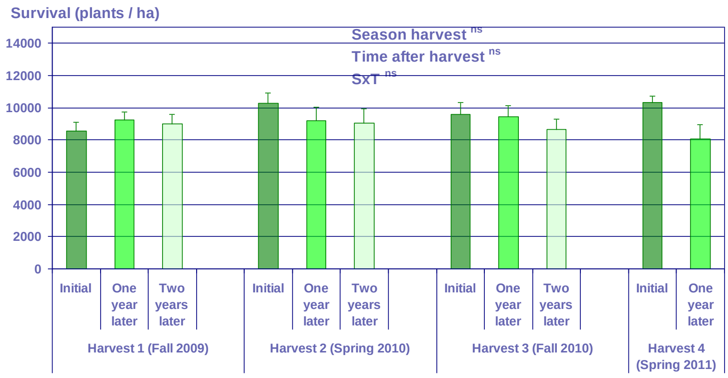


Figure 7: Evolution of mortality at the date of each harvest (dark green) and then one year (apple green) and two years later (light green).

Some results: Mortality was estimated at harvest dates, and one and two years later. Four (2009) to six (2011) years after plantation, planting density was drastically reduced as compared to the initial one (15,000 plants / ha). However, no effect of harvest season was detected. Surprisingly, some dead trees sometimes revived after harvest. Despite a constant decrease in wood N content harvest after harvest, there is no clear trend concerning yield and Δ/WUE (Figure 8). Re-growth measurements were done at the end of 2010 (for the first two harvests), and at the end of 2011 (for the 4 harvests) (Figure 7). Results in terms of main stem height and number of shoots are presented below. At the end of 2011, there was still no difference in terms of stem heights and number of stems between the trees harvested during fall or spring. Re-growth will be monitored again in 2012.

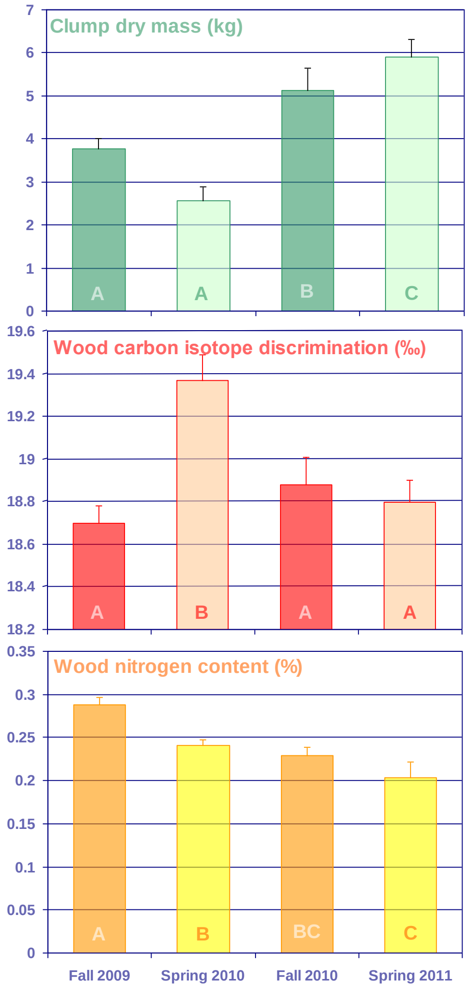


Figure 8: Clump dry mass, wood Δ, and wood nitrogen content at each harvest.

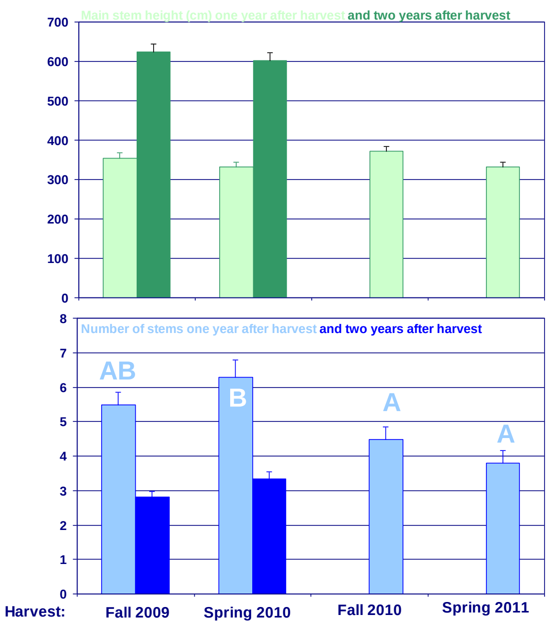


Figure 9: Regrowth in terms of stem height and number of stems one year and/or two years after the four harvests.

In conclusion: Two years after harvests, there was still no effect of the season during which the harvest was done neither on tree dimensions, nor on resprouting and mortality. It seems that, even if leafy trees are harvested, the effect on plantation fertility and re-growth is not significant, even several years after harvest. Re-growth will be monitored for a longer period to confirm the results.

Question 3: Is there an optimal planting density?

Situation: How does competition among plants in dense plantations affect biomass production? Notably in France, two distinct cultural systems exist: a **forest system**, SRC, with density around 1500 trees per ha and rotations lasting 6-8 years, and an **agricultural system**, very SRC, with densities ranging between 6000 and 15,000 trees per ha and rotations lasting 2-3 years. More biomass is supposed to be produced in the denser system, but this higher production can be greatly reduced because of competition among trees.

Objective: The effect of planting density (SRC, 1500 *vs.* very SRC, 7500 trees / ha) on productivity, WUE and N content was assessed.

Partner involved: The studied site was installed and monitored by FCBA under the framework of the project BIOMAGRI (Enerbio).

Trial and protocol: Biomass, WUE and N content were estimated in a 2-year old poplar plantation in la Brosse-Montceaux (77) with different planting densities (7500 and 1500 plants / ha). The 2.15 ha plantation was installed in 2008 with six clones ('I-214', 'Bakan', 'Triplo', 'Dorskamp', 'Skado' and 'Trichobel'). Wood samples were collected and tree dimensions measured in January 2010 for three clones ('I-214', 'Triplo' and 'Bakan') in the denser trial and one clone only ('I-214') in the less dense trial. In July 2011, leaves were collected and stem circumferences were measured for the six clones in the two densities. As it was the first rotation, trees had one stem only.

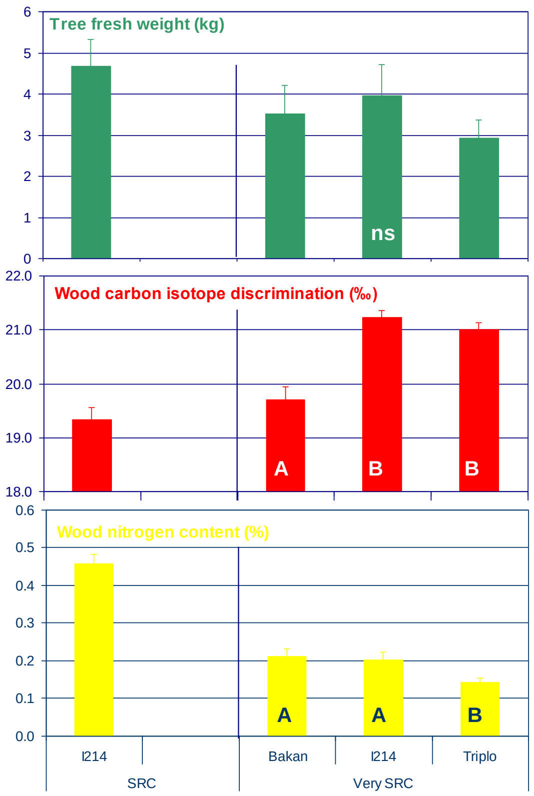


Figure 10: Tree fresh weight, wood Δ, and nitrogen content for the three clones under very SRC and/or SCR regimes.

Some results: Figure 10 shows the biomass production, Δ and N data two years after plantation (1st harvest for the very SRC system). After two years, trees were more efficient to use water in the less dense plantation (wood data). Competition for N was less intense in the SRC.

The clones for which there is the strongest density / competition effect show the highest increase in WUE (leaf data) under dense / competitive conditions… except for the recent clones 'Bakan' and 'Skado' for which there is no effect on WUE (Figure 11).

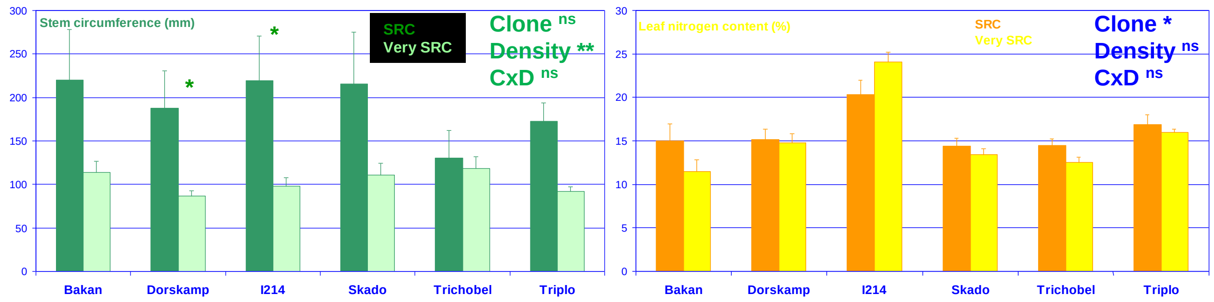


Figure 11: Stem circumference, leaf Δ, and nitrogen content for the six clones under very SRC and SCR regimes.

In conclusion: In the denser plantation, trees were higher, but stems were less thick and with fewer branches because of more intense competition. However, the density effect was not significant after two growing seasons. Consequently, denser plantations are more productive, even if the competition effect has to be checked for a longer time.

Question 4: Do we have to coppice at the end of the first year?

Situation: First year coppicing can stimulate the re-growth during the next year, but it can also affect weak plants when the first year growth has been poor.

Objective: The effect of a first year coppicing on biomass production, re-growth and WUE and leaf and wood N contents was assessed.

Partner involved: The experiment was done in close collaboration with the AILE association. The plantation was belonged to a farmer.

Trial and protocol: Biomass, growth, resprouting, bud phenology, WUE and N contents were estimated in a willow plantation (three clones) in Saint-Sulpice-des-Landes (44) (around 15,000 plants / ha) where a part only of the plantation has been coppiced at the end of the first year. The 2 ha plantation was installed in 2009. Bud phenology and growth were monitored from February till October 2010. Leaf samples were collected in July 2010. Biomass production was determined in December 2010.

Some results: The size of the trees (stem height and circumference) was almost similar for uncoppiced (2-year-old stems) and coppiced trees (1-year-old stem) (Figures 12 and 13). However, this similarity between both treatments was less striking for main stem biomass, because of the combination between height and circumference differences. Nevertheless, the total clump biomass production was very close for the two treatments, especially for some of the clones, because of the production of multiple stems after coppicing.

Neither leaf nitrogen content nor leaf Δ measured in July 2010 were affected by coppicing. N content and Δ (WUE) were never correlated to biomass for none of the clones and treatments.

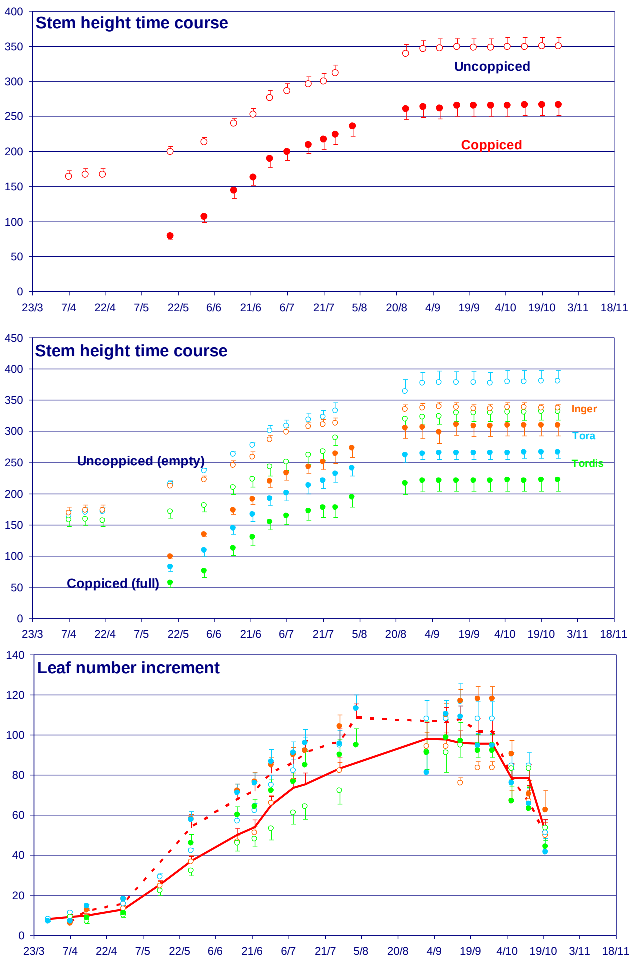


Figure 12: Time course of the dominant stem height increase, and number of leaves for the coppiced and uncoppiced trees during the 2010 growing season.

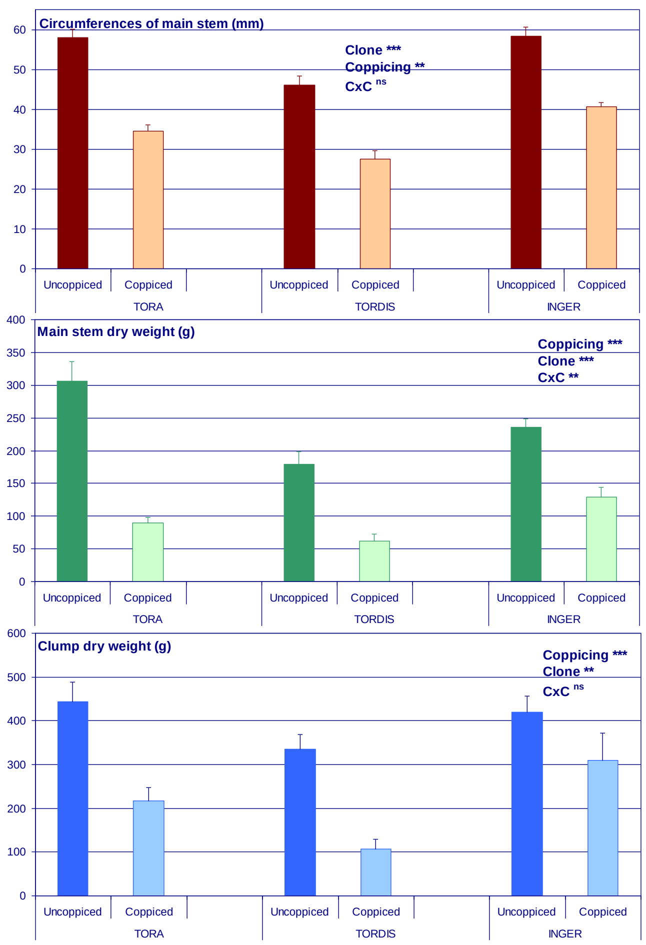


Figure 13: Stem circumference and dry weight, and total clump biomass at the end of the season for the coppiced and uncoppiced trees of the three clones.

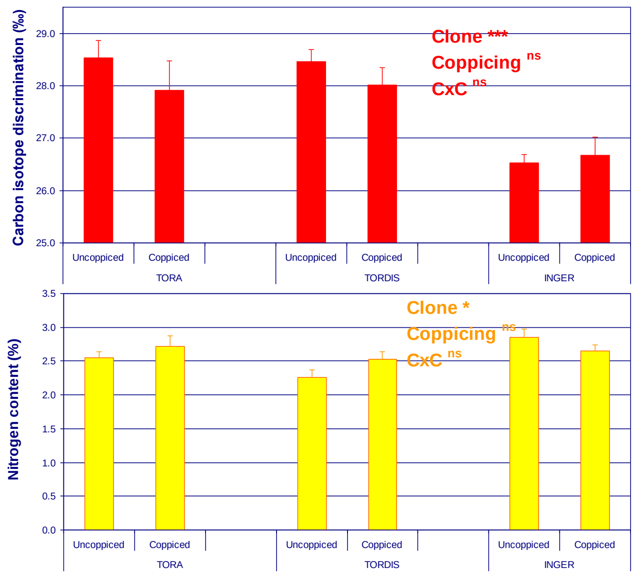


Figure 14: Leaf nitrogen content and leaf Δ in July 2010 for the coppiced and uncoppiced trees of the three clones.

So, in the conditions of our experiment, it was pertinent to coppice the plantation at the end of the first growing season. But the relevance of a 1st year coppicing depends on the 1st year growth. Here, coppiced trees were almost as big as uncoppiced trees after two years.

In conclusion: The first year coppicing has clearly stimulated the growth of the trees.

Question 5: Is it relevant to fertilize SRC plantations?

Situation: Bioenergy crops, such as miscanthus and switchgrass, are generally fertilized, but is it useful to fertilize SRC plantations?

Objectives: The effect of chemical fertilization on biomass production, WUE and leaf and wood N contents was assessed. The results were compared with fertilized and unfertilized miscanthus plots.

Partner involved: The plantation installed under the framework of the Regix project, managed by The INRA Unit AgroImpact was used. Biomass estimations and wood samplings were done in collaboration with the GBFOr Unit of INRA Orléans.

Trial and protocol: Biomass, WUE and N content were estimated in a poplar plantation (three clones: 'Dorskamp', 'Koster' and 'I-214') in Estrées-Mons (80) where some of the blocks were fertilized. The plantation was established during spring 2006 (10,000 plants / ha) and harvested during winter 2009 and 2011. Wood samples were collected during the second harvest, and leaf samples during summer 2011. Fertilization was done in May 2009 and May 2011 (after each harvest) with 60 g / ha of a 39% nitrogen solution (25% nitric, 25% ammoniac, 50% ureic).

Some results: The figures hereafter show the clump dry biomass during the second harvest for the three clones, the main stem height during the summer sampling, and wood or leaf N contents, and leaf or wood Δ at the two sampling dates (winter for wood and summer for leaves) (Figures 13 and 14). There was no significant yield and N content increases in the poplar fertilized plots (but there was a N increase in the miscanthus fertilized blocks).

The three clones were different for their efficiency to use water, but miscanthus was globally much more water-use efficient than poplar.

Wood data (winter 2011)

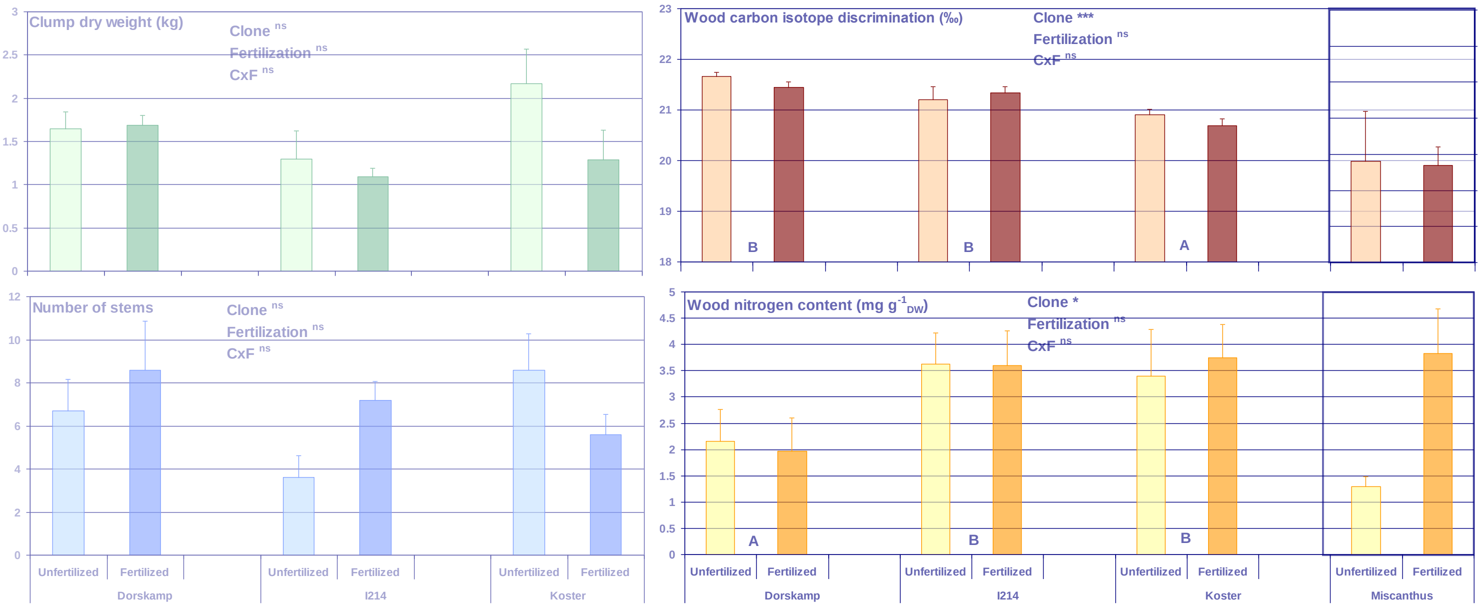


Figure 15: Clump dry weight, number of stems, wood Δ, and nitrogen content for the fertilized and unfertilized trees of the three clones and miscanthus (for the two later traits) during winter 2011.

Leaf data (summer 2011)

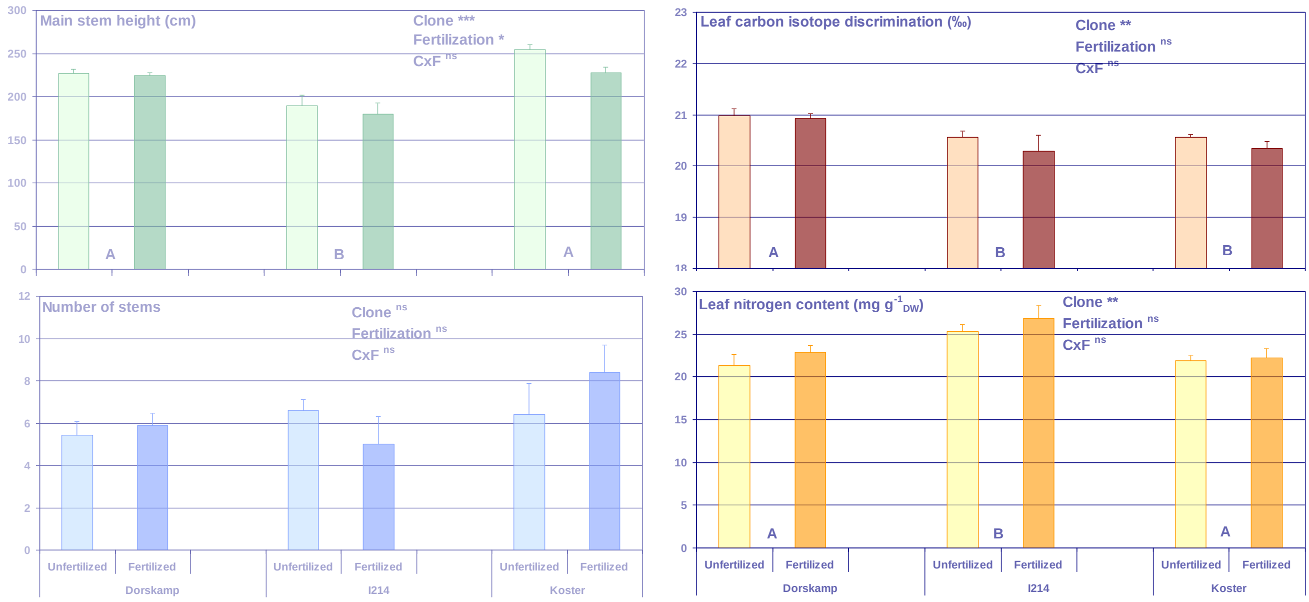


Figure 16: Main stem height, number of stems, leaf carbon isotope discrimination, and nitrogen content for the fertilized and unfertilized trees of the three clones during summer 2011.

In conclusion: The positive impact of a chemical fertilization is striking for miscanthus but inexistent for poplar. Trees do not need to be fertilized. However, once more, our results are dependent on the specific conditions of the experiment and the Estrées-Mons soil is quite rich. Fertilization could benefit to weeds and not to the trees in this case…

Question 6: To what degree the pedoclimatic context affects SRC?

Vosges *versus* Brittany

Situation: Sites in which SRC plantations may be established show various environmental conditions. To which degree yield is affected by these conditions?

Objective: Yield, growth, bud phenology, WUE and leaf and wood N contents of willows growing at two contrasting sites in Vosges (Lorraine) and Brittany were compared. The environmental part in the total phenotypic variance was estimated.

Partners involved: Conventions were established with the Agricultural Chamber of Vosges and the AILE association for the use of the plantations of Attigny (5 ha, Vosges) and Saint-Sulpice-des-Landes (2 ha, Brittany), respectively. The two plantations belong to private farmers.

Trial and protocol: Biomass, growth, WUE and N contents were estimated and monitored in the two willow plantations (Vosges vs. Brittany). Both plantations were established during spring 2009 with three (St-Sulpice) or four willow clones (Attigny) (around 15,000 plants / ha). Bud phenology and growth in height, circumference, and leaf number was monitored every two or three weeks during the entire growing season (February till October 2010). Leaf samples were collected during July 2010, and biomass estimations and wood samplings were realised in November 2010.

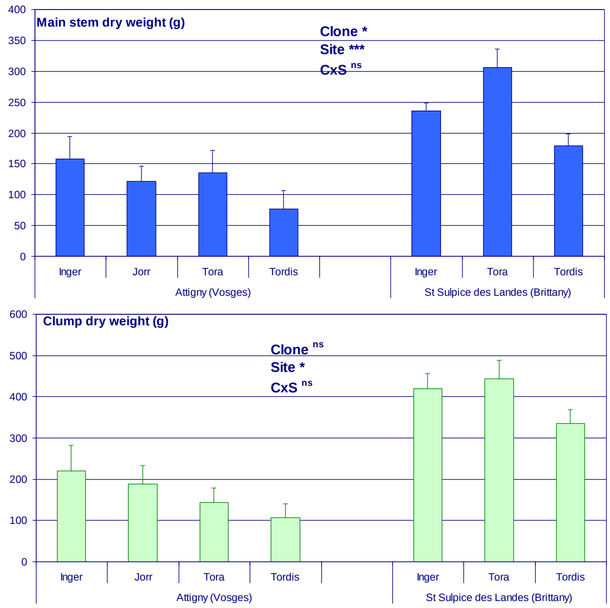


Figure 17: Main stem and clump dry weights of the three or four clones in Attigny and Saint-Sulpice at the end of the second growing season (2010).

Some results: The two sites were not so different in terms of soil composition and climate. However, as shown by the growth and biomass production graphs (Figures 17 and 18), growth was faster at the Brittany site.

There was no significant clone × site interaction for growth traits, showing that clonal response was similar at both sites. Like for tree dimensions, biomass production was much higher in Brittany than in Lorraine, the clones and their ranking at each site were not significantly different.

The site effect, and its interaction with the clone effect, was weak on WUE and wood N content (Figure 19).

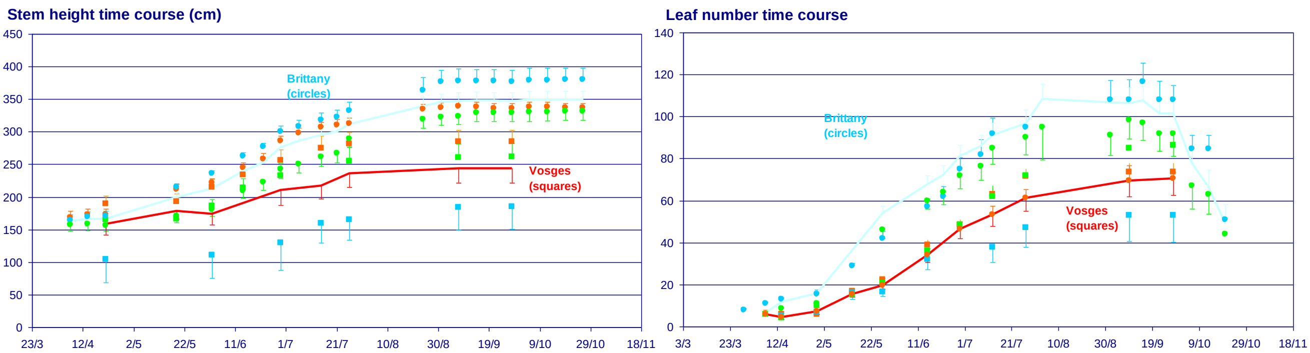


Figure 18: Time course of stem height and number of leaves during the second growing season (2010) for the different willow clones in Attigny and Saint-Sulpice.

Figure 20 shows the significance of the relationships among Δ, N and stem circumference. A positive link between yield and WUE (negative with Δ) was observed for one clone only (‘Inger’) at the most productive site (Saint-Sulpice). This relationship has been highlighted for a higher number of clones, under productive conditions only, for the willow clones of the SYLVABIOM project.

In conclusion: In spite of quite similar climate and soil conditions at the two sites, yields in Brittany and in Lorraine were very different, highlighting the difficulty to predict biomass production from growth conditions. Plantation management can also be an important factor, highly influencing biomass production, and small differences among sites (the organic matter content, in this case?) can imply huge differences in production. Moreover, the Attigny site was damaged by insect pest during year 2011 (*Saperda populnea*), small poplar borer.

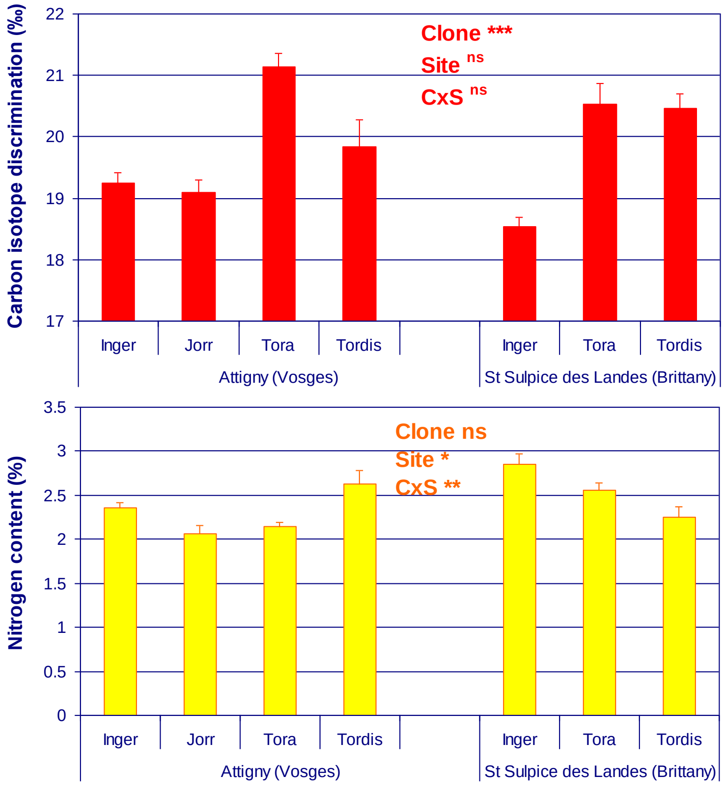


Figure 19: Leaf Δ and nitrogen content for the different clones at the two sites during summer 2010.

		Δ *vs.* Circ.	Δ *vs.* N	N *vs.* Circ.
Saint-Sulpice des Landes	All clones - Uncoppiced	ns	-0.66***	ns
	All clones - Coppiced	ns	-0.61**	ns
	Tora - Uncoppiced	ns	ns	-0.71*
	Tora - Coppiced	ns	-0.85**	ns
	Tordis - Uncoppiced	ns	-0.65*	ns
	Tordis - Coppiced	ns	ns	ns
	Inger - Uncoppiced	-0.69*	ns	ns
	Inger - Coppiced	-0.83**	ns	ns
Attigny	Tordis	ns	-0.82**	ns
	Tora	ns	ns	ns
	Inger	ns	ns	ns
	Jorr	ns	ns	ns
	All clones	ns	-0.55***	ns

Figure 20: Correlations among leaf Δ, stem circumference, and leaf nitrogen content at the two sites, for the different clones, and under coppiced or uncoppiced regimes in Saint-Sulpice.

Various locations in Brittany

Objective: Yield, WUE and leaf and wood N contents of willows growing at five sites Brittany were compared. The environmental part in the total phenotypic variance was estimated.

Partners involved: The plantations established by the AILE association under the framework of the project Wilwater were used. Only the sites for which it was possible to distinguish the different planted clones were used. The site selection and the field campaigns were done in close cooperation with AILE.

Trial and protocol: Biomass, growth, WUE and N contents were estimated and monitored in five plantations of willow in Brittany (about 15,000 plants per ha): La Prénessaye (22; 1 ha), Saint-Ségal (29; 1 ha), Pleyber-Christ (29; 4 ha), Saint-Gilles (35; 2 ha), and Kerlavic (29; 3 ha). Three to four clones were present at the different sites, and plantations were established and harvested at different dates (see table with site details in Annex 1.1). Two fall (November 2009 for the first four sites cited above, and 2011 for Kerlavic only) and a summer (June 2011 for the first four sites) campaigns were done. Tree dimensions and mortality rate were estimated for the different clones at the different locations. Wood samples were collected during the three campaigns and leaf samples during the summer one.

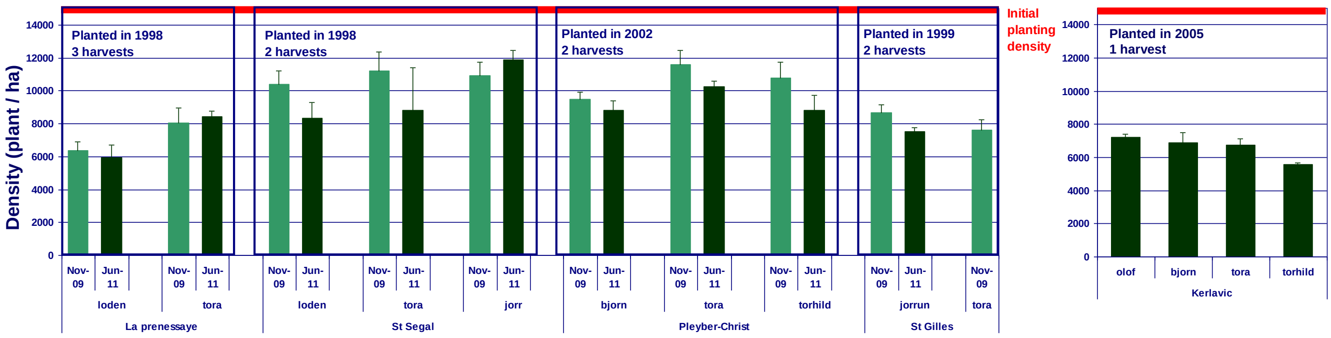


Figure 21: Estimation of planting density in 2009 and 2011 at the five sites, as compared to the theoretical planted density (15,000 trees per ha).

Some results: Figure 21 shows the evolution of the plantation density estimated in November 2009 and June 2011. The initial planting density is supposed to be 15,000 plants per ha. More than 10 years after plantation, density was drastically reduced, being around 6000 plants per ha for the least productive site and around 12,000 plants per ha for the most productive. However, no significant clone, year, and clone × year effects were detected for all sites.

There was no significant effect of the sampling season (November *vs.* July) on wood Δ and the N contents (for the four sites sampled twice).

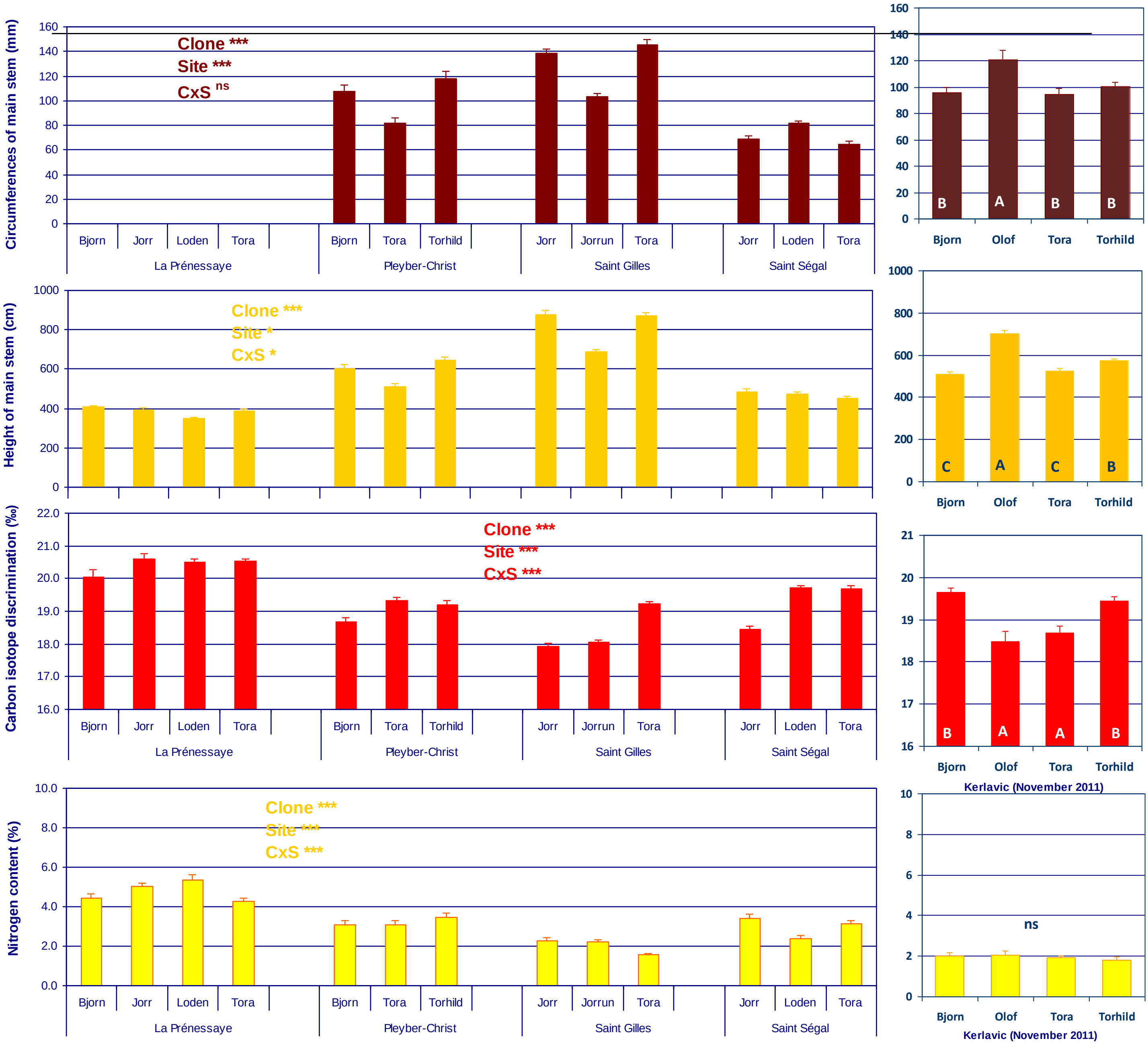


Figure 22: Main stem circumference and/or height, wood Δ, and nitrogen content at the five sites and for the different clones during fall 2009

The yield was significantly different at the four sites (Figures 22 and 23). However, the clone × site interaction was weak for growth traits, showing that clonal response was similar among sites. For Δ/WUE, at leaf and wood levels, similar trends were observed in winter and summer, even if the trees were harvested in the meantime. The site variance was much more important than the clonal effect (Figure 24).

The highly significant clone × site interaction showed that the clonal response to sites for WUE was different for each clone. For the leaf and wood N contents, the site variance was much more important than the clonal effect. The significant clone × site interaction showed that the clonal response to sites for N was different for each clone. Increase as well as decrease was observed from winter to summer. Increase would be expected…

As shown by Figure 25, only a few significant correlations between yield and WUE were observed at the Pleyber-Christ site. However, they were negative (positive between stem circumference and Δ, meaning high yield associated with low WUE) while they are generally positive (meaning high yield associated with high WUE).

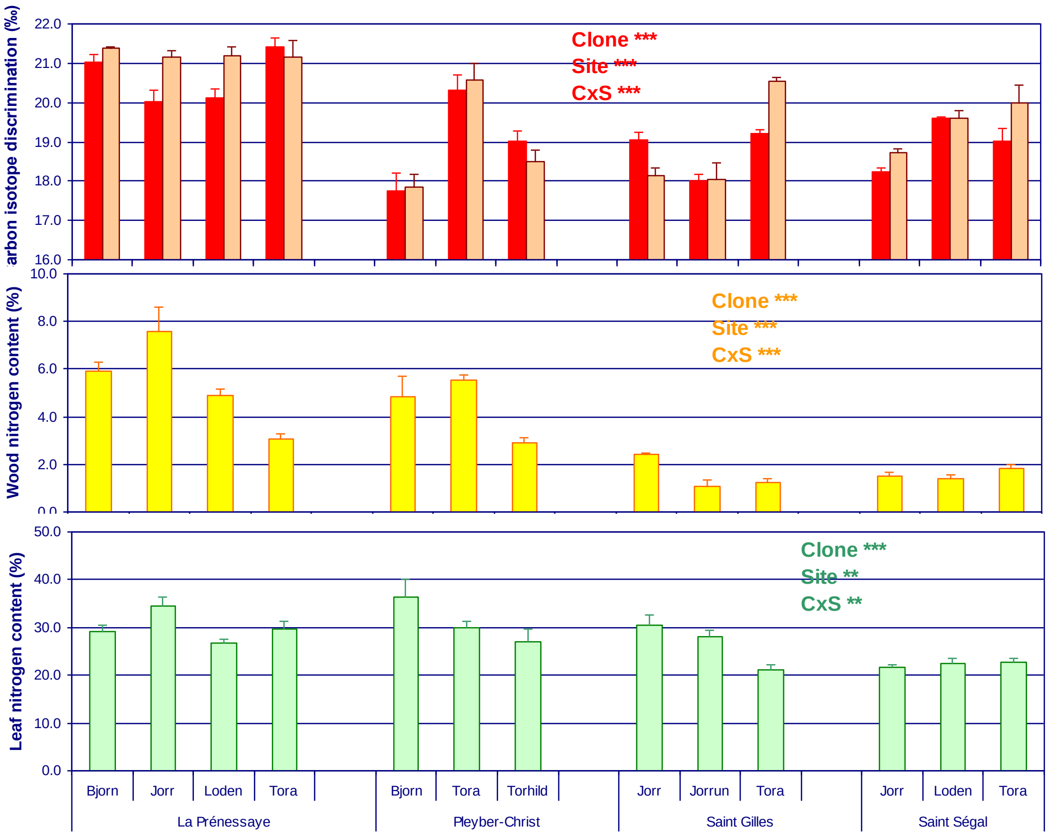


Figure 23: Δ at leaf (pink) and wood (red) levels, and leaf and wood nitrogen contents during summer 2011 at the five sites and for the different clones.

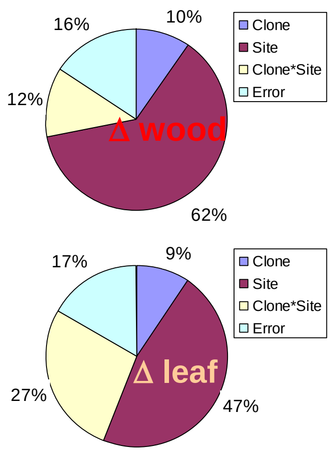


Figure 24: Share of the phenotypic observed variance among its “clone”, “site”, “clone × site”, and “error” components for leaf and wood Δ.

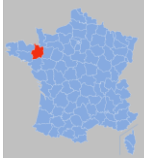
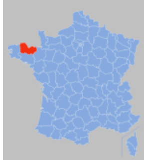
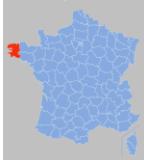
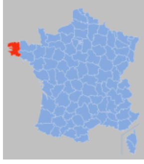
Site	Clone	Δ *vs.* Circ.	Δ *vs.* N	N *vs.* Circ.
Saint-Gilles 	Jorr	ns	ns	ns
	Jorrun	ns	-0.79***	ns
	Tora	ns	ns	ns
	All clones	-0.28*	0.38**	ns
La Prénessaye 	Bjorn	ns	ns	ns
	Jorr	ns	ns	ns
	Loden	ns	ns	ns
	Tora	ns	ns	ns
	All clones	ns	ns	-0.44**
Pleyber-Christ 	Bjorn	0.52*	ns	ns
	Tora	ns	ns	ns
	Torhild	0.65**	ns	ns
	All clones	0.52***	ns	ns
Saint-Ségal 	Jorr	ns	ns	ns
	Loden	ns	ns	ns
	Tora	ns	ns	ns
	All clones	ns	ns	ns

Figure 25: Correlations among wood Δ, stem circumference, and leaf nitrogen content at the four of the sites, for the different clones.

In conclusion: As also shown by the previous experiment, environmental effect (including soil, climate, management… and unpredictable factors) can be huge on yield and sometimes difficult to explain.

However, the ranking of the genotypes under contrasting growth conditions is quite stable, and so, productive clones will remain productive irrespective of conditions.

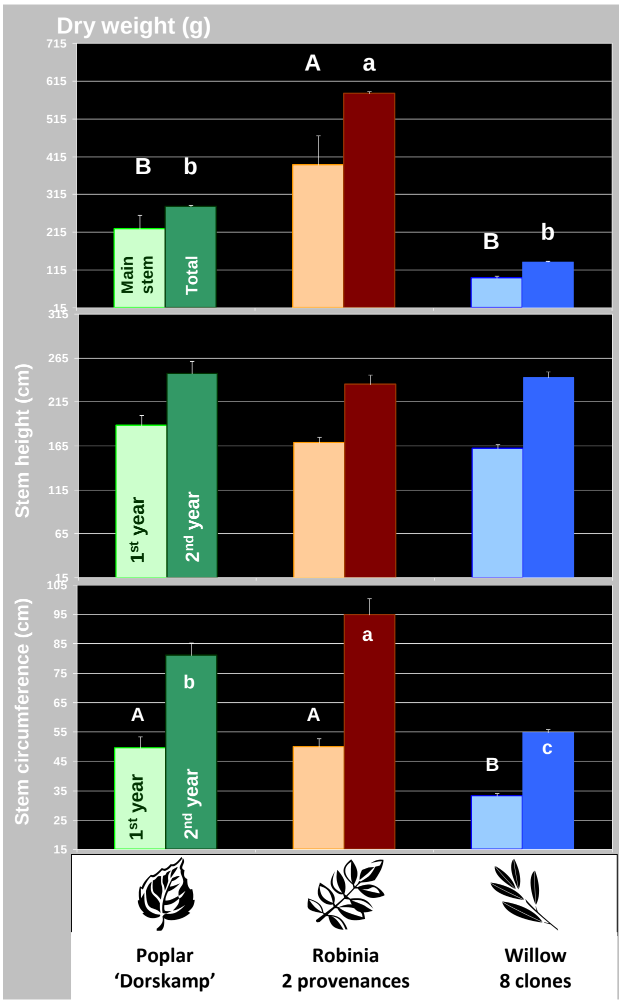
Question 7: What are/is the "best" species for SRC?

Situation: The three most commonly used species, willow, poplar and black locust, have specific ecological requirements. How to adapt the species to site conditions in order to maximize yields?

Objective: The performances of the three species were compared under the same environment.

Partners involved: The plantation has been established under the framework of the ANR Bioenergies project SYLVABIOM in collaboration between the INRA Orléans Unit GBFOr and the CNBF in Guémené-Penfao (44).

Trial and protocol: Biomass, WUE and N content were estimated in Brittany (Guémené-Penfao) where black locust, willow and poplar vSRC grow on the site. The 2.4 ha plantation has been manually established during spring 2009 (12,000 plants / ha for eight willow clones, and 7300 or 1500 plants / ha for the poplar clone 'Dorskamp' and two Hungarian provenances of black locust, 'Nagybudemri' and 'Nyirseg'). Bud phenology and growth in height, circumference, and leaf number was monitored every two or three weeks during the entire growing season (February till October 2010). Leaf samples were collected during July 2010, and biomass estimations and wood samplings were realised in December 2010.



Some results: As shown by Figures 26 and 27, the three species showed similar height at the end of the 2nd growing season… but black locust exhibited thicker stems as compared to both other species at this dry site. As a result, black locust produced significantly more biomass (stem only, and stem + branches) than both other species. During the dry 2010 season, poplar grew much faster during spring time, but the three species were not different anymore in stem height at the end of the season. Drought was mostly damageable for poplar and willow (that lost most of its leaves).

In the very dense plantation, black locust was affected by competition for water. As a result, height was superior in the SRC than in the vSRC. As shown Figure 25, black locust uses water more efficiently than both other species (lower Δ)… at this dry site. Obviously, tissues of the N fixator, black locust, were much richer in nitrogen than both other species.

Figure 26: Stem dry weight (main stem and whole clump, at the end of the 2nd year), height, and circumference (at the end of the 1st and 2nd years) for poplar, black locust and willow in Guémené-Penfao.

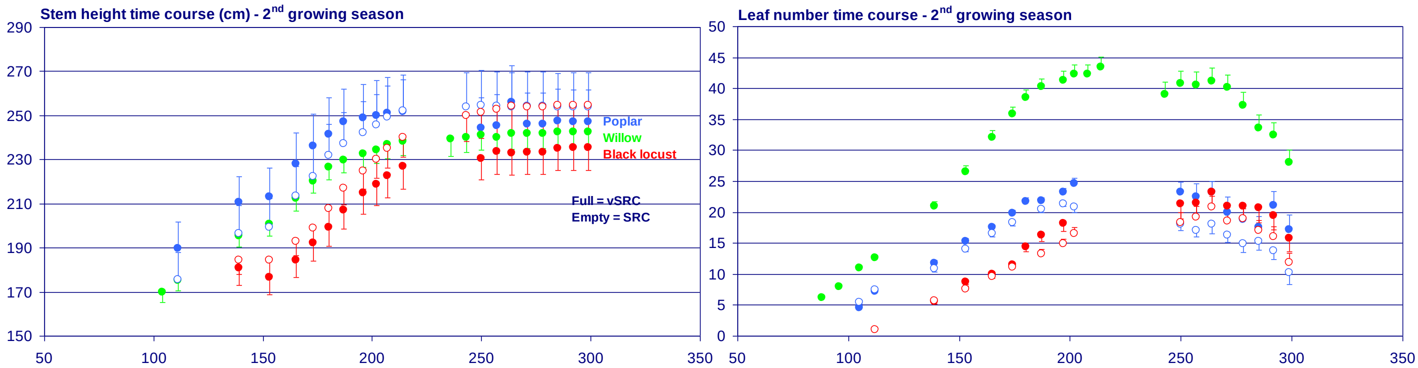
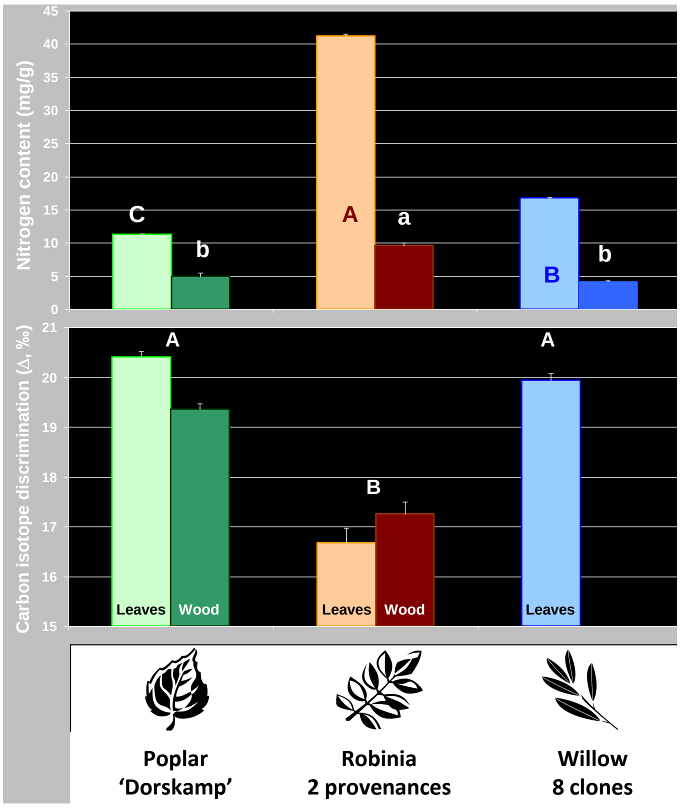


Figure 27: Time course of stem height increase and leaf number increment for poplar, black locust and willow in Guémené-Penfao in 2010 (days of year).



In conclusion: Willow and poplar are the most commonly used tree species for bioenergy plantation in the north of Europe. However, these regions are more and more subjected to summer water stress. Under these conditions, black locust (and probably eucalypt) shows much better performances than water demanding species. It was true in 2010 in Guémené-Penfao, and again in 2011 in Saint-Cyr-en-Val (where the 3 species are also present together; data not shown).

Figure 28: Leaf (summer 2010) and wood (winter 2010-2011) Δ and nitrogen content for poplar, black locust and willow in Guéméné-Penfao.

<u>Question 8</u>: Is sludge spreading a relevant practice?

Situation: Sludge spreading in SRC could be a way to valorise wastes, but do the trees need this additional fertilization?

Objective: The effect of different quantities of sludge (simple or double doses) on biomass production, WUE and N content was assessed.

Partners involved: The site was installed by IDF (Institute for Forest Development) Orléans under the framework of the SYLVABIOM project. Biomass and growth estimations were done with the help of the INRA Unit GBFOr.

Trial and protocol: Biomass production, resprouting, WUE and N content were estimated in a willow plantation in Brinon-sur-Sauldre (18) with sludge inputs or not (two doses). The site (2.3 ha, 10,000 trees / ha, six willow clones) was established during spring 2009. Dehydrated sludge was spread in March 2011: 2 and 4 tons of dry weight per ha (171 U of N /ha maximum). Leaf sampling and tree dimensions measurements were done during August 2011.

Some results: Figure 29 shows tree dimensions and leaf analysis data 6 months after sludge spreading. No significant effect of sludge was observed on biomass production / growth six months after spreading.

Results are likely to be dependent on soil fertility: SRC on rich soils does not need additional nutrient inputs and elements will probably not be assimilated by plants and remain on the soil.

No significant effect of sludge on WUE and N content was either observed.

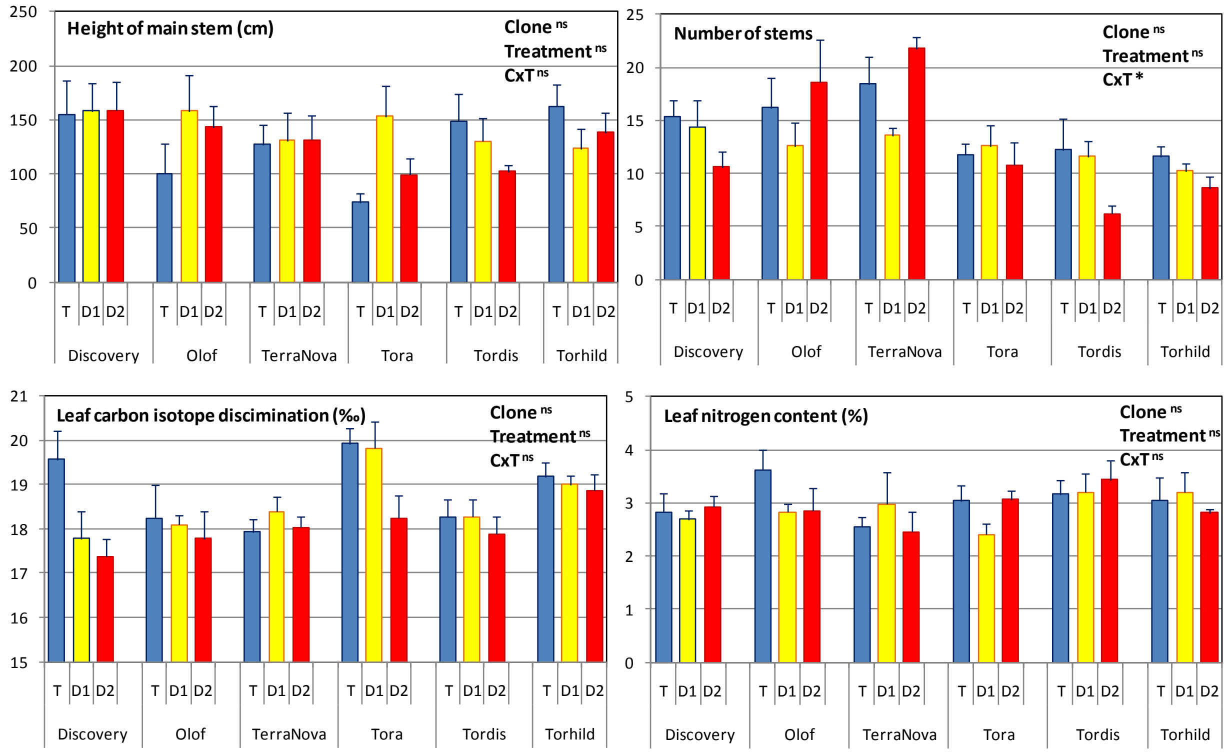


Figure 29: Height of main stem, number of stems, leaf Δ and nitrogen content for the six clones under the control (blue), simple dose (yellow) and double dose (red) treatments.

When considered clone by clone, there is an increase trend for WUE for some clones (notably for 'Tora') under the sludge spreading treatment. Monitoring of sludge effects has to continue for a longer period.

The very dry July 2011 had two negative effects on the experiment: (1) the solid sludge spreading did not penetrate properly into the soil, (2) many trees did not resprout because of the drought (plantation was harvested the winter before).

In conclusion: No. Spreading of dehydrated sludge is a delicate process depending on the occurrence of rain after the operation. It was unfortunately not the case for our experiment and this technique was absolutely not efficient.

<u>Question 9</u>: What is the best cultural antecedent, grassland *vs.* maize?

Situation: To avoid concurrence with food agriculture, SRC plantations will be preferably installed on marginal, less fertile sites.

Objective: The effect of the cultural antecedent (rich *vs.* poor / maize cultivation *vs.* grassland) on biomass production, WUE and leaf and wood N contents was estimated.

Partner involved: The LIMOS was involved. The five studied plantations, differing in their prior cultural antecedents, were part of a PhD thesis in this lab.

Trial and protocol: Biomass, WUE, and leaf and wood N content were estimated in five willow plantations in French Ardennes (8) differing by their antecedent, grassland *vs.* maize cultivation: Ambly-Fleury (2.5 ha), Semuy (3 ha), Amagne (3 ha), Asfeld (3 ha), and Voncq. The plantation were installed in 2006 (the first two), 2008 (the next two), or 2010 (the last one) with 'Tora' and 'Tordis' (about 15,000 plants / ha). The oldest ones were harvested during winter 2009/2010. Wood samples were collected and tree dimensions were measured in October 2010, while leaf samples were collected and biomass was estimated in July 2011.

Fall 2010

Summer 2011

Figure 30: Stem height, wood Δ and nitrogen content at the four of the sites (winter 2010-2011). The cultural antecedent is indicated for each site between brackets.

Figure 31: Stem dry weight, wood and leaf Δ and nitrogen content at the five sites (summer 2011). The cultural antecedent is indicated (it is still unknown for the Voncq site).

Some results: During fall 2010, yield was not linked to the cultural antecedent (Figure 30). However, willow trees showed a better efficiency to use water on the poorer sites (grassland antecedent). The huge growth difference between Amagne and Asfeld could be due to the higher clay content in Amagne. This factor, rather than the antecedent, seems to be a very important limiting factor for growth (see extra-question 11).

In agreement with the measurement done at the end of the growing season, during summer 2011, trees were less water-use efficient on maize antecedent than on the grassland antecedent (Figure 31). WUE estimations done at leaf and wood levels concord: the same trend was observed on both antecedents.

Results have to be interpreted with care as plantations also differed in age… Obviously, leaves were much richer in N than wood. No clear difference was observed among both cultural antecedents in terms of N contents.

Mortality as compared to the initial planted density was more important on the grassland antecedent, maybe because of a more prepared and fertilized soil in the past on the maize antecedent (Figure 32).

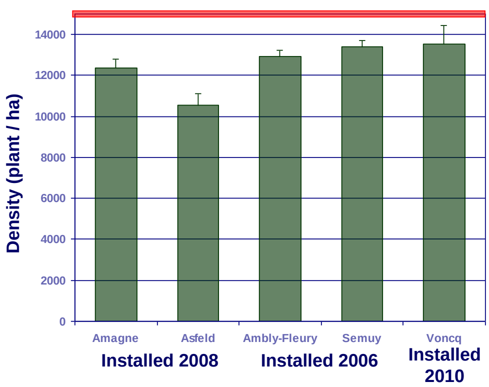


Figure 32: Density of the five sites during summer 2011 as compared to the initial planting density (15,000 trees / ha).

In conclusion: No obvious effect of the cultural antecedent on yield was observed. However, it seems that trees were more efficient to use water on the pasture antecedent, richer in organic matter but poorer in N (2.0 g/kg for the pasture *vs.* 3.1 g/kg for the cropland). Constraints are known to increase WUE, and the harsher conditions of the grassland (soil less fertilized and prepared in the past) could make the plant more efficient to use water. However, the different ages of the plantations on the two antecedents could also interfere with the interpretation. The younger Voncq plantation, where trees also showed a high WUE (lower Δ), could help in clarifying the conclusion, but the cultural antecedent (likely to be a pasture) is still unknown at this time…

<u>Question 10</u>: Is wastewater spreading a relevant practice?

Situation: Sludge spreading in SRC could be a way to valorise wastes, but do the trees need this additional fertilization?

Objective: The effect of treated wastewater and whey from a cheese factory was assessed on biomass production, WUE and wood N content.

Partner involved: The studied plantation is managed by the Unit GBFOr of INRA Orléans under the framework of the TSAR project (Techniques Sylvicoles et Agronomiques Rémédiantes). The plantation is located on the field of the Ecologistique industrial in Courtenay (45).

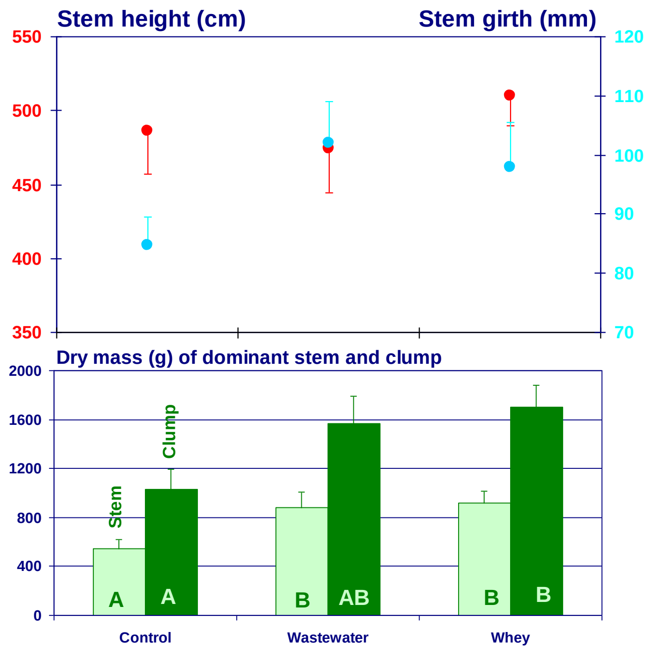


Figure 33: Stem height (red dot), circumference (blue dot), dry weight (light green histogram), and clump dry weight (dark green histogram) for the control, wastewater, and whey spreading treatment at the end of the 3rd year.

Protocol: Biomass production, resprouting, WUE and N content were estimated in a willow plantation in Courtenay (4 ha, about 15,000 plants / ha, two clones, 'Tora' and 'Inger', Installed during spring 2009) with treated wastewater or whey from a cheese factory inputs, or not. Wood sampling were collected and tree dimensions were measured in November 2011.

Some results: At the first harvest, tree dimensions were not significantly different among treatment (Figure 33 for dominant stem height and circumference). However, there was a significant effect of spreading on biomass production, the wastewater irrigated plants being heavier than the control, and the whey irrigated ones being heavier than both other treatments. As shown by Figure 34, planting density was significantly higher in the whey treatment. Yield in this treatment was also significantly higher than the control, the wastewater treatment being intermediate.

Plants irrigated with wastewater were richer in nitrogen than control ones (Figure 35). However, there was no significant impact of irrigation on WUE, but the whey irrigated plants seemed slightly more efficient to use water than both other treatments…

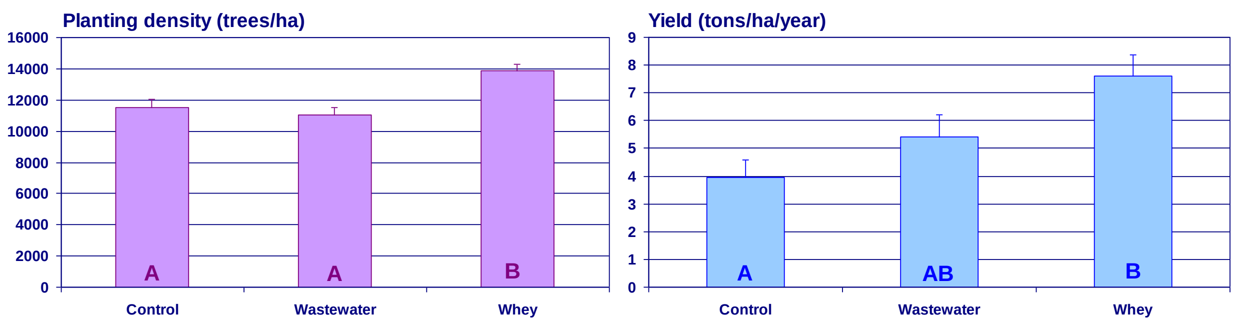
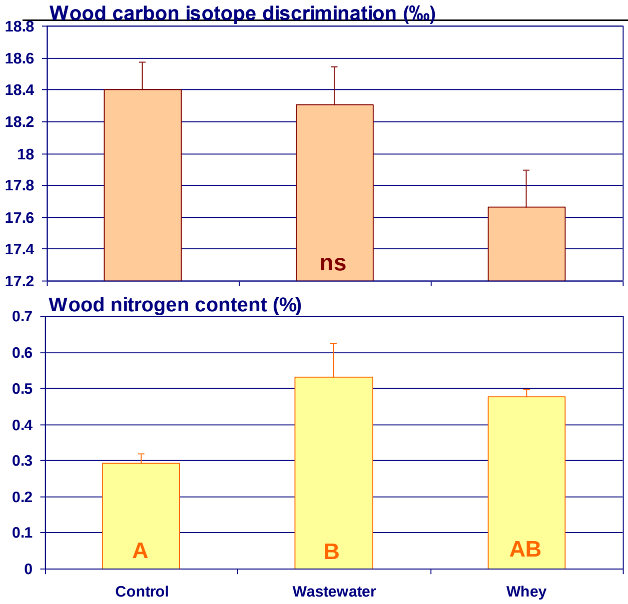


Figure 34: Density and yield (taking into account density) for the control, wastewater, and whey spreading treatment at the end of the 3rd year.



In conclusion: Yes, already at the first harvest, the effect of water and the nutrient it contains on yield is significant. Moreover, it is an efficient way to valorise industrial wastes!

Figure 35: Wood Δ and nitrogen content for the control, wastewater, and whey spreading treatment at the end of the 3rd year.

Extra-question 11: When are conditions really too marginal?

Situation: Marginal sites will probably be preferred for the establishment of SRC plantations in order to avoid concurrence with food agriculture. But is there a threshold of "marginality"?

Objective: The goal of the experiment was initially to study the effect of (1) mixture of black locust and poplar, (2) planting density, and (3) cultural antecedent on yield. However, the chosen site showed much too marginal conditions…

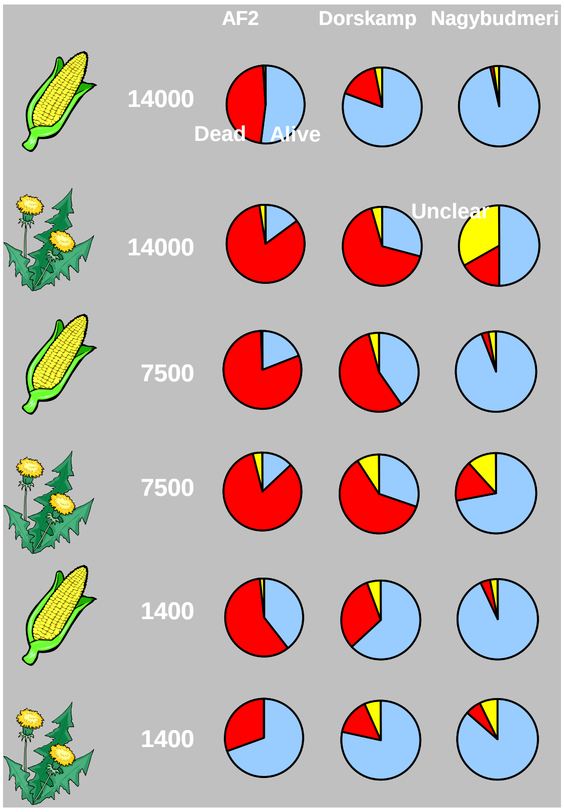


Figure 36: Mortality rates (in red) for the two poplar clones ('AF2' and 'Dorskamp') and the black locust provenance ('Nagybudmeri'), the three planting densities (14,000, 7500, and 1400 plants / ha), and the two cultural antecedents (maize, grass) one year after plantation.

Partners involved: The installation of the instrumented plantation was part of a project funded by the Lorraine Regional Council and INRA. A 5 ha site was selected in Moyenvic (57) and 25,000 poplar cuttings and black locust seedlings were manually planted at three densities (14,000, 7500 and 1400 trees / ha) on two different cultural antecedents (grassland *vs.* maize cultivation) during spring 2010 in collaboration with the INRA Units GBFOr (Orléans) and UEFL (Nancy).

Some results: Figure 32 shows mortality rates at the end of the 1st growing season (2010). For some of the blocks, no tree was still alive. A succession of unfavorable conditions happened in 2010 to explain the catastrophic survival rates at the end of the 1st growing season: **(1)** very wet spring, with plantation still partially flooded a few days before plantation, **(2)** consequently, difficulties to properly prepare the soil before plantation and to apply herbicide after plantation, **(3)** dry summer, implying large soil crevasses, harmful for root development, **(4)** difficulties to control weeds in the double row system and because of non carrying soil, **(5)** very high salt content in the soil (quite usual in this part of Lorraine), and **(6)** vandalism, many trees (among the surviving ones) were intentionally broken (a complaint was filed).

Among all these factors, the most harmful one was probably the very high soil clay content (more than 75%), implying problem with the use of machines for soil preparation or weed control when the soil was too wet, and with crevasses when the soil was too dry. Mortality did not appear to be linked to the cultural antecedent.

In conclusion: There is of course a threshold of marginality. Highly clayey soil and double rows have to be avoided. But even when these two concepts are fulfilled, it is almost impossible to get any profit from SRC under the current French and German contexts, even under quite good site conditions. The remaining problem is to define what this threshold is.

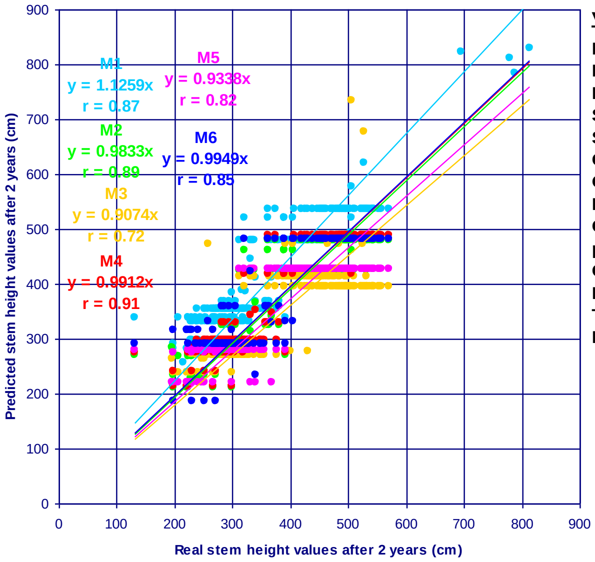
4.1.3.2 Multi-site analysis

Plant, soil, and climatic data related to each of the 20 studied sites (only control conditions) in this workpackage were gathered in a general database. The relationships among these three categories of variables were studied in order to try to establish a model able to predict yield (or tree height after two growing seasons, which is the most commonly available “yield” estimator) from soil and climate variables. Trees measuring between one and eight meters in height after two growing seasons were used. Linear regressions were established. The regressions were established for six conditions: (1) all species and densities, (2) all species, two-year-old roots and stems, (3) very short rotations of willow, (4) very short rotations of poplar and willow, (5) short rotations of poplar, and (6) all species, very short rotations. The regression coefficients, their level of significance (ns=non significant, *=P<5%, **=P<1%, ***=P<0.1%), and the accuracy of the equation (through the regression coefficients and slopes of the relationships between estimated and measured stem heights) are presented in Figure 37. Variation ranges of the variables used to establish the equations are indicated at the bottom of the table.

		Location	Layout	Soil							Climate					
	Constant	Longitude (°)	Planting density (stump/ha)	Stone content (%)	Sand content (%)	Clay content (%)	Organic matter (g/kg)	Nitrogen (g/kg)	C/N	pH	Global radiation (J/cm²)	Rainfall (mm)	Mean temperature (°C)	Evapotranspiration (mm)	Regression coefficient	Slope Estimated / Measured
Model 1 (general)	20536.7 ***	112.4 ***	0.0 **	23.5 ***	-7.9 *	-14.7 ***	49.5 ***	-726.2 ***	-5.0 ns	-87.0 *	-10.4 ***	2.2 ***	-195.3 *	438.7 ***	0.87	1.13
Model 2 (2-year-old roots and stems)	763.6 ns	-98.6 ***	0.0 *	24.6 ***	18.8 **			-87.1 ***	-19.6 ns	-185.8 ***		9.1 ***		-826.1 **	0.89	0.98
Model 3 (willow very SRC)	1927.9 ns				-5.0 ns			27.5 ns	8.9 ns	-39.7 *	-1.3 *			303.8 ***	0.72	0.91
Model 4 (poplar / willow very SRC)	-3015.6 ns		0.0 ***	-12.7 *	-10.4 **			53.0 ns	85.1 *	-166.2 **	0.8 ns			754.5 ***	0.91	0.99
Model 5 (poplar SRC)	-3851.8 ***												333.9 ***	-340.9 ***	0.82	0.93
Model 6 (2-year-old roots and stems, very SRC)	-1049.4			0.5	3.1		18.8							232.1	0.85	0.99
Ranges of variation of the variables used to establish the equations	Min	-4.0	1428.0	0.0	1.2	6.0	6.5	0.5	8.0	4.6	1720.0	286.3	13.8	2.9		
	Max	6.0	13389.0	24.0	85.8	71.0	50.2	3.1	13.7	8.1	1854.4	475.3	16.5	4.4		

Figure 37: The six equations used to predict 2-year old stem height, the level of significance of each term, the range of variation of the variables used to establish the equations, the regression coefficients, and the slope between estimated and measured stem height values.

The relationships between estimated and measured stem heights after 2 years are presented in the following figure (38) for the 6 models (M1 to M6).

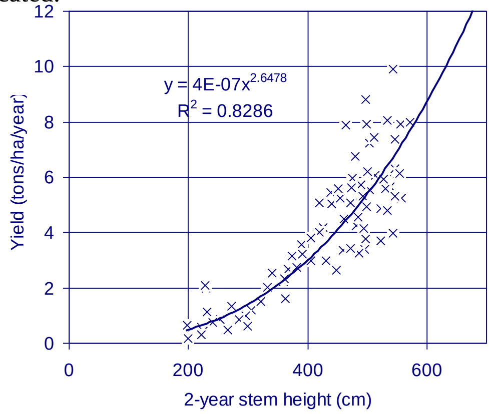


Variable definitions:

Height	Tree dominant height after two growing seasons (cm)
Longitude	Site longitude (°)
Density	Actual planting density (plant/ha)
Stone	Mean stone content (%) as deep as possible (-90 cm)
Sand	Mean sand content (%) as deep as possible (-50 cm)
Clay	Mean clay content (%) as deep as possible (-50 cm)
OM	Mean organic matter content (g/kg)
N	Mean soil nitrogen content (g/kg)
C/N	Carbon – nitrogen ration in soil
pH	Hydrogen potential
GR	Mean global radiation (J/cm²) from April to September, during 2 years
Rainfall	Sum of rainfall (mm) from April till September, mean of 2 years
T°C	Mean air temperature (°C) from April to September, during 2 years
EVP	Mean evapotranspiration (J/cm²) from April to September, during 2 years

Figure 38: Correlation between predicted and measured stem height values for the 6 models. Linear equations and correlation coefficients are indicated.

The best predicting equations were not the ones using more entry variables (*i.e.* models 4 and 6 for very SRC of poplar and willow) and so, it seems possible to predict yields with only a few soil and climate data. Then Figure 39 shows the link between 2-year stem height and yield. However, the tests done to calculate yields of plantations not yet harvested were unsuccessful (values were out from the ranges). The integration of additional sites should improve the prediction.



From the 2-year old stem height, it is then possible to estimate a yield based on the relationships and equation presented on adjacent graph.

Figure 39: Exponent equation linking 2-year stem height to yield.

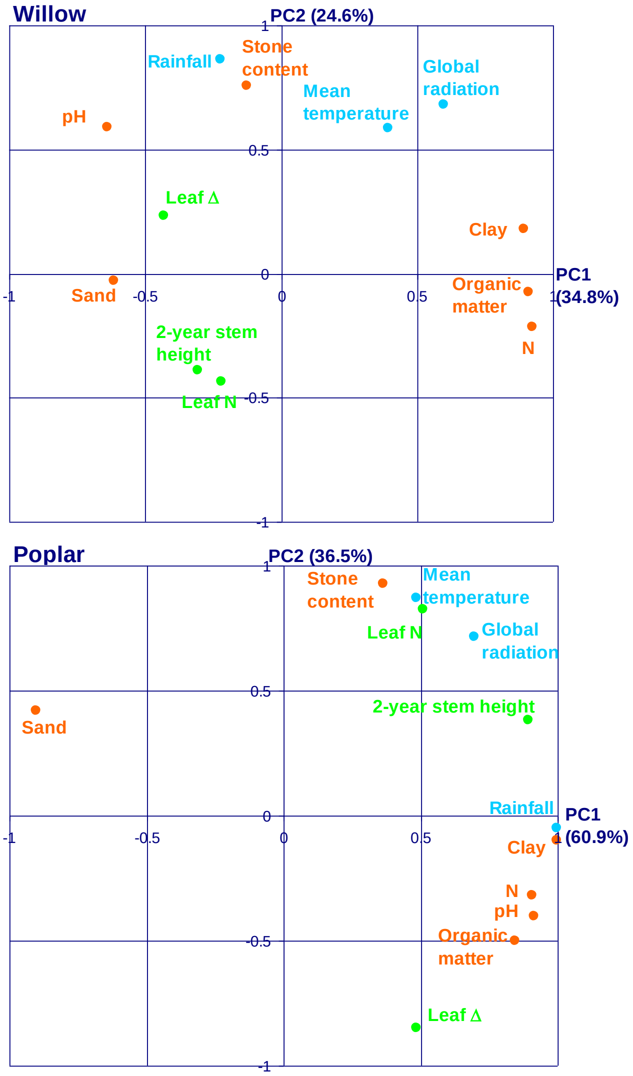
However the correlation tables presented in Annex 1.3 show that there was no significant links between stem height after two growing seasons and either soil or climate site conditions, showing that first rotation growth is mostly dependent on plant characteristics (or on factors not taken into account in the analysis such as plantation management practices) rather than on pedoclimatic conditions.

On the other hand, the general database was used to study the relationships between yield, water-use efficiency (inversely estimated through Δ), leaf / wood N content, and edaphic and climatic site conditions. Principal components analyses (PCA) were used to illustrate the correlations among traits. The main planes of the PCA established for the willow, poplar and for all plantations are represented by Figure 40. The percentages of variation explained by the two principal components (PC1 and PC2) are indicated between brackets. Plant traits are indicated in green, soil traits in orange and climatic variables in blue.

In the PCA planes, close variables are positively correlated, opposite variables are negatively correlated, and orthogonal variables are not correlated. The corresponding correlation tables are presented in Annex 1.2.

Soil and climate characteristics were correlated among them but not with each other. It is indeed logical that global radiation will imply higher temperature, that soil richer in organic are also richer in nitrogen, or that soil clay content is inversely correlated to the sand content. As mentioned above, 2-year stem height (our yield estimator) was not correlated to either soil or climate data. However, surprisingly, at plantation level, 2-year stem height was positively correlated to wood Δ (and so negatively to WUE), **the most productive sites being the ones where the trees were the least efficient to use water (Figure 41)**. This relationship was true for the willow plantations and for the willow / poplar plantations (as shown by the graphs below), but not for the poplar plantations alone (possibly because of the few number of poplar plantations in our network). **So, at the least fertile sites, the less productive ones, the trees improved their efficiency to use water (more biomass was produced per unit of consumed water).** An increase of WUE in response to various kinds of stresses has already been observed (*e.g.* MONCLUS *et al.*, 2006), but never for a large number of sites differing in their level of productivity. Moreover, an invert relationship (*i.e.* the most productive being the most efficient to use water) has been observed for different willow clones at intra-site level, and the level of significance of the relationship was dependent on site favourability (unpublished results from the in progress Ph.D. thesis of Julien Toillon (2009-2012).

A positive relationship was also found between yield and wood as well as leaf N contents, **the most productive sites being the ones where the trees were the richest in N**. Contrarily to water, it seems that more productive is the site, more N will be accumulated in the biomass (even if no correlation was observed with soil N).



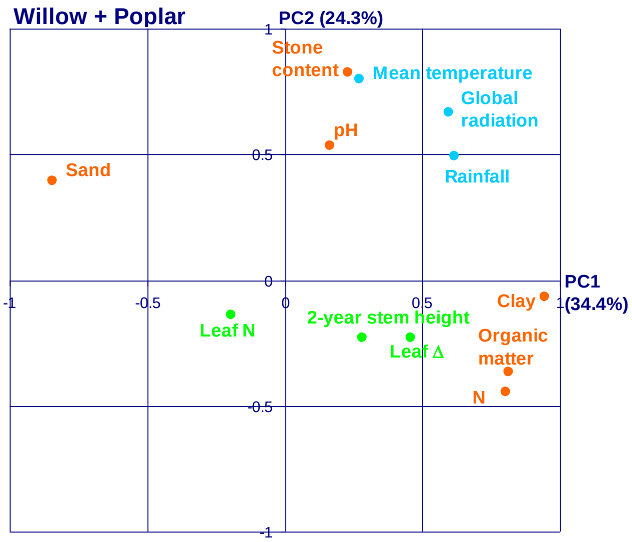


Figure 40: Main planes of the principal component analysis realized for willow, poplar, and willow + poplar plantations with plant (green), climate (blue), and soil (orange) variables. The percentage of variation explained by each axis is indicated.

Figure 41: Relationships between 2-year stem height and leaf Δ for the willow and willow + poplar plantations. The equation and its level of significance are indicated.

4.1.4 Conclusions

Due to the youth of the SRC value chain and especially vSRC in France and Germany, many questions about how best to manage the plantation remain. The choice of plant material, a planting density, the rotation length, the spreading of any waste products adapted to site conditions, etc. are indeed many potential ways to reduce the input requirements (water and N, in particular) and the associated costs.

As part of WP1 of the CREFF project, the impact of a battery of cultural factors on yields was tested on a network of sites in northern France, in collaboration with key stakeholders in the French forestry and agricultural wood energy plantation domain (FCBA, AILE, Chambers of Agriculture, INRA, IDF). These factors can be classified into four categories: plant material, fertilization, planting arrangement, and harvest calendar. The experiments are still lacking back (often limited to the first rotation) and the conclusions are often linked to the specific sites where the factors were tested, but the outline of recommendations are beginning to emerge.

In terms of plant material, mixtures of clones or varieties should be preferred to minimize the risk of pathogen growth. In the long run, competition between clones, potentially variable in terms of growth potential, does not affect overall productivity, less productive clones, repressed, being compensated by overexpression of the most productive ones. In northern Europe, especially poplar and willow are used for SRC. However, global climate change leading to drier summers, such as 2010 and 2011, promote the growth of species such as black locust and eucalyptus (untested yet at the north of the Loire). Black locust has indeed a much more efficient water use (biomass produced per unit of water consumed) when water is limited than willow or poplar that should consequently be reserved for sites that are not likely to suffer long periods of water deficit.

In terms of amendments, inputs of chemical fertilizers generally have little effect on yields of the trees. The spreading of dehydrated sludge is highly dependent on rainfall to allow the penetration of nutrients into the soil and thus, their effectiveness is very uncertain. However, wastewater has shown good efficacy to boost performance by combining a water supply to a nutrient supply.

In terms of arrangement, simple lines should be favoured to facilitate weed control, made very difficult with an arrangement in double rows, still frequently used. The very high densities used for willow (up to 15 000 trees per ha) have little impact on production during the first rotation, offsetting a densely planted trees diameter growth and development of branches affected by competition by an increased height growth. However, in the long term, competition and succession of rotations can cause a mortality of more than half of the plants originally installed (as is the case in Brittany in the oldest plantations from 1998). A balance is therefore to find concerning the length of the revolution (the sum of rotations before replanting).

In terms of harvest timing, cutting back at the end of the first year often has beneficial effects on the growth of the following year, unless the growth has been weak in the first year. In the latter case, coppicing trees would damage even more trees in trouble. Finally, when the soils are not frozen during winter (as is often the case for the Brittany plantations), a spring harvest and export of foliage seems to have little effect on yields of subsequent years. However, the export of nutrients in the leaves out of the plantation is likely to be detrimental in the long run when the process is repeated frequently.

	Biomass production	Water-use efficiency
1. Clonal mixture	=	=
2. Harvest season	=	=
3. Planting density	+	-
4. First year coppicing	+	=
5. Chemical fertilization	=	=
6. Pedoclimatic conditions	Very variable	Not so variable
7. Species	Black locust > Poplar Willow	Black locust > Poplar Willow
8. Sludge spreading	=	=
9. Wastewater spreading	+	=
10. Cultural antecedent	=	Grassland > Maize

Figure 41bis: Summarized general conclusions of WP1 concerning the site-specific objectives.

4.2 Work Package 2 - Improvement of harvesting systems and transport logistics related to specific site conditions

4.2.1 State of the Art

Prior to the project start, data on the time demand and the costs involved in harvesting SRC with different systems were rare and based on isolated studies (BURGER, 2007; BURGER & SCHOLZ, 2004; HARTMANN & THUNEKE, 1997; HEINRICH, 2007; KIENZ, 2007; SCHOLZ & LÜCKE, 2007; TEXTOR & WILWERDING, 2003). Most of these studies focused on the assessment of cutter-chippers like the modified forage harvesters of the companies Claas and Krone/Hüttmann, and on outdated systems like the “Göttinger Mähhäcksler”, a tractor-mounted cutter-chipper which is not in use any more. Similarly, several of these older data are not relevant any more from the current perspective of a dynamically changing field of activity. Moreover, most studies have calculated woodchip production cost on a theoretical basis using an overall approach that included the buying price of a new harvester, its working hours per year, fixed hourly costs for standardized transport units as priced by machine rings, etc. This approach was maintained in several publications issued throughout the running time of CREFF (e.g., HANDLER & BLUMAUER, 2009; LENZ, 2011; REIKE, 2008; SPINELLI *et al*., 2009; VOIGTLÄNDER, 2011). Others have included harvesting calculations in an SRC management model that was based on an assumed field size of 20 ha (GRUNDMANN & EBERTS, 2008) – a scenario which is unlikely to occur in most parts of Southern Germany or North-Eastern France. These scenarios are of theoretical significance and provide important information about general economical aspects of SRC value chains, but they are of limited value for the farmer’s daily and often very individual practice, and are especially so for managing SRC plantations stocking on marginal field sites. Moreover, these models have not included transport costs of the harvesting machine, a key figure which alters harvesting cost calculations significantly. Therefore, the innovative approach of CREFF was to document and analyze a considerable number of harvesting operations in practice, and to process the obtained data in a practice-orientated way. In particular, scientific and technical knowledge was poor for harvests performed motor-manually and with forest machinery (BURGER, 2007; BURGER & SCHOLZ, 2007). However, these harvesting strategies can be expected to play an important role in the management of SRC plantations grown on marginal field sites. Moreover, the knowledge concerning the available harvesting systems was generally low among the farmers who had established SRC. It was a typical scenario that farmers had planted their plantation without a firm idea of how the harvesting will be performed a number of years later. Yet, the plantation design is decisive in that it determines which harvesting machines can be used. This concerns both the spacing between the rows of the trees and their orientation with respect to a given slope. To remedy this lack of knowledge and experience, a major aim of WP2 was to gain first-hand experience with the different harvesting methods and to propagate information concerning their main characteristics and their practicability on different site conditions.

4.2.2 Specific goals

Harvesting activities and transport logistics represent a major and often decisive cost factor in SRC management. This is especially valid for SRC established on small field sizes, unfavourable soil conditions, and sloped or wet areas on which full-mechanised harvesting is not feasible. Thus, the scientific/technical objective of WP2 focused on developing improved and economically viable SRC harvesting and logistic systems which are adapted to the particular site conditions. We have pursued these goals by addressing the following main tasks:

- Selection and analysis of approximately 40-50 different harvest operations in which different harvesting systems were employed: a) fully mechanised (self-propelled cutter-chippers or tractor-mounted cutter-chippers), b) fully mechanised (forestry machinery like feller-bunchers and subsequent chipping), and c) semi-mechanised (motor-manual harvests and subsequent chipping). The three harvesting methods were to be analyzed with regard to their quality and cost performance under the different site conditions.
- Selection and analysis of logistics systems, focusing on aspects like transport distance, available means of transport, widely scattered small size fields, reloading points, etc.. The logistic strategies were to be analysed with regard to their costs and efficiency.
- Development of improved harvesting and efficient logistics systems. Comparisons of the cost efficiency of the analyzed systems were to be performed and possibilities for cost-reduction were to be identified.
- Based on the obtained results, we aimed at generating a tool which facilitates realistic estimations concerning the question of under which site conditions which harvesting and transport systems are most profitable, and under which site conditions a SRC establishment can at present not be recommended.

4.2.3 Activities and results

The main activities and the main scientific / technical results of WP2 consist of the following issues:

- The first comprehensive review paper on the status of SRC in Germany (BEMMANN, NAHM, BRODBECK, & SAUTER, 2010, *Forstarchiv 81*, 246-254; see Annex 2.1).
- Documentation and evaluation of 28 time studies of harvesting (and logistic) operations, 4 chipping operations, and 2 clearing operations.
- The results obtained from evaluating the different harvesting, logistic and chipping operations generated the database for the development of an Excel-based tool for optimizing the costs and the time demand for individual harvests, the *KUP-Ernteplaner* (see Annex 2.2).
- The findings of the time studies were summarized in a report in German language. Yet, it still needs its official approval before it can be disseminated (see Annex 2.3).
- The results of the time studies have also been implemented in an update of a guideline existing in Germany for the management of SRC, in the first French guideline of this kind (see Annex 0.1), and in the data used in the calculation tool developed by WP4 which covers the entire SRC-process chain.
- Performance and evaluation of an experiment designed to assess the effects of different harvesting techniques on the regrowth of six different poplar clones.

Below, we present more detailed information about the main activities and results.

4.2.3.1 The publication "Holz aus Kurzumtriebsplantagen: Hemmnisse und Chancen" (Bemmann, Nahm, Brodbeck, & Sauter, 2010)

This publication was initiated in the CREFF project and was written in collaboration with Prof. Dr. Bemmann of the Technische Universität Dresden. It was published in 2010 in the *Forstarchiv 81*, pp. 246-254. The motivation to write this publication was driven by the lack of an extensive overview describing the status quo of SRC management in Germany. The publication is specifically focused on identifying obstacles which at present hamper the establishment of SRC on significant scales, and on possible ways to overcome these obstacles. Based on the existing literature and personal experiences, we have mainly identified the following obstacles:

- In contrast to the traditional field of agriculture and forestry, no organisational structures exist that bundle and focus activities and knowledge on SRC. Moreover, noteworthy research activities have only recently begun in Germany. An important example is the cultivation of new clones of SRC trees with growth-optimized qualities and pest resistances.
- Similarly, the specialized and comparably expensive technology which is needed to successfully manage the plantations is only scarcely available. This includes technologies for the conditioning of wood chips but also for harvesting, the main field of research of this WP of CREFF.
- Economic and operational risks for the farmers (see also results of CREFF WP5).
- Structural disadvantages of the landscape that hinder the establishment of large and interconnected SRC plantations, particularly in large parts of Southern Germany.
- Lack of knowledge regarding the recultivation of the plantation.
- Administrative obstacles such as refusal of permissions to establish SRC because of nature and landscape conservation matters.

As for possible ways to overcome these obstacles, we have discussed the following possibilities and perspectives:

- Official formulation of concrete regional plans to procure the required supply of renewable energy sources from woody biomass.
- Generation of regional associations designed to bundle resources and to enhance the flow of information, both on the horizontal plane between farmers and on the vertical plane between the different actors of a process value chain.
- Establishment of plantations and management cooperations that may serve as "guideposts".
- Ongoing research activities which should specifically focus on the breeding of new SRC clones and the optimization of harvesting systems.

4.2.3.2 Documentation and evaluation of 28 time studies of harvesting (+ logistic) operations, 4 chipping operations, and 2 clearing operations

Due to a delay in the factual project start, we missed one harvesting season. Still we were able to document 28 harvesting operations in which several different harvesting systems were used. In section 4.2.3.2.1, we describe the different systems with a focus on their productivity. For this purpose, we have grouped different harvesting systems with respect to their technology. In the next section 4.2.3.2.2, we will present main results concerning the involved logistics, and section 4.2.3.2.3 contains essential features of the wood chip production costs of the different harvesting methods. In section 4.2.3.2.4, we will discuss possible ways to optimize the harvest and the logistics of SRC management.

4.2.3.2.1 18 harvesting operations performed with self-propelled cutter-chippers (forage harvesters)

Of the 28 harvesting operations, 18 were performed with modified forage harvesters. Of these, 10 were performed with a New Holland FR9060 forager equipped with the New Holland header 130 FB, five with a Claas Jaguar 890 forager equipped with a GBE1 header, one with a Krone BigX forager plus a Hüttmann WoodCut 1500 header, one with a John Deere 7500 forager plus a CRL header, and one with Claas Jaguar 870 plus a Claas HS2-header. The main results concerning the productivity of these harvesting systems are displayed below in Table 2. Here, MT refers to *Main Time*, i.e. the time in which the harvester was factually driving and harvesting. BT refers to *Basic Time*, i.e. the time required for the necessary operations to harvest the field. In addition to MT (harvesting), BT also includes the time needed for turning the vehicles to harvest the next row. TWT refers to *Total Working Time*, i.e. the overall time needed to harvest the field. In addition to MT and BT, TWT includes times that were spent on discussing the working operations, waiting times, telephone calls, interruptions of the workflow due to machine malfunction, jamming, etc. However, only interruptions of less then 15 minutes duration were included into TWT.

Table 2: Main results of different self-propelled cutter-chipper systems.

Abbreviations in the table head: Prod.: Productivity; MT: Main time; BT: Basic Time; TWT: Total working time. Abbreviations in the column *Machine*: New H: New Holland forager + New Holland header; Cl GBE: Claas forager + GBE1 header; Cl HS2: Claas forager + HS2 header; Kr Hütt: Krone Forager + Hüttmann WoodCut 1500 header; JD CRL: John Deere Forager + CRL header. In the columns displaying productivity, t_{fm} refers to tonnes of fresh material, t_{dm} to tonnes of oven dry material. In the columns displaying productivity, t_{fm} refers to tonnes of fresh material, t_{dm} to tonnes of oven dry material.

Nr.	Machine	Field	Speed MT	Prod. MT	Prod. BT	Prod. TWT	Prod. MT	Prod. BT	Prod. TWT	Prod. MT
			[km/h]	[ha/h]	[ha/h]	[ha/h]	[t_{fresh}/h]	[t_{fresh}/h]	[t_{fresh}/h]	[t_{dry}/h]
1	New H	B. Sch. 1	4.2	1.1	0.8	0.6	58.3	41.1	32.0	26.1
2		B. Sch. 2	4.2	1.0	0.8	0.6	80.0	60.0	48.8	35.7
3		Bockwitz	3.7	0.8	0.4	0.3	51.6	29.6	21.0	23.3
4		Degernau	5.2	1.2	0.8	0.8	78.2	55.4	51.3	35.3
5		Engen 1	4.5	1.6	1.2	0.6	39.8	28.8	14.2	18.0
6		Ihlow	5.3	1.2	0.9	0.8	81.3	59.0	57.7	36.9
7		Kraichtal 1	4.4	1.0	0.8	0.7	59.8	48.5	42.8	24.9
8		Kraichtal 2	6.0	1.5	1.1	1.0	49.7	37.4	32.0	19.5
9		Reinach 1	7.4	2.3	1.6	1.6	6.9	4.8	4.8	3.5
10		Reinach 2	5.5	1.7	1.3	1.3	42.3	32.8	32.0	21.2
11	Cl GBE	Fohnsdorf 1	5.6	1.7	1.2	0.8	88.2	60.2	42.7	35.0
12		Fohnsdorf 2	5.7	1.7	1.6	1.6	69.4	62.7	62.7	25.7
13		Mistelb. 1	4.7	1.6	1.2	1.2	57.9	44.1	43.4	27.7
14		Mistelb. 2	4.2	1.3	0.7	0.7	60.6	31.8	30.3	28.4
15		Mistelb. 3	5.3	1.6	1.2	0.9	26.6	20.5	15.7	16.6
16	Cl HS2	Laisa	4.2	1.2	0.8	0.3	54.3	35.0	15.4	21.7
17	Kr Hütt	Dillingen	4.7	1.0	0.5	0.4	47.7	25.7	19.5	21.5
18	JD CRL	Engen 1	1.7	0.6	0.5	0.4	20.9	15.2	14.9	8.3

Table 2 shows that the productivity of the machines varied greatly. These variations were partly due to the different site conditions on the harvested fields such as the field shape and the yield. For example, the high productivity on Fohnsdorf 2 was due to the length of the field, the rows of which measured 560 m. Thus, the vehicles had spent only few times on turning. Contrastingly, the field in Mistelbach had a triangular shape, the shortest row measuring only 5 m. Therefore, the vehicles had spent almost half of the BT on turning around. On Reinach 1, the low mass productivity combined with a high area productivity was due to the very little amount of biomass stocking on the field. When comparing MT data of the five different forager systems that were obtained on largely comparable field sites, only the John Deere/CRL system displayed a markedly lower performance than the other four systems. This system was used on a poplar plantation (Engen 1) with comparably thick stems that often measured more then 10 cm at cutting height. It had no bars to push the trees into a bent position in front of the cutting mechanism, and had severe problems with harvesting the poplars. Yet, the CRL header is specifically constructed for harvesting willows and it might work notably better when used on willow plantations. However, the New Holland system, which continued the harvest on the same site a month later, had no problems with the poplars and thus showed a markedly better performance. On the Laisa site, the Claas/HS2 system performed in a range comparable to the Claas/GBE1, New Holland and Krone/Woodcut 1500 systems, but it is constructed to cut stems with only a maximum diameter of 7 cm. Thus, it would not have been possible to use this system on sites such as Engen 1. In sum, the New Holland and the Claas/GBE1 system proved to be robust and well-functioning machines and performed in a similar range of productivity. We obtained data from only one time study with the Krone/Woodcut 1500 system, but due to literature and personal communications it seems that this system also works reliably in a comparable range of productivity (BECKER *et al*., 2010).

Three harvesting operations performed with tractor-mounted cutter-chippers

In the course of the project, three harvesting operations were documented in which tractor-mounted cutter chipper systems were used. The first was the chipper constructed by Schmidt GmbH, the other two consisted of modified sugar cane harvesters. They were constructed by the Brazilian company JF Máquinas Agricolas, and had been adapted for the use in SRC plantations by the Danish company Ny Vraa Bioenergy. Table 3 presents the main performance characteristics of these machines.

Table 3: Main results of three different tractor-mounted cutter-chipper systems.
Abbreviations in the table head: Prod.: Productivity; MT: Main time; BT: Basic Time; TWT: Total working time.
In the columns displaying productivity, t_{fm} refers to tonnes of fresh material, t_{dm} to tonnes of oven dry material.

Machine	Field	Speed MT	Prod. MT	Prod. BT	Prod. TWT	Prod. MT	Prod. BT	Prod. TWT	Prod. MT
		[km/h]	[ha/h]	[ha/h]	[ha/h]	[t_{fm}/h]	[t_{fm}/h]	[t_{fm}/h]	[t_{dm}/h]
Schmidt	Engen 2	2.2	0.8	0.6	0.4	7.7	6.1	4.4	3.4
JF Z 6	Merscheid	1.5	0.2	0.2	0.2	4.8	4.5	4.5	2.3
JF Z 20	Tylstrup	2.8	0.6	0.3	0.3	26.4	11.9	11.7	12.2

All three systems had a much lower productivity than the forage harvesters. Especially the first two types had serious problems with harvesting the plantation and eventually, both harvests were terminated prematurely. In fact, both machines are not in use any more. Schmidt is developing a new machine in cooperation with Jenz GmbH, and Ny Vraa Bioenergy uses the double-row harvester JF Z 20. This system worked well and allows for the cost-efficient production of wood chips (see the section on the costs of the harvests). However, its applicability is limited to trees with a maximum diameter of 4 cm. Therefore, its use is restricted to harvesting young and thin trees of a maximum rotation length of two years, the woodchips of which are not preferred by the consumers of SRC woodchips (see the results of the questionnaire elaborated by WP3).

Three harvesting operations performed with the cutter-collecter „Stemster“

On three occasions, harvests performed with the “Stemster” were documented, a tractor-pulled harvesting system constructed by the Danish company Nordic Biomass. This machine cuts whole SRC trees and stores them on a special loading unit on its back. When this loading unit is full, the trees are unloaded at the sides of the field, or sometimes directly on the field itself. The Stemster can be regarded as a cutter-collecter and can be used for two-phase harvesting methods in which the trees are collected and stored for 4-8 months to dry before being chipped. Basic data of the harvests with the Stemster are presented in Table 4.

Table 4: Main results of three harvesting operations performed with the cutter-collecter “Stemster”.
Abbreviations in the table head: Prod.: Productivity; MT: Main time; BT: Basic Time; TWT: Total working time.
In the columns displaying productivity, t_{fm} refers to tonnes of fresh material, t_{dm} to tonnes of oven dry material.

Machine	Field	Speed MT	Prod. MT	Prod. BT	Prod. TWT	Prod. MT	Prod. BT	Prod. TWT	Prod. MT
		[km/h]	[ha/h]	[ha/h]	[ha/h]	[t_{fm}/h]	[t_{fm}/h]	[t_{fm}/h]	[t_{dm}/h]
Stemster	Buggingen 1	5.8	1.3	0.4	0.4	52.0	17.8	14.7	23.6
Stemster	Buggingen 2	6.1	1.4	0.4	0.4	10.7	3.2	3.1	4.8
Stemster	Haine	9.5	1.9	0.7	0.6	61.5	24.0	20.6	27.8

On Buggingen 2, the amount of biomass stocking on the field was very low, most likely due to the excessive growth of weeds. The productivity on Buggingen 1 and on Haine lay in a comparable range. Yet, the poplar stocks in Haine drove out predominantly one stem, whereas the willow stocks in Buggingen 1 drove out multiple shoots. It seems likely that this growth pattern facilitated high driving speed during the harvest of the poplars in Haine. However, on all three sites, the high harvesting speed and the productivity with regard to MT was drastically reduced by the times required to unload the biomass, resulting in a lower BT productivity compared to typical harvests with cutter-chippers.

Four harvesting operations performed with techniques used in forestry

Furthermore, four harvests were performed with techniques used in forestry. Two of them were performed motor-manually with a chainsaw, and two were performed with feller-buncher aggregates (Table 5).

Table 5: Main results of four harvesting operations performed with methods also used in forests. Abbreviations in the table head: Prod.: Productivity; MT: Main time; BT: Basic Time; TWT: Total working time.

In the columns displaying productivity, t_{fm} refers to tonnes of fresh material, t_{dm} to tonnes of oven dry material.

Machine	Field	Prod. MT	Prod. BT	Prod. TWT	Prod. MT	Prod. BT	Prod. TWT	Prod. MT
		[ha/h]	[ha/h]	[ha/h]	[t_{fm}/h]	[t_{fm}/h]	[t_{fm}/h]	[t_{dm}/h]
Motor-manual	Bettenreute	-	-	0.04	-	-	21.3	8.6
Motor-manual	Gengenbach	-	-	0.03	-	-	0.6	0.4
Feller-buncher	Alfdorf	-	-	0.05	-	-	5.0	2.6
Feller-buncher	Vatan	-	-	0.04	-	-	13.7	6.2

With the exception of the field at Gengenbach, its trees being only two years old, the trees harvested had reached stem diameters that only permitted the use of motor-manual felling or the use of forestry machinery. Because all four harvests took longer than one day and the operations could not be documented throughout the whole duration of the harvests, only data concerning TWT are shown in Table 5. Furthermore, different harvesting strategies were employed on all four sites.

In Bettenreute, 17-year old trees were felled motor-manually by one person who also hauled the trees by use of a tractor equipped with a winch. In the meantime, another worker partitioned already hauled trees with a chainsaw into portions of wood which were fed into a mobile chipper by six other persons. Felling and hauling reached a productivity of 0.05 ha/h, felling alone reached 0.12 ha/h.

In Gengenbach, two-year old willows were cut motor-manually by one person. The cut trees were collected and stacked into bundles by two to three persons. After the harvest, these bundles were loaded on a tractor-pulled bolster with a grapple and driven to the storage place. The harvest and the clearing of the field ran with a productivity of 0.03 ha/h, felling alone reached 0.1 ha/h.

In Alfdorf, a special type of forest machine was used. The base machine, the forwarder Ponsse Buffalo Dual, was equipped with the feller-buncher head Ponsse EH 125, a special aggregate for harvesting small trees for energy wood production. The harvested trees were stored directly on the bolster of the forwarder. The trees were unloaded on the headland of the plantation, waiting to be chipped seven months later. The productivity of 0.05 ha/h concerns the harvesting and the clearing of the site, which was performed in the same working process.

In Vatan (France), another feller-buncher head (Westtech Woodcracker C350) was used. It was mounted to an excavator (Case CX130B). In this case, the trees were only cut and laid down on the field. The felling productivity reached 0.08 ha/h. A few months later, the field was cleared by skidding the trees to the sides of the field. However, it was not possible to document the skidding operation. From general experience and literature data (e.g. Burger, 2010), it can be estimated that the skidding to clear the field would take a similar time, so that the productivity of this harvesting method would decrease to about 0.04 ha/h (Table 5).

Four chipping operations

In addition to the harvesting operations, four chipping operations of material previously harvested with the Stemster and forestry techniques were documented throughout the running time of Creff (Table 6). The chipping of the biomass in Haine and in Vatan could not be accompanied. The material of Buggingen 1 and 2 was stacked on a single pile and chipped together, so that a separate evaluation of the biomass of the two fields was not possible. In Alfdorf, a tractor-pulled and crane-fed aggregate (Jenz HEM 561 with John Deere 8330) was used, in Bettenreute a hand-fed and tractor-pulled chipper (Eschlböck Biber 7), and in Buggingen and Gengenbach an unspecified crane-fed chipper manufactured by Wüst which was mounted on a truck.

Table 6: Main results of four different chipping operations.
Abbreviations in the table head: Prod.: Productivity; MT: Main time; BT: Basic Time; TWT: Total working time.
In the columns displaying productivity, t_{fm} refers to tonnes of fresh material, t_{dm} to tonnes of oven dry material.

Machine	Field	Prod. MT	Prod. BT	Prod. TWT	Prod. MT	Prod. BT	Prod. TWT	Prod. MT
		[ha/h]	[ha/h]	[ha/h]	[t_{fm}/h]	[t_{fm}/h]	[t_{fm}/h]	[t_{dm}/h]
Jenz HEM 561	Alfdorf	0.4	0.3	0.2	37.9	29.2	18.6	19.3
Eschlböck Biber 7	Bettenreute	0.02	0.02	0.01	8.2	6.1	5.8	3.5
Wüst	Buggingen	0.5	0.4	0.4	12.0	9.9	9.2	6.1
Wüst	Gengenbach	1.1	0.9	0.9	21.2	18.7	17.5	12.0

The lowest productivity was displayed in Bettenreute, where the trees were cut and fed into the chipper manually. Among the crane-fed chipping operations, the highest productivity was reached in Alfdorf. This was mainly due to the comparably large stem diameters of the 9-year old trees which resulted in a higher density of the biomass flowing through the chipper. The material in Buggingen consisted of smaller trees than in Gengenbach, especially the 2-year old willows from Buggingen 2, and the structure of the biomass pile was not as well ordered as in Gengenbach because the Stemster cannot unload the trees in such an ordered manner as the crane of the bolster trailer. These differences might account for the productivity differences between these two chipping operations, which were performed with a practically identical chipper.

4.2.3.2.2 Basic aspects of the logistics involved in the harvesting operations

The transport of the biomass was usually performed with trailers that were already in the possession of the farmers, and they often used additional trailers borrowed from friends and neighbours. Often, this individual approach rendered it difficult to calculate factual costs of the transport. For transport distances larger than 10 km, trucks were used rather than tractors and trailers in own possession. However, under the perspective of SRC plantations on marginal sites, such transport distances should be avoided because of the already low biomass productivity, and thus, the low profitability of SRC sites on many marginal sites. Our data resulted in the following general costs in relation to the transport distance (Table 7):

Table 7: Approximate dry biomass transport costs in relation to transport distance.

Transport distance [km]	Transport costs [€ / t_{dm}]
1-10	5-10
10-30	10-15
30-50	15-20

The individual approaches rendered it also difficult to develop general optimized transport logistic systems for the practice of the farmers. In addition, the distance between the different farmers was usually very large and the transport distance from the field to the end user, this often being the farmer himself, was often comparably small. These findings highlight that the farmers who manage SRC are still only few, and that they have to manage their SRC plantations largely independently of each other. Under these circumstances, to develop new logistic systems such as employing joint reloading points as a potential means to facilitate transport logistics seemed not recommendable.

However, the biomass transport was often not optimally organized and the forage harvesters or chippers had to wait for empty transport units. In such cases, the farmers had underestimated the time required to drive to the storage place and to return to the field, and had overestimated the time it took to fill of the containers with woodchips. The differences in BT and TWT productivity (see tables above) were in the main caused by such transportation delays. Such misjudgements can be avoided by a proper planning of the harvest, and allowed for identifying means to improve the harvesting and transport operations on an individual basis. As a means to facilitate this planning, the calculation tool *KUP-Ernteplaner* was developed (see section 4.2.3.3 55 and Annex 2.2). Based on a number of figures the operator needs to enter, this tool calculates the time required for the harvest, the time required for the transportation cycles, and the costs for different harvesting possibilities and transportation logistics.

4.2.3.2.3 Costs of the wood chip production

In this section of the report, we present data on the costs of harvesting operations. Table 8 shows the costs for the harvests performed with self-propelled cutter-chippers. The costs for the transport of the foragers and for the biomass transport are not included, nor is the 19 % value added tax (VAT) included. The column *Costs TWT* shows the wood chip production costs of different aggregates. The costs for the New Holland harvesting system were calculated with 400 €/h, the current price for harvesting with this machine in Germany. Because the only forage harvester located in Southern Germany is a New Holland aggregate, it is likely to be the most often used system in this and the surrounding areas.

Table 8: Costs for the production of wood chips with different forage harvesters.
Abbreviations in the table head: *MT*: Main time; *BT*: Basic Time; *TWT*: Total working time. Abbreviations in the column Machine: *New H*: New Holland forager + New Holland header; *Cl GBE*: Claas forager + GBE1 header; *Cl HS2*: Claas forager + HS2 header; *Kr Hütt*: Krone Forager + Hüttmann WoodCut 1500 header; *JD CRL*: John Deere forager + CRL header.
In the columns displaying costs, t_{dm} refers to tonnes of oven dry material.

Nr.	Machine	Field	Costs MT	Costs BT	Costs TWT
			[€/t_{dm}]	[€/t_{dm}]	[€/t_{dm}]
1	New Holland	B. Schuss. 1	15.4	21.8	27.9
2		B. Schuss. 2	11.2	14.9	18.3
3		Bockwitz	17.2	30.0	42.3
4		Degernau	11.3	16.0	17.2
5		Engen 2	22.3	30.7	62.4
6		Ihlow	10.8	14.9	15.3
7		Kraichtal 1	16.1	19.8	22.5
8		Kraichtal 2	20.5	27.3	31.9
9		Reinach 1	114.7	165.1	167.6
10		Reinach 2	18.8	24.3	24.9
11	Claas + GBE1	Fohnsdorf 1	9.1	13.4	18.9
12		Fohnsdorf 2	12.5	13.8	13.8
13		Mistelbach 1	11.6	15.2	15.4
14		Mistelbach 2	11.3	21.5	22.6
15		Mistelbach 3	19.3	25.0	32.6
16	Claas + HS2	Laisa	11.5	17.8	40.7
17	Krone + WoodCut	Dillingen			
18	John Deere + CRL	Engen 1	41.1	56.4	57.8
Mean (excl. Reinach 1, Dillingen, and Engen 1)			14.6	20.4	27.1

Table 8 shows that the costs for producing wood chips with forage harvesters vary greatly. As the previous tables have indicated, this variance is due to (1) the biomass stocking on the field, a notable example being Reinach 1, and (2) due to the organisation of the harvesting logistics and the shapes of the fields. Excluding the sites of Reinach 1, Engen 1, and Dillingen, the harvesting operations of which must be regarded as untypical, the mean costs calculated for TWT amount to 27.1 €/t_{dm}.

A correlation between the biomass stocking on the harvested fields and the productivity of the foragers with regard to main time (MT) shows a reasonable correlation between the two parameters (R^2=0.68; Figure 42). Parameters that have weakened this correlation are different water contents of the biomass from different sites, and their soil conditions and their planting design. However, the correlation coefficient decreased further in similar correlations using the productivity data of the foragers with regard to basic time (BT) and to total working time (TWT; R^2=0.49 and R^2=0.36, respectively; Figure 42).

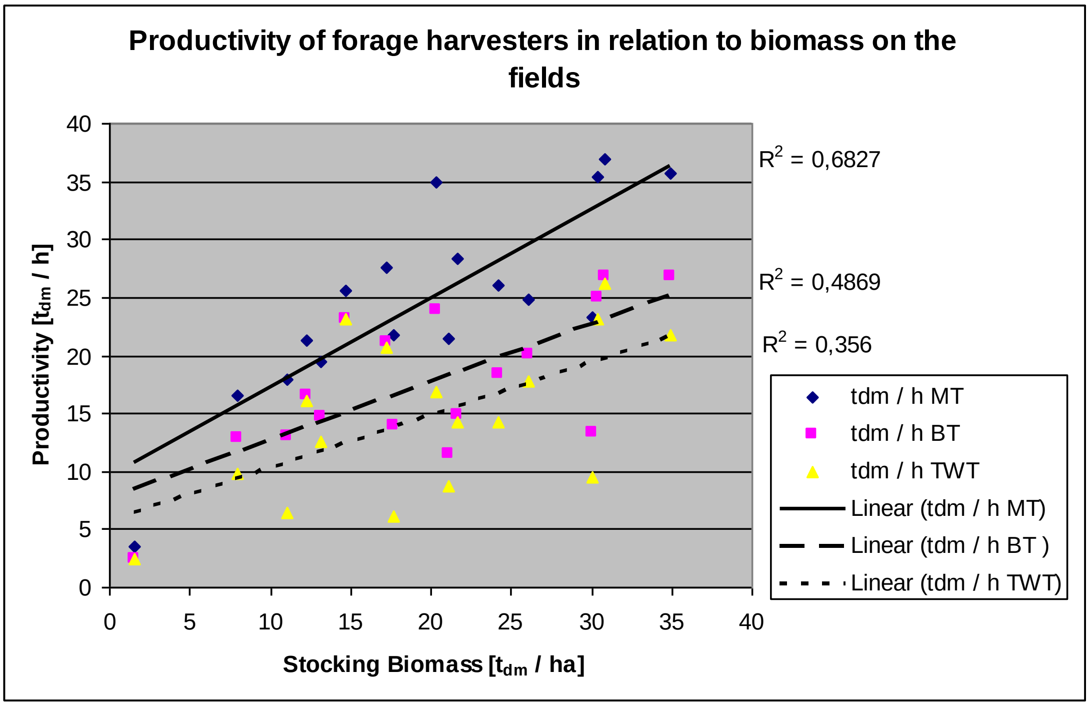


Figure 42: Correlations between biomass stocking on the fields and the productivity of the forage harvesters in relation to MT (main time), BT (basic time), and TWT (total working time).

The difference in p between the correlations in which data of MT and BT are used are generally caused by the time needed to turn the vehicles, and thus, can be attributed to the shape of the field and the availability of headlands. The differences in p between the correlations in which data of BT and TWT are used are mainly caused by waiting times and the other activities attributed to TWT. Because the costs and margins of a harvest are directly linked to the productivity of the machine, a producer must strive to come as close as possible to an optimized workflow which is realized by matching the time consumption and the operative processes represented by BT. Furthermore, to optimize the relation between machine productivity and costs, he should consider in advance parameters like the shape of a field. Fields of 1 ha can have very different shapes which affect the production costs of woodchips, as exemplified by the following table (Table 9). This highlights the importance of considering potential disadvantages of a given field in advance, and, most importantly, to organise the harvest properly and well in time.

Table 9: Costs arising from turning the vehicles due to different shapes of a field of 1 ha size.
The first two lines represent possible dimensions of a rectangular field. The third line represents a field of triangular shape with one angle of 90° and two angles 45°. The time for one turn was assumed to be 45 seconds, the spacing of the rows three metres, the hourly costs for the forager 400 €, and the hourly costs for two tractor-trailer units, each of a capacity of 35 m³, was assumed to be 2x63=126 €.

Field width [m]	Field length [m]	Number of turns	Turning time [min]	Costs [€/ha]
20	500	5	3.8	33
100	100	32	24.0	210
141	141	46	34.5	302

Of the tractor-mounted cutter-chippers, only costs for the JF Z 20 could be determined. The harvests with the Schmidt system and the JF Z 6 were terminated because the machines were not functioning and seemed not appropriate for harvesting the fields. The costs for the production of wood chips for the JF Z 20 were rather low and reached 14.5 €/t_{dm} under typical conditions.

The costs for producing woodchips with the methods in which the processes of harvesting and chipping are separated are given below in table 10.

Table 10: Costs for the production of wood chips with different methods in which the activities of harvesting and chipping are performed separately.
Abbreviations in the table head: *MT*: Main time; *BT*: Basic Time; *TWT*: Total working time. Abbreviations in the column Machine: *Mot.-man*: Motor-manual harvest; *Feller-bun.*: Harvest performed with feller-bundles systems.
In the columns displaying costs, t_{dm} refers to tonnes of oven dry material.

Machine	Field	Harvest			Chipping			Total costs TWT
		Costs MT	Costs BT	Costs TWT	Costs MT	Costs BT	Costs TWT	
		[€/t_{dm}]	[€/t_{dm}]	[€/t_{dm}]	[€/t_{dm}]	[€/t_{dm}]	[€/t_{dm}]	[€/t_{dm}]
Stemster	Buggingen 1	8.0	23.4	28.3	27.0	32.4	35.1	63.4
	Buggingen 2	39.1	130.5	133.8	27.0	32.4	35.1	168.9
	Haine	7.2	18.5	21.5			35.7	57.2
Mot.-man.	Bettenreute			3.0	32.7	43.6	46.0	49.0
	Gengenbach			130.8	22.6	24.4	25.4	156.2
Feller-bun.	Alfdorf	31.0	35.1	37.6	12.5	15.6	22.0	59.6
	Vatan			29.4			35.7	65.1

In general, the costs for the production of woodchips displayed in Table 10 are higher than compared to the other methods. Often, the chipping alone is already as expensive as the harvests with cutter-chipper systems. Adding the costs for the harvesting process, production costs often double the costs of the cutter-chipper systems. Yet, the site in Bettenreute with its 17-year old trees is an exception in that the felling could be achieved with comparably low investments. Here, calculations were performed assuming an hourly wage of 15 € (following KTBL, 2006). Then, the costs for the one person who has felled and skidded the trees amounted to only 3 € including cost for the employed machinery. Moreover, instead of letting six persons feed a mobile chipper manually, what resulted in chipping costs of 46.0 €/t_{dm}, chipping the trees with a service provider would have lowered the chipping costs to about 25.5 €. However, harvesting younger SRC trees is clearly less cost-efficient. For example, the amount of biomass stocking on Haine was in a range between the two sites Kraichtal 1 and 2. All three sites were stocked with poplars aged two to three years. Yet, the TWT production costs of the Stemster system were 57.2 €/t_{dm} as compared to 22.5 and 31.9 €/t_{dm} at Kraichtal. In addition, one needs to be aware of the fact that fresh wood chips are prone to rot if they are not used very quickly, losing up to one third of their initial biomass. By performing the two-step harvesting methods described in Table 10, this problem could be overcome because the biomass of the harvested material can dry to about 35 % water content or less, and thus increase the value of the product. Moreover, a way to reduce harvesting costs is to exclude hourly wages from the calculation if large parts of work can be performed by in-house efforts. For example, at the site in Gengenbach, the work was performed by the entire family of the farmer on a weekend instead of pursuing typical weekend activities. Hence, without calculation 15 € for each family member, the production costs for dried woodchips would decline to 54.8 €/t_{dm}, a value which might render this way of managing SRC sites attractive especially for farmers who intend to use the woodchips in their own burner. To summarize, Figure 43 shows the wood chip production costs as they have been determined in the performed time studies.

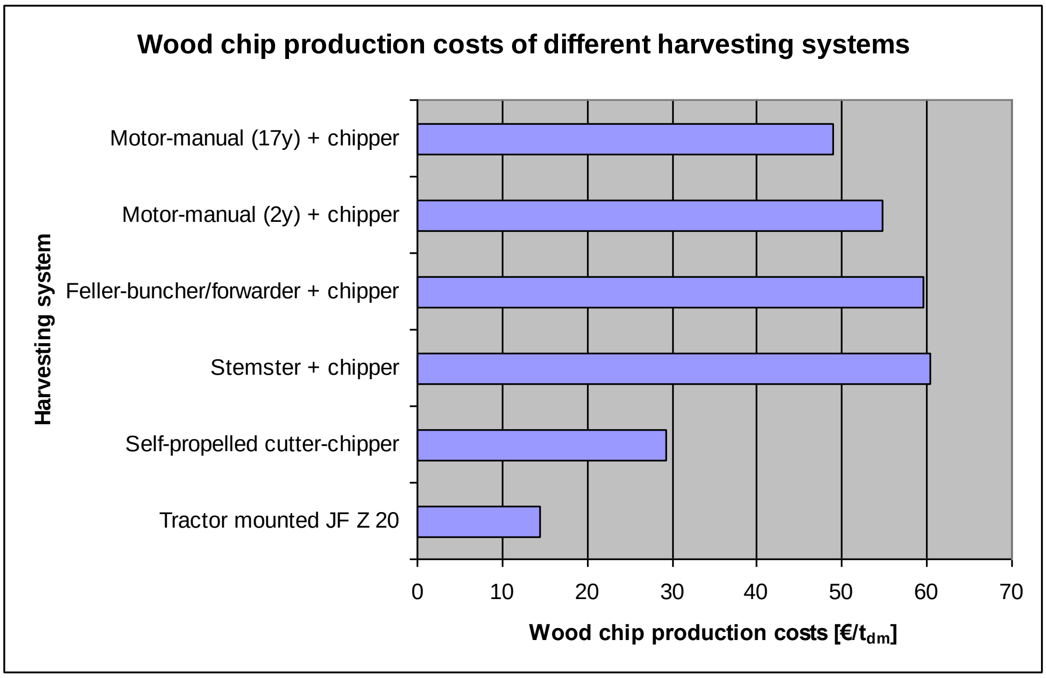


Figure 43: Comparison between the wood chip production costs of different harvesting systems, referring to tonnes of oven dry material. Not included are the costs for the transport of the harvesting aggregate, for the transport of the biomass, and VAT. The bar *Tractor mounted JF Z 20* refers to a time study performed with this cutter-chipper, the bar *Self-propelled cutter chipper* refers to the mean of 9 representative harvesting operations performed with the New Holland aggregate, the bar *Stemster + chipper* to the mean from two representative harvesting and chipping operations performed with the Stemster. The next bar refers to a harvest performed with a Feller-buncher/forwarder system and a mobile forestry chipper. The last two bars refer to motor-manual harvests of 2-year old willows and 17-year old poplars and the chipping. As for the harvest of the 2-year old trees, the value refers to the harvest as being calculated without hourly wages for workers (see text).

However, also costs for the transport of the harvesting aggregates need to be considered. Often, these costs are considerable and should ideally be shared among farmers that want to use the machine in a given region. At present, transport costs for forage harvesters on low platform trucks can be estimated to be 5 €/km if a transport service provider is used, and to about 2 €/km if the machines are transported on own equipment of the harvesting companies such as Fa. Roth in Southern Germany, who owns a New Holland forager. The transport costs for the Stemster were also about 2 €/km. Mobile chippers used in forestry are often available in the surroundings of the chipping location and their relocation costs can be estimated to rank between 50 to 200 €.

Finally, the expenses for the recultivation of a SRC plantation should also be addressed. The limited data available consist of values that range from 1,000 to 6,000 €/ha (BECKER & WOLF, 2009) and from 500 to 5,000 € / ha (GROSSE *et al*. 2010). Typical recultivation operations are estimated to cost between 1300 and 1500 €, but have in practice also amounted to 2,500 € / ha (GROSSE *et al*., 2010). In the two time studies we have performed, the recultivation costs in Bettenreute amounted to 1,881 €/ha. In this case, a small excavator to remove the stumps of 17-year old poplars was rented for six days, and an hourly wage of 15 € was assumed. The second clearing operation amounted to 9,000 €/ha. On this occasion, the driver of a Fendt 936 Vario performed three operations on the field in succession: 1) grubbing, 2) using a rotary hoe, and 3) mulching. Recultivation costs of this dimension are obviously inflated and put an end to all profitability calculations for SRC management. They need to be avoided by any means, but in this case, it was not possible to find another service provider that was willing or able to perform the recultivation in question.

4.2.3.2.4 Optimization of harvesting and logistic processes

A core objective of WP2 was to develop strategies to optimize the harvesting and logistic procedures of SRC management, and if possible, to identify ways to improve the machinery employed in the harvesting operations.

With regard to the self-propelled cutter-chipper systems in the combinations Class/GBE1 and New Holland (perhaps also Krone/Hüttmann, which we have barely documented), we are positive that they are running in a reliable way. The standard technology for harvesting corn has been adapted to harvesting SRC material, a solution that appears to function well in these cases. With regard to the tractor-pulled cutter chippers the situation is different. Here, the systems we were able to document did not function in a satisfying way, or, as the JF Z 20, were only applicable to small dimensioned trees. The problem with the Schmidt-chipper was not only its liability to jamming and technical breakdown, but also that the wood chip quality was not suited for commercial use. This was largely due to the working principle of the screw chipper that produced many pieces with over-length (see data of WP3). Thus, the situation with regard to tractor-pulled chipper systems is unsatisfying, although a functioning aggregate would be desirable as it might reduce the working costs in comparison to forage harvesters. One solution that we would recommend is to reconstruct the tractor-pulled cutter chipper in such a way that is based on a drum chipper system. This is precisely what the Schmidt GmbH has now developed in collaboration with Jenz GmbH, a leading company with a long experience in the field of chipper construction. This chipper has only been demonstrated a few times in 2012, and we have so far not been able to document its performance. With regard to forest machinery, the productivity of the Ponsse Buffalo Dual system, which consisted of a combination between a feller-buncher system and a forwarder, ranked in similar dimensions as when a feller-buncher and a forwarder are used separately. However, it proved to be an advantageous solution because only one machine is needed to perform the activities instead of two, which results in lower machine transportation costs, less planning of appointments, and less soil compaction. Hence, the innovative system used at Alfdorf seems to constitute a recommendable improvement.

Nevertheless, SRC is not always profitable and the risk of mismanagement needs to be avoided. An optimized planning of the envisaged SRC management is of crucial importance. It should always be designed to fit the individual plantation and take the availability of harvesting machines into account. However, as a broad rule, we propose considering the scheme presented below (Figure 44) as a guideline to decide whether the establishment of SRC is recommendable or not. Several authors have identified shortage of water as the main factor that limits SRC biomass production (e.g., MURACH *et al*., 2008; RÖHLE *et al*. 2010). Hence, establishing SRC plantations on marginal sites with a low water availability can in general not be recommended. However, SRC can be established on fields that are regarded as marginal because of a soil water content that renders the growth of annual crops critical. But also here, it should be taken into account that harvests with forage harvesters and other heavy machinery can become problematic on non-frozen soils. In particular, the woodchip-filled trailers can produce deep tracks in soft and moist soil, which can destroy the soil surface of a SRC plantation and terminate a harvest. Due to the tight time schedule of the service providers which usually don't allow waiting for a frost period to come, this danger can hardly be avoided. These risks can be avoided by planting SRC aimed at longer rotation periods which can be harvested with forest machinery or motor-manually – ideally, by in-house efforts. Depending on the planned use of the biomass, different times of the harvesting season are also recommended. For example, material that is harvested for use in the same winter season should be harvested early when the demand for raw material is high, e.g. in November and December. Material that is harvested for a use in the following season should be harvested at the end of the season, e.g. in February or early March, to avoid negative influences on the biomass quality due to a prolonged storage during the winter months.

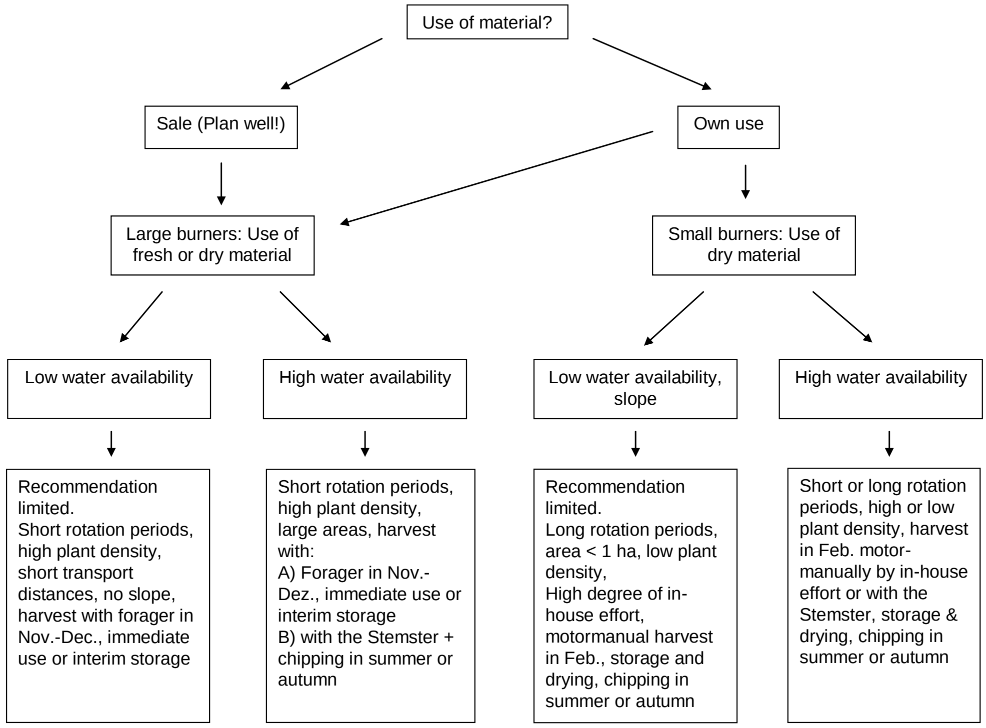


Figure 44: Guideline and decision scheme for the establishment and the harvest of SRC on (marginal) field sites (see text).

4.2.3.3 The German harvest calculation tool "KUP-Ernteplaner"

To provide the possibility for a more in-depth planning, we developed a new and detailed calculation tool which is mainly based on the findings of our field studies, the *KUP-Ernteplaner* [SRC-harvest-planner; see Annex 2.2 for the electronic version of this report]. This practice-orientated tool allows entering site specific characteristics, and thus, it generates a sound estimation about the expected production costs and margins for the woodchips based on individual requirements. Several calculation tools which cover the entire range of the life cycle of a plantation have been developed in the recent years, but all are poorly equipped for the calculation of the most important and the most complex working step, the harvesting operations (e.g., the model developed in the project Agrowood, the model developed by the Bayerische Landesanstalt für Forstwirtschaft (LWF), or the *KUP Rechner* developed by the Landesanstalt für Entwicklung der Landwirtschaft und der ländlichen Räume). The *KUP-Ernteplaner* fills this gap and can be easily handled by its users. Basically, it consists of three sheets in which key figures need to be entered: The sheet *Ertragsschätzung* [Estimation of yield] for estimating the amount of biomass stocking on the field and the approximate time required for the harvest, and two sheets for calculating the harvest itself. The user can choose between a sheet that calculates harvests performed with cutter-chippers, *Hackgutlinien* [Wood chip lines], and another sheet for harvests in which the harvest and the chipping is performed separately, *Ganzbaumlinien* [Whole tree lines]. In both sheets, the expected costs for the harvest are displayed both numerically and graphically. Among others, key parameters that need to be entered in the sheets are the following:

Ertragsschätzung: Field size, type and age of plant material, the quality of the soil / the water availability

Hackgutlinien: Transport costs for the harvester, type of the harvester, type of transport units for the biomass, driving distance from the field to the destination, largest stem diameter of the trees at cutting height, potential costs for storage and a second transport of the biomass from the primary destination to the end user, and the expected price for the woodchips.

Ganzbaumlinien: Transport costs for the employed machines, type of machine used, largest stem diameter of the trees at cutting height, cost for the chipper, type of transport units for the biomass, driving distance from the location of the chipping to the destination of the wood chips, and the expected price for the woodchips.

The instructions about how to handle the tool are contained in the sheet *Anleitung* [manual]. To perform the calculations, the *KUP-Ernteplaner* works with data and formulas contained in the sheets *Erträge* [yields], *Ernte* [harvest], *Transport*, and *Definierte Namen* [defined names]. These four sheets can not be changed by the user. In case the user would like to enter individual or more general input data, he or she can always enter such alternative values for all relevant positions on the three input sheets explained above (on these sheets, see input options written in blue font). The formulas operating in the background will then access these alternative values to perform the calculations.

Among the most important outputs, the *KUP-Ernteplaner* presents the following results (see Figure 45):

- The time required for the harvest
- The time required for filling a transport unit with chips, and for one cycle to unload and return a transport unit
- Costs of the machine transport, of the harvest, and of the biomass transport
- Costs for producing one t_{dm} woodchips
- Total harvesting and transport costs versus the margin gained from selling the biomass

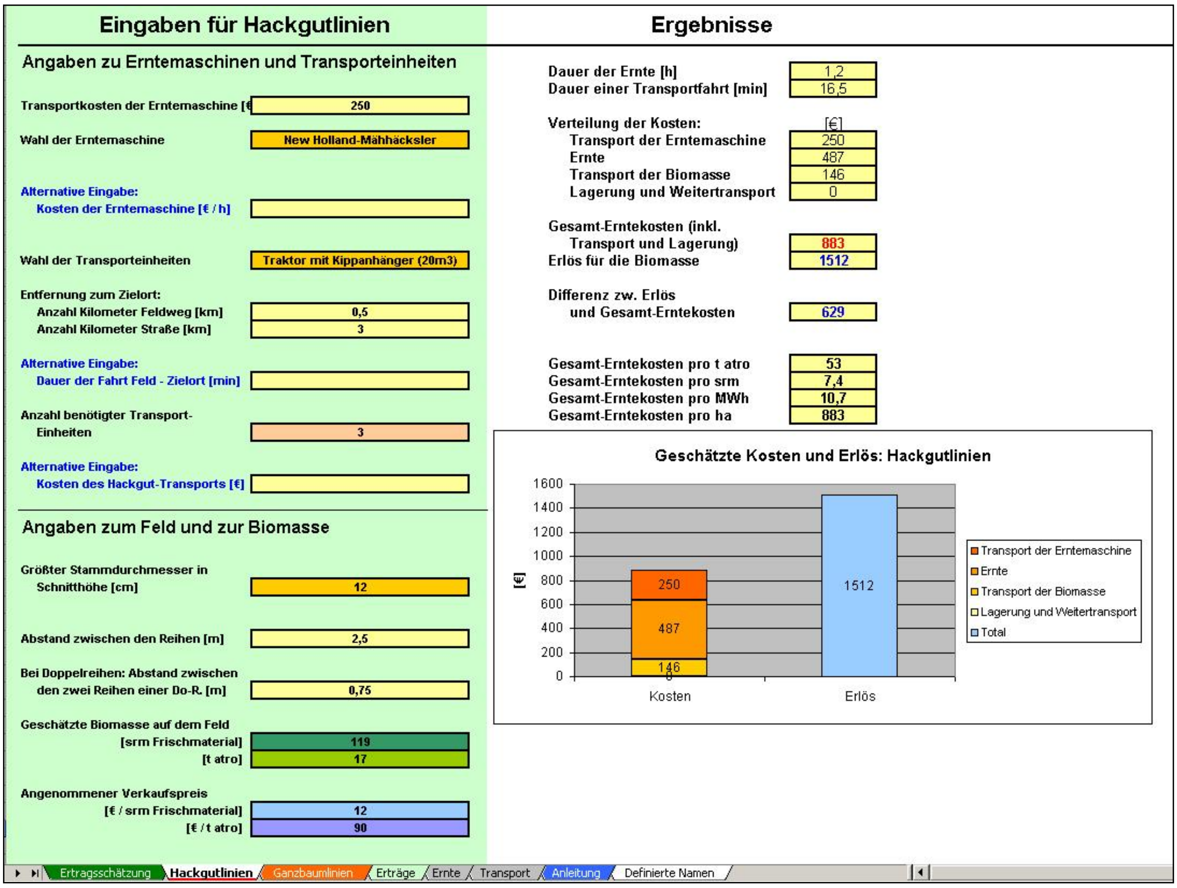


Figure 45: Screenshot of a part of the sheet *Hackgutlinien* of the KUP-Ernteplaner.

To keep our tool as detailed as necessary and, at the same time, as simple as possible, we have not included other costs that result from the establishment and the management for the field site. Yet, for a complete assessment of the costs involved managing a SRC-plantation, these costs will have to be considered in addition. Such costs can be estimated or calculated by using the already existing literature or calculation tools, and in the present context, by the scenarios of the cost model developed in CREFF by WP4 (see the respective section on this model by IER in this report).

Combining such models with *KUP-Ernteplaner* will provide a more complete picture of the entire production chain. Yet, KUP-Ernteplaner is important on its own. It fills a large gap and helps the practitioner 1) to plan harvesting operations on a specific field site based on a realistic scenario, 2) to see which parameters affect the calculations in which ways, and to find ways to reduce the expected costs, and 3) to consider in advance whether it would be recommendable to establish a plantation on a given field site. This is of particular relevance when considering establishing a plantation on marginal field site. For example, if the options “bad” or “very bad” water availability on the sheet *Ertragsschätzung* are chosen, the resulting margins will be comparably small or even negative. Even after repeated harvesting during a period of 20 years, it is possible that the overall monetary profit is very limited or that the overall marginal return will not cover the costs for the establishment, the maintenance and the recultivation of the SRC plantation. This is especially the case with the methods depicted in the sheet *Ganzbaumlinien*, which tend to be more cost-intensive than the cutter-chipper systems on the sheet *Hackgutlinien*. This reflects the above-given recommendation that SRC plantations of marginal field sites should best be managed in such a way that most activities are performed by the farmers themselves.

However, the KUP-Ernteplaner is not yet fully developed. The *Anleitung* [manual] needs to be written and a few improvements of calculations need to be implemented. The present version in the Annex should not be distributed. Yet, the tool will be finished by the end of March 2012.

4.2.3.4 German report

To increase the knowledge about SRC among practitioners and interested people in Germany, we have compiled a German report about the data presented already in section 4.2.3.2 *Documentation and evaluation of 28 time studies of harvesting (+ logistic) operations, 4 chipping operations, and 2 clearing operations*; see Annex 2.3. This report contains the tables shown in section 4.2.3.2, but also additional information about the field sites on which the operations were performed. Thus, it provides a representative overview on typical SRC sites and the parameters associated with harvesting. Moreover, it contains our recommendations for optimizing the SRC management and the harvesting as presented in section 4.2.3.2.4. The report will be spread to all farmers and partners who have collaborated in the CREFF project, and will also be disseminated via the electronic mail distribution system of the *Netzwerk Kurzumtriebsholz und Miscanthus* in Baden-Württemberg, and via the national platforms that concert and bundle information about SRC such as the *KUP-Netzwerk* coordinated at the TTZ in Bremerhaven.

4.2.3.5 Guidelines, Model WP4

Moreover, the basic findings of the WP2 of the CREFF project have already been included in guidelines such as the first French manual on the establishment and management of SRC (see Annex 0.1), and an update of a previous version of the guideline *Anlage und Bewirtschaftung von Kurzumtriebsflächen in Baden-Württemberg* (http://www.mlr.baden-wuerttemberg.de/mlr/bro/Kurzumtriebsflaechen.pdf). They were also included in the already mentioned model to describe different scenarios of entire process chains developed by WP4.

4.2.3.6 Harvest of Six Different Poplar Clones and a Regrowth experiment

By utilizing financial resources provided in the framework of the CREFF project, we were able to directly compare the yield of six different poplar clones that grow on the plantation Kraichtal 1. In 2008, the clones Hybrid 275, Max 1, Max 3, Max 4, Muhle Larsen and Spickermann were planted on a field with a rich soil that was previously used as corn field. The harvest was performed with the New Holland forager. The different clones were planted in alternating double rows and the biomass of each row was weighed after being harvested at the farm of the owner. Figure 46 displays the yield differences with Muhle Larsen and Hybrid 275 performing worst.

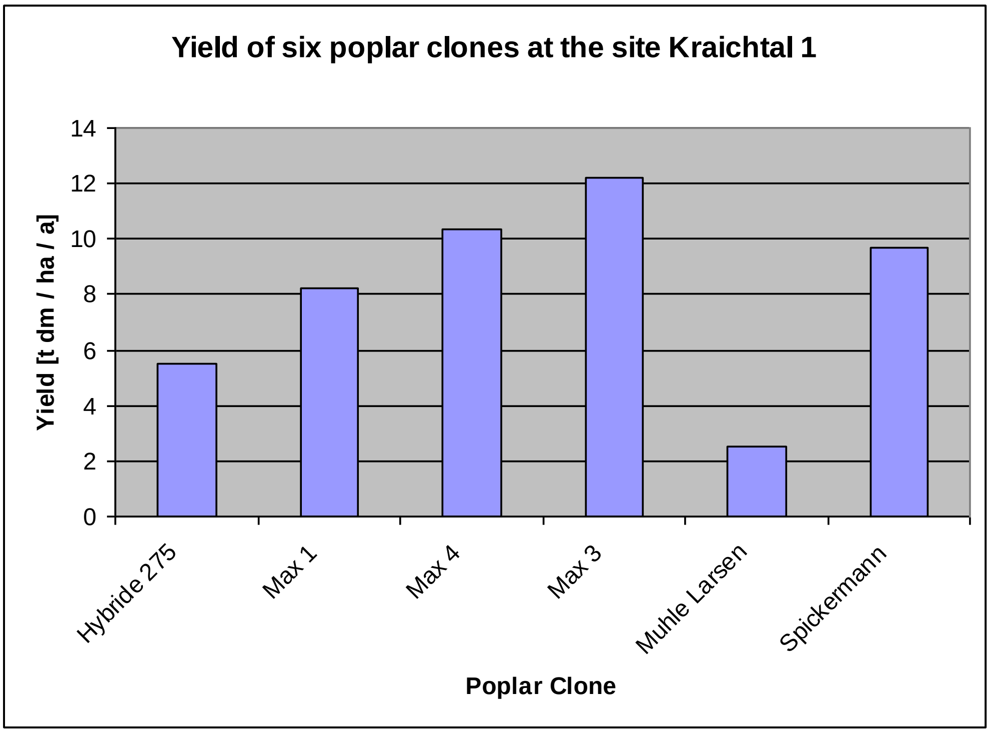


Figure 46: Biomass productivity of six poplar clones on the site at Kraichtal 1.

After the harvest, we performed an experiment in which the effects of different cutting methods on the regrowth of the different poplar trees was assessed. The stumps of the poplars were treated in three different ways:

1) Cut normally with the New Holland forage harvester and the 130 FB header at the harvest,

2) cut down to ground level with a chainsaw to produce a clean cut after the harvest, and

3) destroyed and split with an axe after the harvest.

Moreover, for the Max 4 clone, a fourth treatment was performed: The trees were cut by the New Holland harvester in on average 28.2 cm height, i.e. considerably higher than usual (average: 9.9 cm). The purpose of these treatments was to simulate four different harvesting methods:

- a “normal” cut from a forage harvester
- a clean cut as performed with a chainsaw
- a destructive cut of the trees as employed by the shredder technique of the BioBaler
- a normal cut from a forage harvester under conditions of a notable snow cover. In such cases, the trees are cut above the snow level. After thawing, the remaining stumps will have considerable heights as reflected in our fourth experimental variation.

From January to March 2012, we have determined the number of shoots per stock, the diameter of the shoots of a stock at breast height, the height of the longest shoot, and the rate of loss of the different clones and treatments. Our data indicate that the different modes of treatment have no effect the regrowth patterns of the stocks, not even the destructive variation (ANOVA analyses performed with Microsoft® Excel 2003 showed non-significant results). As an example, Figure 47 shows the height of the longest shoot of the stocks. Again, Muhle Larsen and Hybride 275 performed worst, ranging close to total loss, but the treatments seemed not to affect the clone-specific productivity. However, only very limited data were available for Hybride 275, and this particular set of data needs to be regarded with caution.

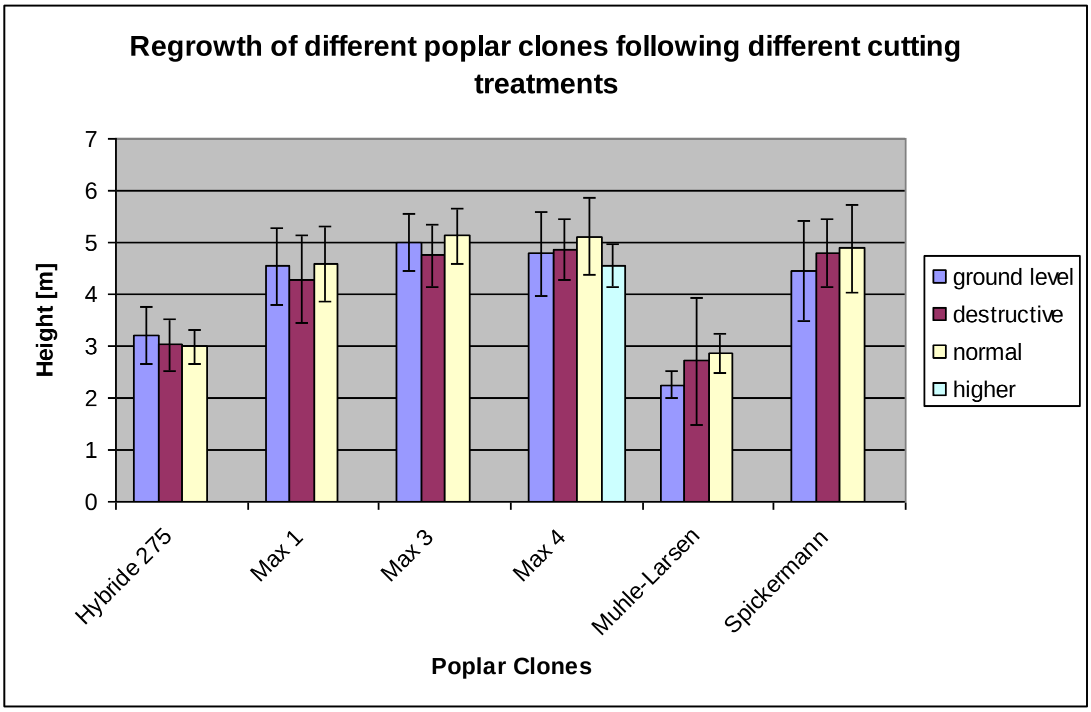


Figure 47: Shoot height of six different poplar clones that were cut in four different variations.

Hence, it can be inferred that also different kinds of harvesting technique will have very little or no effect on the vitality and the regrowth patterns of different poplar clones, at least during the vegetation period following the harvest. This finding seems to support previously heard assertions that the destructive harvesting variation as utilized by the BioBaler has no effect on the regrowth of harvested trees.

4.2.4 Cooperation with other projects, institutes, and results of cooperation

Throughout the running time of CREFF, the FVA has cooperated with a number of institutions, organizations, and projects.

The following corporations have helped in planning and documenting harvesting and clearing operations: Austria: Francisco Josephinum Wieselburg; Denmark: Ny Vraa Bioenergy I/S; France: INRA Orléans, AILE, and Cuma Breizh energie; Germany: Biovision Landschaft und Energie Gmbh & Co. KG, CNH Deutschland GmbH, Frank Gmbh, JVA Bettenreute, Landwirtschaftliches Lohnunternehmen Herbert Roth, Landwirtschaftliches Technologiezentrum Augustenberg (LTZ), Schellinger KG, Solarcomplex AG, and Viessmann Werke GmbH & Co. KG. We have worked in particularly close cooperation with the Institut für Forstbenutzung und Forstliche Arbeitswissenschaft at the University of Freiburg. A member of this institute, Janine Schweier, has also performed a number of time studies and we have exchanged information about harvesting operations and several data.

The following corporations have helped to spread news regarding CREFF and have invited Dr. Frank Brodbeck and Dr. Michael Nahm to give presentations about CREFF and harvesting techniques: Landwirtschaftliches Technologiezentrum Augustenberg (LTZ), and Netzwerk Kurzumtrieb und Miscanthus. The Institut für Waldwachstum at the University of Freiburg (IWW, Professor Dr. Heinrich Spiecker) has asked members of CREFF and ProBioPa at the FVA to organise two excursions to SRC plantations and to inform students about current research projects. These excursions were met with very positive resonance.

At the FVA, mutual contacts to the research projects “Biomasse aus Kurzumtrieb” and ProBioPa were especially valuable for contacting farmers and for obtaining different kinds of information about the status of SRC management in Baden-Württemberg.

In the process of writing the review paper *Holz aus Kurzumtriebsplantagen: Hemmnisse und Chancen,* which was initiated and written to a large extent in CREFF, we have collaborated with Prof. Dr. Albrecht

Bemmann from the Professur für Forst- und Holzwirtschaft Osteuropas at the Technische Universität Dresden.

In the process of establishing the pilot cooperations in WP5 of Creff, we have worked with GESA gGmbH in Wuppertal, and with Cosylval and UPM Stracel in the Alsace.

Our manifold collaborations have facilitated and deepened the assessments of our tasks in many regards. Most notably, they provided access to data and resources that would have not been accessible otherwise.

4.2.5 Shortcomings, obstacles, problems in the course of the project

Shortcomings: We could not perform as many harvesting operations as we had planned, in particular such harvesting operations with "unusual" harvesting technology, or harvests on soils of unfavorable quality, and harvests on slopes. Therefore, except for harvests on small-sized fields, the aspect of documenting harvests on marginal field sites seems underrepresented in our data stock. However, this result reflects the current state of SRC management in Central Europe. Not many SRC plantations have been established on unfavorable soils recently, and the trees on those that have been established take comparably long until they reach dimensions recommended for harvesting them. Thus, such plantations were not covered to the extent we had planned within the running time of CREFF.

Obstacles: The strong dependence of the harvests on the weather conditions made it difficult to plan trips to harvesting operations. Moreover, machines have broken down just before the planned activity. Hence, on several occasions, the harvesting, chipping and clearing operations were cancelled or postponed at short notice, sometimes only when we had arrived at the field. Yet, this a typical and inevitable obstacle associated with field work. Most notably, it constitutes an obstacle for farmers and for service providers who need to plan their activities well in advance and often have to follow a tight time schedule. However, there is little one can do against obstacles that are due to external factors. One way to reduce effects of adverse weather conditions for harvests is to avoid establishing SRC plantations that are to be harvested with fully mechanized systems on a sloped site or on a site that is known to be very wet during the winter season.

Problems: It turned out that the costs for the units used for optimized transport logistics are difficult to quantify. One can offer general theoretical calculations based on standardized data, but these standards are often of low value for the farmers and in practice. First, each farmer uses predominantly his own and often very old transportation equipment. Such transportation units are difficult to value in monetary assessments of involved production costs. Most farmers will not use and organize transport units that might in theory be better suited, because these units would cause additional costs compared to using own equipment. In addition, the used transport units contain usually different capacities, what results in even greater differences to establishing ideal transport chains. Moreover, each field site requires an individual approach. Among the parameters that determine the optimal choice of transport units are the form and the accessibility of the fields or their headlands, and the amount of biomass stocking on the fields. However, we have aimed at providing the practitioner with the best possible solution to plan the transport logistics of a given harvest. For this purpose, we have implemented appropriate input possibilities for individual plantations and site conditions in the *KUP-Ernteplaner*.

Despite these shortcomings, obstacles, and problems, it was possible to collect sufficient data to gain a representative overview on the current state of the art of applied SRC harvesting and logistic systems, and to develop recommendations and a tool for an improved use of these systems.

4.2.6 Discussion and conclusion

The wood chip production costs for the different harvesting systems obtained in WP2 of CREFF have confirmed the results of other authors. With regard to forage harvesters, our cost calculations fall in generally similar ranges, but were usually higher. For example, the mean value for woodchip production excluding transport units that we determined from 15 representative time studies of forage harvesters was 27.1 €/t_{dm}. However, KIENZ has calculated wood chip production costs of about 20 €/t_{dm} including the use of tractor-trailer units, BURGER (2007) has given 28 €/t_{dm} including transport costs for 20 km, HANDLER and BLUMAUER (2009) have reported woodchip production cost of 9-32 €/t_{dm} excluding the transport units, ECKEL *et al*. (2008) have reported about 10-20 €/t_{dm} wood chip production costs for forage harvesters without transport, and SPINELLI *et al.* (2009) have reported total harvesting costs including the transport of 11-35 €/t_{fm}, what would equate about 5-17 €/t_{dm}. In sum, the costs determined in CREFF lie slightly above the calculations of the other authors. This is partly due to different values used. For example, HANDLER and BLUMAUER (2009) have calculated with 320 €/h machine costs for the harvest with the Claas/GBE1 forager, whereas the current hourly costs for the new New Holland forage harvester is 400 €/h. Moreover, the time studies performed in Italy and Austria involved fields of higher productivity than most of the fields seen in CREFF, and the farmers had already gained enough experience to establish the fields and to organize the harvest in optimized ways. In addition, lower production costs can also be expected in the following rotation periods. In CREFF, the time studies performed with forage harvesters concerned almost exclusively fields in the first rotation, but biomass production is likely to increase after the first harvest. Finally, it appears that in practice, operations often take longer and can become more expensive than calculated, especially under suboptimal management and harvesting conditions. For example, VOIGTLÄNDER (2011) has calculated costs for two harvesting operations that amounted to 103.4 and 142.7 €/t_{dm}. Such disproportionate costs are obviously a result of plantation mismanagement, similar to our field Reinach 1. With appropriate establishment and management guidelines and the *KUP-Ernteplaner* at hand, the farmers are now better able to plan and organize their harvests. This is also valid for the alternative harvesting methods available. For example, the cutter-collecter Stemster was tested and documented in Germany for the first time in the framework of CREFF, the first reliable data about the modified sugar cane harvester JF Z 20 were collected in CREFF, and the first data for the feller-buncher/forwarder system were obtained in CREFF. Hence, we were able to provide significant information about harvesting techniques that are only rarely used at present, but which might become more important in future. However, with the exception of the JF Z 20, an aggregate of limited applicability, the full-mechanized harvesting systems are in general cost-intensive on fields with low biomass productivity, as can be expected on marginal field sites with low water availability. Apart from a more rational organisation of the harvesting operations, it is at present difficult to promote innovative ways by which the costs could be reduced in significant dimensions. Ideally, SRC plantations on marginal sites in Southern Germany should be closely located to the end user, and they should be managed in long rotation periods with as much work as possible being performed by in-house efforts, implying that the farmer sets aside calculating his and his familie’s own working time in monetary terms. However, it remains doubtful if many farmers will choose such an approach. Thus, it is likely that SRC material from sites with unfavourable properties will only be of very local significance, and will not play a major role in establishing pathways of renewable energy cycles under the current market conditions.

4.2.6.1 Unsolved problems and further scientific needs

Although the data obtained in CREFF have already allowed for formulating recommendations and for developing the calculation tool *KUP-Ernteplaner*, many questions still remain open at present. With regard to harvesting operations, unsolved problems and further scientific needs consist of the following issues:

- Document more harvesting operations on slopes and other critical site conditions typical for marginal field sites to substantiate the few data available.
- Document also more “usual” harvesting operations to determine the exact amount of biomass stocking on a field, and thus, to validate the biomass production model for SRC plantations developed in the BMBF-funded project ProBioPa at the FVA.
- Document new harvesting systems. The market for harvesting technology is very dynamic and several companies have announced to develop upgraded versions of their machines or entirely new systems. New harvesting systems need to be documented to stay up-to-date, to provide and spread relevant information about them, and to adapt the tool *KUP-Ernteplaner* to these developments.
- Document harvests of the second rotation period. Until now, almost all available data on harvests concern harvest of the first rotation period. Yet, it can be assumed that the productivity and the costs of the subsequent harvests will often differ considerably from these first data. In particular, it can be expected that the biomass productivity will be greatly enhanced on at least some plantations after the first cut. At present, the *KUP-Ernteplaner* calculates these supposed changes in the biomass productivity of SRC trees based on general assumptions. Moreover, the regrown shoots often display a lateral outgrowth at their base, what might affect the workflow of harvesting aggregates. Therefore, potential effects on the productivity of the harvesting aggregates need to be evaluated as well.

With regard to the regrowth of stocks after harvesting, the following issues should be addressed:

- Replication of the experimental treatment of the stocks of SRC trees that we have performed with six clones of poplars. Additional kinds of plants should be tested to determine potential effects of the different harvesting methods, especially willows. With regard to the experiment performed at Kraichtal 1, the ongoing documentation of the development of the growth patterns will be valuable to trace potential after-effects of the different cutting methods applied, such as the stability of the stock architecture or fungi infections.

Moreover, we recommend to interview the farmers who had harvested SRC plantations during the last seasons about their experiences and opinions about SRC management and harvesting. Were they satisfied with the wood chip quality, would they recommend establishing SRC, would they recommend the harvesting system they had used? Such information from the practitioners is of great importance for a practice-orientated evaluation of SRC management and would complement the now existing data in crucial respects.

4.3 Work Package 3 - Value added Conditioning of SRC raw material

4.3.1 State of the Art

4.3.1.1 Material utilisation

4.3.1.1.1 Substantial utilisation

In the last years the most important substantial utilisation form of SRC material is fibre and ground wood pulp production of the paper and pulp industry (KIRCHBAUM 2008; GEROLD, D. et al. 2009). Another utilisation path the use of SRC raw material for derived timber production purposes e.g., particle boards (GEIMER & CRIST, 1980). Primary production precondition is the use of SRC stem assortments with a sufficient diameter size (> 7 cm). Poplar in wide space planting is thereby the most commonly used species for those purposes. Applied rotation period is mostly between 10-20 years. Harvesting is done with forest machinery for bigger dimensions (GEROLD, D. et al. 2009). Production results for paper are satisfactory, but showed some mechanically processing problems for example during the process of debarking or pulp composition which lead to lower opacity and tensile strength, which resulted to a reduction of the poplar raw material share of around 1-30 % in some production facilities (KRICHBAUM, 2008). Results for particle boards show no relevant restrictions, even under consideration of the high bark content of up to 29 % (GEIMER & CRIST, 1980).

4.3.1.1.2 Energetic utilisation

Caused by rising prices for fossil energy and a changing energy politics in the last years, the demand for renewable solid biofuels is rapidly growing. Especially heat production by thermal conversion is consuming a majority of the available renewable solid biomass fuels (MANTAU, 2010; DBFZ, 2009). A big share of the necessary solid biomass is provided by wood chips out of several sources. In contrast to substantial use, the round wood quality (shape, and stem defects) or shares of branches or bark are of lower importance. Due to cogeneration the supply with sufficient wood fuel for energetic installations is of huge importance not only during the heating period but also throughout the whole year. Possible utilization paths are the thermal and/or electrical conversion by combustion, pyrolysis and gasification through stoves, boilers and CHP (Combined Heat and Power) installations of different sizes and type. Studies on willow show for most burner systems an admixture of 10-15 % to the standard raw material carries only low risks of slag formation (HJALMARSON & INGMAN, 1998). Several burner systems are running with up to 100 % admixture without any signs of technical problems, whilst others show signs of early ash melting and coat formation e.g., in the cyclone inlet pipe (MYRINGER et al., 2009; VICTORÉN, 1991). Another fast growing utilization path for SRC material is the pellet and briquette market (HIRSMARK, 2000; NÄSLUND, 2003).

4.3.1.2 Material properties and conditioning by storage

After harvest of SRC material in form of chips or whole shoots, in many cases the material has to be conditioned by a natural storage process or by technical drying, in order to condition the initial water content to a level, which is suitable for different utilisation paths. Aim of this process can be quality preservation and quality improvement in order to provide a storable product of high quality throughout the year. Following storage and drying processes for SRC wood chips are possible. At the basis of an intensive literature study, WP 3 identified the important factors, which have an influence on the quality of SRC material during a storage process. Those factors can be categorised in outside and inside factors. Outside factors include the characteristics influenced by site and harvesting process. In addition to that, the local climate does have an important influence on storage result (e. g. rain, wind, insulation, temperature and air humidity). The factor plantation management comprises the influences of various variables, for instance spacing, treatment, rotation, harvesting method and harvesting time on the material quality and the final storage result. Against that inside factors describe the variables, which influence the material quality and storage result by storage management processes like pile size, storage type, storage duration and more. Decision which storage type will find appliance is in the first place determined by harvesting technique. This will either provide chips, whole shoots or in case of bigger dimensions stem assortments. After harvesting the material is directly transported to a consumer, or is stored in one of the above mentioned ways (Figure 48).

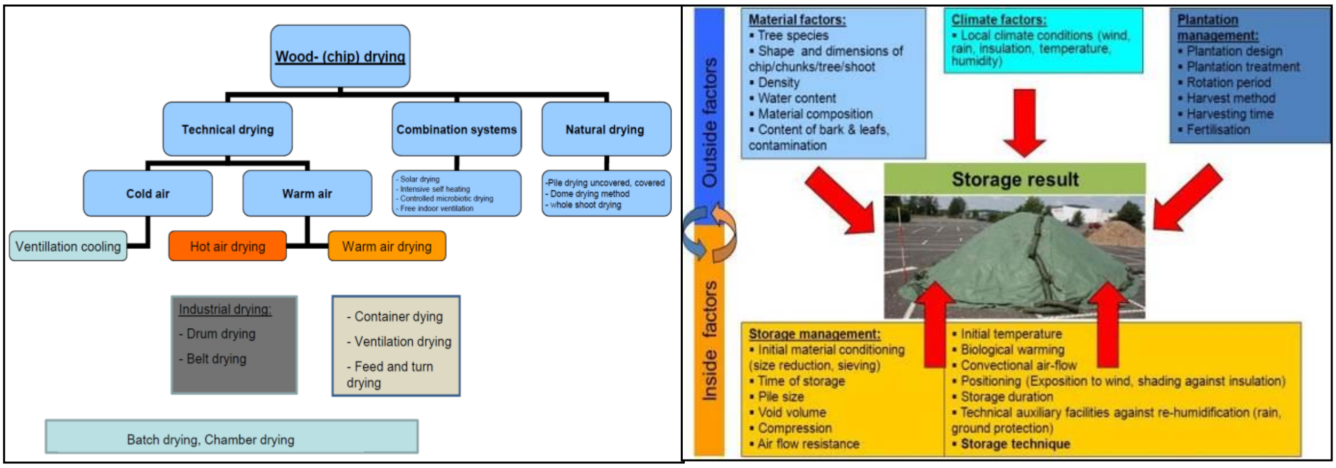


Figure 48: a) Overview on possible drying techniques for SRC wood chips b) Illustration of the „outside" and „inside" factors, affecting material quality and storage result

In case where material is stored using natural drying methods, it has to be prepared in covered or uncovered chip heaps, either with or without an air ventilation system (e. g. dome-drying-method) or whole shoot piles. Higher dry matter losses can be expected in case of high water content as well as high shares of fines, green matter, small chip sizes and non ideal storage heap size time and duration (SCHLOZ & IDLER, 2005; GOLSER et al., 2005; THÖRNQVIST, 1985).

Most important indicator, for the overall evaluation of storage success is the comparison of water reduction from storage start to end and occurring dry matter losses. Reason for the high dry matter losses within wood chips piles are an increased biological, physical and chemical decomposition activity (JIRJIS & THELANDER, 1990; THÖRNQVIST, 1985). A sign for zones of high decomposition processes can be high temperature zones within the heap. Heat is generated by chemical oxidation and pyrolysis, respiration of living wood cells, metabolism activity of microorganism and by hydrolyses processes through moisture adsorption (BLOMQVIST & PERSSON, 2003). Most important factors for microbiological decomposition are amongst others moulds and several wood-decaying fungi. Due to their metabolic activity organic matter is consumed through aerobic degradation into water and carbon dioxide. Especially cellulose, hemicellulose but also minimal shares of lignin are degraded. As found by LEHTIKANGAS (1998), microbial processes occur up to 60 °C but decline at higher temperatures. Produced heat can accumulated in large and compacted piles. Outside zones close to surface show lower temperature, caused by more intensive cooling, inner zones show with high decomposition activity show high temperatures. A chimney effect, which can be a driving force for material drying, is caused by temperature and vapour pressure (HOGLAND & MARQUES, 1999). Moisture is moving from heaps centre to outer zones, where the saturated air condensates. This effect leads to unequal water content allocation in the heap, creating a dryer inner zone and a wetter outer zone, often called condensation horizon (Figure 49). Spores of moulds are important from a work hygienic and overall health perspective, as they can be hazardous to health when inhaled in higher concentrations (NELLIST et al., 1991; BRUNNER & OBERNBERGER, 1997; KIRSCHBAUM, 1998, SPIKERMANN, 1999; THÖRNQUIST & LUNDSTRÖM, 1982).

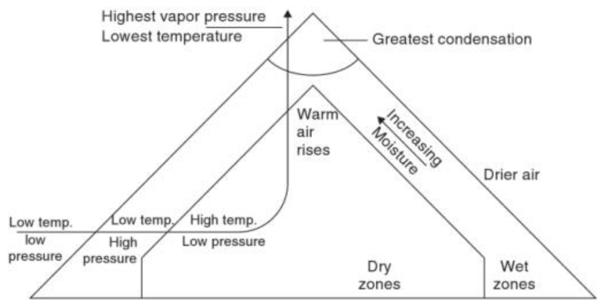


Figure 49: Chimney effect in storage piles (CURTIS, 1980)

4.3.2 Specific goals

Within the WP3 the main objective is to identify and characterize the quality parameters of wood material from short rotation coppices (SRC) of small field sizes and under unfavourable site conditions. Thereby a strong emphasis is given to the customer needs of the energy sector; including quality management aspects leading to a quality based best practice decision support system for SRC material.

Actual and potential consumers of SRC products have an increasing demand for material of high quality. With respect to these facts, WP3 considers the special expectations of storage and conditioning. In a further task, the simulation of storage under laboratory conditions will be playing a major role in the planning and implementation of a storage simulation device, which will allow the simulation of various options of storage by varying the feedstock and the relevant parameters as well under controllable and reproducible microclimatic conditions.

In order to obtain detailed information about industrial user oriented technical and economic framework requirements, experiences and constraints concerning SRC material, WP3 conducts a detailed online based survey.

Finally productive and efficient storage technologies are identified. Therefore storage trails at facilities of different industrial partners and farmers are performed while for selected cases the inner and outer metrological conditions are monitored.

The scope of WP3 is summarised in four main task groups:

Task 1: Material analysis and evaluation methods for quality parameters characterising important end product requirements

Task 2: Designing of a device to simulate the behaviour of different wood chips under diverse microclimatic scenarios

Task 3: User oriented detection of technical and economic framework requirements, experiences and constraints concerning SRC material for the identification of productive and efficient technologies and strategies

Task 4: Identification and development of best practise methods for storage and conditioning by implementation of pilot studies at industrial installations. Description and conclusions of effectiveness and efficiency of different storage technologies

4.3.3 Activities and Results

4.3.3.1 Material and methods (Activities)

Material analysis and evaluation methods for quality parameters

4.3.3.1.1 Material analysis of physical and chemical properties

Within this task, methods for the identification of quality key parameters for SRC material have been identified. As a common standard for the biomass analyses for all the different parameters, WP 3 is currently using the European standard catalogues. The classification of SRC material refers to the European standard CEN/TS 14961. This norm catalogue characterises the different basic raw materials of wood chips and other organic combustibles.

Within this standard catalogue SRC materials can be categorises under the topic of “full tree” (above ground tree biomass) material from SRC as well as stumps from SRC.

Beside the combustible specifications the standard describes classifications, definitions and the testing procedures for the acquisition of parameters.

Amongst others the quality parameters of special importance are water content, ash content, particle sizes, bulk density, heating value and contaminations. Quality control has to take into account these parameters.

In order to characterise SRC material for an energetic and/or substantial end use, it was necessary to assess and identify the characteristics of SRC material in some basic parameters.

WP 3 (in collaboration with WP 2) obtained SRC material samples as far as possible from accompanied harvesting operations. Sample drawing, sample preparation and parameter analysis were and are done in dependence on the described European standard catalogues.

Table 11: List of accompanied harvests and harvesting characteristics and abbreviations

Species	Clone	Stand age at harvest	Comments	Chipper type	Location of harvest	Date of harvest	Short sample describtion
Wood chips							
Poplar	Max 3	15	Stem wood	Eschelbök, Biber 7	Bettenreute (D)	17.11.2009	**Be, Max 3 (Sth), 15 J.**
Poplar	Max 3	15	Branch wood	Eschelbök, Biber 7	Bettenreute (D)	17.11.2009	**Be, Max 3 (Asth), 15 J.**
Poplar	AF 2	2	n. C.	Claas Jaguar, header GBE - Biomass Europe	Fohnsdorf (A)	26.11.2009	**Fo, AF 2, 2 J.**
Poplar	Monviso	2	n. C.	Schmidt Wood-chipper	Fohnsdorf (A)	26.11.2009	**Fo, Monviso, 2 J.**
Poplar	Max clones	2 to 3	Mixed clones	Claas Jaguar 870	Allendorf (D)	09.03.2010	**Al, Max Misch., 2-3 J.**
Poplar	Max 4&5	3	Mixed clones	John Deer forage harvester 7500, CRL header	Engen (D)	12.02.2011	**En, Max 4&5, 3 J.**
Poplar	Max 4&5	3	Mixed clones	Eschelbök, Biber 70	Engen (D)	12.02.2011	**En, Max 4&5, 3 J.**
Poplar	Max 4&5	2	Mixed clones	Schmidt Wood-chipper	Engen (D)	12.02.2011	**En, Max 4&5, 2 J.**
Poplar	Max 3	3	n. C.	New Holland forage harvester FR 9000, 130 FB	Neuenbrüg (D)	25.03.2011	**Ne, Max 3, 3 J.**
Poplar	Spickermann	3	n. C.	New Holland forage harvester FR 9000, 130 FB	Neuenbrüg (D)	25.03.2011	**Ne, Spickermann, 3 J.**
Poplar	Max 4	3	n. C.	New Holland forage harvester FR 9000, 130 FB	Neuenbrüg (D)	25.03.2011	**Ne, Max 4, 3 J.**
Poplar	Max 1	3	n. C.	New Holland forage harvester FR 9000, 130 FB	Neuenbrüg (D)	25.03.2011	**Ne, Max 1, 3 J.**
Poplar	Muhle Larson	3	n. C.	New Holland forage harvester FR 9000, 130 FB	Neuenbrüg (D)	25.03.2011	**Ne, Muhle Larson, 3 J.**
Willow	Tordis	3	n. C.	New Holland forage harvester FR 9000, 130 FB	Bad Schussenried (D)	10.03.2011	**Ba, Tordis, 3 J.**
Willow	Tordis	3	n. C.	New Holland forage harvester FR 9000, 130 FB	Degernau (D)	11.03.2011	**De, Tordis, 3 J.**
Willow	Inger	3	n. C.	Claas Jaguar, header GBE - Biomass Europe	Fohnsdorf (A)	26.11.2009	**Fo, Inger, 3 J.**
Willow	Tordis	4	n. C.	JF Máquinas Agricolas 192 Z6	Merscheid (L)	26.02.2010	**Me, Tordis, 4 J.**
Willow	Tordis	3	n. C.	Laimet HP-21	Steinbach (D)	23.02.2011	**St, Tordis, 3 J.**
Willow	Tordis	3	n. C.	Jenz HEM 561	Steinbach (D)	23.02.2011	**St, Tordis, 3 J.**
Willow	Tordis	3	n. C.	John Deer forage harvester 7500, CRL header	Steinbach (D)	23.02.2011	**St, Tordis, 3 J.**
Willow	Tordis	3	n. C.	New Holland forage harvester FR 9000, 130 FB	Reinach (CH)	24.03.2011	**Re, Tordis, 3 J.**
Willow	Inger	2	n. C.	JF Máquinas Agricolas JF Z 20	Tystrup (DK)	19.01.2011	**Ty., Inger, 2 J.**
Poplar, Birch	natural rejuvenation	2 to 8	poplar 10 %, birch 90 %	Eschelbök Biber 80	Wuppertal (D)	21.04.2010	**Wu, Misch, 2-8 J.**
Whole shoots/Stems							
Poplar	Max 1-4	3	Mixed clones	Nordic Biomass Stemster II	Haine (D)	09.12.2010	**Ha, Max 1-4, 3 J.**
Poplar	Japan 105	9	n. C.	Ponsse Buffalo Dual EH 25	Alfdorf (D)	18.02.2011	**Al, Japan 105, 9 J.**
Poplar	Max 4	6	n. C.	Motor manual	Gäufelden (D)	11.03.2011	**Gä, Max 4, 6 J.**
Willow	Inger	3	n. C.	Nordic Biomass Stemster II	Buggingen (D)	15.02.2010	**Bu, Inger, 3 J.**
Willow	Inger	2	n. C.	Nordic Biomass Stemster II	Buggingen (D)	15.02.2010	**Bu, Inger, 2 J.**
Willow	Tordis, Inger	2	Mixed clones	Motor manual	Gengenbach (D)	01.02.2011	**Ge, Tordis & Inger, 2 J.**

For a detailed description of the conducted analysis steps please see annex 3.1

4.3.3.1.2 Design of a simulation device

The determination of the quality parameters emerged as an important preliminary work for the development of a lab scale device for the simulation of storage processes of SRC material. Within this working task WP 3 exceeds the grants demanded task.

After an intensive planning and design process leading to the theoretic development concept, WP 3 took actions for the actual realisation of the simulation device, including the necessary measurement-, data collection- and steering- technology.

Planning and construction processes are illustrated in the results

4.3.3.1.3 Scientific approach of the empirical study

Target groups are illustrated by Figure 50 and 51 are divided into the main groups of energetic and substantial users for SRC material. Within these groups the active use of SRC material is not obligatory but is classified within the questionnaire.

The questionnaire focuses on companies in Germany, but includes some exceptions by taking into account some companies from Austria. The used language for the questionnaire is German.

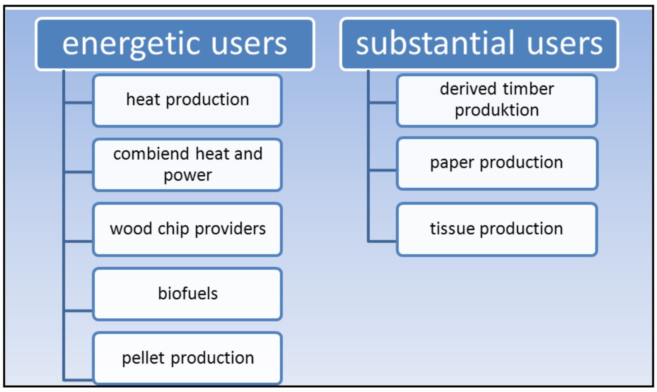


Figure 50: Target groups for online questionnaire divided in energetic and substantial users

4.3.3.1.4 Survey design and procedure

One aim of the study is to obtain representative inclusion coverage for the semi- quantitative approach of the questionnaire. Therefore it is important to collect an adequate number of relevant company's for the sample.

Against the background of experiences from other studies (WEBER 1997, HOFMANN 2010) it is necessary to aim for at least 100 evaluable replies of the questionnaire to gain statistical evaluable data. An arithmetical calculation of the necessary average sample number was not possible because of the high amount of different criteria and attributes. Based on the experiences for above mentioned studies, it was necessary to interrogate at least 200 to 300 different companies. Therefore it was essential to identify and inform a substantial amount of different companies to create a detailed distribution frame. Distribution frame been created for companies and for relevant organisations like communities regarding all the target groups mentioned above. In addition several organisations where directly contacted to assure the distribution of the questionnaire within their members.

Figure 51 shows some of the announcements the organisations published.

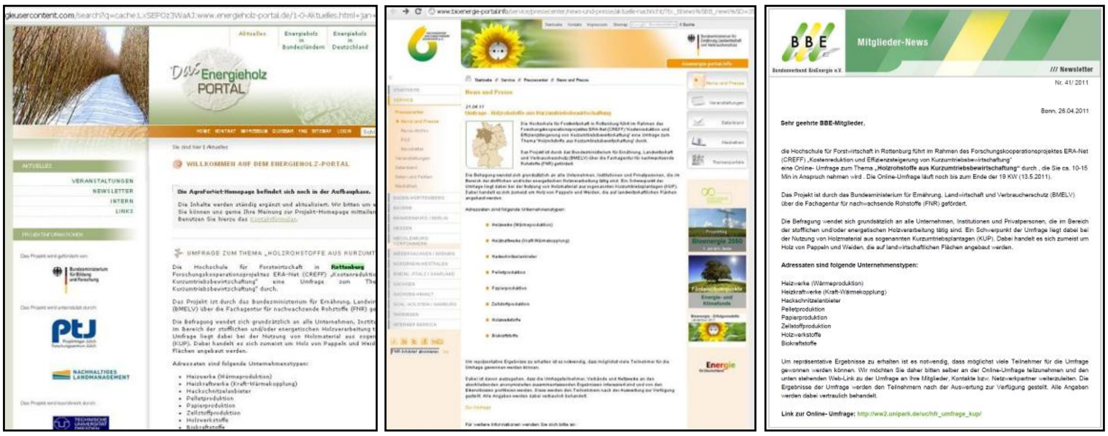


Figure 51: Exemplary announcements for questionnaire of organisations in the bioenergy sector

The distribution frame, which was used to directly contact companies in the field of energetic and substantial wood utilisation, contained over 1300 companies.

4.3.3.1.5 Question design and used software

In a first step the questionnaire was developed.

Mayor topics are:

- General data of company and production
- Type and utilisation of standard wood raw material
- Storage and condition processes
- Experiences and expectations with and around SRC material
- Quality management for wood raw material

In form and content the questions were constructed using state of the art scientific terms and referred to the current norms for solid wood material.

Questions have been designed in a multiple choice form. Some questions allowed the active weighting of different aspects and the chance to add customised attributes to the questions context.

After each main topic the participant had the chance to write their summarising statement.

In the next step the questionnaire was transferred to the internet based software EFS Survey of the company Globalpark AG. It was identified as the best possibility to achieve the different objectives of the questionnaire and offered a brought variety of questions types and interlinkages between the questions. For example it was possible to guide the participant to the questionnaire depend on the answers they gave. This prevented the participants to fill in not necessary questions for their case (e.g., no active SRC users).

Figure 52: a) Example for a multiple choice question b) Question type with integrated factor weighting and free input options

After the data input, the software created an internet address where the questionnaire was accessible by the participants. After a preliminary introduction page, which describes the purpose of the study the questions start by showing one question at each browser window. The overall progress of the questionnaire was illustrated by a percentage scale at the upper part of each question (Figure 52).

In order to statistically evaluate the questions, only answers from participants were taken into account, which have finished the whole questionnaire.

The final data could be transferred to different Excel or SPSS data formats or could be shown in an online analysis.

Pre-test of first draft and final procedure

The first draft of the questionnaire underwent a pre-test phases to check the information distribution for the participants, different interlinkages of the questions and to test the data logging and data output performance of the software. Therefore 12 experts in the field of wood chips utilisation took part in the pre-test. As a result of a number of questions were restructured and clarified.

The online questionnaire was started at 18.04.11 and finished at the 18.06.11 with sufficient rate of return (see results). Data examination is conducted with Microsoft EXEL.

4.3.3.1.6 Best practise methods of storage and conditioning - pilot studies

In the context of this working task WP3 conducts 10 different pilot storage trails at eight different locations respectively seven partners. After an intensive initial preparation and planning process the trials have been established in cooperation and support of the partners. The storage was conducted directly after harvesting. In the process WP3 established four storage trails of uncovered whole shoot/stem segments and six storage trails of wood chips, which were uncovered, covered, or stored under roof. Figure 53 shows the locations of the different storage trails and two exemplary harvests.

Table 12 illustrates the characteristics of the conducted storage trails.

Figure 53: a) Locations of storage trails in middel-/south Germany b) Example of whole shoot harvest with Stemster from Biomass Europe c) Example for prepation of storage chip material with forage harvester from New Holland

Table 12: Characteristics of wood chips and whole shoot/stem storages (n.c.= not conducted)

Species	Clone	Stand age at harvest (years)	Comments	Chipper type (for whole shoots after storage)	Location of storage	Storage specifics	Storage duration (days)	Short sample describtion
Wood chips								
Poplar	Max clones	2 to 3	Mixed clones	Claas Jaguar 870	Allendorf (D)	TOP TEX covered (40 m³)	129	**Al, chips covered, poplar, 2-3 J.**
Poplar	Max clones	2 to 3	Mixed clones	Claas Jaguar 870	Allendorf (D)	not covered (40 m³)	129	**Al, chips not covered, poplar, 2-3 J.**
Poplar	Max 4&5	3	Mixed clones	John Deer forage harvester 7500, CRL header	Storzeln (D)	under roof, ventilated disc. (200 m³)	57	**St, chips u. roof, poplar, 3 J.**
Willow	Tordis	3	n. C.	New Holland forage harvester FR 9000, 130 FB	Krauchenwies (D)	TOP TEX covered (80 m³)	151	**Kr, chips covered, willow, 3 J.**
Poplar, Birch	natural rejuvenation	2 to 8	poplar 10 %, birch 90 %	Eschelbök Biber 80	Wuppertal (D)	TOP TEX covered (40 m³)	174	**Wu, chips covered, birch/poplar, 2-8 J.**
Poplar, Birch	natural rejuvenation	2 to 8	poplar 10 %, birch 90 %	Eschelbök Biber 80	Wuppertal (D)	not covered (40 m³)	174	**Wu, chips not covered, birch/poplar, 2-8 J.**
Whole shoots/Stems								
Poplar	Max 1-4	3	Mixed clones	Jenz HEM 581Z	Haine (D)	not covered (hight 3 m)	127	**Ha, whole shoots, poplar, 3 J.**
Poplar	Japan 105	9	n. C.	JENZ HEM 561	Alfdorf (D)	not covered (hight	205	**Al, stems, poplar, 9 J.**
Willow	Inger	3	n. C.	Wüst CH-3537 Eggiwil, Typ HD 810	Buggingen (D)	not covered (hight 3 m)	191	**Bu, whole shoots, willow, 3 J.**
Willow	Inger	2	n. C.	Wüst CH-3537 Eggiwil, Typ HD 810	Buggingen (D)	not covered (hight 3 m)	191	**Bu, whole shoots, willow, 2 J.**
Willow	Tordis, Inger	2	Mixed clones	Wüst chipper	Gengenbach (D)	not covered (hight 3 m)	105	**Ge, whole shoots, willow, 2 J.**

Aims of the pilot storage trails:

- Implementation of pilot storage trails in context of storage and conditioning of SRC material (for wood chips and whole shoot bundles)
- Identification of storage-, conditioning techniques and processes with high efficiency, heading for an increased product/material quality of SRC material
- In case of the storage trails with chip piles, which are covered respectively uncovered with a TopTex fleece the differences in material quality should be brought into focus
- Investigation of physical and chemical key properties, before and after the storage
- Comparison of results from the different storage types
- Taking into account the requirements of the energetically and substantial users of SRC raw material

Following properties and parameters are analysed:

Table 13: Determined parameters during the storage processes

Determined parameters before and after storage	Continuously logged parameters during storage
Moisture content	Temperature development (for selected cases)
Dry matter loss	Air humidity inside and outside (for selected cases)
Bulk density	
Particle size distribution	
Calorific value	
Ash content	
Ash melting behaviour	
Elementary composition	
Mayor wood components (for selected cases)	

4.3.3.2 Results of activities and Discussion

4.3.3.2.1 Material analysis

The following results show the aggregated results of physical and chemical material properties.

4.3.3.2.2 Physical properties

Bulk density

As Figure 54 and Figure 55 show the average bulk density for willow and poplar at delivery respectively at time of harvest, are slightly at the same level with 301 kg/m³ and 307 kg/m³ for poplar and willow. Nevertheless the maximal and minimal values for willow are 363 kg/m³ and 260 kg/m³. Values for willow differ from 390 kg/m³ to 176 kg/m³. On the other hand the results of the water free bulk density comprise the effects of the high water content within the chips. The average values for poplar and willow are 115 kg/m³ and 143 kg/m³ with partial strongly variable values. For all cases the used chipping technology and referring chip sizes were of mayor importance for all samples.

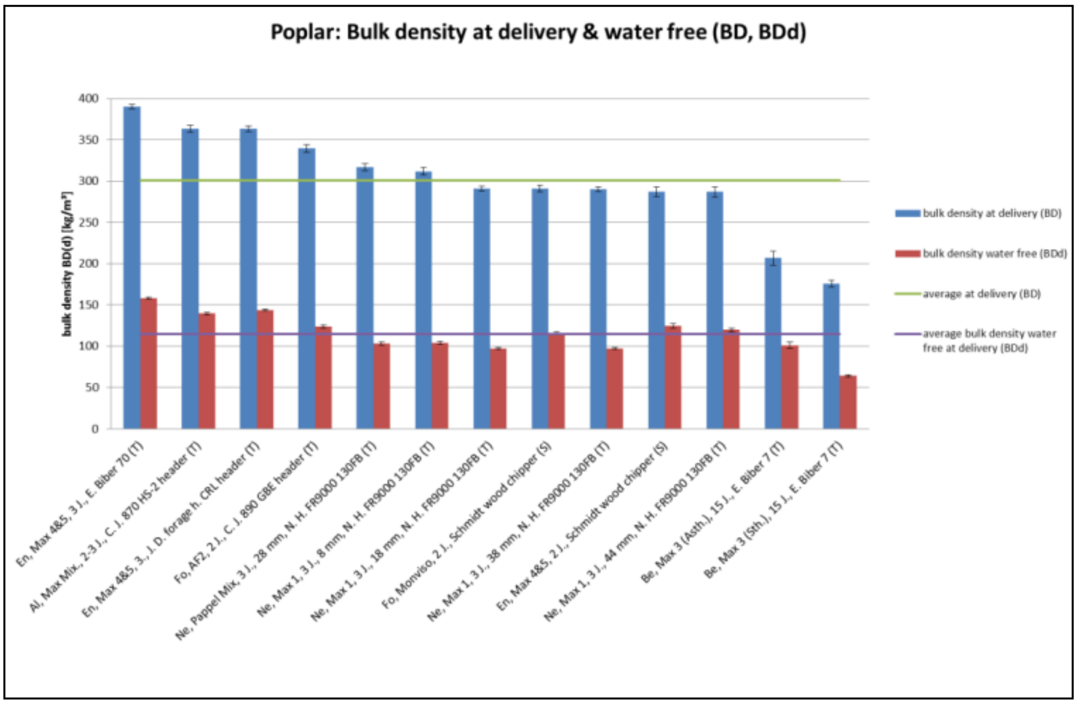


Figure 54: Bulk density at delivery and water free (DIN EN 15103:2009) for poplar with referring average values (T= drum chipper; S= scroll chipper)

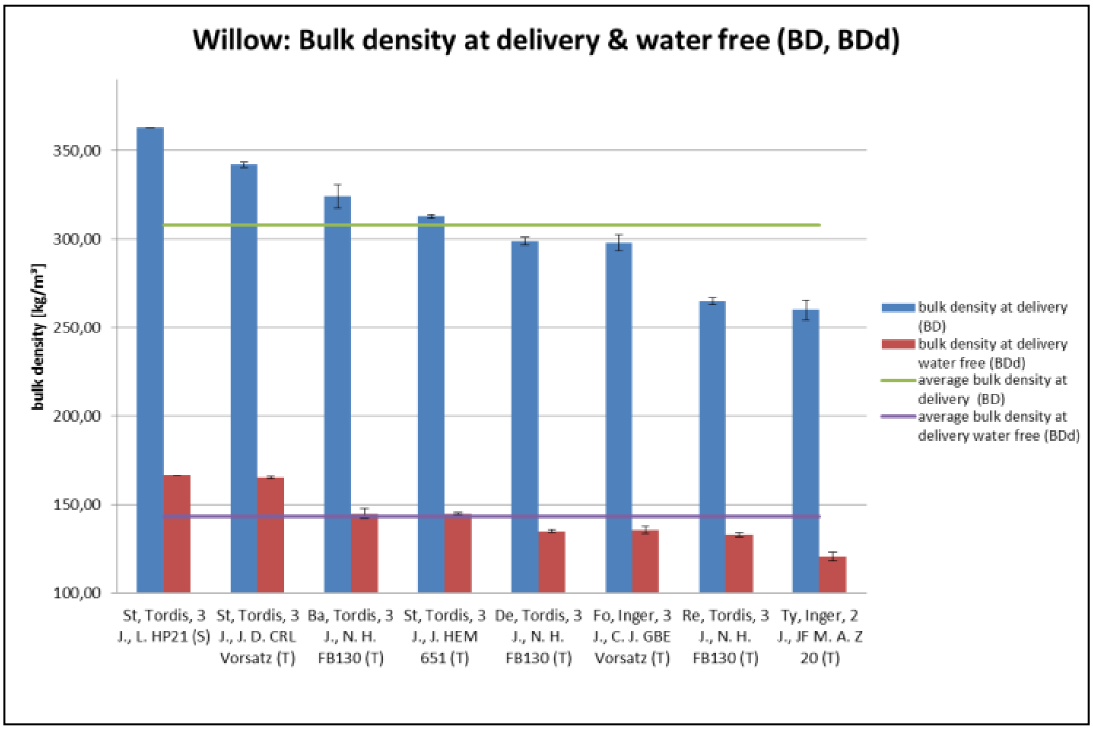


Figure 55: Bulk density at delivery and water free (DIN EN 15103:2009) for willow with referring average values (T= drum chipper; S= scroll chipper)

Particle size distribution (DIN CEN/TS 15149 1:2006)

High shares of small particles or fines within wood chip fuels can cause problems in the fuel feeding process and can affect fuel quality (JIRJIS, 2005)

Following results (Figure 56 and Figure 57) offer an overview about the performance of different chipping systems which have been used during several SRC harvesting operations or after the storage of whole shoots on the field side. Respectively high shares of oversized chip assortments have been measured for the Schmidt wood chipper and in a lower tendency in case of the Jenz HEM 581Z . On the other hand higher shares of fines (over 10 %) have been measured for Jenz HEM 581Z, Eschelböck Biber 70, Jenz HEM 651, JF Máquinas Agricolas 192 Z6 and for the Claas Jaguar GBE header. Very low shares of fines have been measured for Laimet HP21 with ca. 1 %, Eschelböck Biber 7 with 3.8 % and for the Wüst CH-3537 E. with 2.8 to 4.7 %. The forage harvester headers CRL and 130FB gaining results under 5 % fines. Analysis of the chipping trail with the New Holland FR9000 130FB shows that the pre-adjustment of the chipper resulted into significant changes in terms of particle size distribution including shares of fines. For example the 8 mm chip size pre-adjustment resulted into the highest shares in the fine fraction. As a study by FREDRIKSSON et al., 2003 showed, particle size of pulverised SRC material has an influence on burner feeding systems. Feeding systems where blocked by material bridging and compaction caused by binding and electrostatic charging.

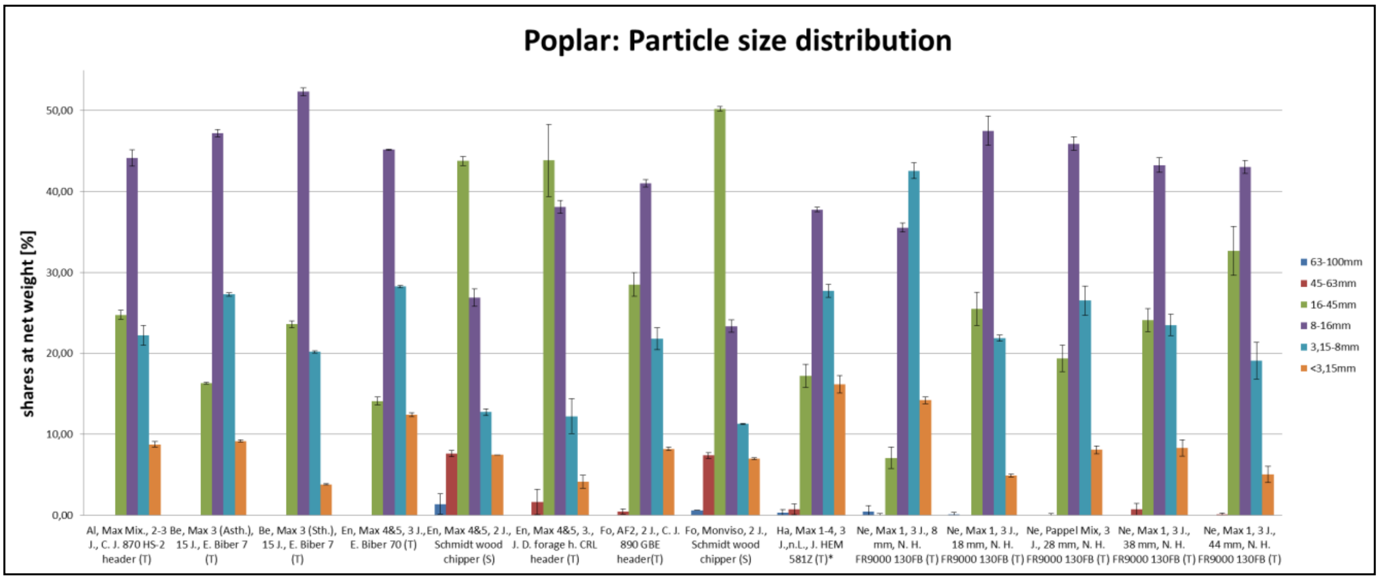


Figure 56: Particle size distribution by illustration of the shares at net weight in the sieving insets according to DIN CEN/TS 15149 1:2006 of different poplar chipping operations
(T= drum chipper; S= scroll chipper ; * = chipping conducted after storage)

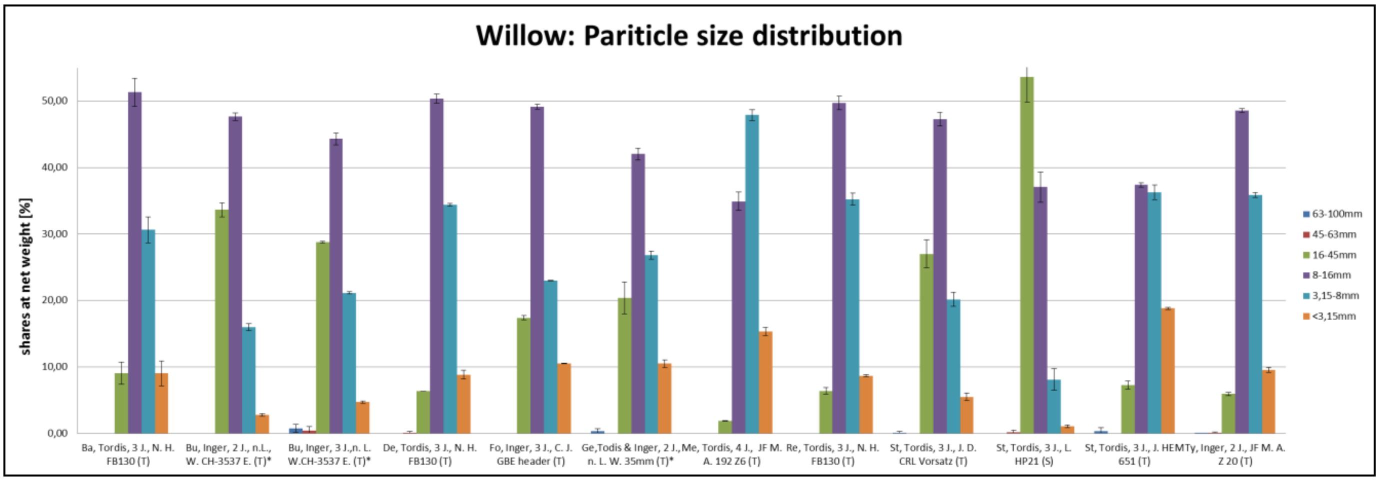


Figure 57: Particle size distribution by illustration of the shares at net weight in the sieving insets according to DIN CEN/TS 15149 1:2006 of different willow chipping operations
(T= drum chipper; S= scroll chipper; * = chipping conducted after storage)

Moisture content

Water content is the one of the most important quality parameters in terms of energetic utilisation of SRC material. It directly affects other parameters like e. g. the net calorific value and bulk density and has an important impact on storage ability of a material.

Figure 58 and Figure 59 are showing the variety of the analysed water contents for poplar and willow directly after harvest. Values for polar differ from 63.5 % to 51.1 % and displays a total average of 58.45 %. Averages for two year old material shows the highest water content, three and six year old materials show lower values. Differences of water content were measured between branch and stem wood of the same stand. While the 15 year old stem wood from a Max 3 clone contained 63.4 % of water the branch wood shows a value of only 51 %. The overall water content for willow is significantly lower with an average of 52.4 %. Values for willow are reaching from 55.3 to 47.8 %. Significant effects of ages were not measured but found in a study of SZCZUKOWSKI et al., (2005), who identified decreasing water content with stand age of several willow clones. Studies from LARFELDT & BEGSTRÖM, 1999, showed for willow, that the water and bark content have an influence on the inflammation and burn-off behaviour as well as technical problems of fire bed grate, which can also lead to a reduction in combustion stability.

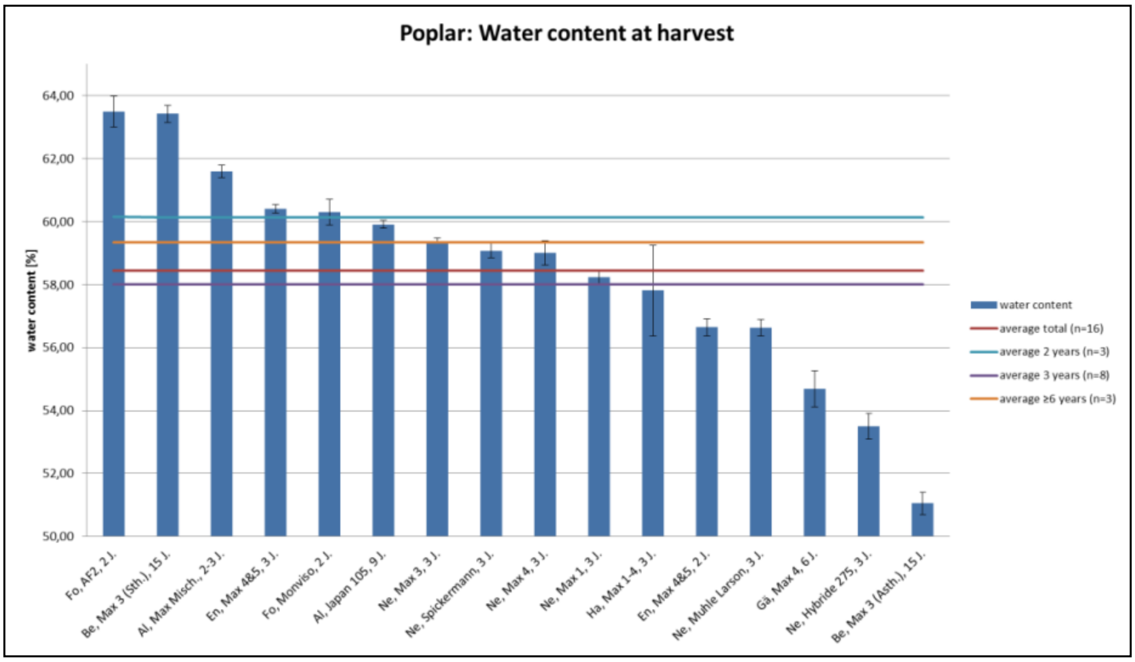


Figure 58: Water content at harvest for poplar, including the average values for two, three and ≥ six year old material according to DIN EN 14774-1:2009

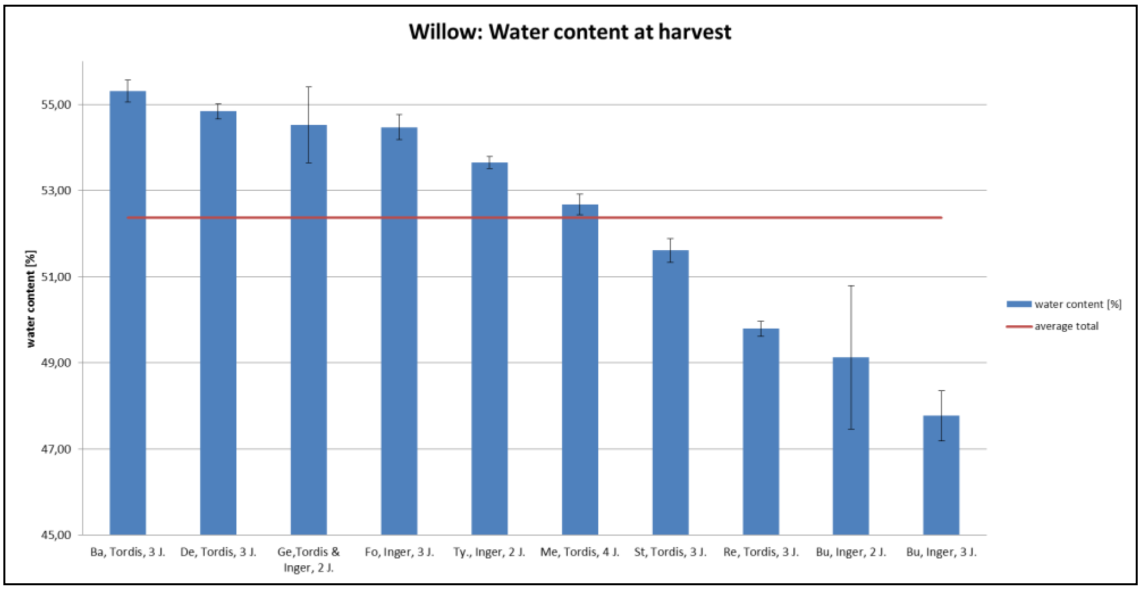


Figure 59: Water content at harvest for willow according to DIN EN 14774-1:2009

Calorific value

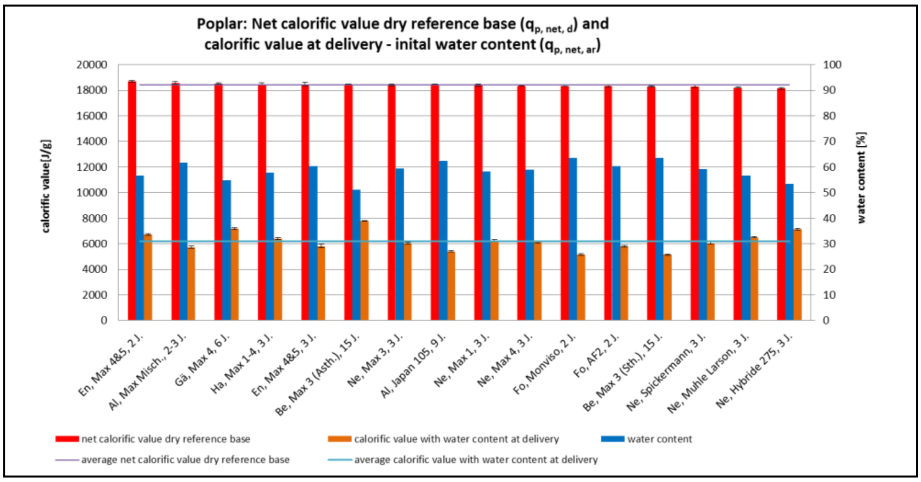


Figure 60: Net calorific value dry reference base and average in relation with water content and resulting calorific value at delivery respectively initial water content and average for poplar according to EN 14918:2010

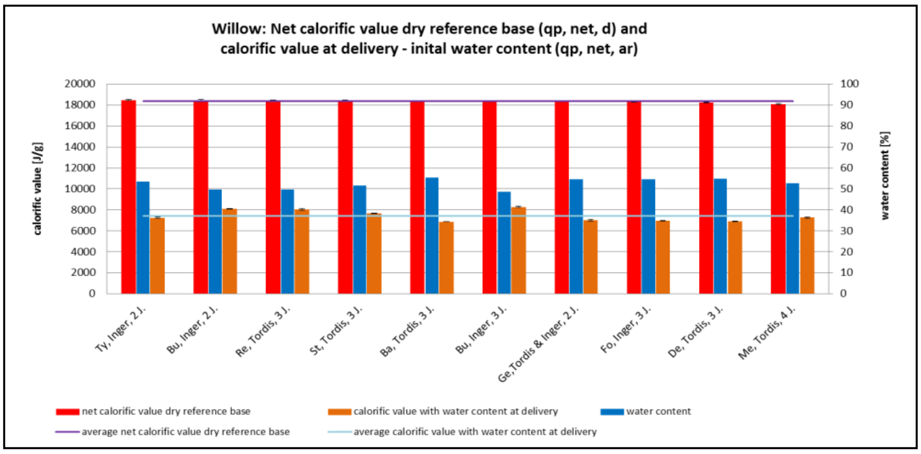


Figure 61: Net calorific value dry reference base and average in relation with water content and resulting calorific value at delivery respectively initial water content and average for willow according to EN 14918:2010

Above and below figure shows the net calorific value the absolute dry samples and in relation to these values the calorific value with the initial water content at time of harvest is illustrated. The net calorific value determines the energy output, which can be utilized without condensing technology. It is an important factor to describe and determine the material's economic efficiency during an energetic utilization process (HARTMANN, 2009). As analysis shows the net calorific value dry reference base are quite at the same level for poplar and willow with an average of 18402 J/g and 18362 J/g. Furthermore the calorific value at time of delivery (harvest) is strongly affected by the amount of water within the material, which is shown in the correlation analysis in Figure 62. For poplar it ranges from 5144 J/g to 7779 J/g with an average of 6197 J/g. Willow on the other hand shows a slightly higher average with 7435 J/g with a range from 6876 J/g to 8268 J/g.

For willow stand age and dry reference based calorific value does shows a significant correlation (R^2=0,55), which is supported by SZCZUKOWSKI et al. (2002), who found an comparable coherency with one to three year old willows. Poplar does not show this connection. Besides water content, the actual share of willow and polar bark can influence the calorific value, which has lower energy content than wood (KLASNJA et al., 2002)

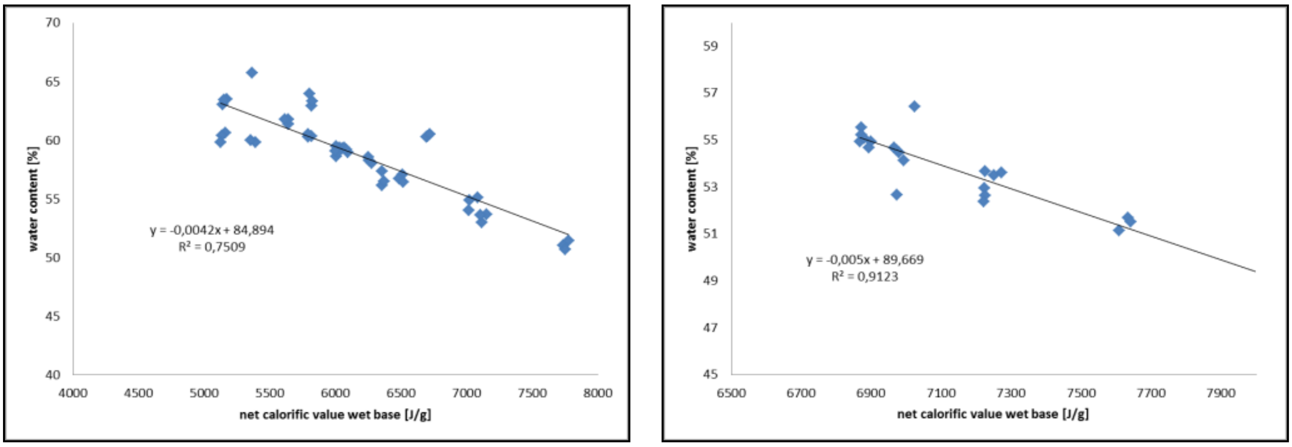


Figure 62: Correlation between water content and net calorific value wet base a) Poplar after harvest b) Willow after harvest

Ash and silicate content

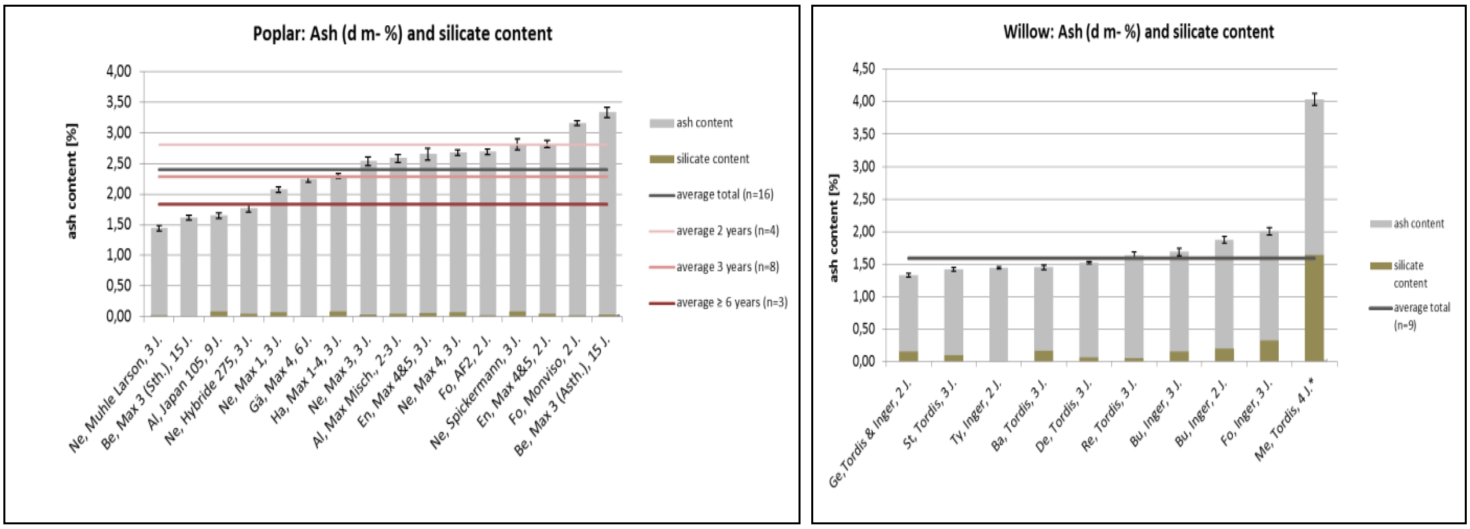


Figure 63: a) Ash and silicate content dry matter based for poplar with added average ash content including averages for different stand ages, ash content determination according to DIN EN 14775:2009 b) Ash and silicate content dry matter based for willow with added average ash content, ash content determination according to DIN EN 14775:2009 (* = not taken into account for average

The mineral content of biomass is crucial factor for thermal conversion in terms of calorific value, ash generation, design of combustion chamber, dimensioning of ash removal systems and cost for ash disposal. It affects as well the mechanical durability for wood processing systems like chippers or further refinement processes like pelletising.

As results for poplar material show (Figure 63a), ash content of the dry matter is varying between 1.45 % to 3.33 %, whereas the average ash content is 2.4 %. Significant differences are existent between two year old and older/equal as six year old poplars, which show a one per cent lower ash content. Willow (and Figure 63b) on the other hand shows an average of 1.6 % with a minimum value of 1.33 and a maximum of 2 %. In one example the measured ash content shows a strongly different ash content of over 4 %, which is not used for the average calculation. Stand age of two years compared to three years, does not show a strong effect on ash content his finding is supported by the study of STRÖMBERG, 2004. On the other hand a study of SZCZUKOWSKI et al. 2002 on willow showed a significant ash content reduction over stand age from one to three years. Nevertheless shares of bark in the material have an impact on the height of inorganic material in the ash fraction. These are higher in the bark of poplar and willow, which leads to the conclusion, that ash content is higher in younger stands, as they show higher shares of bark. In one to two year old stands of poplar and willow, bark content is between 18 - 27 %, older stands 10-15 % (KLASNJA et al., 2002). According to ADLER (2007) and the proportion of bark in willow stands decreased with increasing stand age, which may lead to lower ash contents. As To a large extent the silicate content does not play a major role the analysed samples. Willow samples show a significant higher share of silicate than poplar.

Correlation analysis in Figure 64 illustrates the dry matter based ash content of willow in regard to the gross calorific value. It shows a relation between both values. For poplar no significant relation is measured.

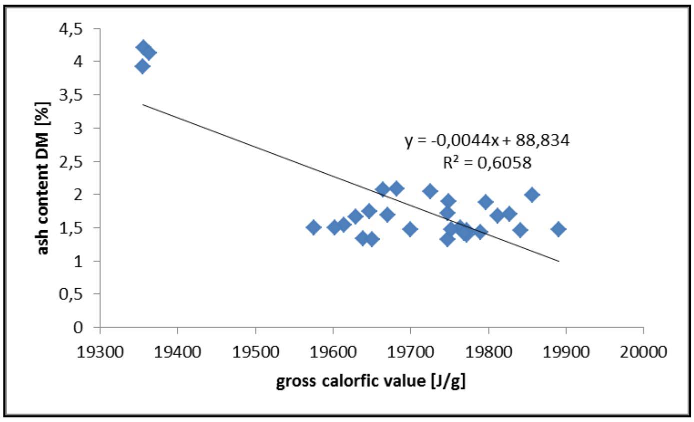
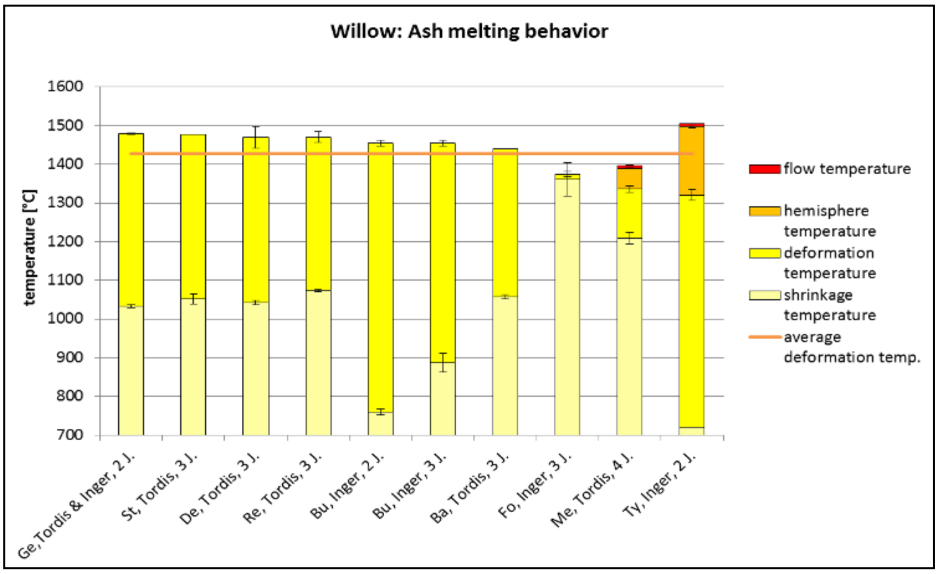


Figure 64: Correlation between ash content (DM based) and gross calorific value from willow after harvest

Ash melting behaviour (DIN CEN/TS 15370:2006)



Ash melting behaviour in particular characterises the properties of ash under high temperature surroundings like in firing chamber of biomass burners. One negative effect of thermo-chemical conversion within the firing chamber could be the occurrence of slagging processes. To avoid these processes, it is important to maintain an accurate operation. Deformation temperature of a solid fuel should not be exceeded within the fire bed (HARTMANN, 2009).

Figure 65: Ash melting behavior for willow, showing the different characteristically temperature borders including an average for deformation temperature, according to DIN CEN/TS 15370:2006

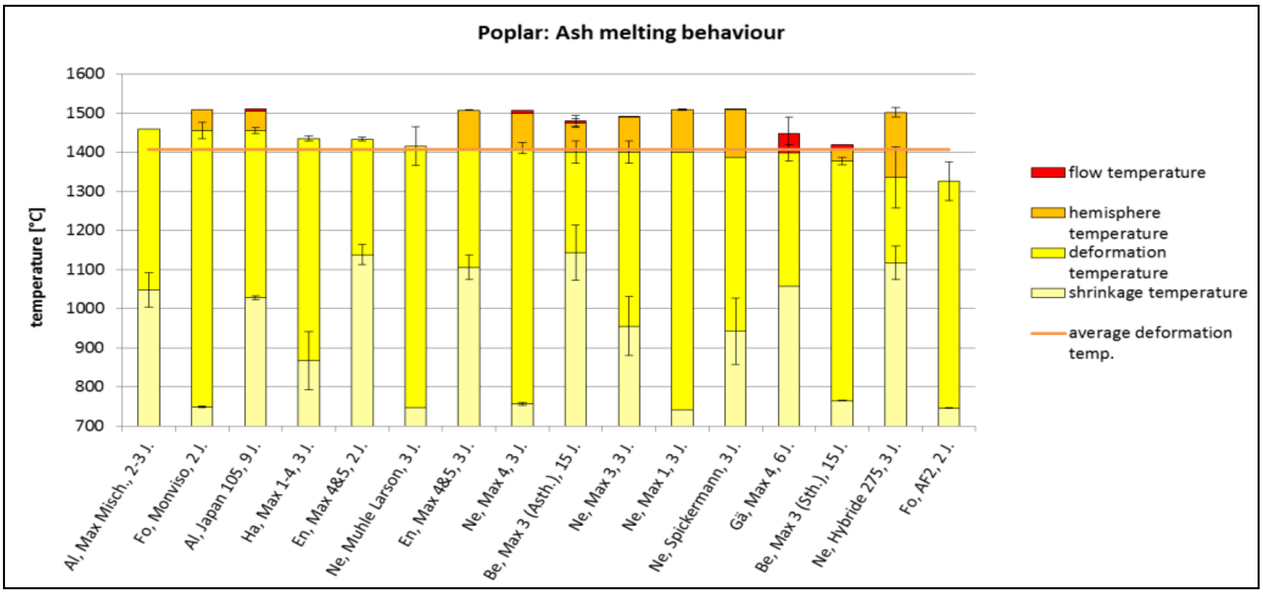


Figure 66: Ash melting behavior for poplar, showing the different characteristically temperature borders including an average for deformation temperature, according to DIN CEN/TS 15370:2006

When the walls of the firing chamber are covered with dust and ash residuals, heat transfer declines and exhaust gasses is less cooled. This effect of higher exhaust temperatures can lead to slagging processes (KOPPE, 2007). Figure 65 and Figure 66 show the measured ash melting temperature borders for poplar and willow material. A general result is, that the hemisphere and flow temperature borders could not be determined for all the samples in the analyse process. Reason for these developments is that in many cases no signs of characteristically deformations could be observed and the specimens maintained a stable surface form. The average for shrinkage temperature for poplar is at 932 °C and at 1020 °C for willow. Deformation temperature average reaches a value of 1406 °C for poplar and 1428 °C for willow. Deformation temperature is of great importance. In case of exceeding of this temperature border, ash particles can a start bonding with surfaces (KOPPE, 2007). Poplar branch wood (Be, Max 3, 15 J.) showed a 23 °C higher deformation temperature than stem wood. This finding is confirmed by the elemental analysis, which shows twice as high Ca and Mg content in the branch wood with a high share of bark. Both elements have an important impact on the increase of deformation temperature as they serve as suppressing elements during slag formation (KALTSCHMIDT, 2009). A direct clone comparison is possible by looking at the material with same age and plantation treatment coming from the same stand in Neuenbrück (Ne). Here Max clones showed the highest borders, followed by Muhle Larson, Spickermann and Hybride 275. Material from younger poplar stands view a slightly higher deformation temperature compared to older stands. 2 years ca. 19 °C higher than three year old stands. Reason for this result can be found in higher Ca an Mg of the younger stands with higher shares of bark. For willow the clone Tordis showed an average of 1439 °C. Inger on the other hand views a lower average value of 1401 °C. Comparison of willow stand ages show a 30 °C higher deformation temperature for three year old stands in regard to two year old stands. In 10 cases a hemisphere temperature for poplar is determined the average is 1491 °C. For willow only two samples showed values the average here is 1444 °C. Flow temperature for polar is detected for nine samples. The average here is 1486 °C. In general the limits of variation for the important deformation temperature are quite narrow and fluctuate in a range of ca. 150 °C for poplar and willow. Willow shows an average of 1451 in two cases. Generally the overall average values for poplar and willow would be higher, because the heating microscope can reach temperatures of 1500 °C. A study of HANSSON & LINDGREN, 1995 for willow showed deformation, hemispheric and flow temperatures all over 1360 °C, only in one case these temperature border were lower than 1300 °C. In a study of RÖNNBÄCK et al. (2011), the share of slag tendency during combustion of willow material was considerably low at around 1 % of initial fuel weight percentage.

In the analysis no signs of characteristically shape changes could be measured for several samples at that stage, no values could be calculated. In a recapitulatory consideration the ash melting behaviour of SRC material in regard to other biomass materials like miscanthus or landscape management material can be evaluated as non-critical for most thermal conversion processes.

Elementary composition

Compared with nearly or bark free woody biomass, SRC material ashes contain a higher level of silicionoxide and alkali metals (e.g., K, Ca, Na, Mg). These characteristics may affect the use of SRC material as fuel source common boiler systems. Additionally these elements play a key role in affecting the melting properties of a biomass.

High concentrations, or the absence of specific elements, can damage boilers through corrosion or deposits on the burner gate. Compared to SRC wood, concentrations of macronutrients and some heavy metals (Cd, Zn, Co, Cd, Zn, Cu, Ni) are significantly higher in poplar bark (THARAKAN et al., 2003) and in the bark of willow and their small branches (ADLER, 2007; DIMITRIOU et al., 2006). Whilst the content of N, P, K, Mg, Cu and Zn is higher in small branches (ADLER et al., 2005).

Table 14: Average values for elemental composition of poplar and willow dry matter based; color variations are marking concentration variations between poplar and willow as well as between the stand ages; *= Oxygen content is a computed value (n.c = no change)

Poplar element content DM based					
element	average total (n=16)	2 years	3 years	≥ 6 years	R^2, years/elem. content
C m-%	**49,24**	49,17	49,24	49,33	0,033
H m-%	**6,16**	6,19	6,13	6,22	0,150
N m-%	**0,44**	0,56	0,43	0,26	**0,477**
S total m-%	**0,03**	0,03	0,04	0,01	**0,317**
O cal. m-%*	**41,73**	41,24	41,89	42,35	**0,322**
Cl total mg/kg	**80,63**	50,00	111,25	50,00	0,037
P mg/kg	**930,88**	1149,75	946,13	590,67	**0,409**
K mg/kg	**3959,81**	5642,50	3599,63	2903,33	**0,432**
Na mg/kg	**15,68**	12,80	18,30	14,40	0,006
Si mg/kg	**265,63**	391,75	235,38	200,00	0,086
Ca mg/kg	**8078,13**	8870,00	7968,75	6073,33	**0,267**
Mg mg/kg	**602,00**	688,75	584,75	440,67	**0,446**
As mg/kg	**0,76**	0,80	0,80	0,80	0,000
Pb mg/kg	**1,00**	1,00	1,00	1,00	
Cd mg/kg	**0,48**	0,64	0,32	0,55	0,062
Cr mg/kg	**1,66**	3,63	1,00	1,00	0,029
Cu mg/kg	**3,27**	4,68	3,11	1,93	**0,354**
Ni mg/kg	**3,64**	11,55	1,00	1,00	0,034
Hg mg/kg	**0,07**	0,07	0,07	0,07	0,000
Zn mg/kg	**37,03**	38,78	38,01	31,50	0,078

Willow element content DM based				
element	average total (n=10)	2 years (n=2)	3 years (n=7)	R^2, years/elem. content
C m-%	**49,08**	49,23	49,16	**0,298**
H m-%	**6,13**	6,19	6,14	0,137
N m-%	**0,45**	0,41	0,46	0,051
S total m-%	**0,02**	0,02	0,03	0,210
O cal. m-%*	**42,48**	42,51	42,64	**0,295**
Cl total mg/kg	**60,89**	57,00	63,00	0,000
P mg/kg	**924,67**	857,50	943,86	**0,398**
K mg/kg	**2823,33**	3345,00	2674,29	0,011
Na mg/kg	**26,64**	41,10	22,51	**0,280**
Si mg/kg	**262,78**	200,00	280,71	**0,472**
Ca mg/kg	**4732,22**	5105,00	4625,71	0,004
Mg mg/kg	**533,33**	454,50	555,86	**0,610**
As mg/kg	**0,80**	0,80	0,80	n.c.
Pb mg/kg	**1,00**	1,00	1,00	n.c.
Cd mg/kg	**1,52**	0,81	1,72	0,115
Cr mg/kg	**1,00**	1,00	1,00	n.c.
Cu mg/kg	**3,01**	2,70	3,10	**0,471**
Ni mg/kg	**1,00**	1,00	1,00	n.c.
Hg mg/kg	**0,07**	0,07	0,07	n.c.
Zn mg/kg	**69,09**	70,28	68,76	0,052

Bark had a higher concentration of inorganic elements and ash, relative to wood. Willow clones as a group had a higher specific gravity, bark percentage and calcium concentration relative to hybrid poplar clones,

Table 14 shows the elemental composition of poplar and willow samples as average values for the totality of the samples and in consideration of the stand age of the plantations. Comparison between poplar and willow shows some major differences in terms of element content. Whilst poplar views higher values at the elements Cl, K, Ca and Mg, the elements O, Na, Cd and Zn are present in lower shares compared to willow. Reasonable concentration variations are as well visible in regard to the stand age. Especially two year old poplar stands seem to have higher element contents compared to older stands. Willow samples on the other hand show a more undifferentiated allocation. Whereas elements like K and Ca occur in higher concentrations within two year stands, Mg, Cd and Cu content is higher in three year old stands. For C, H, N and S found average values showed a lower elementary concentration compared to informative values of DIN EN 14918:2010. Especially the accumulation of cadmium (Cd) particularly in biomass of willow and function of willows as phytoextractor respectively vegetation filter for Cd in has been previously reported by PERTTU & GÖRANSSON (1998) and KLANG-WESTIN & ERIKSSON (2003). This context is of importance for an energetic utilisation as chip or pelleletised wood fuel.

Solid biofuel fuel indice: For results see annex 3.1

Material analysis - chemical properties

Accessory mayor wood components: For results see annex 3.1

Extractives: For results see annex 3.1

Design and Development of a simulation device

Purpose of the lab scale device is the simulation of storage behaviour of SRC materials regarding different microclimatic and technical scenarios. To achieve this WP 3 developed a catalogue of requirements for the device and the needed measurement-, data collection- and regulation technology.

For the storage device a vessel was needed, which is able to hold the needed amount of material (different species, particle sizes, mixtures) and resist the physical stresses of the load as well as possible chemical stresses. For the emptying of the vessel a technical solution was developed to allow the extraction of the material out of the standing simulator. Another important part was the development of a controllable air ventilation system, able to expose the material to different air volumes, air speed and temperatures. Therefore, an industry fan and an electrical heat generator are adapted. For the homogenisation of the airflow WP 3 developed in cooperation with the constructing company an air dosing system on the basis of throttles and perforated metal plates. Furthermore the possible heating or cooling of the outer vessel walls offer the opportunity to simulate changing microclimatic conditions for the material inside. For the application of heat or cold conditions a refrigerated circulator will be used.

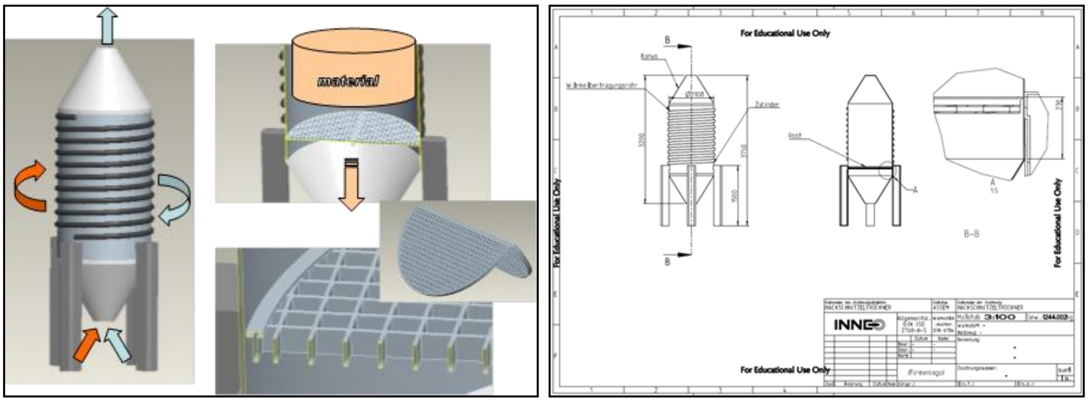


Figure 67: a) Illustration of the schematic functional principle of the simulator, showing the material filling process and the function of the extraction grate at the lower part **b)** First CAD development construction step

On the basis of this catalogue of requirements, WP 3 created a first “CAD” model (computer-aided design), which unites the different system requirements and techniques (cf. Figure 67).

Figure 68 shows the first draft of the data acquisition system, which is designed to implement all the different parameter measuring sensors in one Lab View based user interface.

In order to practically realise the simulator some changes of the technical design were necessary. At basis of the pre-development steps the final version of the simulator was implemented in cooperation with a steel construction company. That process lead to the final implementation-focused construction scheme seen in Figure 69.

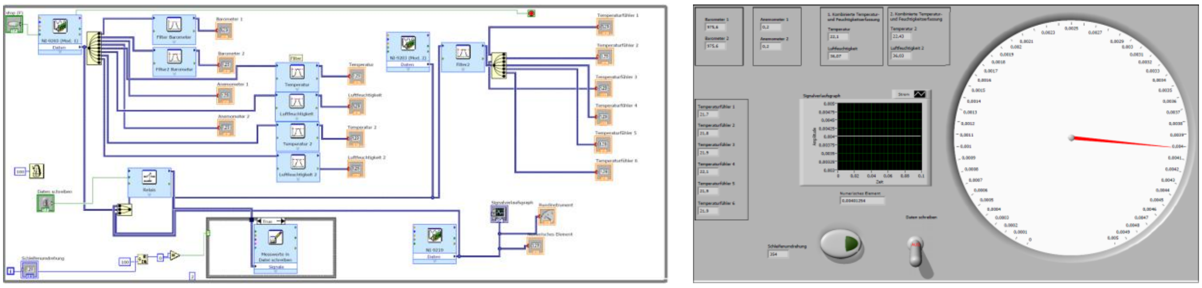


Figure 68: a) LabView block diagram with regulation and measurement interlinkage for the lab scale storage device b) Lab view frontpanel parameter display for the lab scale storage device

Figure 69: a) Final construction scheme with modified air in- and outlet system, adapted heat/cooling system at the intermediate wall, sensor access points and load bearing elements b) Construction phases of the simulator, showing channels of the heat/cooling system c) Finishes prototype of simulator at prepared location at HFR's laboratory

For more illustrations of the simulator see annex 3.1

4.3.3.2.3 User oriented technical and economic framework – survey

Empirical study – Survey among consumers

Data evaluation shows, that within the online period of the questionnaire 139 different companies took part in the empirical study and finished the questionnaire. Thereby 135 participants took part from Germany (cf. below figure) and four from Austria. As for some question types is was possible to give more than one answer the population can exceed 139 participants.

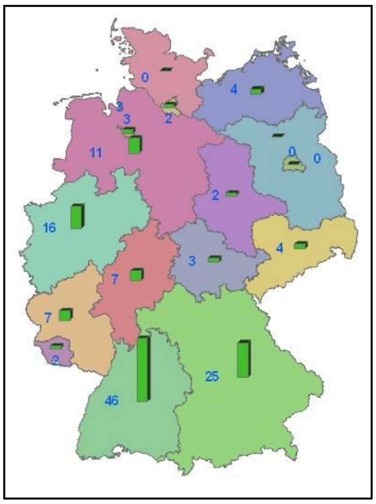


Figure 70: Allocation of survey participants on federal state level

Within this part some selected results of the general data evaluation will be shown.

As the following results show, the share of private companies, who took part in the questionnaire, is 71 %. Other business types allocate in the remaining 29 %, where communal companies have the highest share (10 %). Important business areas are wood chips providers (29 %), heat producers (22 %) and others (29 %). Smaller shares aggregate in 11 % heat and power producers and pellet producers 3 %. In conclusion the share of companies, who uses wood for energetic purposes, is 38 % including pellet producers. Substantial user group shows a total share of only 4 %.

For the illustration of continuative question concerning the general company structures and production data, standard wood raw material utilisation and used storage and condition processes please see annex

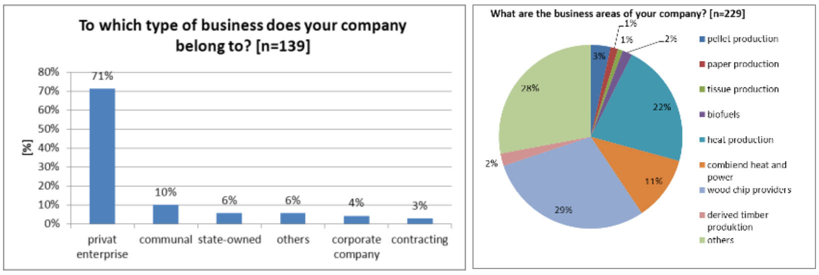


Figure 71: a) Business types of companies b) Business areas of companies

Following figures show the results concerning the experiences and estimations with and towards SRC material and quality aspects. Questions were structured to exclude participants for continuative questions, in cases where actual experiences are required to answer or knowledge of SRC in general is necessary.

Figure 72 shows that 93 % of the questionnaire participants have already heard of SRC. On the one hand only a minority of 34 % is already using SRC material. On the other hand the planning or the continuous future use is 72 %, showing that the interest in the new material source is very high.

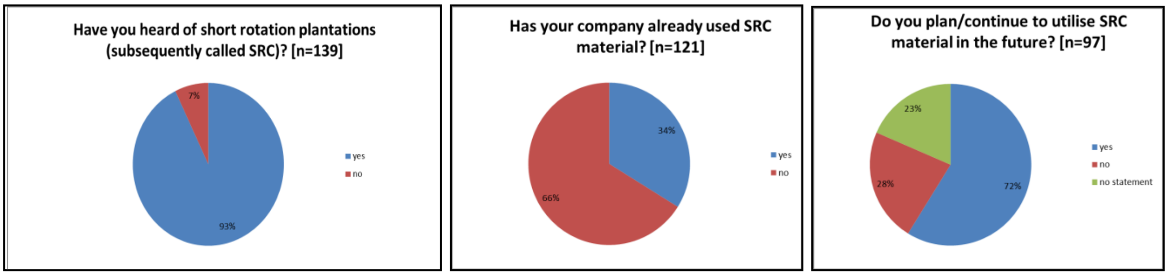


Figure 72: a) Knowledge of SRC b) SRC utilization c) Plan for SRC utilization

Below figure illustrates the experiences and estimation of usability of SRC material. The tendency within this sector was very clear. 82 % of companies declare a general usability, by giving a weighted vote within the positive classes 1-3. Most important circumstances of increased use of SRC are rising prices for their standard material (2.06), comparable quality (2.12), and growing availability (2.22). Most essential application field is the thermal/electrical conversion of the material (1.67). The substantial use is weighted lower (4.43).

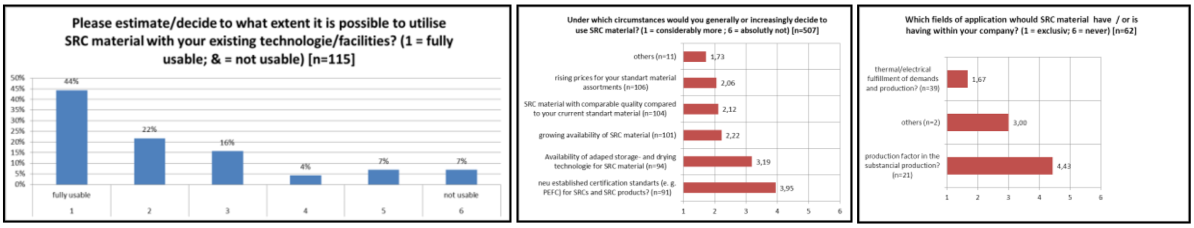


Figure 73: a) Usability of SRC b) Reasons for increased use c) Fields of application

Figure 74 shows the results concerning the preferred species and rotation period. Poplar shows the highest weighted value with 1.97 followed by willow with a much lesser rating of 2.79. Companies answer the question of ideal rotation length with a clear vote for longer rotations (4.59).

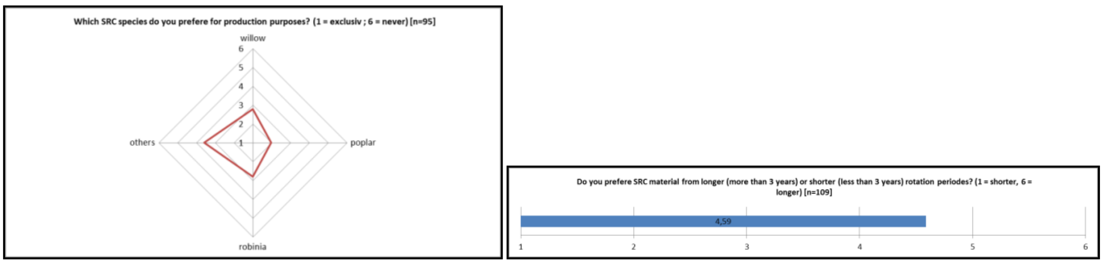


Figure 74: a) Preferred species b) Longer or shorter rotations

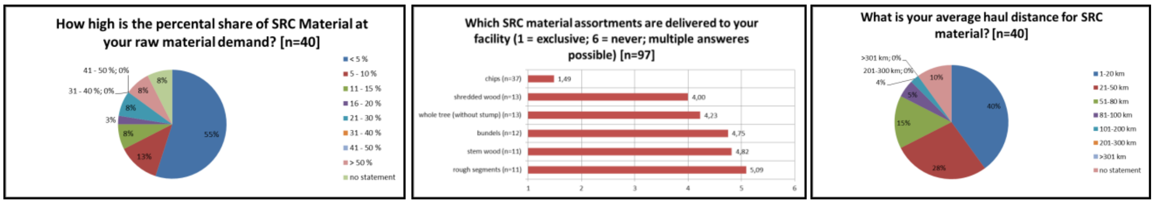


Figure 75: a) Percent share in production b) Delivered assortment c) Average haul distance

Above figure shows, that SRC material is up to now of minor importance in terms of quantities. 55 % of the companies, which use SRC material have less than 5 % share in their production. Main assortment, which is delivered to the companies are chips (1.49), all others show a rather are low rating. The average haul distance tends to be short. 40 % declare to have a haul distance of 1-20 km. 28 % quote 21-50 km.

In Figure 76 most participants (42 %) quote that the SRC material is delivered to them directly after harvest. When delivered, the material has ≤ 50 % water content according to the biggest group of participants (30 %). 18 % declare that the material has ≤ 35 %. Nevertheless the variety of answers is quite high, tendency of all groups shows, that the water content is rated rather high. Knowledge about mineral or ash content of the delivered material is low. 45 % answered with no statement. Next biggest group of 18 % rates the ash content ≤ 3 %. Followed by 13 % and 10 % of participants who say the ash content is ≤ 1.5 respectively ≤ 2 %.

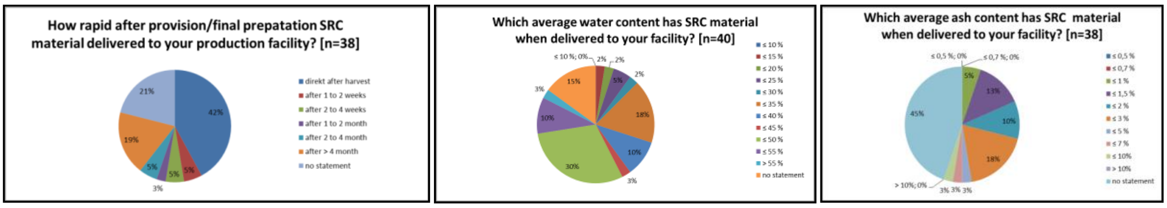


Figure 76: a) Material delivery b) Average water content **c)** Average ash content

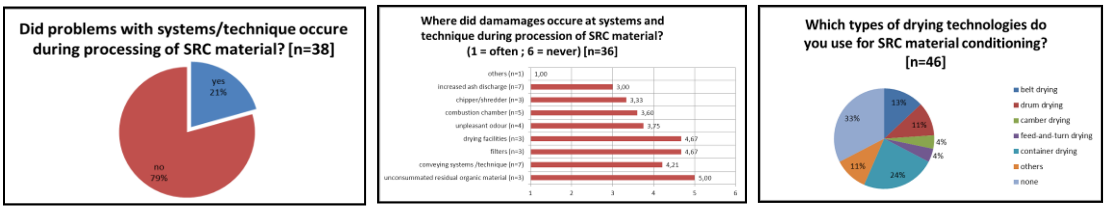


Figure 77: a) Technical problems b) Occurring damages c) Types of drying technologies

In Figure 77, 79 % of the participants said, no problems occurred during SRC material processing. In cases where problems arise, with a value of 3.00 increased ash discharges, problems with chipper and shredders (3.33) and problems within the combustion chamber took place. Most frequently used active drying technique for SRC material is container drying (24 %) and belt drying (13 %). 33 % of the SRC using companies don’t use active drying systems.

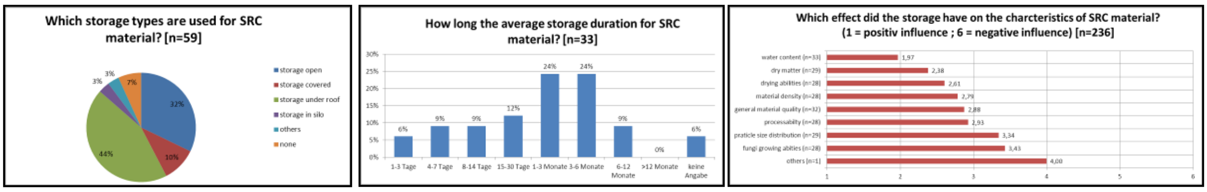


Figure 78: a) Storage types b) Storage duration c) Effects of storage

Figure 78 points out the results concerning the experiences with SRC material storage. 44 % of all companies store SRC material under a roof, followed by 32 % who store in the open and 10 % who uses a covered storage type. Average storage time divides the participants into two main groups with 24 % each, who declare the SRC storage time is 1-3 respectively 3-6 month. When asked for the most important effects of storage, companies answered with the value 1.97 for water content, 2.38 for dry matter losses and 2.61 for drying abilities.

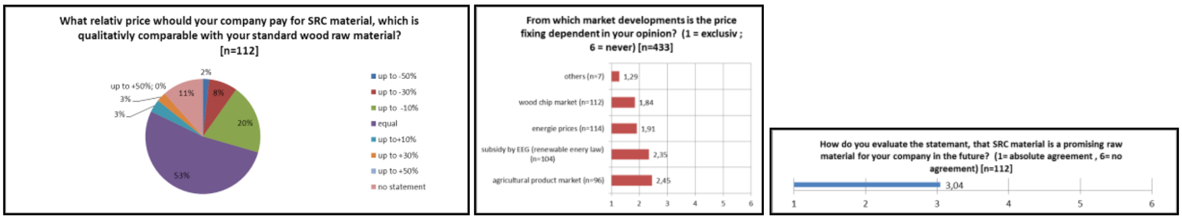


Figure 79: a) Price indexing b) Market developments c) Evaluation of SRC future

Especially the prices indexing of SRC material in comparison with standard material is of interest for all suppliers of these materials. As seen in Figure 79, 53 % of the asked companies would pay an equal price for a qualitatively comparable (to their standard material) SRC material, with a slight tendency to pay little less. The most important market development for the price fixing is the wood chip market (1.84) directly followed by energy prices (1.91). With a little less importance the subsidies by EEG (2.35) and the agricultural product market (2.45) are mentioned. To give a summarising answer regarding the general future of SRC material, the companies were asked to give a weighted estimation, if SRC material is a promising material for their companies the given rating was 3.04. That indicates a positive perception toward the SRC material.

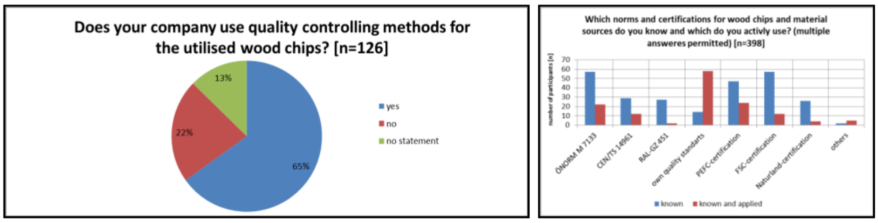


Figure 80: a) Quality controlling b) certification and norms

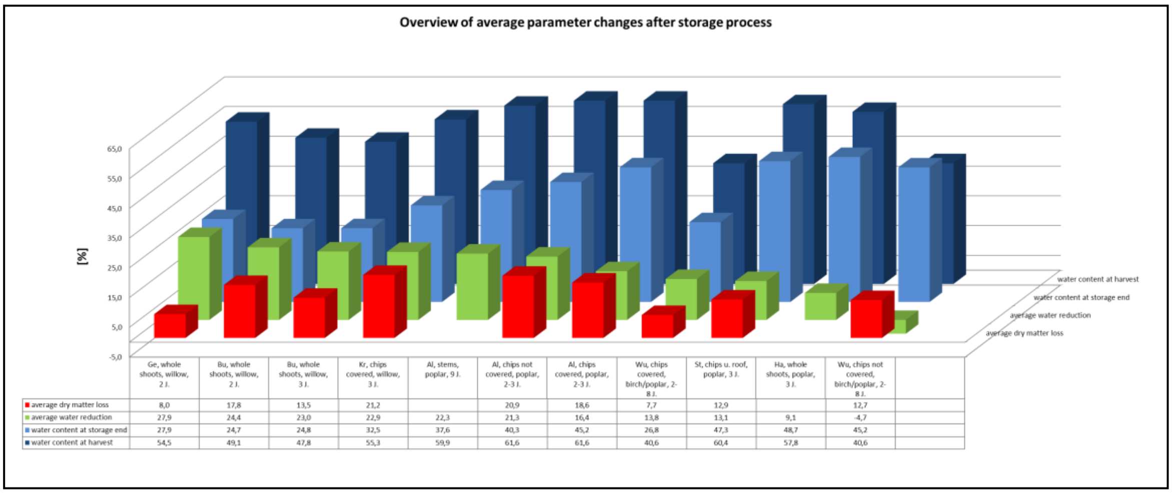
As seen in the last figure of this part, 65 % of the companies are using quality controlling methods for their wood chips. Thereby FSC and PEFC certifications have the highest awareness level. PEFC certification is applied much more than FSC. Most companies apply their own quality standard. Austrian ÖNORM M is well known and applied in some cases. Chip quality standardisation according to European CEN/TS 14961 standard is not known so much and the application rate is even lower.

4.3.3.2.4 Pilot studies

In this part the strongly summarised results of the storage pilot trails are shown. Figure 81 views different parameter changes before and after the storage process. On the one hand especially whole shoot storages show the highest water reduction abilities, on the other hand this storage type offers the lowest rates of dry matter losses compared to other storage types. Highest water reduction is measured at the inner layers of the chip pile storages. Especially the top and outer layers close to the surface have the lowest water reduction in many cases the top layer even displays a higher water content compared to the initial water content at harvest. This indicated a condensation horizon in the surface areas and for the very high water content development in the outer areas of the uncovered chip piles, a rewetting process due to precipitation. As observed the wetter outer layer in chip piles show the comparably stronger dry matter losses. One explanation for these losses could be the height of microbiologic activities in the wet zones (SCHOLZ et al., 2005).

Chips storage under a breathable coverage show good results in terms of water reduction and limited amount of dry matter losses. Uncovered piles have the lowest performance in preventing dry matter losses and are reaching even negative value for water reduction.

Dry matter losses are affected by storage type and in cases of the chip storages in Krauchenwies (Kr) and Wuppertal (Wu) by the final height of water content within the heaps layers after storage (correlation 0.90 and 0.71). Literature studies on the drying efficiency of SRC material show diverse results. Whereas uncovered chip pile storages with or without technical passive ventilation systems showed a low water reduction or even higher final water content (BURGER & WEISSENBÖCK, 2006; PARI et al., 2008; KOFMAN & SPINELLI, 1997; JIRJIS et al., 2008).



	Ge, whole shoots, willow, 2 J.	Bu, whole shoots, willow, 2 J.	Bu, whole shoots, willow, 3 J.	Kr, chips covered, willow, 3 J.	Al, stems, poplar, 9 J.	Al, chips not covered, poplar, 2-3 J.	Al, chips covered, poplar, 2-3 J.	Wu, chips covered, birch/poplar, 2-8 J.	St, chips u. roof, poplar, 3 J.	Ha, whole shoots, poplar, 3 J.	Wu, chips not covered, birch/poplar, 2-8 J.
average dry matter loss	8,0	17,8	13,5	21,2		20,9	18,6	7,7	12,9		12,7
average water reduction	27,9	24,4	23,0	22,9	22,3	21,3	16,4	13,8	13,1	9,1	-4,7
water content at storage end	27,9	24,7	24,8	32,5	37,6	40,3	45,2	26,8	47,3	48,7	45,2
water content at harvest	54,5	49,1	47,8	55,3	59,9	61,6	61,6	40,6	60,4	57,8	40,6

Figure 81: Averages of water contents, water reduction and average dry matter losses before and after storage; Results computed out of initial measurement of the SRC material directly after harvest and by summarising the measurement of balancing bags respectably whole shoot analysis (for Al and Ha no dry matter losses are determined)

Covered heaps as well as whole shoot and rough wood chips storage showed a higher water content reduction rate (BURGER & WEISSENBÖCK, 2006; KOFMAN & SPINELLI, 1997; PARI et al., 2008; JIRJIS, 1995; JIRJIS et al., 2008; SCHOLZ et al., 2005). According to GIGLER et al (2000) the drying progress of whole shoot storages, is directly affected by the diameter size of the shoots and the presence of bark, which reduce the drying rate with growing diameter and with existence of bark.

Literature results on dry matter losses show the same tendency as found in this elaboration, with high rates of losses for uncovered chip piles and especially small chip sizes, whilst whole shoot storages show the lowest reduction rates (SCHOLZ et al., 2008; SCHOLZ et al., 2005)

As Figure 82 illustrates, the development of net calorific value of the wet material before and after storage, is quite divers. One trail (Wu, chips, not covered) shows a negative development as the water content after the storage process is higher as in the beginning.

All other trails show a strong rise in net calorific value. Once again the whole shoot storage have the highest net calorific value after storage (average 11.54 MJ/kg), followed by the covered storages with an average of 11.24 MJ/kg and 9.43 MJ/kg for uncovered piles. As results for the material out of the balancing bags show, there is no significant relation of gross calorific value (dry based) between positions of material within the heaps. Net calorific value (wet base) on the other hand is strongly influenced by actual water content within the layers.

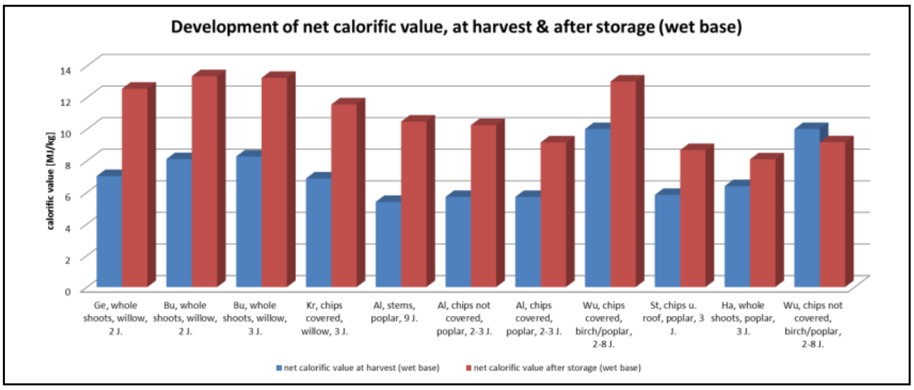


Figure 82: Comparison of net calorific value before and after storage, based on the calorific determination according to EN 14918:2010

This development is viewed in below figure, showing the changes of net calorific value wet based of the storage types. The averages illustrate, that the whole shoot storage is superior (average +64.8 %) compared to the other storage types, which have +51.6 % for the covered piles and +35.59 % for the uncovered piles. Ventilated storage under roof storage achieves a rise of +48.6 %. Changes in net calorific value after storage are affected by water content differences, but as well through biological degradation processes. Alteration in wood component composition can have an important impact. Cellulose bears an energy content of ca. 17-18 MJ/kg DM auf, polyoses ca. 16-17 MJ/kg DM and lignin a much higher energy content of 26 MJ/kg DM. Extractives can show up to 33-38 MJ/kg DM (STRÖMBERG, 2005, KOLLMANN, 1951). Taking into account the higher energy content of lignin, which is mostly not affected by degradation processes, an increase of net calorific value and gross calorific value can be explained.

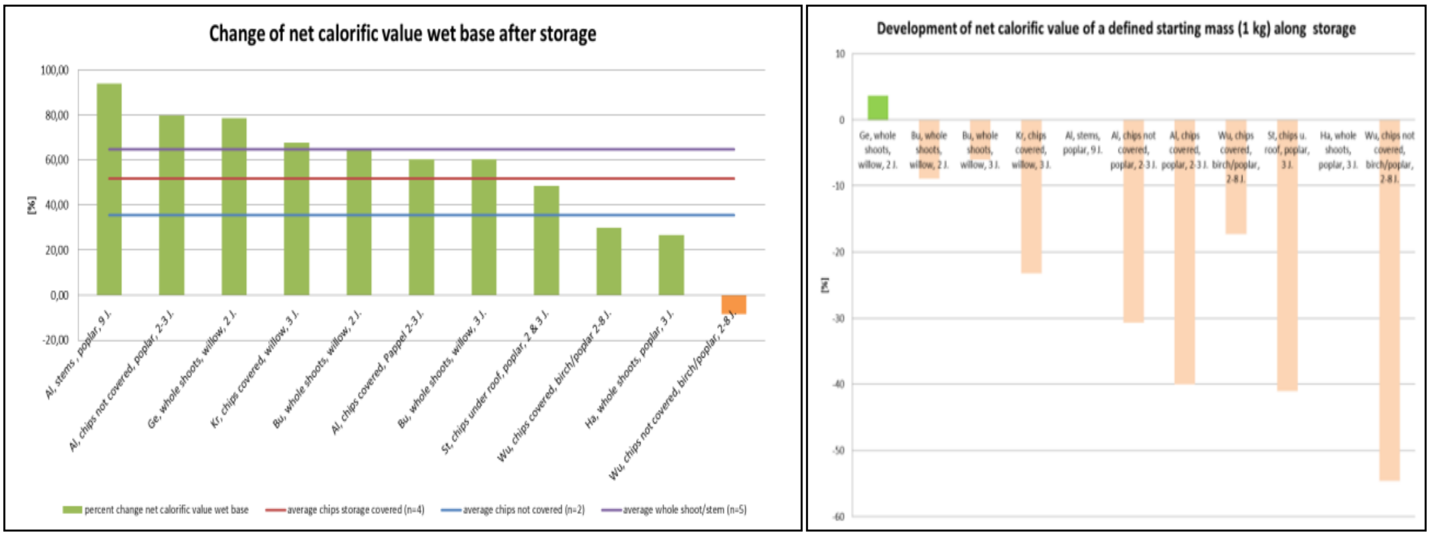


Figure 83: a) Net calorific value development in per cent after storage including averages for the different storage types b) Energetic balance of net calorific value of storage under consideration of a defined storage mass (Al, stems, poplar, 9 J. and Ha, whole shoots, poplar, 3J. now no calculation possible)

Last consideration of this part is a balancing sheet on which is shown the positive effects of rise of net calorific value (wet base) and the negative effect of dry matter losses, which influences the whole energetic balance. Dry matter losses reduce the overall energy content of the examined storage mass. In order to maintain an overall positive energy balance the effect of a higher net calorific value by water reduction throughout storage has to be bigger than the energy loss caused by dry matter losses. Figure 83b shows that this is given only in one case (Ge, whole shoot storage). In this case the dry matter losses could be counterbalanced by a strong water reduction and an along going rise of net calorific value. Generally it has to be taken into consideration, that the potential energetic cost and climate footprint for an energy consuming technically drying process are approximately much higher.

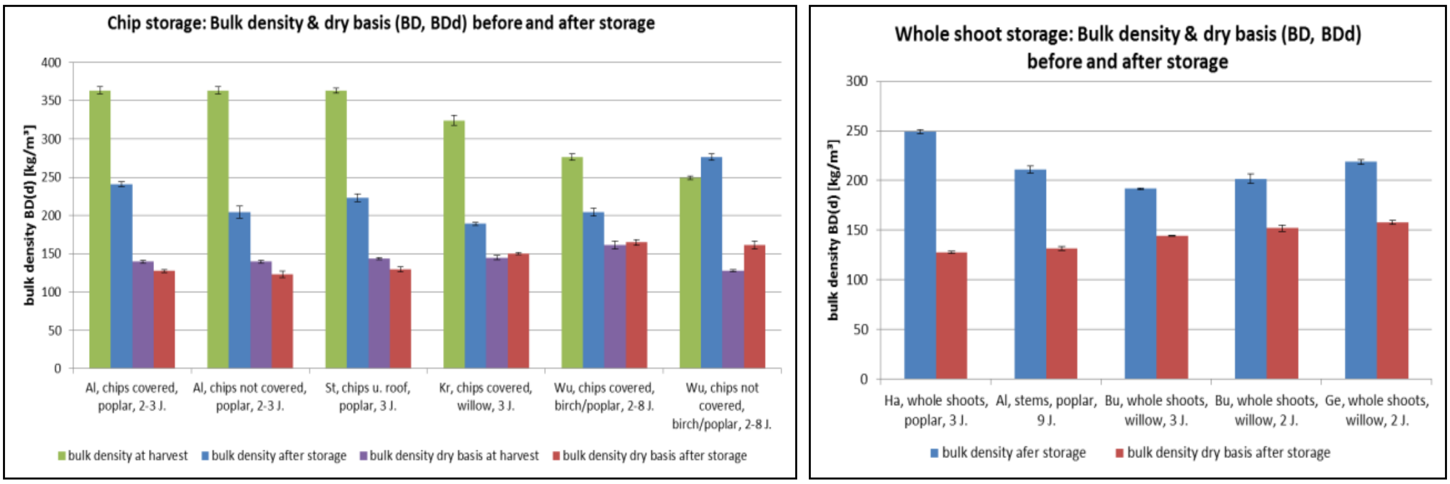


Figure 84: Development of bulk density and bulk density dry basis before and after storage for **a)** chip storages **b)** Whole shoot storages

Above figure illustrates the development of bulk density during material storage. Except in one case bulk density (at delivery / fresh bases) is much higher at time of storage start. As seen in Figure 85 the water content and dry matter losses occur in varying height during the storage process. This is the most important reason for the observed drop in bulk density.

Figure 85 support that conclusion by showing a highly significant relation between water reduction and bulk density reduction fresh based as well as between dry matter loss and bulk density reduction dry basis throughout storage. Bulk density is therefore strongly influenced by the referring storage process.

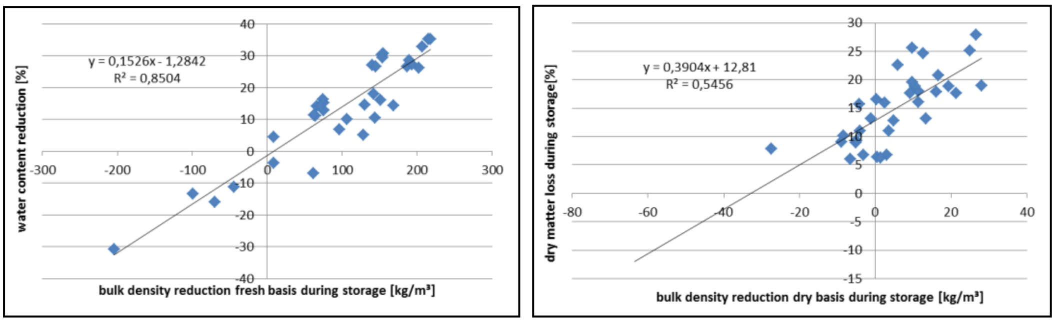


Figure 85: a) Correlation between water content reduction and bulk density reduction fresh base during storage b) correlation between dry matter loss and bulk density reduction dry basis during storage (values calculated by analysis of balancing bags of chip storages)

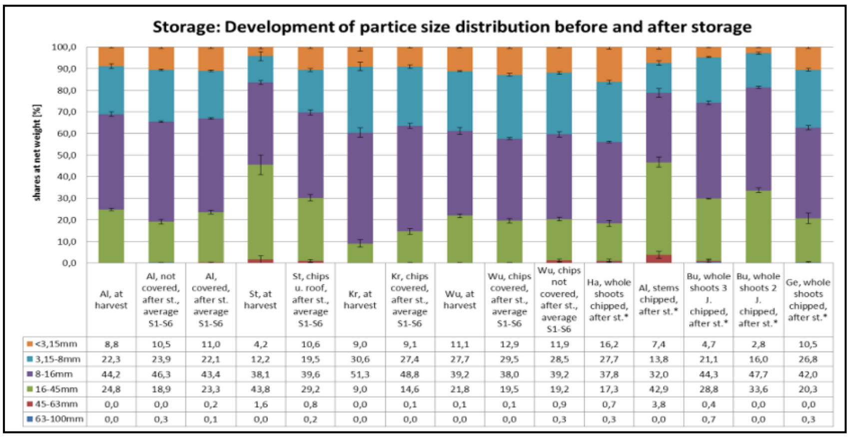
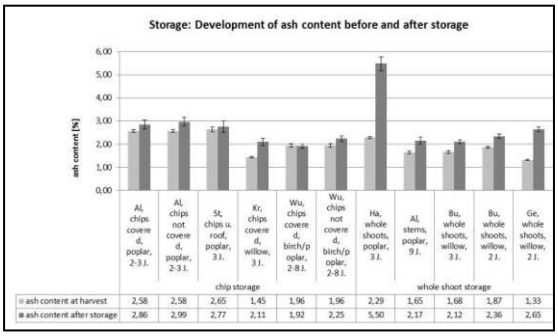


Figure 86: Development of particle size distribution through storage (*=trails with final chipping, no values at time of harvest)

Small particle sizes offer a large specific material surface area were microbes can attack (WIHERSAARI, 2005). Below figures illustrate the effect of storage on chip particle sizes. For some cases particle size distribution analysis shows a relation between dry matter loss and fine fraction share within the balancing bags for the storage in Storzeln (R^2=0.80) and Allendorf storage covered and uncovered (R^2= 0.50; 0.46). Especially the balancing bags at the outer layers of the chip pile storages, which also view high rates of dry matter losses and rewetting in most cases, show the highest shares of fines compared to the inner layers. As measured in all trails, the fine fraction share (< 3.15 mm) generally rises throughout the storage process. In most cases this relation is as well found for the 3.15 - 8 mm fraction. Figure 87 shows two examples for the particle size distribution development within the storage heaps and before and after storage. SCHOLTZ et al. (2005) identified particle size as a main and significant factor for the SRC material drying process. With tremendous impacts on final water content and dry matter losses during storage. Bigger ship sizes thereby showed better results than smaller chip sizes.

Figure 87: Changes of particle size distribution before an after storage including average for balancing bags S1-S6, describing different heap layers a) Krauchenwies chip storage b) Allendorf chip storage

Whilst many material quality parameters are strongly affected by storage, ash content development is not an exception. Figure 88a shows a rise of ash content in most of the storage types in analysis. Average rise (without Haine storage) is 0.45 % of DM. One slightly significant explanation for this development could be the dry matter losses during storage (cf. Figure 88b**)**. Whereas dry matter is degraded by biological activities during storage, the minerals are existent in a more concentrated mass per dry weight unit, as inorganic ash does not decompose. Strong raises of ash content during storage are often found in comparative studies and can only be explained by strong secondary impurities, as found by THÖRNQVIST (1985) for forest residual material and by JIRJIS et al. (2008) for different poplar storages during non proper chips handling, chipping or transport.



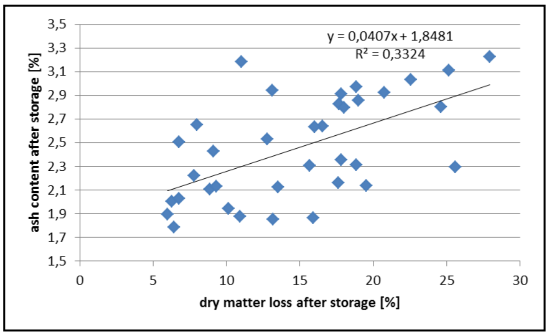


Figure 88: a) Development of ash content DM based before and after storage b) Correlation between the factors ash content after storage and dry matter loss

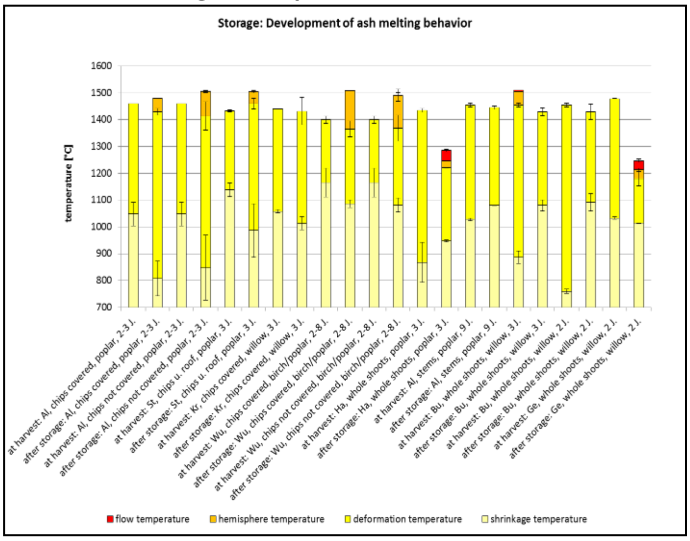


Figure 89: Development of ash melting behavior for chip storage types, showing different characteristic temperature borders including an average for deformation temperature before and after storage, according to DIN CEN/TS 15370:2006

As Figure 89 illustrates, ash melting behaviour is directly affected by the storage process.

Whilst shrinkage temperature, before and after storage, changes with no significant variation. Deformation temperature on the other hand shows a decline in after storage in most cases. Average value at time of harvest was 1444 °C, the average after storage is 1367 °C showing a decline of 77 °C. Thereby the uncovered chip piles show a higher variation of values in the different heap layers as the covered heaps. In case of the Allendorf storage, the average deformation temperature is lower in the uncovered pile. Another finding is that in many cases a hemispheric and flow temperature was measured after storage. Those borders could not be proven in any case for the samples at time of harvest. This indicates a negative effect of storage on the ash melting behaviour of SRC material. A reason for this development could be changes in biomass chemical composition caused by biological degradation processes.

As described above, biological activity moulds and bacterial affect the material properties. One possibility to describe the extent of biological activities within chip piles and whole shoot storages is offered by the temperature and air humidity development throughout the storage process. Figure 90 and Figure 91 show two examples of heat development and air humidity in covered chip pile storage and whole shoot storage. Average inner heap temperature of the chip storage (small chip size) rises quite rapidly after beginning of the storage trail. In comparison of the different sensor locations it is visible, that the inner layers of the heap have the most rapid increase and highest temperatures compared to the outer layers. Temperature at the inner layer (position S4) reaches the maximum temperature of 64.3 °C after six days of storage and stays at a comparably high level for several weeks. The outer layers show lower increase rates and maximal temperatures. At the middle of the storage period, the temperatures in all layers drop slowly but maintain a temperature around 25 °C. Findings of SCHOLZ et al. (2008) support these results by observing equally high temperatures of ca. 60 °C in storage boxes and in outside chip heaps of willow and poplar. As correlation analysis shows, there is only a not significant relation between outside and inner heap temperature (R^2=0.26).

According to findings of SCHOLZ et al. (2005), the height of average and maximal temperature in heaps, influenced by chip particle size, affects the proportion of dry matter losses and referring microbiological activity. Whilst heaps with small chip sizes show a decline of dry matter losses with raising temperatures, heaps with rough chips show a contrary trend. One explanation could be the available oxygen level for microbes.

Inner air humidity of the covered chip pile in Figure 90b is constantly higher than the outer and not significantly dependent and reaches 100 % for several weeks.

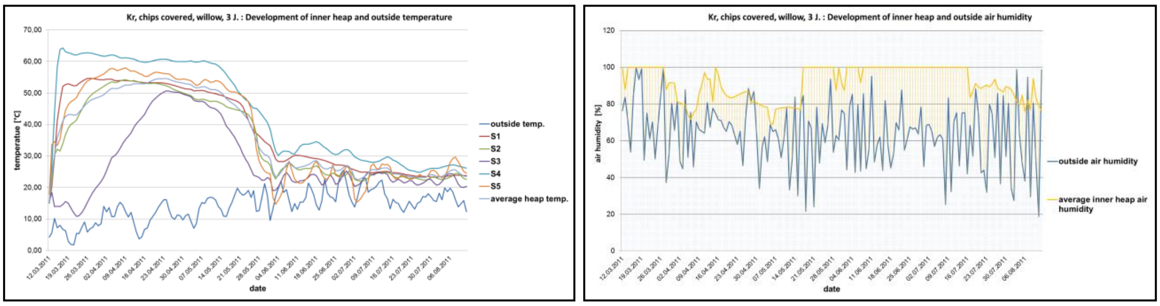


Figure 90: a) Development of inner heap (S1-S5) and outside air temperatures of the Krauchenwies covered chip storage period b) Development of average inner heap air humidity (S1-S5) and outside air humidity of the Krauchenwies covered chip storage period

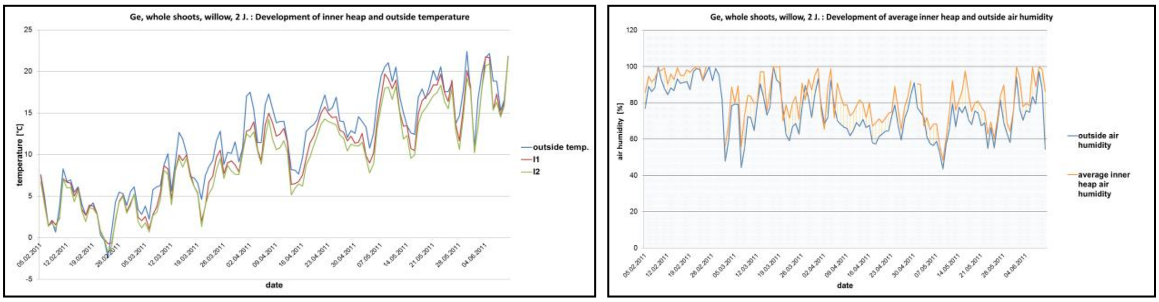


Figure 91: a) Development of inner heap (I1 & I2) and outside air temperatures of the whole shoot Gengenbach storage period b) Development of average inner heap air humidity (I1 & I2) and outside air humidity of the whole shoot Gengenbach storage period

In case of the whole shoot storage in Gengenbach, the inner heap temperature (sensors I1 & I2) are growing along with the respective outer temperatures. Measurements even show that the temperature at the heaps middle are constantly lower compared to the outside temperatures. Top levels in outer temperature are slightly buffered and deferred at the inside. Inner heap air humidity on the other hand is constantly higher than the outside temperatures, but is still showing the same run of curve. 100 % air humidity is only reached in some peaks, but not constantly present. Unlike the chip storages, the whole shoot storage shows a high correlation for the value of outside and inner heap temperature as well as outside and inner heap air humidity (R^2 = 0.97/0.79), proving a strong influence of the ambient climatic conditions. Buggingen whole shoot storage generally shows comparable relations for inner and outer heap temperature and air humidity (R^2 = 0.96/0.71). Results for the ventilated under roof storage show no temperatures over 60 °C and a strong cooling effect during and directly after the ventilation phases, with a rapid increase afterwards. Air humidity is influenced by the ventilation phases, where the inner air humidity is correlation with the outside air humidity. For temperature and humidity figures of the not listed storages, please see annex 3.1.

As observed, microbial activity can raise the temperature over 60 °C, which can lead to a chain of chemical reactions leading to even higher temperatures and potentially to a spontaneous combustion or self ignition (JIRJIS, 1995). The exact circumstances for a high temperatures and self ignition is not yet fully known, but dependent on the material and storage conditions e.g., pile high, inner temperature accumulation, oxygen level, water content, heterogeneous material layers, material compaction, layers with lower compaction and oxygen level (THÖRNQVIST, 1985; THÖRNQVIST, 1987; RICHARDSON et al. 2002; HOGLAND & MARQUES, 1999; JIRJIS, 2005).

However dry matter losses are mostly caused through microbiological activity of moulds, their mycelium growth, spore generation and germination is highly affected by the degree of material humidity, pH value, available oxygen, surrounding material temperature (SCHOLZ et al., 2005). Especially the “Water Activity”

(Aw), which describes the available water for microbiological growth, is not necessarily linked to water content (WEIDENBÖRNER, 1998). In most cases mould degrade cellulose, polyoses and other carbon hydrates. Lignin on the other hand, generally but with exceptions is not degraded in a lager extent.

Compared to harvesting material, the element composition of the material after storage does not show high variations for C, H, N, O and most other elements. Exceptions to this development are the contents of Si, Na, Cl and S with show comparably much higher contents after storage (cf. annex 3.1).

4.3.4 Conclusion

4.3.4.1 SRC material

Compared to residual forest chips, SRC chips have comparable physical quality parameters. To achieve a high chip quality in terms of chip shape and particle size distribution, it is important to use chippers, which are capable to process even small diameter shoots. Standard forest chippers with standard calibration for forest conditions seem to be not favourable for small diameter shoots. Special Forage harvester’s headers and smaller screw and disk chippers can produce a comparably high chip quality with low shares of fines. A comparably lower bulk density of willow and poplar chips can lead to a necessity to adjusting feeding units for burners to a higher feed rate to compensate the lower energy content per gravimetric unit. The combustion parameters for willow and poplar characterised by high water contents at time of harvest (ca. 52-58 %), which excludes an instant use in small combustion systems. Whist the gross calorific value is comparably at the same level of residual forest wood chips, the net calorific value at delivery is strongly negatively influenced by a considerably high water content. As found in the analysis the ash content of poplar and willow, which reaches values of 1.6-2.4 % are slightly higher than round wood chips, which may lead to sintering, inflammation and soot blowing problems in unfavourable cases. Nevertheless measurements show no critical ash melting behaviour, elemental composition and the calculated combustion indicators for burning behaviour is equally non-critical. As for poplar no combustion experience in an industrial scale are available, in some cases heat production with 100 % willow material is possible, during combined heat and power production a reduction to a admixture share of around 15 % is favourable. SRC material has a higher content of heavy metals than wood chips. Whilst it does not affect the combustion process, it could lead to consequences for ash handling, or water handling if a flue gas condenser are applied. In Literature no sound data for additional costs for SRC combustion can be found.

4.3.4.2 Survey

As evaluation of the consumer survey shows the overall knowledge of SRC is well spread. On the one hand, SRC material is not used in a high extent at the moment, which is a more or less foreseeable in regard of limited material availability and plantations. On the other hand the company’s estimations for future utilisation and technical processing ability of SRC material are high. Companies prefer an energetically utilisation path, material from longer rotation periods (> 3 years) and species poplar in front of willow. In case where SRC material is delivered to the companies it is mostly delivered as chips directly after harvest from a rather short haul distance. Knowledge about water content of SRC material is well spread and declared values are comparably high. Knowledge about ash content is not high. Technical problems with SRC material does not occur very often, nevertheless in case of appearance, problems are affecting ash discharge, burning chamber as well as shredders and chippers. The material is often stored under roof or open for mostly one to six month with high effects on water content and dry matter development. SRC material in most cases is not dried technically. Nevertheless most used techniques are container and belt dryers. Companies declare, that the price fixing of SRC material is mostly affected by the wood chip market and energy prices and answered, that they are willing to pay an equal price in comparison with a qualitatively comparable standard material, nonetheless with a slight tendency to a lower price rate for SRC material. The overall question on the estimation, if the material is a promising raw material for the companies is answered rather positive.

4.3.4.3 Storage

As results show, storage of SRC material does affect the material quality parameters in terms of water content reduction, higher net calorific value, slightly higher shares of fines as well as higher ash contents in connection with a marginally lower deformation temperature and a change in elemental composition. On a material quality point of view, whole shoot storage seems to be favourable, followed by covered chip pile storage. Nevertheless in most cases the decision of getting involved in SRC cultivation is done after a careful consideration of possible alternatives and a detailed calculation of cost for planting and harvesting. Unfortunately the aspect of handling and distributing the product is often not a primary focus of initial considerations. Especially the aspects of conditioning of the material, which exist either as chips or whole shoots after the harvest, is playing a mayor role for the economic success of whole SRC operation. It is furthermore relevant to decide in advance of the plantation implementation, what to do with the material after harvest. Meaning in which form the material should be processed and if it is necessary to condition the material, not only in terms of an intermediate storage but for quality improvement purposes. As SRC materials have comparably high water content after harvest, which could exceed 55 %, not all energetically utilisation paths are possible or reasonable. For example if the material will be used in small burners, water contents higher than 30 % can be critical for an interference free and effective operation. Therefore the material has to be dried. Active technical drying should only be considered, if there is a possibility to utilise residual heat resources, for examples from biogas- or a heating plants. Bigger heating plants are able to use chips, which contain higher water contents, either by mixing different chip assortments or use of adapted burner technologies able to process higher water content. In consideration of the overall energy balance of the conducted storages, this utilisation path seems to be favourable compared to a long storage period. In all cases, where dry SRC material is needed, it has to be conditioned by a drying respectively storage process. As project results show, storage of whole shoots from harvest until late summer reveals the lowest dry matter loss by reaching water contents around 25 %. Verified by other studies SRC chip can alternatively successfully be stored as uncompressed piles on solid ground with a maximal height of four to five meters but with a breathable agro-fleece as precipitation coverage. A rougher chips size for a longer storage period should be chosen to increase inner heap air exchange. Inner heap temperatures and dry mater losses are higher, but nonetheless water content reaches values around 35 %. This method has the advantage of saving an additional conditioning step, because the chips are already produced at harvest unlike whole shoots, which have to be chipped in an additional handling step after storage with a high risk of secondary contamination with sand and/or soil. At present stage the demand of new alternative chip sources is growing strongly. This offers SRC cultivators new market areas for their product diversification.

4.4 Work Package 4 - Integrated economic analysis of chains for SRC

4.4.1 State of the Art

About 26 million hectare of energy crops (including short rotation forestry) are demanded to reach the goal of the European Commission with regard to the share of biomass within the total European energy mix (Proplanta 2009). Currently within Germany about 1,000 hectare of agricultural land are cultivated with SRC whereas in Sweden about 13,500 hectare are used for willow SRC in a commercial way (Proplanta 2009, Lantmännen 2009). Experience from Sweden shows that the main obstacle for more widespread SRC cultivation is the lower profitability compared to other options of agricultural crop cultivation (Proplanta 2009).

At present the production of wood fuels from SRC is only marginally competitive with other fuels and bio-fuels (e.g. chips from wood residues), which is especially due to high establishment, maintenance and harvesting costs of the SRC plantations. The cost of wood chip production from SRC poplar cultivation is estimated to be in the same order of magnitude than for other energy crops like Miscanthus and whole grain crops, but considerably higher than for wood fuels from forest residues. For economic operation a wood-fuel (wood chips) price of around 65 EUR/t fuel has to be achieved, which is pracitcable especially at good sites and low establishment and operation costs.

One of the strategies to increase the number and area of SRC plantations resulting in an improved market share is to successively use small, scattered and unused fields and at the same time to establish large area projects with a size of more than 50 ha. One approach is the establishment of producer-associations and especially producer-consumer co-operations (see WP5). For small scale SRC-cultivation the use of special-machinery and a collaborative use of machinery seems to be one big advantage and improvement of efficiency.

The competitiveness of SRC-cultivations and wood-fuels are strongly related to site characteristics such as plot-size, location, distance to wood-processing plants and installations, and logistics. Also the operation of cultivation equipment such as seeding and harvesting machinery is related to site characteristics; on smaller plot areas the operation is relatively more expensive and time-consuming than on larger plot areas.

For regions and countries with a small scale agricultural structure, such as South-West Germany and North-East France, small field sizes are rather the rule than the exception. Due to the ‘economies of scale’ principle for these regions the economics for a competitive production of wood fuels from SRC may be challenging and have to be assessed in detail from an economic point of view.

4.4.2 Specific goals

Against this background the goal is to identify and analyze the economics of production systems and process chains for the supply of wood from SRC. A specific focus is put on small fields of marginal site conditions. The regional focus is on Baden-Württemberg and the Orleans-Nancy region. Here, small-farm systems are widespread.

Process chains and production systems for cultivation on sites with medium conditions as well as especially for marginal sites, will be analyzed for their economic and environmental characteristics to examine economic and environmental feasible cultivation under the mentioned conditions in these regions and identify potentials. As far as possible, the calculations are based on data from the project sites. Other data are taken from literature.

4.4.3 Activities and Results

4.4.3.1 Definition of typical process chains and scenarios

On the basis of different process chains, which are covering all working steps for the production of SRC-wood, the costs and revenues for different product variations have been calculated.

For all process chains which were analyzed, eight so called process modules were identified. Figure 92 shows an exemplary process chain for SRC-wood with the main process modules.

Figure 92: Exemplary process chain for providing SRC-wood with individual process modules (working steps)

The system boundary extends from field preparation to recultivation of the plantation after 20 years. The economic analysis included all steps that take place in the agricultural area, as well as all activities which take place after harvest, such as transport, storage and processing (optionally), up to the delivery of the wood to the end user.The further processing or conversion of the wood-fuel (e.g. heating plant) is not part of the balance.

During the lifetime of the plantation the process modules harvest, transport and storage occure several times, depending on the rotation period, whereas the modules field preparation, planting and maintenance take place only in the first year of the 20 years useful time of the plantation.

In addition to the costs for the identified process modules the yearly costs for rent and fixed- and indirect costs for the farm (insurances, costs for energy and water, maintenance for buildings, and others) have been considered.

For analyzing the different parameters a standard process chain was defined (see figure 93). The single working steps that are considered for each process are described in more detail in Annex 4.1.

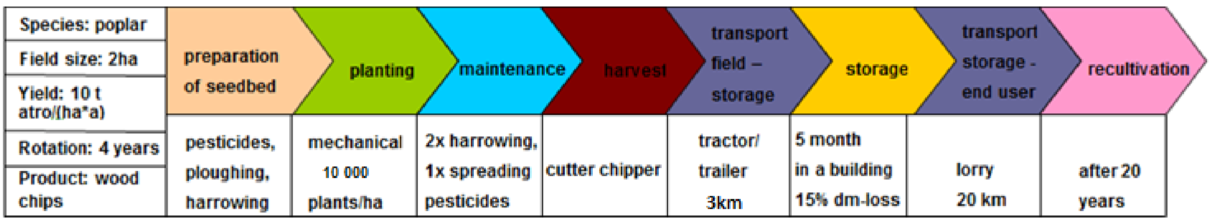


Figure 93: Standard process chain (SRC) for the production of SRC-wood

4.4.3.2 Economical assessment – methods and calculation model

Methodological approach

Figure 94 exemplary shows the stream of payments over a time period of 20 years and rotation period of four years.
The total costs for the first year includes costs for preparing the seed bed, planting and maintenance as well as for fixed and indirect costs and rent (every year). In all other years without harvest there are only yearly costs for rent and fixed and indirect costs.
The green bars show the profits (costs minus revenues) in the years of harvest. The green bar in year 20 shows the profit minus the costs for recultivation of the site in the last year.

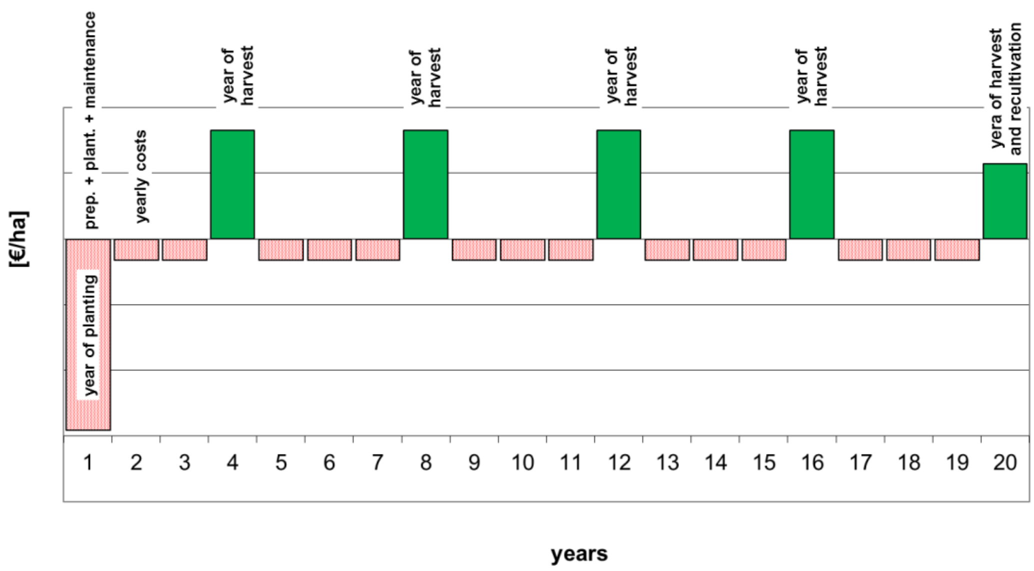


Figure 94: Exemplary cashflow of a SRC cultivation over 20 years with a 4-years rotation period

To compare the costs for SRC with the costs for the cultivation of annual crops, the costs, which occur in different time periods (€/ha) are modified as yearly costs (€/ha/a).The yearly costs are identified following the annuity method in imitation of VDI guideline 2067 (2000).

With this method, the deposits and payments of different time periods (see figure 94) are distributed equally over the 20 years.

For every working step costs for machines, fuels, wages and materials are considered in €/ha (figure 95).

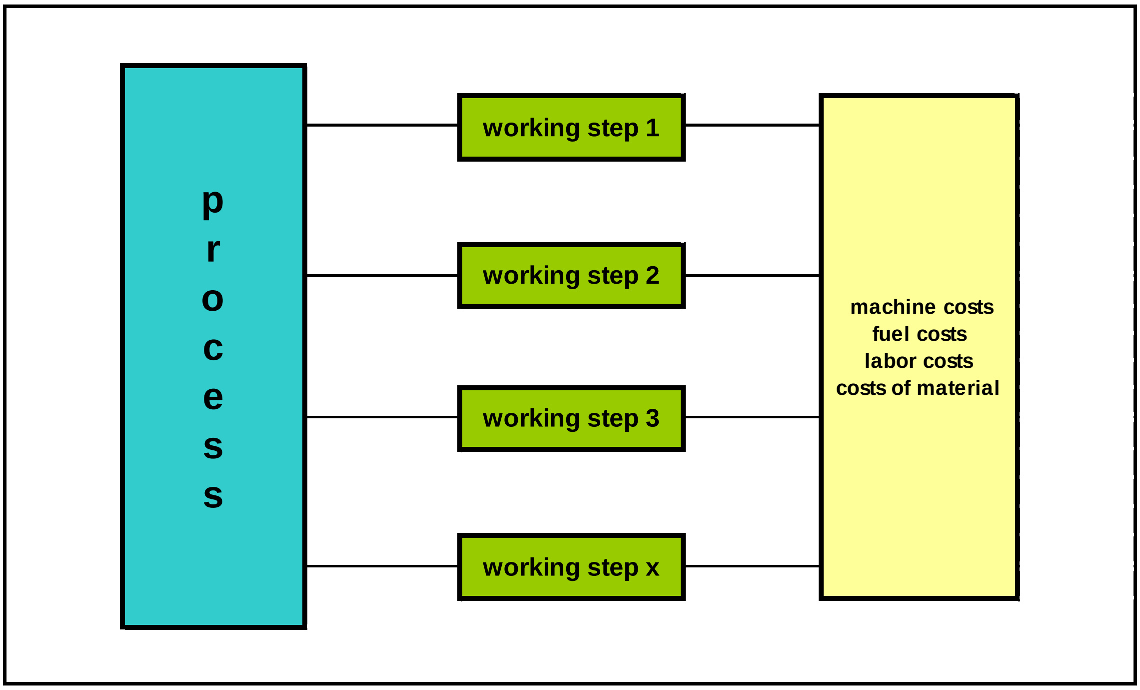


Figure 95: Construction of a process chain and costs considering the cost accounting

The method for cost calculation is explained in more detail in Annex 4.2.

<u>Excel-based calculation model</u>

The defined process chains have been implemented in an Excel-based calculation model (see Annex 4.3) which has been developed for the project. The aim of this model was to provide a tool to analyze the effect of parameter variations on the costs and to analyze their impact. Furthermore a calculation model is helpful to support the consultation of farmers within the project. As mentioned above, the costs were calculated as yearly costs (€/ha/a) providing an easier way for the farmers to compare SRC costs with those of the common annual crops. The tool and calculation model was used for the economic analysis of SRC production in the project, but should be tested more intensively also with stakeholders in a subsequent project. In this context the model could also be extended by data and processes which will be collected in a subsequent project.

The structure of the model as well as the possibilities of combinations of the processes is shown in figure 96. Figure 97 shows the parameters that can be used as input for the model (input-sheet). Using the input-sheet, the processes for cultivation and provision of SRC wood for every process module can be selected. The output sheet in figure 98 shows the selected processes from the process modules, the costs of each module, the revenue as well as the profit. The results on the composition of the total costs are represented by a bar chart and a pie chart.

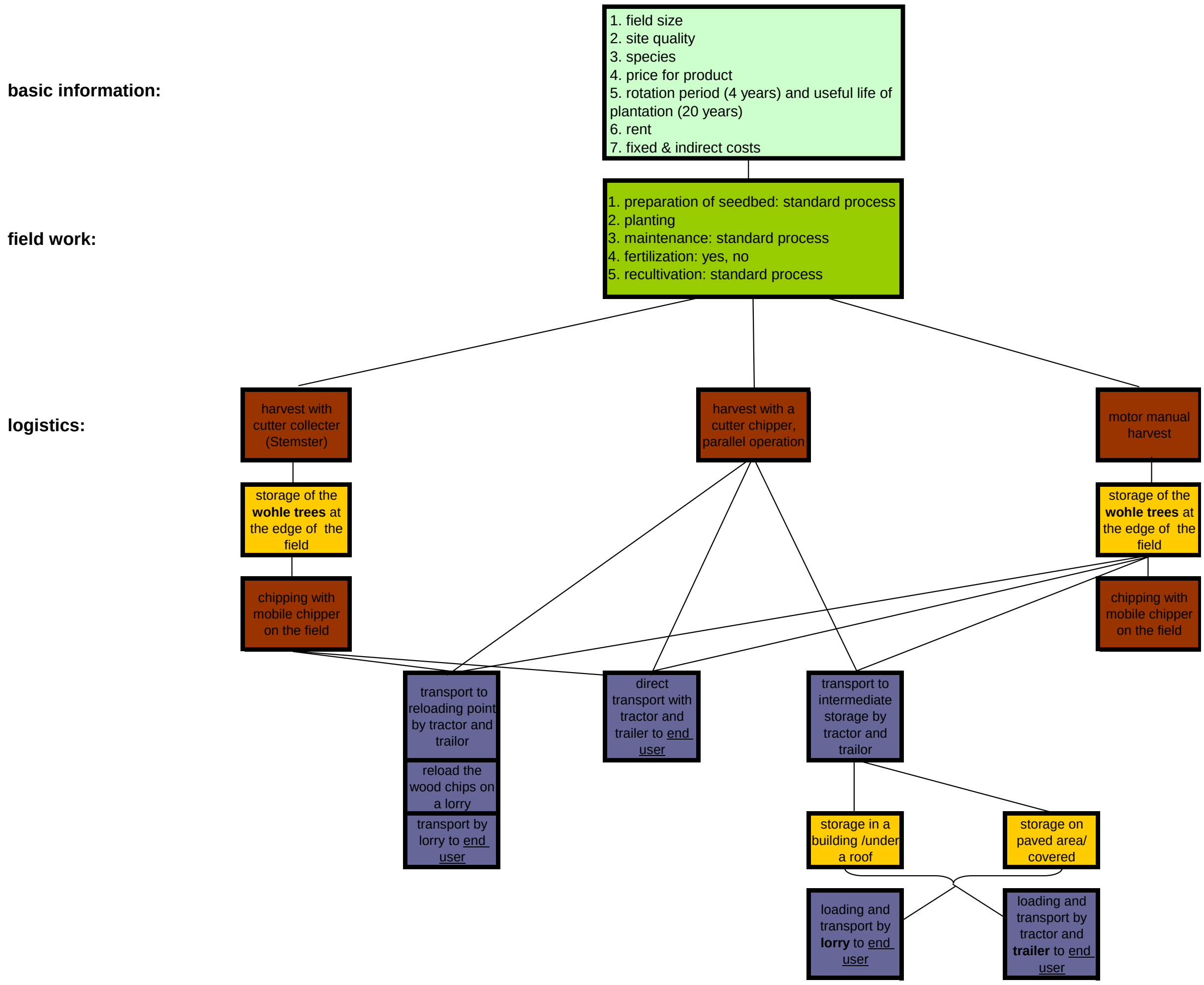
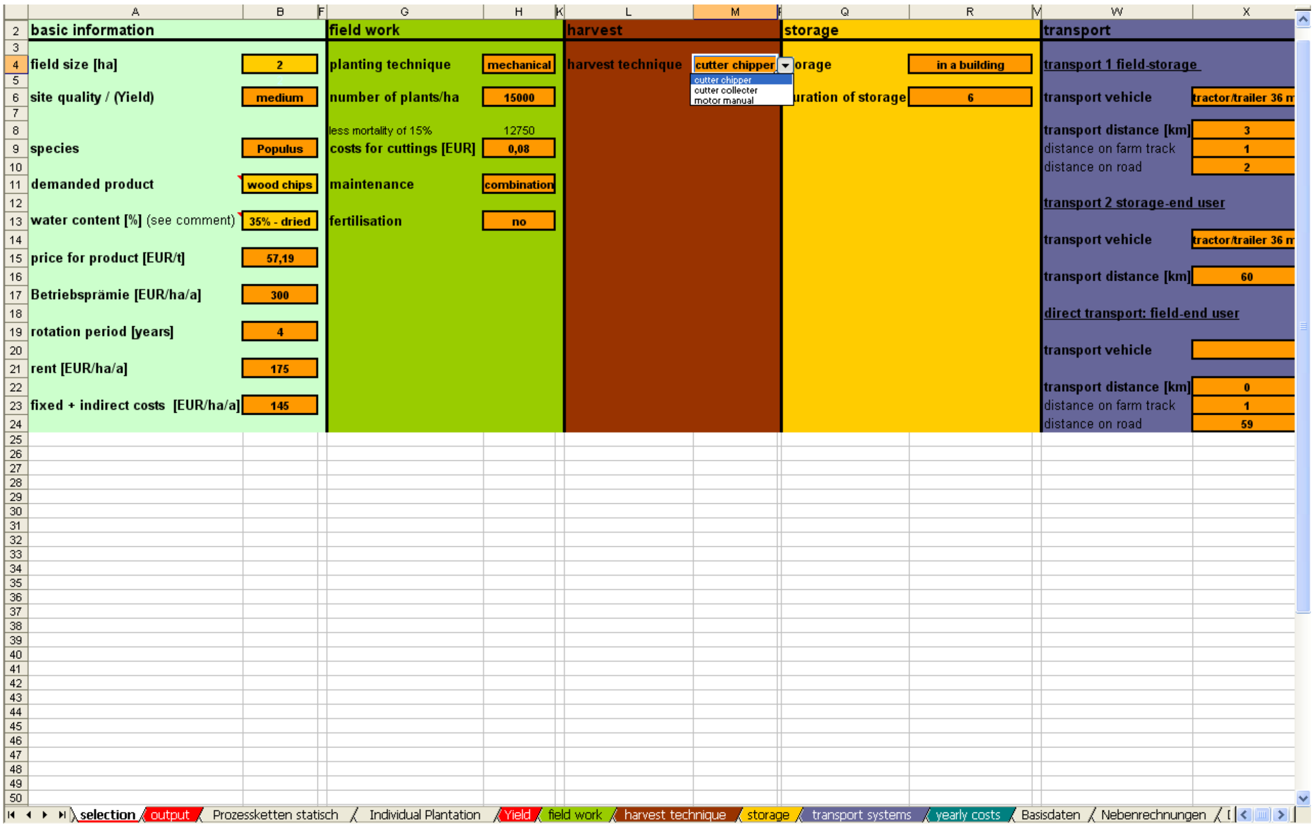


Figure 96: Basic structures of the calculation model



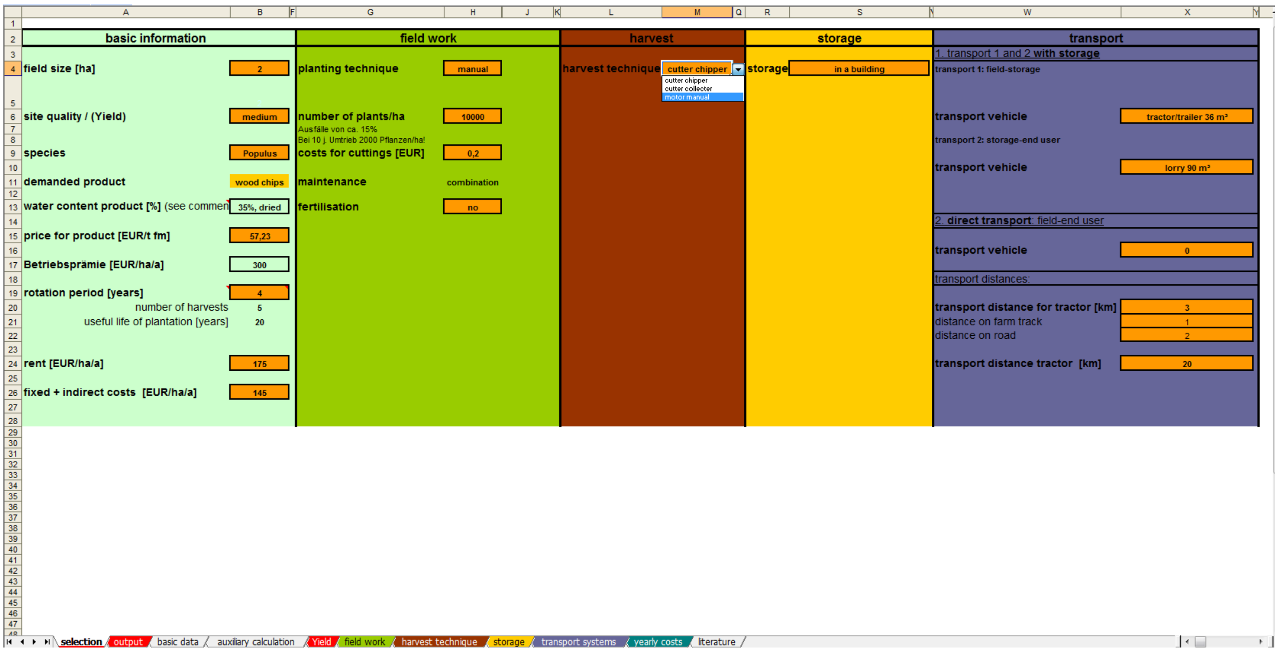


Figure 97: Input sheet of the calculation model

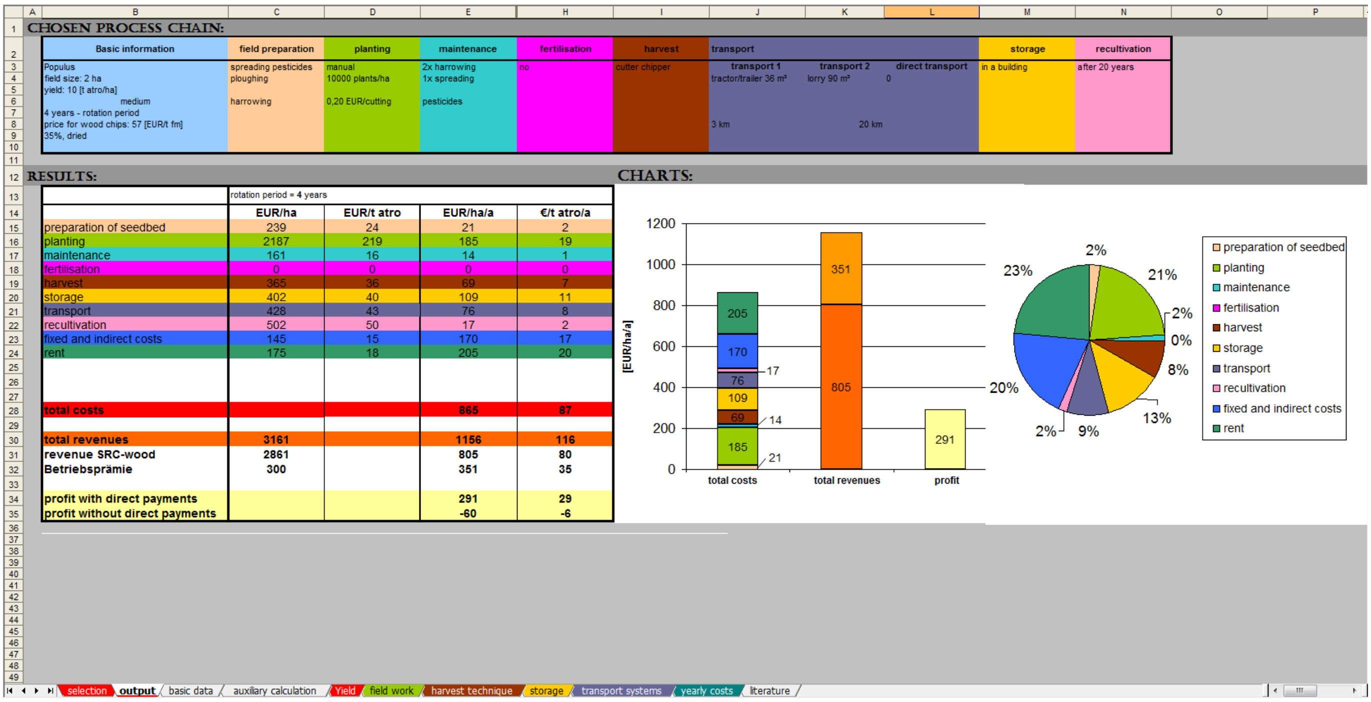


Figure 98: Output sheet of the calculation model which shows the chosen process chain, the costs for every process and charts of the results

4.4.3.3 Economical assessment – Results

The first part of the following chapter shows the total costs of the standard process chain. Based on this assessment the second part describes the influence of variable parameters on the total costs, what is investigated by a parameter analysis (Figure 9). The third part deals with modifications of the standard process chain with regard to different field sizes, willow as cultivated species and analysis of harvest- and transport systems.

Standard process chain

a) Overview on costs and revenues

For the standard process chain (see figure 93) the total costs of SRC cultivation were calculated to be 865 €/ha/a. The total revenues (right bar) amount to 1,156 €/ha/a which are separated in direct payments (based on financial supporting scheme by EU) and revenues for selling the wood chips. The price for selling the wood chips was calculated as 57.32 €/t fresh matter at a water content of 35%.

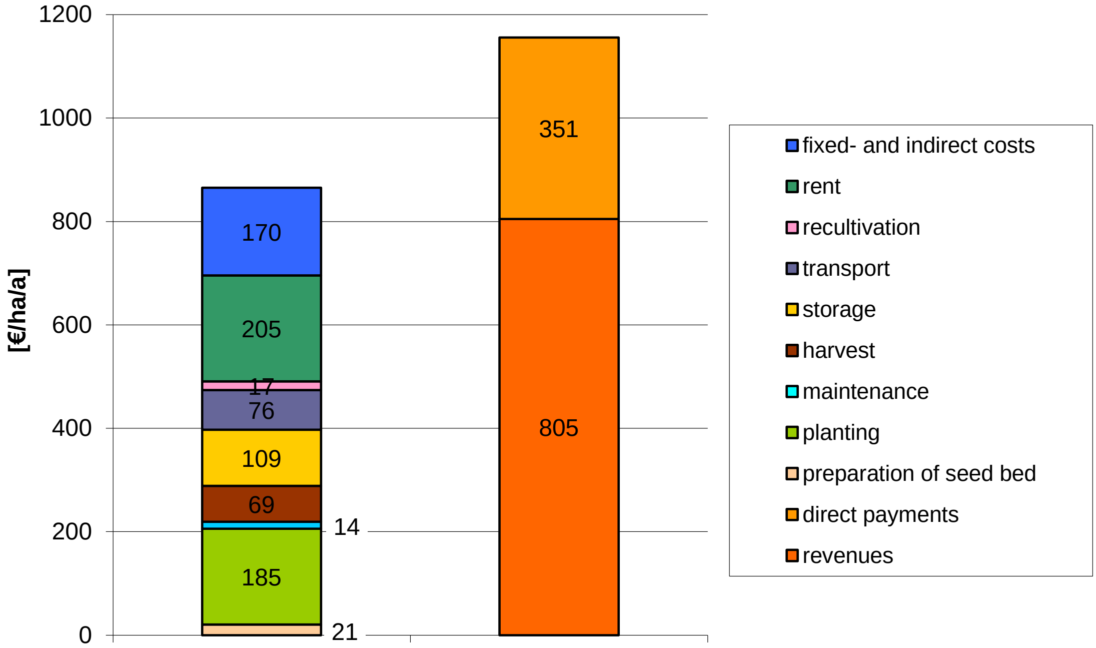


Figure 99: Costs and revenues of SRC cultivation based on the standard process chain in €/ha/a (price for wood chips: 57.32 €/t, 35% water content)

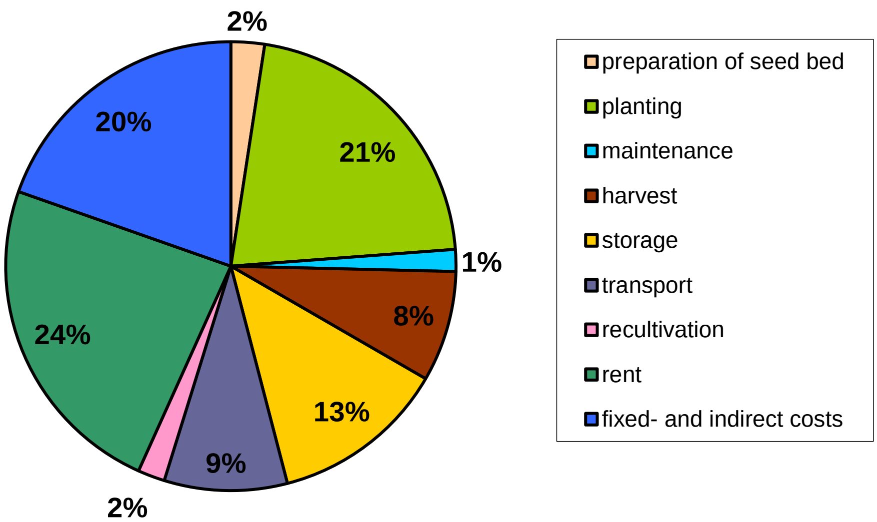


Figure 100: Share of costs for each module on the total yearly costs of SRC production with the standard process chain

The largest share with more than 40% of the total yearly costs is caused by the yearly fixed and indirect costs as well as the rent (see figure 100, based on figure 99). Fixed and indirect costs were taken exemplary for a farm of 150 hectares and include costs for electricity, water, fuels, maintenance of buildings and machinery, taxes, insurance, fees and possible other overhead costs. Planting of the SRC takes about 20% of the yearly costs (the costs for planting which occur once at the beginning of cultivation have been transferred to yearly costs (€/ha/a) following the annuity method in imitation of VDI guideline 2067 (2000). This is mainly due to the high costs for the cuttings which for the standard process chain are assumed to be 0.2 € per cutting. Storage, transport (20 km) and harvest contribute 13%, 9% and 8% to the total yearly costs. The costs for preparation of the seed bed and for recultivation are fairly negligible (≤ 2%).

b) Parameter analysis

For the most important factors affecting the costs of SRC cultivation a parameter analysis was done, based on the standard process chain (see figure 93). It shows the impact of the parameter variation on the total costs in €/ha/a, by changing only one parameter while the other parameters of the model remain unchanged. For the parameter analysis parameters with a high range of variation or with uncertain data are used. The 100%-values (numbers in brackets) are the numbers which were defined for the standard process chain.

The parameter analysis shows that the rent and the costs for cuttings have the greatest influence on the total yearly costs. This is due to the fact that the rent and the planting (which is mainly determined by the costs for cuttings) have a share of 24% and 21% within the total yearly costs of SRC cultivation (see figure 100). The next bigger effect is caused by the transport distance, the amount of yield and the costs for storage, whereas the required time for harvesting and especially the working load of the harvest machine have little influence.

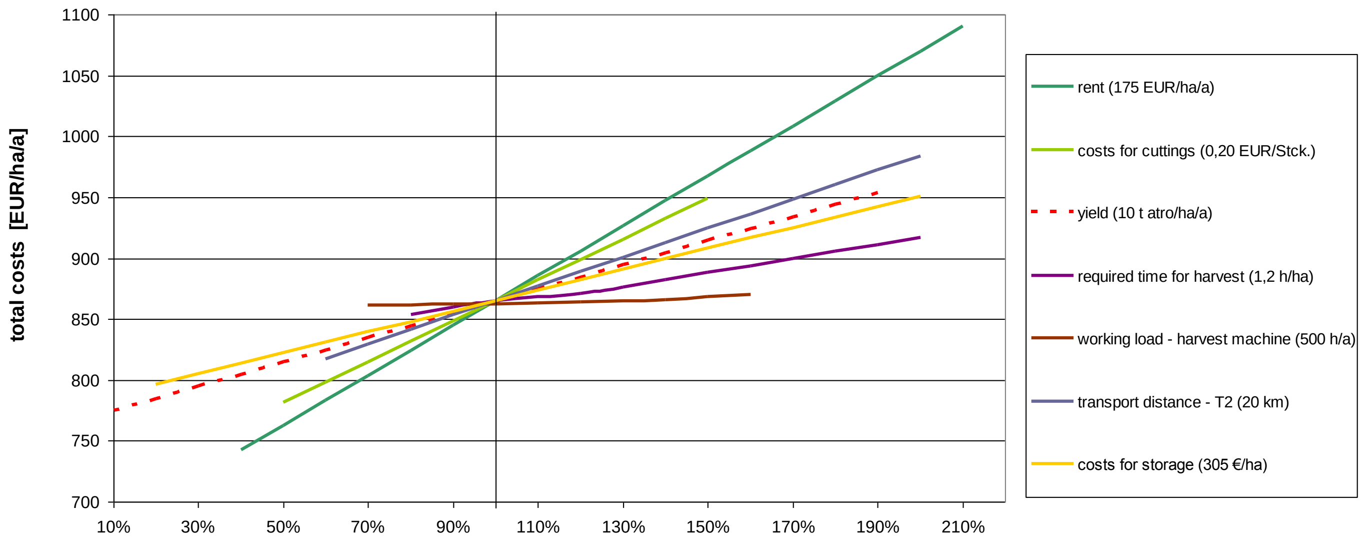


Figure 101: Parameter variation analysis for the costs of SRC cultivation

Following, the results are discussed in detail.

The total costs are mainly affected by the costs for rent, as these costs occur every year. About 64% of agriculture area in Germany is categorized as rented sites. There is a high variation of costs for rent within Germany (86 €/ha/a in Brandenburg – 366 €/ha/a in Nordrhein-Westfalen), which depends on the region, soil quality, climate, size shape of the field and others. Because of the focus on marginal sites a lower value has been assumed for the standard process chain (175 €/ha/a) (AGRAR.DE 2008).

The costs for cuttings are the highest costs within the costs for planting. Therefore costs for cuttings have another important impact on the total costs, although these costs appear only once during the useful life of the plantation. The costs for poplar cuttings are between 0.10 – 0.30 €/cutting (literature research).

A further factor which has great influence on total costs is the amount of yield, which directly affects costs for storage and transport. This is especially important for evaluating SCR cultivation on marginal sites where lower yields compared to higher quality sites have to be assumed.

The range of the yield is very high, because it is influenced by many factors like the climate and soil conditions, rotation period, species and different growth per year. In the context of this work it was not possible to consider all of these factors in full detail. For the calculations literature values (KTBL 2008) were used.

The distance for transport is an important aspect and the marginal costs for the maximum transport distance (if the profit is negative) should be taken into account for each process chain assessment. The range which was analyzed is between 5 and 200 kilometres.

The costs for storage also depend on many different factors (climate, weather, storage facilities, etc.). For the standard process chain storage of wood chips in a storage building is assumed. Detailed assumptions for storage are described in Annex 4.2.

At present there are not enough data available on the duration of harvesting with different machines, for different rotation periods and different tree species. Therefore the influence of the time for harvesting on the total costs is shown in the parameter analysis for a range from 1 to 2.4 machine hours/ha. The working load of the harvest machine is analyzed because of the potential of a higher working load, when SRC will be more established and the harvest machines will be used more efficiently. If SRC is better implemented in agriculture, higher working loads and therefore lower costs are expected. Nevertheless, the working load has the smallest impact on the total costs per year of the considered parameters.

Modifications of the standard process chain

a) Modification of field sizes

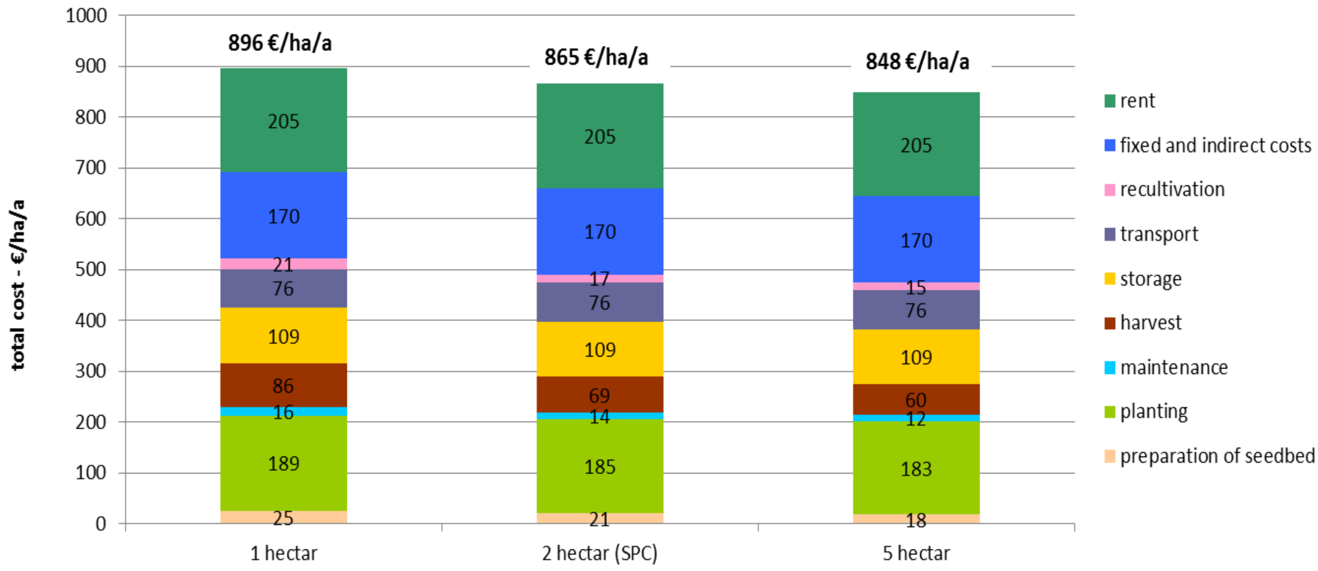


Figure 102: Comparison of total costs of SRC cultivation for different field sizes

(SPC = standard process chain)

As the focus of the project is on marginal and small field sizes, the influence of the field size on the total costs is analyzed for 1, 2 and 5 hectares (Fig. 9). These field sizes correspond to the results of the questionnaire for farmers (Annex 5.0). Most of the already existing as well as the potential SRC sites of the participants in the survey are smaller than 2 hectares. To illustrate the cost effects for bigger field sizes, the total costs of a 5 hectare field are shown additionally. The field size affects the working steps which are done on the field, because of a higher specific time demand for preparing and cultivating a smaller field compared to a larger one. The calculation of the time demand per hectare for the different field sizes is explained in Annex 4.2. In contrast, the transport costs and storage costs per hectare are not affected by field sizes.

Figure 102 shows that from 1 to 5 hectares the total costs of SRC cultivation are decreasing. The difference between 1 and 2 hectares is about 30 €/ha/a, between 1 and 5 hectares the difference is about 50 €/ha/a.

b) Modification of species: poplar and willow

To compare the cultivation of poplar (standard process chain) and willow for SRC it is assumed that willow is cultivated with 13,000 plants per hectare gaining a yield of 7 t_{atro}/ha/a on a medium site. The costs for willow cuttings are lower than those for poplar cuttings (0,08 €/cutting for willow, 0,20 €/cutting for poplar). For the cultivation it is assumed to fertilize the field after the first harvest. There are several data available showing a positive effect of fertilization on growth of willow but not on poplar (KTBL 2006, Scholz et al. 2004, Rehfuess 1995). For the calculations the other assumptions remained unchanged compared to the standard process chain. It is assumed that the measures for field works like preparation of seedbed, maintenance and recultivation and the yearly costs (rent, fixed and indirect costs) are the same as for poplar. Therefore the same costs were assumed. For the harvest of poplar and willow the same time for harvesting is assumed, as there are not enough data available at present.

Figure 103 shows the share of total costs for the willow process chain compared to the standard process chain (poplar). The total costs for the cultivation of willow (732 €/ha/a) are lower than those for poplar (865 €/ha/a). The cost difference is about 130 €/ha/a based on the assumption described above. Because of lower costs for the cuttings (willow: 0.08 €/cutting, poplar: 0.20 €/cutting) the planting costs for the cultivation of willow are much lower. The lower yields for the willow compared to the poplar cultivation results in lower transport and storage costs due to the lower amount of wood per hectare to be stored and transported to the end user. .

The calculation of revenues is based on the yield assumptions for willow and poplar. For willow the total revenues amount to 914 €/ha/a, for poplar they amount to 1,156 €/ha/a. Thus, the willow cultivation results in 242 €/ha/a lower revenues compared to poplar cultivation. These lower revenues are not compensated by the lower costs for willow cultivation (130 €/ha/a). Thus, for this case, if the site conditions are suitable for both species, poplar appears to be the preferred species.

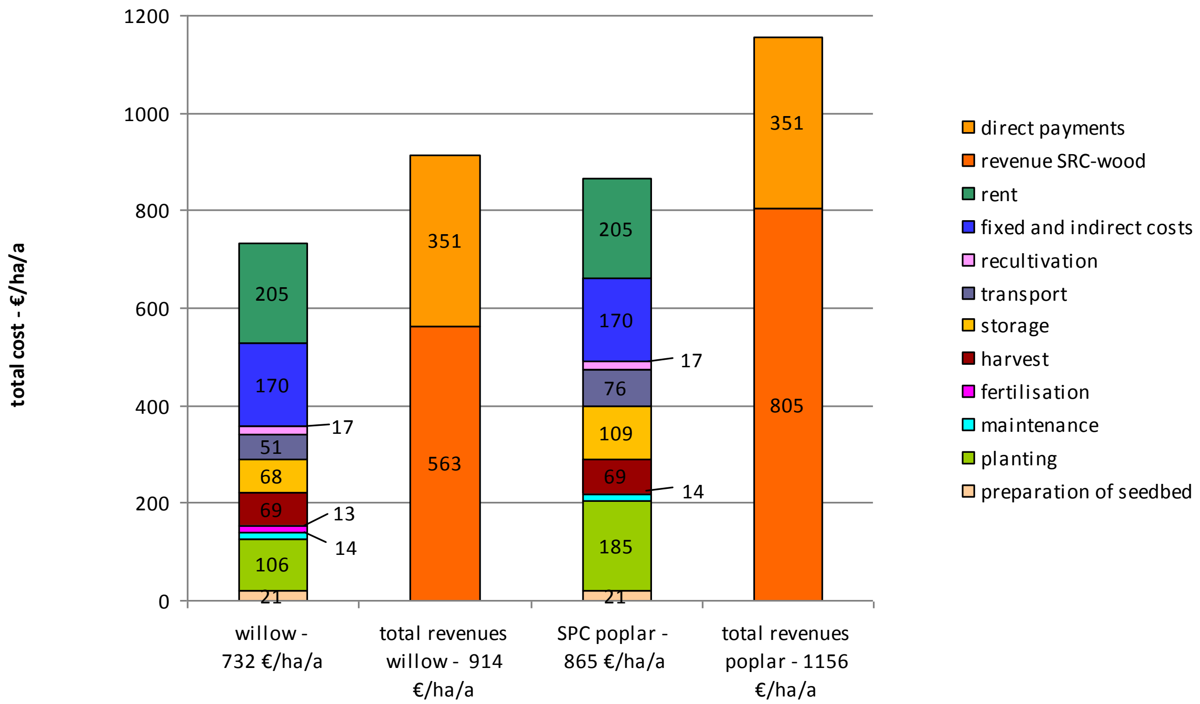


Figure 103: Comparison of total costs for the cultivation of willow and poplar

(difference of costs: 133 €/ha/a; difference of revenues: 242 €/ha/a)

c) Modification of harvest techniques

Figures 104 and 105 show the comparison of costs for three different harvest techniques. Those are harvest by a cutter chipper, by a cutter collector and motor manual harvest. These harvest techniques are chosen because they are commonly used or they have a potential of usage in the future, when SRC will be better established in the research area at small and marginal sites, like the cutter collector.

For all harvest methods, the costs for transport of the harvest machines to the SRC site were not considered. At present these costs can be very high because there are only little harvest machines for SRC available (See WP2). Therefore the current transport distances are very long and the transport costs high.

Cutter chipper

For cutter chipper harvesting only one working step was calculated, because the harvest and the chipping happens in one step. A tractor drives parallel to the cutter chipper to store the wood chips. Therefore wages for two workers are considered.

Cutter collector

The cutter collector “Stemster” is carried by a 102 kW tractor. The cutted trunks are moved away to a storage place near or at the field side by another tractor. After a storage period the stems are chipped by a mobile chipper at the field.

The cutter collector could have (besides the motor manual harvest) a beneficial effect for the harvest of small field sizes and marginal sites in the future. It is not as heavy as a cutter chipper and the farmer can use his own tractor and is more flexible with regard to the time of chipping the wood. If there is enough space at or near the field site to store the whole trees, the wood can be chipped, when the conditions are good and there is no need for a storage building and an extra transport.

Motor manual

The motor manual harvest is done by a chain saw. Two workers are needed for harvesting the trees. One for cutting the trees and one for hold the stems and putting them aside. The trunks are moved to the field side by a tractor for directly chipping them by a mobile chipper or storing them at the field side. Therefore two more workers are needed. The mobile chipper can chip the trees up to a diameter of 27cm.

The harvest by chain saw of the ten years old trees takes much more time and more workers .Because of the older and bigger stems, the moving and the chipping of the stems is more expensive than for the four years old stems for the cutter collector harvest. For the moving of the stems the need of a stronger tractor was considered and the chipping of the older stems needs more time.

The major cost component includes the wages for the workers. As many farms are family businesses, the members of the family are working on the field. The costs for the work being done by the farmer or the family are often not considered for the economical evaluation. To know whether a cultivation of SRC is profitable for the agricultural management or not, it is very important to consider all the costs for the own work.

Based on the rotation period the harvesting of the SRC takes place e.g. every 2, 3, 4 or even 10 years. Figure 12 refers to the costs in the year of harvest in €/ha. As the cultivation of the SRC is assumed to last for 20 years the costs for harvesting have to be transferred resulting in yearly cost for harvesting in €/ha/a (figure 105). The costs for the cutter chipper and the cutter collector harvest are assumed for four years rotation while the motor manual harvest is assumed for a ten years rotation.

Focusing just on the year of harvest (figure 104), the cutter chipper-harvest has the lowest costs. There is only one working step needed and less workers are demanded than for the other harvest techniques. The sole costs for the motor manual harvest (without moving trunks and chipping) process are higher than the total costs of the other harvest techniques. The costs of 461 €/ha of sole motor manual harvest include machine costs of 8 €/ha, fuel costs of 25 €/ha and labour costs of 429 €/ha. Compared to the costs for cutter chipper harvest (365 €/ha) there are much higher machine- and (173 €/ha) fuel costs (131 €/ha) but much lower labour costs (61 €/ha). This shows the labour-intensive character of motor manual harvest. The sole harvest costs for the cutter collector consists of machine costs of 134 €/ha, fuel costs of 50 €/ha and labour costs of 55 €/ha.

Additionally there are costs for moving trunks and chipping. These costs are lower for cutter collector harvest because of the lower yield in the year of harvest for 4-years rotation period. However, referring to the 20 years of SCR site cultivation (figure 105), the annuity of the costs for motor manual harvest are lower than those for the cutter collector and about those for the cutter chipper because there are only 2 harvests within 20-years.

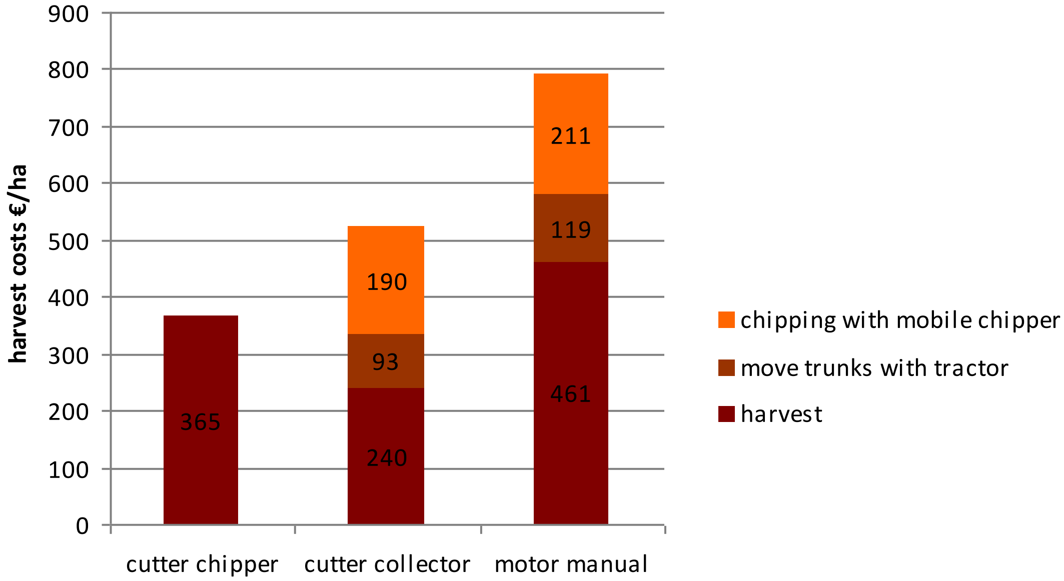


Figure 104: Composition of costs for the different harvest techniques per hectare

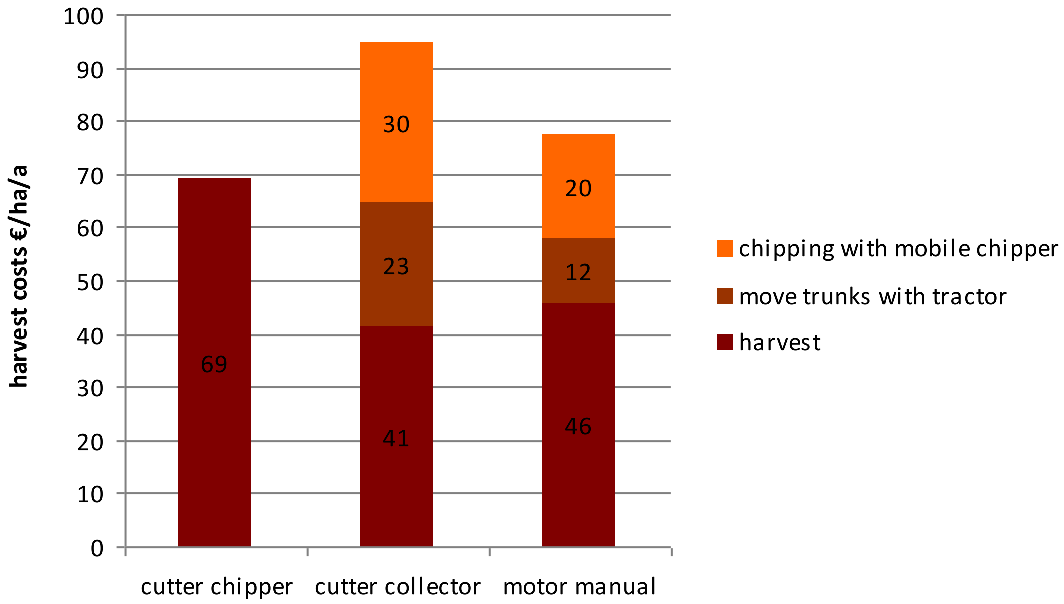


Figure 105: Composition of costs for the different harvest techniques per hectare and year for 20 years useful life and a rotation period of 4 years for cutter chipper- and cutter collector harvest and 10 years for motor manual harvest

(Yield assumed: 10 t_{atro}/ha/a)

Figure 106 shows the costs for the three harvest techniques in the context of the total costs in €/ha/a. For the process chain with a cutter collector harvest, a storage of the whole stems on the field is assumed. For storage on the field no costs are calculated. The motor manual harvest is considered for a 10-years rotation, why a direct comparison with the costs for the cutter chipper – and cutter collector harvest is only possible to a limited extent.
The planting costs are much lower due to less trees per hectare for a 10-years rotation (2,000 trees per hectare, for 4-years rotation: 10,000 trees per hectare). This is due to increased space requirements of older trees. Because there are only 2 harvests within 20 years and because of the lower yield per hectare and year (7.6 t_{atro}/ha/a), which is assumed for a 10-years rotation, the annuity of the storage costs is also lower.

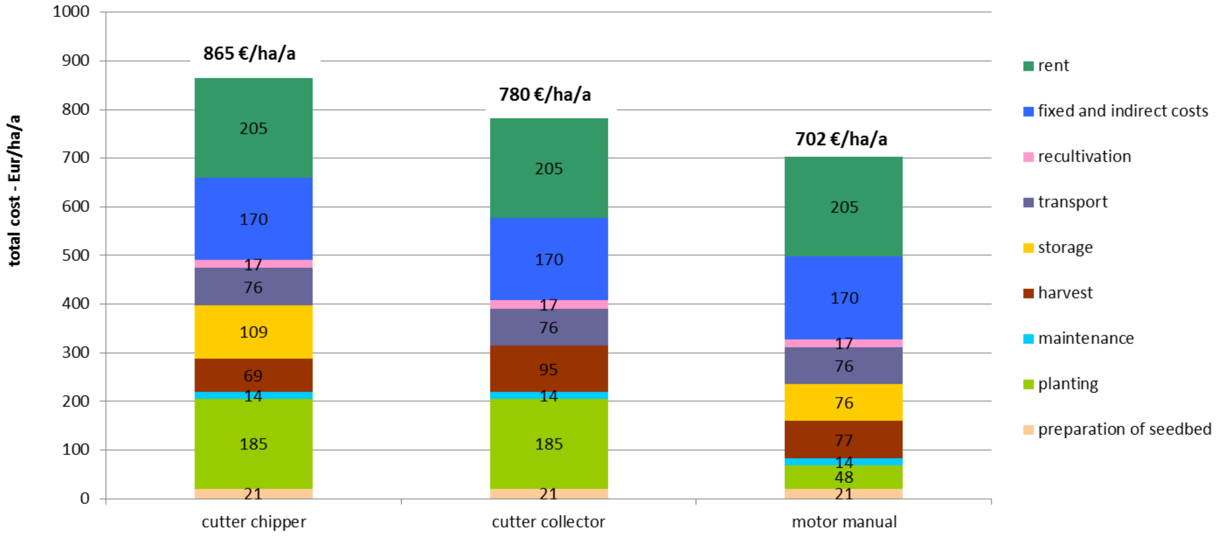


Figure 106: Comparison of total costs (€/ha/a) for the three different harvest techniques

d) Modification of transport systems and transport distances

Different options for SRC transport are possible and state of the art. The effect of the transport on the total yearly costs and on the profit (total yearly costs minus total yearly revenues) is analyzed for four different options (figure 109 and 110). The differences between these transport options are transport by tractor and trailer or by lorry and storage or no storage of the SRC-material. For total yearly cost calculation all the other processes from the field preparation to the harvest and the recultivation remain unchanged (see figure 107 and 16).

Transport “T1” is the transport from the field to the storage site or farm. “T2” means the transport from the storage site or farm to the end user (see figure 107 and 108). For T1 a distance of 3 km from the field to the storage site or farm is assumed for all calculations. Variations of transport distance (Fig. 109 and 110) are examined for T2 (up to 200 km).

For the transport options with an intermediary storage it is assumed that the storage in the building results in a water loss from 55% to 35%. For the dried material a higher wood chip price is assumed (57 €/t fm instead of 36 €/t fm, see figure 107 and 108).

Figure 107: Transport system **with** storage. Transport to storage site (T1) with tractor and trailer; transport from storage to end user (T2) either with tractor and trailer or with a lorry

Basic Information						T1	Storage	T2	
water content 35%; price for wood chips 57 EUR/t FM	field preparation	planting	maintenance	fertilization	harvest	tractor and trailer	yes	tractor and trailer lorry	recultivation

Figure 108: Transport system **without** storage. Transport to storage site (T1) with tractor and trailer; transport from storage to end user (T2) either with tractor and trailer or with a lorry (including reloading)

Basic Information						T1	Storage	T2	
water content 55%; price for wood chips 36 EUR/t FM	field preparation	planting	maintenance	fertilization	harvest	tractor and trailer	no	tractor and trailer Lorry (including reloading)	recultivation

The comparison of tractor/trailer and lorry for different transport distances in figure 109 shows the following results on the total yearly costs for SRC cultivation:

- The yearly total costs are clearly growing with growing transport distances form storage/farm to the end user.
- The cost curves including the transport options by tractor/trailer (with and without intermediate storage) are much steeper compared to cost curves including the transport by lorry. The main reason for the higher costs and the steeper slopes for transport by tractor/trailer is the higher time demand compared to transport by lorry (differing driving speeds and tolerable transport loads).
- In general, the lowest yearly total costs for SRC cultivation include the direct transport by lorry (without storage). Only for very short distances the direct transport by tractor/trailer (without storage) is cheaper than the transport by lorry.

The comparison of transport by tractor/trailer and lorry with and without storage shows the following results on the total yearly costs for SRC cultivation. Not for all cases the total yearly costs are lower if there is no storage:

- Transport by lorry **without storage** is cheaper than transport by lorry **with storage** for all transport distances.
- Direct transport by tractor /trailer is cheaper than transport by tractor/trailer with storage up to a transport distance of about 75 km.
- Comparing all options of transport and storage/no storage, the direct transport by lorry leads to the lowest yearly costs. Up to a distance of about 15 kilometres also direct transport by tractor/trailer (**without storage**) is characterized by comparably low costs. For more than 15 km both options of lorry transport (with and without storage) cause the lowest costs.

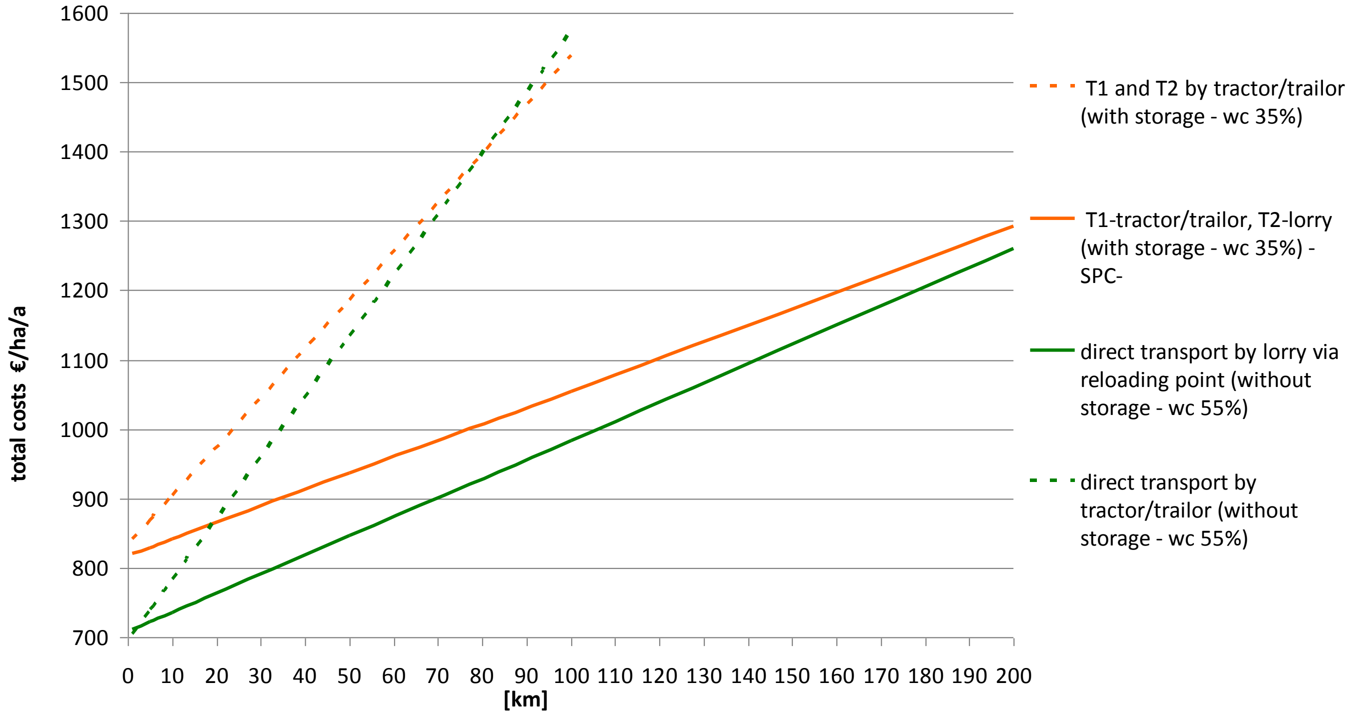


Figure 109: Comparison of costs €/ha/a of various transport systems by a rising transport distance (SPC- standard process chain)

Figure 110 shows the profits for the process chains with and without storage, for different transport means and transport distances in €/ha/a. The profit is defined as the difference between the revenues for selling wood chips and the costs for SRC cultivation. It is assumed that wood chips with a water content of 35% (after storage) will earn a price of 57 €/t fm, whereas for wood chips with a water content of 55% (delivery to the end user without storage) 36 €/t fm will be achieved. Thus, the relevant factor is the price difference of the stored and fresh wood chips.

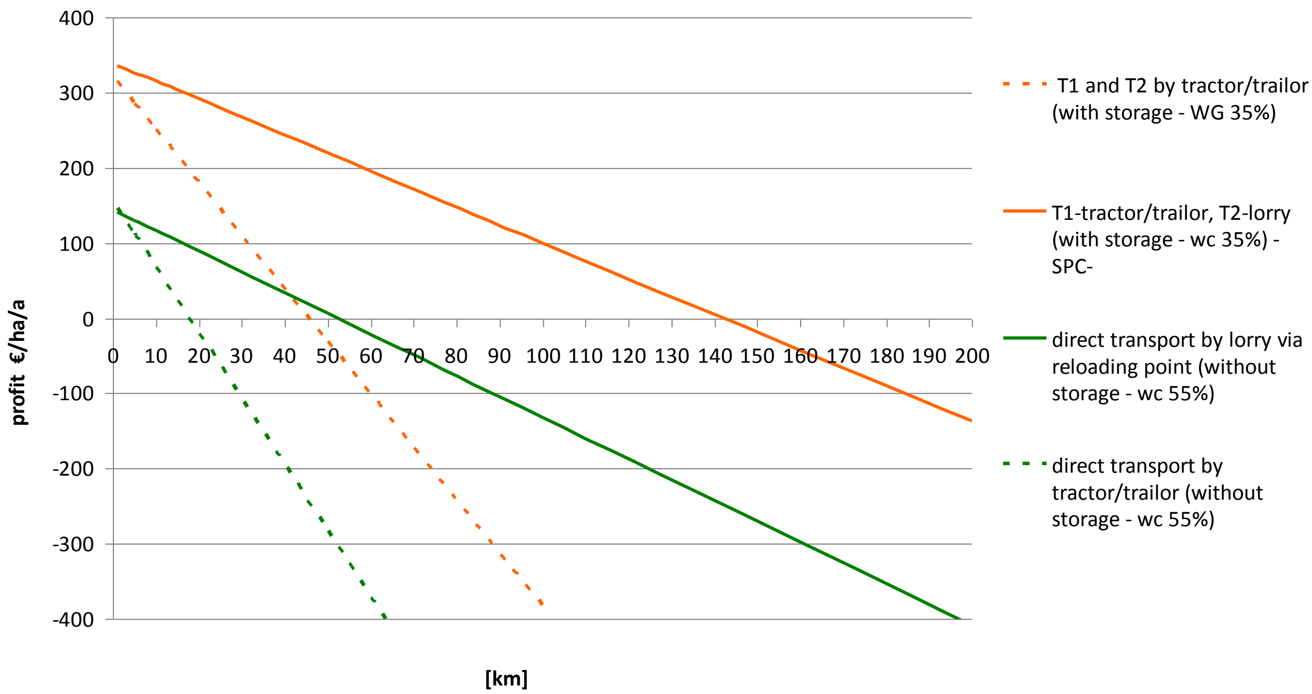


Figure 110: Comparison of profits €/ha/a of various transport systems by a rising transport distance (SPC – standard process chain)

The comparison of tractor/trailer and lorry for different transport distances shows the following results on the yearly profit for SRC cultivation:

- Based on the given assumptions the highest profit can be achieved for the SRC cultivation process chain with transport by lorry and an intermediary storage. Transport distances longer than 140 km result in negative profit data.
- Using exclusively tractor/trailer for transport to the storage and to the end user a profit can be achieved up to a transport distance of about 45 km.

The comparison of transport by tractor/trailer and lorry with and without storage shows the following results on the yearly profit for SRC cultivation. For the SRC cultivation process chains without storage the results differ clearly:

- In general, for all transport options and transport distances (up to 45 km) the profits without storage are lower compared to the storage cases.
- Nevertheless, delivery of the fresh wood-chips may be an option for short transport distances. For those cases (small) profits still can be assumed.
- The direct transport by tractor and trailer of fresh wood chips achieves the lowest profit. The profit is only positive up to a transport distance of about 20 km.

These results show that an intermediate storage may be well worth in most of the cases because of higher prices for dried material.

Due to the fact of longer distances between marginal sites or rather small field sites and the farm, there can be higher transport costs. As mentioned above, the distance from farm to field for all shown transport systems is assumed to be 3 kilometres. Therefore, a higher transport distance results in a proportionally increase of costs and decrease profits (Fig 17 and 18), which does not lead to any changes of the preferibility of the shown transport systems.

4.4.3.4 Risk analysis

Risks and effects of the cultivation of SRC have been evaluated by a SWOT-Analysis. The SWOT analysis is a strategic planning method for project or business ventures, with the aim to identify the positive and negative key factors for the specific/planned project. It represents the basic analytical framework for strategy research. The available information is broken down in four areas: “Strength”, “Weaknesses”, “Opportunities” and “Threats”. According to this, KOTLER et al. 2008 defines a strategy as the result of the opportunities and threats of the technological and economic environment and the strengths and weaknesses of the company.
Criteria which concerning SRC have been classified as belonging to the above mentioned four categories.

The following analysis is divided into two SWOT tables regarding the cultivation of SRC on a field with good or medium conditions (see table 15) and for the cultivation on a marginal site (see table 16). To interpret these tables it should be considered that the cultivation on a field with **good or medium conditions** implicates, that the cultivation before the SRC was **more intensive** than the SRC cultivation itself. The cultivation on **a marginal site** implicates, that the cultivation before the SRC was **less intensive** than the SRC cultivation itself. The criteria in the several categories are a sampling of results of the project work, statements from literature (BURGER 2004 & 2008, BUND 2010, DBU 2010, RÖDL 2008, an others) and an expert consultation.

Strength deal with the advantages of SRC on good or medium sites respectively marginal sites; Opportunities deal with the chances which are offered by the cultivation of SRC. While Weaknesses mainly deal with criteria which will not change (which can be at most attenuated), when SRC is established in agriculture, Threats deal with criteria which have to be reduced to establish SRC.

Each category of the SWOT tables is separated into “ecological criteria” and “economical/socio-economical criteria”.

1. Establishment on good/medium site

Table 15: SWOT analysis for the cultivation of SRC on good/medium sites

Strength	**Weaknesses**
Ecological • More extensive land use • Positive affection of the landscape – biotope network and Increase of biological diversity in the landscape scale in cleared agricultural landscapes • Shelter for game • Soil conservation: reduction of wind -and water erosion, accumulation of humus, .less leaching of nutrients,*less soil compaction • Storage of CO_2 • Reduced use of fertilizers and pesticides - Possible to combine with organic farming • Emissions are lower than those for straw-based fuels (for cultivation and combustion) ***Economic/ socioeconomic*** • Diversification of income in agriculture • Little effort • Field keeps the status as agricultural site (rotation period < 20 years) • Good sales potential for wood (Dendromasse) • Use of established harvest methods > no drastic change in cultivation methods • Low costs because of fully mechanized work • Vegetative reproduction because of homogeneous planting material, low costs • Strengthening of regional economy • Breaking work peaks in agriculture	***Ecological*** • Monoculture ***Economic/ socioeconomic*** • Low flexibility for adaption to the market and political guidelines • Long-term fixation of capital and field • Problem of renting fields and increased expenses in advance • Lower biomass yield compared to agricultural production (eg. maize) • Revenues are lower than for grain • High investment in the year of establishment • Neighbor fields could be affected by the shadow and the roots of trees. There has to be kept a minimum distance
Opportunities	**Threats**
Ecological • Diversification of cleared landscapes and Increase of biological diversity in the landscape scale in cleared agricultural landscapes ***Economic/ socioeconomic*** • Chance for diversification for the agricultural business • Increased revenues from rising oil prices • Opportunity to use SRC material for wood gasification (expensive) • Intensive field of research – Opportunity for innovations and significant potential for development • partnership of convenience (machinery rings) can be founded • Field of development for rural regions	***Economic/ socioeconomic*** • Shortage of information stand • Lack of specialized knowledge, especially about harvest • Less experience with harvest and storage of SRC-material because of mainly younger plantations in the research area • Uncertain log-term decline • Partial change of management practices (new harvesting machines) • Missing (harvest-) technology and high costs due to the fact of not yet established special machine • use of a few licensed clones that are present in large numbers (risk that existing resistances are broken by pathogens) • Prices for grain are increasing (Worth cultivate more grain) • Change of funding programmes • Change of land use and competition of land use • Information of amendment is not well known everywhere . There is still insecurity about that. • Further need for research, development and political support of implementation

2. Establishment on marginal site

Table 16: SWOT analysis for the cultivation of SRC on marginal sites (⇒ Arguments valid only for establishment on marginal sites)

Strength	**Weaknesses**
Ecological • Positive affection of the landscape – biotope network and Increase of biological diversity in the landscape scale in cleared agricultural landscapes • Shelter for game • storage of CO_2 • Emissions are lower than those for straw-based fuels (for cultivation and combustion) ***Economic/ socioeconomic*** ⇨ Possible use of previously unused marginal sites • Diversification of income in agriculture • Little effort • Field keeps the status as agricultural site (rotation period < 20 years) • Good sales potential for wood (Dendromasse) • Use of established harvest methods > no drastic change in cultivation methods	***Ecological*** • Monoculture ⇨ degradation of biodiversity in species-rich wasteland ***Economic/ socioeconomic*** • Low flexibility for adaption to the market and political guidelines • Long-term fixation of capital and field • Lower biomass yield compared to agricultural production (eg. maize) • Revenues are lower than for grain • High investment in the year of establishment • Neighbor fields could be affected by the shadow and the roots of trees. There has to be kept a minimum distance ⇨ Lower yield on marginal sites ⇨ Higher costs on small field sites ⇨ Difficult to drive on wet sites or on slopes
Opportunities	**Threats**
Ecological • Diversification of cleared landscapes and Increase of biological diversity in the landscape scale in cleared agricultural landscapes ***Economic/ socioeconomic*** • Chance for diversification for the agricultural business • Increased revenues from rising oil prices • Opportunity to use SRC material for wood gasification (expensive) • Intensive field of research – Opportunity for innovations and significant potential for development • partnership of convenience (machinery rings) can be founded • Field of development for rural regions	***Economic/ socioeconomic*** • Shortage of information stand • Lack of specialized knowledge, especially about harvest • Less experience with harvest and storage of SRC-material because of mainly younger plantations in the research area • Uncertain log-term decline • Partial change of management practices (new harvesting machines) • Missing (harvest-) technology and high costs due to the fact of not yet established special machine • use of a few licensed clones that are present in large numbers (risk that existing resistances are broken by pathogens) • Prices for grain are increasing (Worth cultivate more grain) • Change of funding programmes • Change of land use and competition of land use • Information of amendment is not well known everywhere . There is still insecurity about that. • Further need for research, development and political support of implementation

Strength and Opportunities from an ecological point of view

SWOT-Tables 2 and 3 show clearly that the ecological criteria appear as Strength and Opportunities of SRC rather as Threats or Weaknesses.

Main criteria for ecological strength of SRC are advantages for biodiversity, landscape, soil and low emissions.

At present there is no established methodology to measure the effect on biodiversity. However, the impact of cultivating SRC on biodiversity is often expressed by the numbers of plant or animal (especially insects) species compared to other fields with conventional crops. There is some literature about phyto- and zoo-biodiversity in SRC which deals with development of insects and birds and some improvement measures which can support biodiversity in SRC (for example: DBU 2010, BURGER 2004b, JEDICKE 1995, HELBIG & MÜLLER 2010). GLASER & SCHMIDT (2010) found much more plant species in a 2 years old SRC (average number of species: 21) than on arable land (5.7) and even more than on extensive grassland (17.3). When the trees are older (8 years old SRC) there can be found only 15.9 plant species (average number) however, this are much more species compared to arable land.

Positive effects on soil quality are less soil compaction than for cultivation of annual crops, accumulation of humus because the leaves stay on the field and reduction of erosion due to a perennial planting. Furthermore the need for pesticides is very low as well as the need for fertilizer.
According to the testimony of PALLAST et al. 2006, there is no need for fertilizing if site-adapted species are used and agricultural sites contains more nutrients compared to forest sites. On marginal sites with poorer nutrition, due to a less intensive land use before, it is possibly necessary to use more fertilizer than for medium or good sites. Using no fertilizer improves the life cycle analysis immensely. The share of production and application of fertilizer is over 60% of the total energy for the production of 1 tone wood chips and 83% of the emission of greenhouse gases (RÖDL 2008). Table 4 shows some life cycle indicators which demonstrate the environmental impact of wood chips production from SRC cultivation with and without fertilizer.

Table 17: Comparison of life cycle indicators for production of 1 t wood chips from SRC cultivation (inclusive all processes which have to be done on the field site) with and without fertilization. (Based on RÖDL 2008)

	Without fertilizer	With fertilizer
Total energy demand [MJ]	136,5	361,2
CO_2-emissions [kg CO_2 / t_{atro}]	11,5	22,1
N_2O-emissions [g N_2O / t_{atro}]	0,7	129,4
Global warming potential gross value [kg CO2-equivalents / t_{atro}]	11,9	62,2
Global warming potential net value (GWP input (storage of trees) – GWP output) [kg CO_2-equivalents / t_{atro}]	-1839	-1789

Compared to cultivation of annual crops, what is done mainly on medium or good sites these are strong criteria for enhance ecology by cultivating SRC. It also means if SRC is cultivated on a site with a more intensive cultivation before, many ecological advantages can be identified as Strength of the SRC cultivation. There are Opportunities to diversify cleared landscapes, improve soil quality and reduce emissions, amount of fertilizer such as pesticides. However, considering that most SRC within the examination area are cultivated on marginal sites the number of criteria decreases, because of less potential of ecological enhancement.
The ecological criteria for “Strength” are only fully valid, if SRC is cultivated on medium/good sites. This is because of the assumption of a higher conservation value of marginal sites, as marginal sites are often used as uncultivated land
Weaknesses and Threats from an ecological point of view
As mentioned above there are only few ecological criteria for Weaknesses and Threats. Regarding the fact that SRC is cultivated as monoculture, there is no advantage compared to other annual crops. Additionally for SRC on marginal sites, which can be species-rich wastelands there is a risk of degradation of biodiversity. As there are only few approved clones which are planted in monocultures there is a risk that existing resistance of pests of these clones can be broken. This criterion is valid for SRC on medium or good sites as well as on marginal sites.
Strength and Opportunities from an economic and socioeconomic point of view
There are some criteria, defined as Strength which can support the decision of a farmer to cultivate SRC. The diversification of income (which is also an Opportunity for SRC and also valid for marginal sites), low workload compared to annual crops, no drastic change in cultivation methods and the breaking of work peaks due to harvest during winter season. These criteria have also been chosen by the farmers who participated in

the survey which has been performed within the project (Annex 5.0). However, criteria like the good sales potential, lower costs compared to annual crops and increasing prices are critical what is also proved by the survey. Figure 111 shows the price development for wood chips in the last 4 years. The criterion of rising prices for wood chips can be identified as most important from the perspective of farmers and is linked with the Opportunity of continually rising wood prices due to rising oil prices.
The cultivation of previously unused sites is an additional criterion for Strength of SRC on marginal sites, while breaking work peaks due to harvest in winter and a low workload compared to annual crops are no valid criteria for SRC on marginal sites for which a more extensive cultivation before the SRC is assumed.

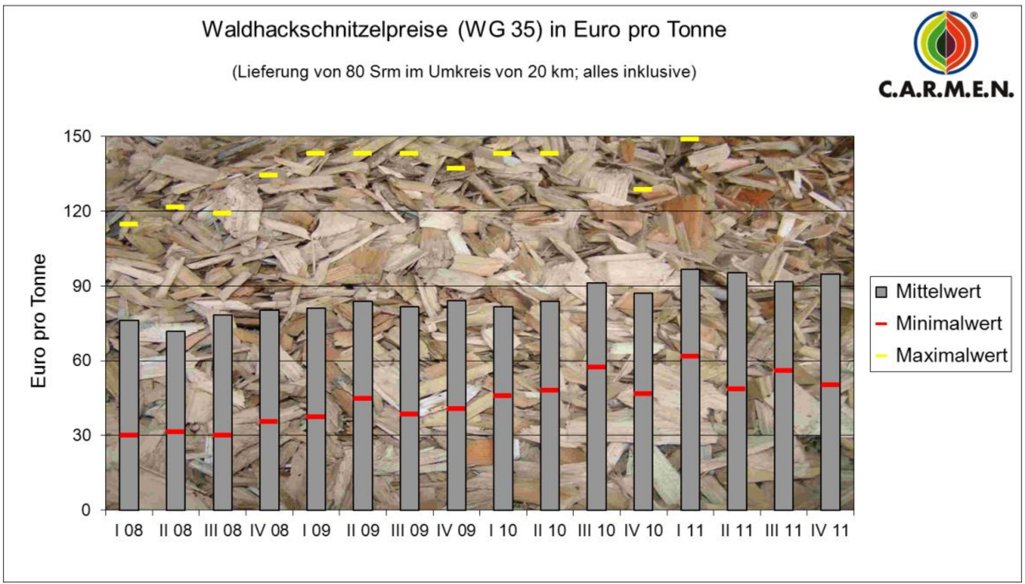


Figure 111: Development of prices for wood chips (forest material) from 2008 to 2011 in €/t $_{fm\ 35\%}$ (CARMEN 2009)

The strengthening of regional economy by marketing of regional renewable fuels can be a criterion from the community and regional political perspective to support the cultivation of short rotation coppices. Especially for rural regions SRC, as an innovative, still relatively unknown renewable energy source can be a chance for the local economy. There are several examples of regions or villages which focused on renewable energies and were supported by national programmes. In this context networks to share knowledge and machinery ring can be founded.
A major Opportunity lies in the development- and innovation potential of SRC, because there is a lot of research going on. These Opportunities are provided in the field of cultivation as well as in the technologies for the energy technical utilisation of SRC-wood.

Weaknesses and Threats from an economic and socioeconomic point of view

The effect of a SRC as a perennial crop has positive influence on ecology but expect of the lower costs compared to annual crops, there are negative influences on economy. Compared to annual crops there is a reduced flexibility for market adaption and response to political guidelines. Land and capital are fixed for long time what is unusual for most farmers who cultivate annual crops. However, the long usage of land is a bigger problem for SRC on medium/good sites than on marginal sites, where another use is unlikely. The criterion of lower yield compared to other crops like maize is a strong criterion against cultivation on medium/good sites but is not valid for SRC on marginal sites, where the production of crops with better prices is rather untypical. On marginal sites there are other problems which can arise instead, like a lower yield, higher costs (for small field sites) and difficulties for the heavy machines if the site is wet or on a slope.

Most criteria for Threats like the poor level of information, the lack of knowledge, less harvest experience and not yet established harvest technologies, only result from the fact that SRC is not implemented in agriculture so far and show approaches where specific action is necessary and possible to support a better implementation of SRC (see also Annex 5.0 –survey among farmers -“Recommendations for action”). These Threat-criteria are valid for SRC on medium/good sites as well as for marginal sites. The increasing prices for grain what make it even more attractive to cultivate it, does not apply for SRC on marginal sites, where it is not assumed to cultivate grain, as well as the competition of land use, which is strong on medium/good sites but hardly present on marginal sites.

4.4.3.5 Summary of results

In the work within **work package 4** an economic evaluation and integrated assessment of SRC cultivation was carried out taking into account the conditions of small scale and marginal land, as it is often the case in Germany and particularly in the test regions of Baden-Württemberg or France. For the economic evaluation a calculation tool was developed which can be used to test variations of parameters and conditions for SRC cultivation. The following main results were achieved:

- The economic assessment of various process chains, representing the small scale and marginal land conditions showed that the largest share of costs is caused by the rent (24%) for agricultural land and by the establishment of the cultivation (21% of total cost). Also fixed and indirect costs determine (20%) the overall costs to a large extent.
- The effect of field size on costs was demonstrated. On a five hectare field the cultivation costs (848 €/ha/a) were about 5% lower than on a one hectare field (896 €/ha/a).
- The specific cultivation costs per hectare were clearly lower for willow (732 EUR/ha a) (- 15%) compared to poplar (865 EUR/ha/a). However, the yield is also lower (8 vs. 10 t/ha/a) (-20%).
- The choice of harvesting technique and the mode and distance of transport have clear effects on the costs. Regarding different harvesting techniques the total costs for SRC cultivation vary from about 865 €/ha/a using a cutter chipper to about 780 €/ha/a using a cutter collector for harvesting. However, it has to be regarded that the choice for the appropriate harvesting technique depends on the type and quality of wood demanded by the consumer e.g. size of wood chips or water content. The transport costs are highly influenced by the distance from field/storage to the consumer. For cost optimal solutions the combination of technologies and processes of SRC cultivation have to be identified with regard to the site and the quality requirements of the consumer.
- The socio-economic background and motivations of stakeholders for SRC cultivation were evaluated through a questionnaire survey in Germany and France (together with WP5). The results show that additional offers for information and consultation should be provided, but should concentrate on giving a deeper understanding of the whole process chain and the long term character of the crop cultivations. Research is needed especially for cost-efficient and feasible harvesting technologies for small and marginal sites.
- A SWOT-analysis was performed to evaluate the environmental and economical effects and the chances and risks of SRC cultivation on marginal sites compared to the conditions of good/medium site. Ecological criteria appear as Strength and Opportunities of SRC rather as Threats or Weaknesses, while they are only fully valid, if SRC is cultivated on medium/good sites. This is because of the assumption of a higher conservation value of marginal sites, as marginal sites are often used as uncultivated land.

It became clear that the cultivation of SRC may contribute to the diversification of cleared landscapes and may increase the biological diversity. Thus the site specific conditions and the reference value/system determine to a large degree the balance of the environmental impact of SRC cultivation.

4.5 Survey among farmers on the opinion, motivation, implementation problems of SRC production among farmers (Work Packages 4 & 5)

4.5.1 Introduction (WP 5)

In order to analyze the broader framework for the SRC production in the study regions and to identify the reasons, why farmers decide to invest or not to invest in SRC, a large scale quantitative survey has been carried out conjointly with IER (Institut für Energiewirtschaft und Rationelle Energieanwendung, Universität Stuttgart) between March and July 2010. The questionnaire was spread among farmers and focused on operational information on their enterprise, the attitude towards renewable energies in general, the awareness and attitude towards SRC, the aspired financial returns by SRC and possible business models between SRC producers and consumers.

The questionnaire was distributed online and in paper form within selected areas in Baden-Württemberg and North-Rhine Westphalia in Germany as well as in the Département du Haut-Rhin in France.

Overall, more than 1,700 questionnaires were distributed.

The results of the survey will help to analyze and understand the current framework of SRC in Germany and France for farmers' point of view and allow interpreting the hesitative reaction of many farmers when it comes to decision making concerning SRC plantation. It will also enable to determine incentive mechanisms and improvements in the legal-, financial- and technical framework of SRC production in order to foster SRC production as source of renewable woody biomass.

At present, most of the research results available have been obtained for medium to good sites and the presumptions of a large field size for the SRC-plantations. However, these site conditions can rarely be found in South-West Germany and North-East France. CREFF was thus based on the hypothesis that SRC are predominantly established on unfavorable sites (soil, size, form, location).

4.5.2 Summary of the results (WP 5)

In total, 135 farmers have participated in the survey of which 21 own a SRC plantation. The participating farmers are unevenly distributed among the four regions formed throughout the study area, namely the Bas-Rhin in Alsace, North Rhine-Westphalia and Baden Württemberg. The county of Hohenlohe in Baden-Württemberg has been analyzed as a separate region as due to support from the agriculture administration the response rate was more than a third of all responses.

Attitude of farmers towards biomass for energy purposes

82% of the participating farmers have a positive attitude towards the use of biomass for energy purposes. Furthermore, for 49% of the farmers, the interest in production of biomass for energy purposes has increased during the last years. About 30% do own a biomass energy production facility (heating plant or biogas plant) and 43% of those are already producing biomass for their own plant.

However, 90% of the questioned farmers were saying that there is a slight or severe competition between the production of energy crops and food production.

Level, need and sources of information on SRC

Only 20% of the 135 farmers have never heard of SRC so far. In the region of Bas-Rhin in France, this proportion however reached 52%.

60% of all participants said that they feel not fully informed and 88% of these farmers would like to have more information about SRC. Furthermore, 90% of the farmers, who are already own SRC plantations (SRC owners), and 47% of the farmers without SRC are interested in acceding a "SRC-network". This shows that an important need of information prevails among farmers.

The most important source of information, as stated by the vast majority of all farmers, are agricultural journals. Field visits and information meetings seem to play an important role for 72% of the SRC owners.

This shows a clear difference between the information acquisition of SRC owners and farmers without SRC. Field visits and the information meetings require an active information demand by truly interested farmers. Furthermore, it has been observed that 95% of the 21 SRC owners have neighbors owing an SRC. In contrast this proportion was lower for farmers without SRC (13%). Of these farmers 67% said that they are not fully informed on SRC. This confirms the hypothesis that pilot co-operations could offer a certain multiplication effect by knowledge-transfer and offering experience within a region.

Attitude towards SRC production and the future of SRC

The vast majority of the farmers showed a positive attitude towards SRC. Whereas SRC owners nearly exclusively named positive arguments for SRC production, farmers without SRC also stressed cons (f.ex. unsuitable for agriculture). For both groups, the argument "interesting production option" is especially underlined.

Regarding the future evolution of SRC, 71% of the farmers said that its importance will increase due to the increased demand for biomass and the increasing information level. Only 26% of the participants answered that SRC will remain on its low implementation level cause by a lack of suitable sites, a low level of profitability and the competition to food production has been addressed as a hindering factor for a wider spread of SRC plantations.

Arguments for SRC production

More than 90% of the participants selected arguments from the category "Intensification and increase of revenues". The most frequently named arguments for SRC are „the usability of marginal sites and fallow land for SRC" by respectively 71% and 61% of the SRC owners. The chances for SRC are thus seen in the activation of so far barely used sites leading to an increase of the financial revenue (intensification).

Arguments against SRC production

Arguments of the category "insufficient profitability" have been named by 89% of all the participants. SRC owners (57%) and farmers without SRC (49%), 50% of the participants in total consider the "high investment costs" as critical. 48% of farmers without SRC named the "long lasting binding of sites and capital" as a disadvantage for SRC. 41% of the participants stressed the "low prices for SRC biomass". In addition

72% of the participants named arguments in the category „uncertain business conditions", to 71% the "lack of harvest machinery/technology" has been selected. For 56% of the farmers without SRC "the uncertain market conditions" for SRC material is the major obstacle.

Will to invest in SRC production within the own company and reasons for or against an investment

36% of the farmers without SRC would not invest into SRC. 55% of the participants answered this question with "maybe" and 8% said "yes" to SRC investment.

This shows that the majority of the participants (63%) would invest "yes" or "maybe" into SRC production.

Asked why they would like to invest 94% of the potential SRC investors ("yes", "maybe") and 85% of the SRC owners selected arguments from the category „ intensification and increase of revenues" as pros for SRC production. The creation of a "new source of income" is of great importance for the potential SRC investors (54%). 50% of the SRC owners stressed out the importance of biomass production for their own consumption.

All participants rejecting SRC investment named arguments from the category „operational reasons" as hindering factor. Most prominent hereunder the argument "Lack of suitable fields" was addressed by 80% in combination with the argument "business focus on other products". In addition, "lack of knowledge" was seen as obstacle for 50% of the participants.

Characterization of typical SRC sites

Those farmers, who showed a certain disposition, the potential SRC investors ("yes", "maybe") have been asked to describe the characteristics of their potential fields for SRC. 65% of the offered fields are said to be small (<2ha) and situated at long distance from the farm (92%). In 62% of the cases, the future SRCs would be established on marginal sites, the rest on medium site conditions. Only 10% would be fallow land.

The already existing SRC plantations have been to 41% established on previous agricultural fields and to 62% of medium soil quality. 58% of these fields also have size smaller 2 hectares.

Business concepts for SRC production between producers and consumers of SRC biomass

58% of the farmers without SRC and 75% of the SRC owners strove for business concepts with a high degree of cooperation with the SRC consumer side. This clearly speaks for the approach that co-operations between SRC producers and consumers can support SRC investments by offering markets, developing of supply- and value chains and to overcome starting constraints.

SRC potential in the project area

The participants of the survey described 250 ha of either potential or already established SRC sites. The average, potential SRC area per farm for the entire research area is of 1.8 ha, corresponding to 2.4% of the individual area of the farm. Based on the data is possible to calculate an economical potential for the future SRC production in the research area. The calculation results in a total of 13,000 ha of potential SRC sites, representing 0.4% of the agricultural land of all research areas in average. With a moderate yield assumption of 8 t atro/ha/yr, 107,000 t atro of SRC biomass could be produced per year on this area.

To evaluate the SRC potential of 0.4 % of agricultural land: Projected to Germany`s agricultural area 0.4% would lead to 68,000 ha SRC, 14 times the SRC area of 5,000 ha from 2011 and a biomass yield of 0,5 Mill t dm/yr 11% of the yield of energy wood from forestry (4.8 Mill t dm). For more details on the calculation, please refer to the entire survey report (Annex 5.0)

Perception of a profit margin for SRC production

53% of the SRC owners and 43% of the farmers without SRC expect a minimum profit margin of 400-600 €/yr/ha from SRC production.

The results of the survey enabled the formulation of a range of recommendations for action as has been outlined by WP4. Furthermore, the research hypotheses of CREFF and WP5 could be reflected, which will be outlined in chapter (4.6.4.1).

4.5.3 Recommendations for action (WP 4)

As a result of the interpretation of the survey, several **actions** were recommended. These were regarding offers of information/consultation, research and politics to support the production of wood from short rotation coppices. In the following ten important selected results are highlighted:

- Future information and advisory service concepts, agro policy and research must be orientated for the cultivation of SRC primarily on more unfavorable, mainly small and subjectively less profitable areas ("marginal sites"), as these areas are selected by farmers as "potential SRC-land" and also have been realized by SRC owners. Only then the mostly positive attitude of farmers towards SRC and the calculated, quite promising potential for SRC of approximately 0.4% of agricultural land for the establishment of SRC can be used. On properly selected "marginal" sites, with more efficient production and logistics, SRC could compete with the low profit margin levels of competing standard market crops.
- Future information and advisory service concepts, agro policy and research must aim at the establishment of co-operation between SRC producers and SRC consumers involving SRC service companies to overcome a lack of information and uncertainties and risks related to production and marketing. Only then appropriate prices for SRC biomass can be negotiated and communicated to

farmers at an early stage, efficient production systems, harvesting techniques and supply chains can be established.

- There still is a clear demand for further information among all stakeholders. Therefore additional offers for information and consultation for operators of short rotation coppices as well as for farmers without short rotation coppices should be provided.
- Journals are an important source of information for most farmers. Offers for information should be expanded especially regarding short rotation coppices to provide specific information events and inspection of plots, so that comprehensive practical information can be gained and networking can be improved.
- Especially the offers for operators of short rotation coppice should be applied to the whole supply of services (from planting to harvesting and buy-off). Particularly concerning harvesting, there is a great demand for information. There is only little practical experience yet.
- The high initial investments (upfront capital costs) which are required to start up a short rotation coppice are often seen as an obstacle. Therefore special support programmes should be provided and so could contribute to the decrease of these obstacles.
- Especially long term commitment to plots and capital investment could be eased, if there is traceable full cost accounting on hand based on expected economic life of coppices. Based on full cost accounting plausible annual fixed charges can be calculated and high initial investments and the invested capital can be classified and evaluated.
- Planting machines and harvest machines need high capacity utilisation to cover the expenses. The survey has shown that farmers have rather small plots (up to 3 hectares per farm, single plots < 2 hectare) available for short rotation coppice in short or intermediate term projects. The elaboration of services offered, as well as the development of planting- and harvesting machines (e.g. tractor pulled cutter collector) should be considered to allow an economical sustainable management of short rotation coppice plots and the further expansion of short rotation coppices.
- Survey has shown that from farmer’s point of view marginal sites play an important role in the establishment of short rotation coppices. Therefore research should pay special attention to cultivation of short rotation coppices on marginal sites. Possible competition between plots for energy crops on short rotation coppices and plots for food crops should be defused that way.
- Survey has shown that there are considerable differences between the operators of short rotation coppices and farmers without short rotation coppices regarding the rating of aspired business models. Widespread information on advantages and disadvantages of business models which are supposed to manage short rotation coppice plots are not available yet.

Here the practical consultation can be applied, and furthermore brochures should give additional information on this matter.

- Operators of short rotation coppices pointed out that the current legal situation is a drawback. Legal security for farmers has improved with the amendment of the Federal Forest Act in favour of short rotation coppices and agro-forest systems since 06.08.2010. Also regulations for the financial support of woods have been improved since the revision on 21.05.2010. The practical application of these amendments is to be pursued.
- Programmes like the “150 hectare programme” in Baden-Württemberg, from which most data are collected, are an essential instrument to gain practical experience, from which both operators of short rotation coppices and framers without short rotation coppices can benefit. Therefore appropriate programmes should be initiated in further more regions.

That way additional practical data can be collected and problems concerning planting and harvesting can be dealt with.

- In this context the research in planting, maintenance (e.g. herbicide application) and harvesting (e.g. development of cost-effective technique) is a vital element to support an economical successful and ecological sustainable management of short rotation coppices.

4.6 Work Package 5 - New business concepts for successful implementation of a product-oriented wood fuel value chain from SRC

4.6.1 State of the Art

To foster the breakthrough of SRC for energy production, research oriented on implementation along the supply- and value-chain is urgently needed. Hereby research needs to provide optimized value chain models and to respond to implementation problems by developing innovative collaboration and business concepts in close cooperation with SRC-producer-consumer co-operations. At the beginning of the project in 2008, research results in this field were rare and only a few ongoing projects (i.e. AGROWOOD (www.agrowood.de)) were dealing with this problem. Currently, research projects start to focus increasingly on the importance of the value chain optimization, the integration of the different business partners and the development of adapted business concepts (i.e. AGROFORNET (www.agrofornet.de)).

Apart from a large scale quantitative survey on bioenergy in agriculture in general carried out by ZALF, Leipzig, quantitative surveys among farmers on chances and obstacles of SRC are rare.. France has not been included yet in these kind of research topics.

4.6.2 Specific goals

Despite of the increasing demand and prices for woody biomass, SRC plantations as an option for farmers of producing woody biomass are still very rarely implemented especially in the CREFF project area. What are the reasons for the hesitations among farmers? What obstacles need to be removed so that SRC will become financially more interesting? What are the chances of SRC from the point of view of the farmers? And how is it possible to provide a secured market to the farmers so that business risks are decreased and SRC becomes more appealing?

The overall goal of WP 5 is to identify the reasons why farmers do not invest in SRC production. For that purpose, the following hypothesis has been tested.

The low level of implementation of SRC production is caused by:

1. a lack of knowledge about SRC amongst farmers, politicians, and other stakeholders,
2. a lack of knowledge about SRC products (chips/industrial wood) among industrial consumers,
3. undeveloped markets and unclear quality criteria for the final product,
4. the absence of regional business- and logistics co-operations building up supply- and value-chains between producers and consumers.

In result and in combination with the central assumption, that SRC will often only be established on less favourable site, fields with lower soil quality and unfavourable forms- these shortcomings lead to a low efficiency along the SRC supply – and value chain with comparably high production costs. This ends in an unfavorable profitability level of SRC compared to competing agricultural products.

The second goal of WP 5 was to test whether the establishment of **co-operations between consumers and producers** have not only important effects for improving the efficiency of SRC-value-chains, but as well are preconditions to overcome obstacles and constraints for implementation of any SRC-value-chains (**WP5)**. We have initiated and moderated the implementation of 2 producer-consumer co-operations for SRC production. The pilot-initiatives were consisting of the industrial partners offering a potential market for SRC products and defining the demanded product quality. These so called "pilot co-operations" were aimed to serve as an attraction point for potential consumers, producers, forest- and agricultural service providers, and the interested public arena. They should offer a communication forum, which will transfer knowledge, help to detect and eradicate production-related, economic and environmental barriers and help to develop and customise business models supporting establishment of improved, product-oriented SRC production and supply- and value-chains between regional SRC-producers and industrial -consumers.

4.6.3 Activities and Result

4.6.3.1 The producer-consumer cooperation model

The industrial consumers of woody biomass are relying on a constant supply of large amounts of raw material, having defined quality properties and a profitable price-level. Typical consumers of SRC material are wood-energy plants, pellet plants, particle board manufacturing or the pulp industry. On the upstream end of the value chain, the potential SRC producers (mostly farmers) need established and guaranteed markets with price-levels that allow a profitable SRC-management even under unfavorable site conditions.

In order to combine the requirements of both ends of the value chain, the project has tested the establishment of co-operations between producers and consumers as preconditions to overcome obstacles and constraints for implementation of any SRC-value-chains. The so called "pilot co-operations" have been expected to improve the efficiency of SRC-value-chains. Production processes could be coordinated and adjusted more easily, leading to cost reductions.

Furthermore, the co-operations should serve as an attraction point for potential consumers, producers, forest- and agricultural service providers as well as the interested public. They should offer a communication forum, which will transfer knowledge, help to detect and eradicate production-related, economic, institutional, social and environmental barriers and help to develop and customize business concepts supporting establishment of improved, product-oriented SRC production and supply- and value-chains between regional SRC-producers and industrial -consumers.

The establishment process of these pilot co-operations were guided and moderated by the project team. Regular workshops and interviews were used to analyze the situation, and to conceptualize and define solutions.

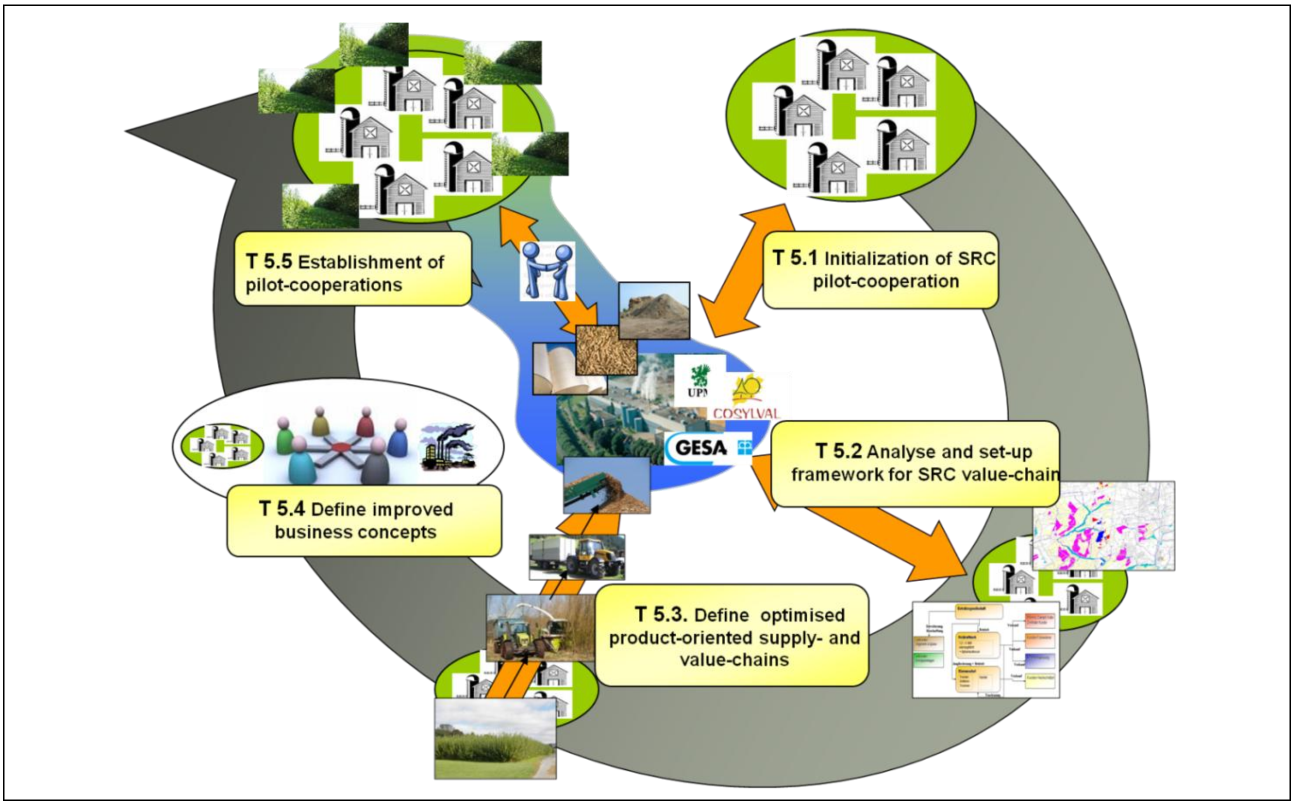


Figure 112: The 5 steps for the establishment of pilot co-operations

As shown in the above graph, the initialization process of the pilot co-operation was structured along five distinct steps. The activities as well as the results of each implementation level are presented in the following chapters.

4.6.3.2 T5.1. Initialization of SRC pilot co-operations

As a first step of the initialization potential SRC consumers as “nuclei” for the pilot co-operations had to be identified in Germany and France among the CREFF project partners. The selection should also cover both project countries, Germany and France and the regions , where respective project partners are active. Relying on formerly established contacts with the researcher team, two so-called “industry partners” showed very clear and early interest to participate in the project, assuring the role of the biomass consumer. The two “industry partners” thus served as nuclei around which a producer-consumer co-operation for SRC production should be initiated within the course of the project.

The “GESA” co-operation in North-Rhine-Westfalia, Germany

The pilot co-operation in Germany has been build around GESA gGmbH, a biomass centre in North Rhine Westphalia (NRW), looking for additional biomass, considering SRC material in order to increase their wood biomass supply. This co-operation started very early and straightforward. Together with CREFF, GESA invested intensive work into the identification of interested farmers by repeated publications (refer to annex 5.4) of articles in agricultural journals in NRW and numerous presentations at SRC conferences on SRC in the region of GESA. The offer announced to potential SRC investors from the side of the industrial consumer GESA was a fixed price for each delivered ton of SRC biomass in the form of a long-term supply contract (option for 20 years). For easing the spread of information and to jointly push forward the development of SRC in North Rhine-Westphalia, a close collaboration with ZEBIO (Zentrum für biogene Energie) has been established.

Nevertheless, even though a large number of farmers were invited and broad publicity has been done, two information workshops for the initiation of the pilot co-operation with GESA had to be cancelled due to insufficient participants. Feedback from farmers was very low.

Only at the end of 2009, after further appeals in agricultural newspapers, a small group of interested farmers showing a serious will to invest in SRC could be brought together.

The “COSYLVAL/UPM” co-operation in the Alsace, France

The French pilot co-operation is build up around the industrial consumer UPM Stracel in Strasbourg and COSYLVAL, the local Cooperative for forestry service provision and consultancy in Alsace/France.

UPM Stracel is a paper production facility in Strasbourg, using woody biomass for their energy production in CHP plant. UPM usually do not enter into direct contact with farmers or forest owners, but works with different suppliers. One of them is COSYLVAL, which delivers wood biomass from its harvesting activities within private forests in the Alsace. For this reason, UPM and its supplier COSYLVAL joint to promote SRC in the region as an additional source of biomass.

The mobilization of farmers has been organized in a similar way as in NRW. Articles on SRC and calls for interested farmers have been published in local agricultural newspapers and COSYLVAL/UPM passed the information through its own, rather large network of agricultural partners. Analog to the GESA co-operation, UPM and Cosylval offered a fixed price for each delivered ton of SRC biomass in the form of a long-term supply contract. After the first information workshop in May 2009, a group of 5 interested and motivated farmers could be found.

Figure 113: First information meeting in Alsace, a group of 5 interested farmers could be identified, May 2009

Figure 114: First visit of an SRC plantation with the interested group of farmers and COSYLVAL

4.6.3.3 T5.2. Analyze and set up framework for SRC value chain

After the initialization of the pilot co-operations and the identification of interested farmers the establishment of SRCs at the farmers' sites has been supported in both of the co-operations. The offered sites have been visited and individual plantation concept has been formed and compiled in form of short guidelines for the farmers until the end of 2009. These guidelines have been compiled conjointly by all research partners. They provided side-specific advice for the establishment (species, clone, spacing and rotation), maintenance and potential harvest techniques for the SRC.

The annexes 5.1 and 5.2 present one example for a plantation concept.

4.6.3.4 T5.3. Define optimized product-oriented supply- and value-chains

Within the T5.3 step of the pilot co-operation establishment process, the aim was to develop, an optimized and cost effective value chain with regard to the regional framework (as defined in T 5.2), the available technical equipment of each farmer and the possibility to resort to diverse service providers, to present it within the co-operation and to discuss it.

The development of optimized and effective value chain models for each co-operation has been based on technical and scientific input from all research partners.

A respective workshop in both co-operations has been held; the value-chain proposal by CREFF was discussed with all counterparts and completed according to the comments by the farmers and/or the industry partner.

The T5.3 workshop with UPM/COSYLVAL took place in December 2009, with the GESA cooperation in fall 2010, the farmers had already established their SRC plantations and experiences could be shared.

Figure 115: T 5.3. Meeting at GESA

Figure 116: T 5.3. Meeting at COSYLVAL/UPM

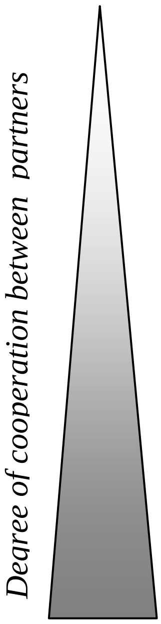
The presented proposals for an optimized supply- and value-chain held during these workshops can be found as annex 5.5

4.6.3.5 T5.4. Define improved business concepts

4.6.3.5.1 Definition and presentation of existing cooperation models in the biomass production sector

Due to the newly evolving bioenergy market, farmers have to face new types of business partners such as energy companies, timber traders or operating companies of heat- or power plants. Adapted business models can help to overcome possible doubts or hesitations of farmers for investing in SRC. For this reason, as a first step existing co-operative business models have been compiled from agribusiness, forest sector and biomass sector.

The range of business concepts is rather large. The different models can be differentiated by the degree of co-operation of farmers and consumers for the production and commercialization process (symbolized by grey arrow in the graph below) and thus a varying degree of business risk bearing.



- **Casual purchase of biomass:** very low degree of integration, plantation management and commercialization under own responsibility of the farmer, changing customers according to price
- **Guaranteed purchase contracts:** low degree of integration, plantation establishment by farmer, constant purchase partner with guaranteed prices over a certain period of time ;
- **Service oriented model:** low to medium degree of integration, Consumer offers long-term purchase contract, consumer offers services from SRC establishment to harvest and harvest logistics.
- **Leasing model:** low to medium degree of integration, farmer leases his sites to industrial partner, plantation establishment, management and commercialization by leaseholder;
- **Technical and financial co-operation:** high degree of integration, plantation establishment by farmer, financial support and technical presetting by industry partner, guaranteed purchase at below-market price;
- **Institutional integration:** High degree of integration: plantation establishment by farmer, long-term purchase contracts with industrial partner. Farmers own shares in the industrial business and thus receives beside of the sales revenue also a share of the business success of the industrial partner.

Graph 1: overview on the possible models along an increasing gradient of cooperation intensity.

A detailed presentation of the different business models along this gradient of co-operation can be found in the annex 5.3.

During a workshop, the different business concepts were presented to the co-operation partners. They further served as a basis for discussion and orientation in order to develop adapted business concept for each individual co-operation.

4.6.3.6 Offered business concept of the industry partners at initialization

At the start of the project, the industry partners formed an “offer” to come into business with potential SRC producing farmers. Business concepts selected were in both cases already in use by the industry partners. In both co-operations there have been contacts with farmers, but only in their role as private forest owner. **GESA** offered a long-term guaranteed purchase contract to the cooperating SRC biomass producing farmers. In order to stimulate the decision making process and to reduce the financial doubts of the farmers, a price above the market price for bioenergy wood chips was offered for the SRC wood chips over a period of 21 years.

Any additional services or technical assistance have not been offered to the farmers as for plantation establishment and management. This technical consultancy as well as the contact establishment between SRC service providers and the farmers was offered by the CREFF research partners (see T.5.2, chapter 4.6.3.3and T 5.3, chapter 4.6.3.4).

The following graph illustrates the responsibilities for the different process steps along the SRC value chain resulting from the initial business concept. Thus, in this early period, GESA merely offered a market with a fixed price for the produced SRC biomass without however supporting or interfering in the establishment and/or production of the SRC. In addition, GESA has not defined special requirements for the SRC biomass quality at this state of SRC market initialization in order to enable the farmers to gain experience in a first phase. The farmer is responsible for the entire SRC production, from plantation establishment to the transport to the industry partner.

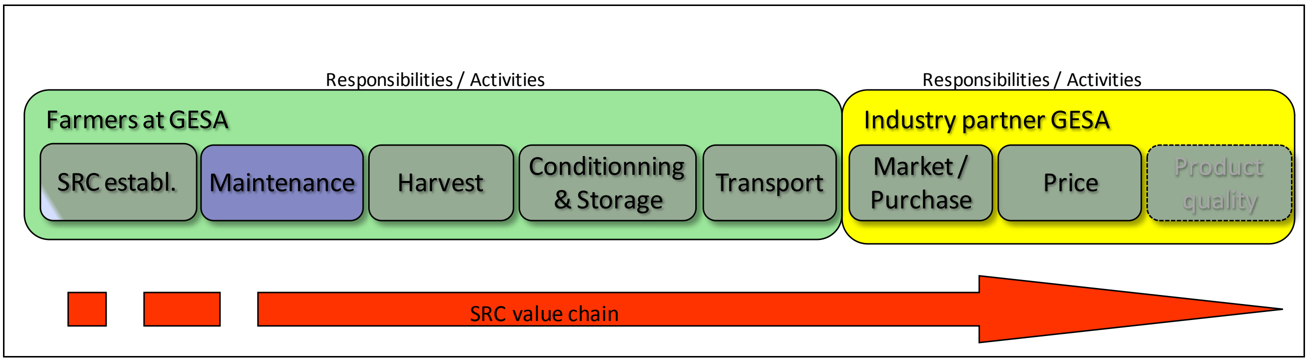


Figure 117: Business model of GESA at start of the pilot co-operation.

As **UPM Stracel** has organized its biomass supply through biomass traders and production residues, COSYLVAL as one of the suppliers took over the position as initiator of contacts to farmers, which are in some cases are also private forest owners in the region of Alsace. Cosylval offered a long term purchase contract with price conditions fixed between UPM and Cosylval at forehand. The price level offered was also slightly above the market price for bioenergy wood chips.

Moreover, in order to support the initiative of the first farmers to invest in SRC, UPM Stracel offered a financial support per hectare SRC established.

In general, the COSYLVAL cooperative acts as the middleman and service provider between biomass producers or forest owners and the industrial consumer of the biomass. Technical assistance is offered to the members of the cooperative. Furthermore, COSYLVAL cooperates with a range of service providers in order to cover the entire value chains from the production to the commercialization.

In the field of SRC, COSYLVAL had only restricted technical and practical know-how at the beginning of the project. Nevertheless, they played a major role in identifying and mobilizing interested farmers to participate in the cooperation. They guaranteed the purchase of all the produced SRC biomass according to the price defined by UPM Stracel. Further on, COSYLVAL could resort to their already existing cooperation with service providers, notably nurseries and plantation service providers.

Thus, in the early stage of the pilot co-operation, the farmers (green color) were responsible for the management of the entire SRC production. COSYLVAL provided support in distinct management steps (i.e. plantation establishment) and above all offered guaranteed commercialization possibilities together with UPM as final biomass consumer with a price defined by UPM Stracel.

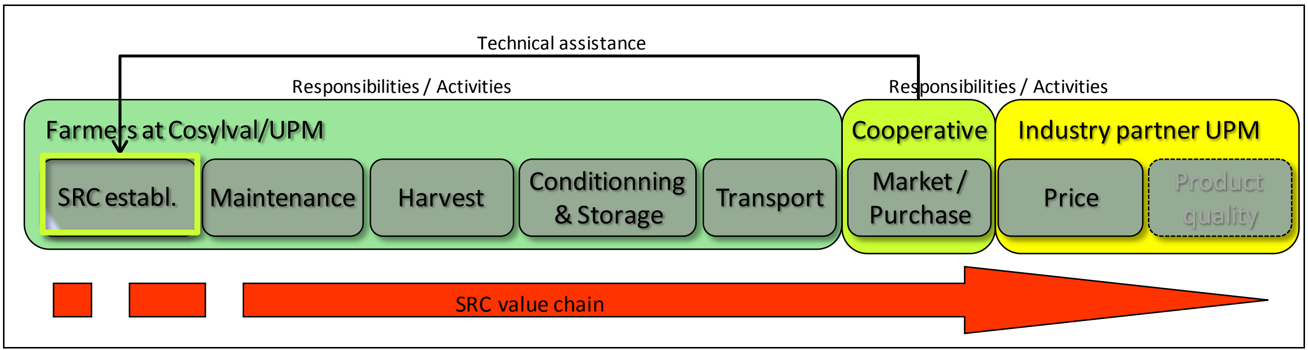


Figure 118: Business model of COSYLVAL/UPM Stracel at start of the pilot co-operation.

4.6.3.7 Development of the business concepts after the initialization phase of the pilot co-operations at the end of the project

One of the goals of WP5 was to improve existing business concepts in a way that they help to overcome SRC implementation obstacles at start, reduce costs and result in increased efficiency for both consumer and producer.

During the project, producers and industrial consumers in both pilot co-operations could increase their know-how and gain experiences within the SRC business sector and the proposed business concept could be discussed and improved.

Both industrial partners claimed that SRC will remain a secondary business field for the enterprise as the resulting quantities of biomass will presumably remain rather small in compare to their total biomass turnover.

For this reason, GESA does not plan to offer know-how or consultancy capacities by themselves. However, as they see provision of technical assistance and know how as crucial to convince farmers for SRC production, GESA strives to offer this services based on partnerships with specialized SRC service providers, e.g. in the field of plantation establishment and also harvest operations. For harvest operations, transport and logistic GESA and one of the farmers, who already offers wood harvest services, will offer these in a team.

Thus, the farmer remains technically responsible for the establishment and management of his SRC plantation, but can resort to GESA with its service providers for professional advice and operational support on plantation establishment, harvest, conditioning and transport.

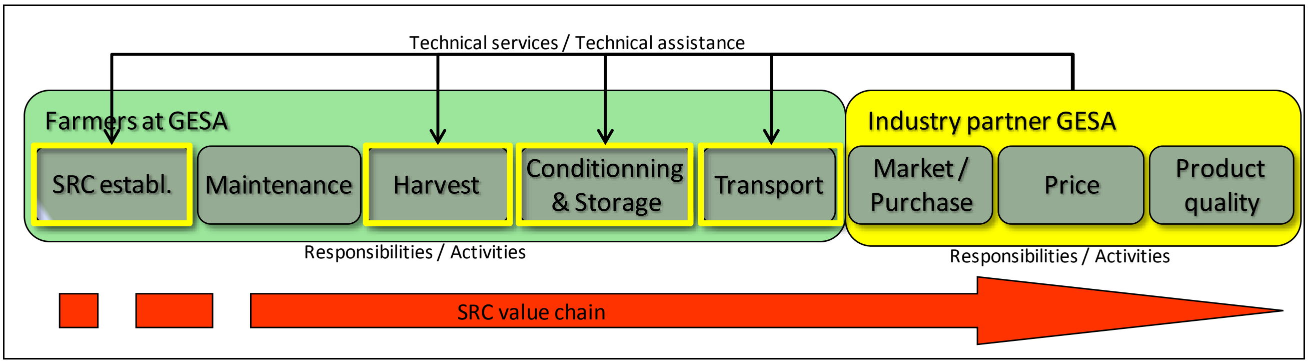


Figure 119: Planned business concept of the GESA co-operation after the initiation phase of the pilot co-operation.

Furthermore, discussions have started within the GESA co-operation for a collaborative investment in harvesting machinery as it is so far inexistent in the region. This would lead to an improved integration of one of the most expensive steps of the value chain within the pilot cooperation, notably decreasing the production costs.

UPM wants to keep its position as partner of COSYLVAL, offering a certain price level for SRC biomass through COSYLVAL, who will act as contract partner for a long-term purchase contract. COSYLVAL wants to further acquire its own technical know-how about SRC so that they can offer improved consultancy service for farmers in the Alsace regarding plantation establishment, management for example. However for the planting and harvesting operations, they will revert to a range of co-operating service providers. The farmer remains technically responsible for the entire SRC production process. A closer collaboration on SRC with the German side of the Rhine Valley, where a much larger SRC area has already been established (about 100 ha of SRC), is also considered. By harmonizing harvest operations in Baden and the Alsace in time the fix transport costs of the harvesting machine can be minimized, which inevitably leads to a decrease of the overall production costs.

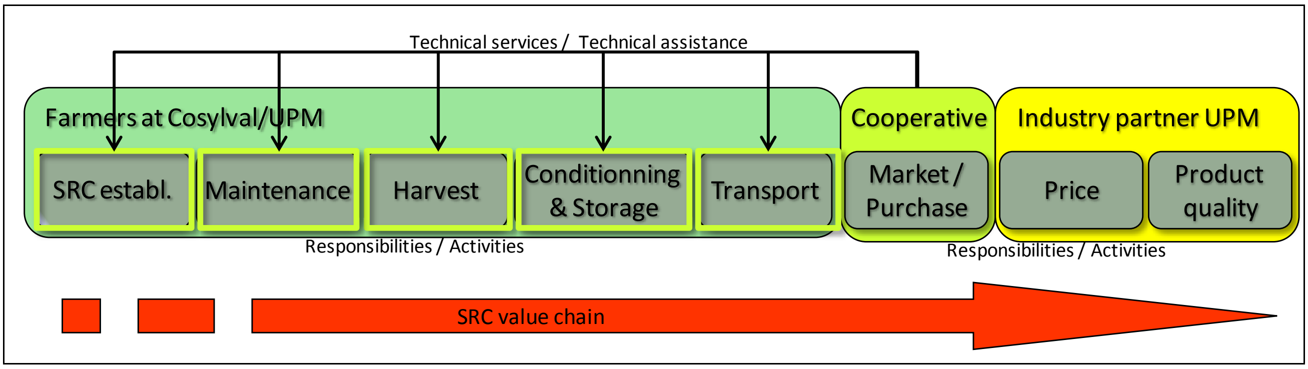


Figure 120: Planned business concepts of COSYLVAL/UPM Stracel co-operation at the end of the project.

4.6.3.8 T5.5 Establish pilot co-operations

At the end of the project, WP 5 can look back on two established, but still too small pilot co-operations with a slightly increasing number of SRCs.

4.6.3.8.1 Achievements

In the framework of the pilot co-operations in Germany and in France, so far about 17 hectares of SRC have been established. The following table and pictures contain more detailed information. Additional SRC plantations will be established also in 2012.

Pilot Co-operation	Region	Area (ha)	Species	Establishment	Soil	Former land-use
COSYLVAL/ UPM, Alsace/France	Limersheim	1	Poplar	April 2010		Corn
	Hombourg	4	Acacia	Fall 2010	Sandy loam, alluvial	Pasture
	Selestat	1	Acacia	Fall 2010	Sandy loam, alluvial	Pasture
	Sélestat	1	Willow	July 2011	hydromorphic gley soil, anmoor	Corn
	Sélestat	1	Willow	July 2011	hydromorphic gley soil, anmoor	Corn
	Selestat	(3)*	Willow	(2012)	hydromorphic gley soil, anmoor	Corn
GESA, North Rhine-Westphalia/ Germany	Wuppertal	3	Poplar	April 2010	Medium heavy clay, sandy in deeper layers, slightly stony	Pasture
	Hagen	4	Poplar	April 2010/2011	Heavy clay sand, weathered soil, very stony	Pasture
	Wesel	2	Poplar	April 2010/2011	Very dark sand, no stones	Pasture/wind fall
	Hagen	(1)	Poplar	(2012)	Heavy clay sand, weathered soil, very stony	Pasture
TOTAL		21	*) Planned for 2012			

Table 18: SRC established in the framework of the pilot co-operations during 2010 -2011 and planned for 2012.

Figure 121: Poplar SRC plantation in Wuppertal, summer 2010

Figure 122: Poplar SRC plantation in Hagen, summer 2010

Figure 123: Willow plantation on very wet site in Sélestat, Alsace, summer 2011

Figure 124: Willow plantation on very wet site in Sélestat, Alsace, summer 2011

The development and implementation of technical and organisational aspects of the SRC value-chain of each co-operation have been initiated and monitored by WP 5 and will be further developed after the project ends. As described above future business concepts for both pilot co-operations have been discussed and drafted.

At GESA co-operation, besides of the 3 participating farmers, 8 more farmers have showed interest by contacting GESA or by participating at information meetings. In total, 40 ha of additional SRC plantations could be established in the GESA co-operation. These farmers have not decided to start with SRC production and to enter the pilot co-operation due to diverse reasons in 2010. Some of these farmers are located at a too long distance from GESA, which inevitably would lead to very high transport costs, resulting in a situation, that GESA cannot offer them an attractive market for their SRC products. Other still have leased their fields and wait for the end of the leasing contract. Moreover, several farmers claimed, that they have planned to establish SRC on grasslands, but could not get an allowance for ploughing-up of grassland. In result the EU regulation to protect grasslands was and still is one of the main obstacles for SRC production. During project lifetime it was mainly a problem of GESA co operation, but cause similar problems in the Alsace, but the amount and proportion of grassland is much lower in this region of France.

4.6.3.9 Outlook and feedback on CREFF project and pilot co-operation

In the end of 2011, a workshop has been organized for both pilot co-operations in order to discuss future activities within the co-operation and to receive feedback on the project activities, achievements and an evaluation of the co-operation approach tested. This has been done in form of a standardized interview focusing on a certain number of distinct thematic blocks, as presented hereafter.

Farmers have been informed about results of the survey among farmers (see chapter **Erreur ! Source du renvoi introuvable.**) to reflect the general findings and their former statements with their current experiences and resulting attitude on SRC at the end of the project.

Development of the SRC sector during the project period?

Asked if the total SRC area in the co-operation and in the region have developed as expected, the answers differ between SRC producers and consumers. The - low - increase in area met the expectations of the farmers, it did not for the industry partners. They have expected a higher SRC area in the co-operation and in the region.

The possibility to commercialize SRC biomass has however improved notably bewteen 2009 and 2011. According to the farmers and industry partners, this is mainly due to the increasing number of wood biomass heating plants and due to the decreasing availability of woody biomass from standard sources like wood industry and forests.

During the project, SRC service providers (plantation, harvest etc.) largely grew in numbers in Germany and to a lesser degree in France. However, the co-operation partners don't believe that these companies will take over a major role in mobilizing higher numbers of farmers for SRC production. In order to be really successful, they need to cooperate with a SRC biomass consumer so that a complete service package can be offered, from plantation to harvest and commercialization of the biomass (price, defined product).

Changes in attitude on SRC among farmers during the project period?

The majority of the co-operation partners consider that the interest of farmers about SRC production has remained unchanged over the projects lifetime. According to the farmers, increased prices for traditional agricultural products such as wheat and corn, together with increased land pressure due to biogas production, has lead to a low competitiveness of SRC.

However, most of the cooperating farmers consider that their SRC plantation have a certain multiplication effect. Repeatedly they are contacted by interested farmers and many farmers came to visit the existing plantations. However, the questions about harvest technology and economical profitability, which could not - yet – been answered seemed constantly an obstacle for these farmers to invest into SRC.

Have the goals of the pilot co-operation model been achieved?

Nearly all of the co-operation partners consider that the pilot co-operation approach supports to bring potential producers and consumers of SRC biomass together and to ease the knowledge transfer and information exchange among the partners. The establishment of contacts between producers and consumers would have been more difficult without the given frame of the cooperation model. Some of the farmers even doubt if they had decided to invest into SRC at all, if there had not been the given assistance by the CREFF project, a guaranteed price and market for the produced biomass from the side of the consumer partner.

Nevertheless, it was also claimed that at present the number of biomass consumers, the biomass market largely increased in comparison to the beginning of the project in 2009.

Within the cooperation, the quality requirements by the industry partner have been defined, but only partly communicated to the farmers. According to GESA, this was done on purpose in order to enable the farmers to gather experience in a first hand free of any restriction, how to set-up the production. In fact, GESA stated to prefer biomass from longer rotations. The consumers assume, that longer rotations do not meet interest of the farmers, who are supposed to focus on fast financial return of their investment.

According to the farmers, the instructed quality requirements mostly concerned the water and stone content of the delivered biomass and seemed to be fulfilled easily. Furthermore, they mostly consider that it is still too early for making clear instructions on the storage, conditioning and transport operations. This will be done shortly before the harvest.

According to all the co-operation partners, it is still too early to evaluate the effectiveness of the pilot cooperation on production cost reduction and optimization of the value chain, as no harvest has been carried out so far.

Nevertheless, the majority agrees that the pilot co-operation has created an information platform for the cooperating SRC producers and consumers as well as for the general public.

The majority also rather agrees with the fact that the co-operation enabled discussions on the most suitable business concept between SRC producers and consumers. However, it seems still too early for the evaluation or selection of an optimal business concept as further experience has to be gathered.

Have the farmers' expectations regarding the CREFF project been fulfilled?

In general the expectations on the CREFF projects have been fulfilled for the majority of the participants. However, diverse shortcomings were stressed out. The industry partners repeated that they expected the number of SRCs in the region would increase faster and that higher amounts of woody biomass can be acquired. The uncertainties about the harvest were mentioned by several farmers and industry partners. Even though the cooperation with and the technical assistance by the CREFF project partners have been complimented, more frequent field visits by the CREFF team would have been appraised. One farmer also claimed that the distance between the cooperating farmers is rather large in NRW, which makes collaboration and sharing of experiences rather difficult.

Nearly all of the participants rather agree that the framework for SRC production has improved over the years. In Germany, the clarification of the legal status of SRC sites as agricultural land was an important step. The confirmation by the Region of Alsace for the provision of financial support until up to 50% of the SRC establishment costs will have beneficial effects on the SRC sector. Nevertheless, important uncertainties remain regarding the harvest operations.

SRC has become a new business focus of most farmers even though it will keep a secondary position in comparison to traditional agricultural production. The produced quantities are rather small and will presumably not increase in the near future.

Future evolution of SRC in general?

The majority of the co-operation partners said that SRC production will increase in the future, even though it will always remain a minor agribusiness sector. Further on, both industry partners expect further SRC sites from within the co-operation rather than by new farmers.

One of the farmers puts his expectation for a further spread of SRC production in the ongoing rise of prices for fossil fuels. If a certain price level is passed, he said, alternatives such as SRC will become more and more appealing and financially rewarding.

For the majority of the co-operation partners, the main reason for the slow evolution of SRC in the co-operation and the region is the "insufficient availability of suitable sites. High investment costs, they said, can be reduced by financial support or value chain optimizations. However, the land pressure will increase exponentially in the future. In line with this argument, they see prohibition to turn grassland to fields or SRC as a clear hindering factor for SRC development. This argumentation shows that farmers see "suitable" sites for SRC in marginal, unfavorable sites, which are already mostly grasslands.

Planned evolution of the individual SRC production?

All of the questioned farmers claimed that they will establish further SRC sites in the near future. The produced biomass shall again be commercialized to the co-operating industry partner, in two cases, a part of the biomass will also be used for private consumption.. Asked for the reasons and directions of new SRC plantations, some of the farmers want to establish SRC on marginal sites to increase the value of these sites. Others want to gain more experience with SRC production and further diversify the sources of income.

The planned SRCs will be established on sites with medium to marginal conditions, which corresponds with the findings from the survey among farmers (see chapter 4.5).

What services should be provided in the framework of the SRC co-operation in order to make SRC production more appealing?

Nearly all of the farmers have agreed that increased technical assistance is crucial and needs to be included within the SRC producer consumer co-operation model and offered from the beginning. Furthermore, technical assistance should not only be given at the moment of plantation establishment but all along the SRC management in the first years.

GESA shares this point of view and aspires to further develop this service in cooperation with a local professional partner. COSYLVAL strives to gain further experience in order to be able to provide the needed technical assistance to the farmers by themselves.

The majority of the co-operation partners think that a increasing the number of information meetings in the region will not help to attract more farmer and convince them to start SRC production. Information meetings seem often too vague and too abundant.

What business concept would be useful to develop for an SRC co-operation?

The statements to the kinds of business concepts that should be offered to SRC producers, were rather clear. For the majority of the farmers and the industry partners a direct purchase of the biomass without any given contract between both business partners is feasible and should be an option for farmers that do not want to be bound to a consumer partner.

However, the option of long term contracts is appealing to the majority of the co-operation partners as it seen to clearly reduce the risk.

The "land leasing model", where the consumer partner leases farmland, as well as the "institutional integration model", where the producers are share-holder at the consumer company, has been rejected by all of the farmers. For the "technical and financial cooperation model", where the consumer offers not only a long-term contract, but also services, 50% gave positive feedback, which fits to the findings from the survey among farmers (see chapter 4.5).

All farmers would vote for the "service oriented model" meaning a long-term purchase contract plus all services from technical assistance, plantation establishment, harvest, transport and commercialization either offered by the industry partner alone or in cooperation with SRC service providers.

Would financial incentives bring forward SRC production?

A further very clear statement has been given to the effect of financial incentives on the development of SRC production in the region. All but one farmer, claim that SRC would be brought remarkably forward if financial support would be available, especially for the establishment.

What changes in the political framework would foster SRC production?

The general prohibition of ploughing-up of grassland should be changed to a case-to-case decision. SRC, they said, is not comparable with a normal field regarding environmental impact. Secondly the acceptance of SRC as official compensation measure for impacts on nature and landscape (construction of roads, buildings, mining) would further support SRC establishment and has the advantage, that agricultural land is not turned into forest, as it is often the case – especially in Germany.

4.6.4 Conclusions

Conclusions have been drawn from all activities such as the establishment of producer-consumer pilot co-operation and the survey among farmers (see chapter 4.5) and the results from the survey among industry partners (see chapter 4.3.3.2.3). Both surveys especially allow to set the experiences from within the pilot co-operations to a wider context.

4.6.4.1 Test of the project and WP5 hypothesis for confirmation

"Short rotation coppice"– what are the hindering factors for a further spread of this production type? And furthermore, can SRC be seen as a potential to valorize unfavorable sites that are not suitable for standard agricultural production due to soil quality, size, form, location and steepness?

These have been the main research questions of the WP 5. The results of the survey as well as the experiences in the framework of the pilot co-operations enabled to reflect the above mentioned assumptions and hypotheses (chapter 5. 2)).

- **Assumption: SRC are predominantly established on marginal sites of small, scattered and irregular shape**

The basic assumption of the CREFF project could be confirmed by the survey as well as by the experiences within the producer-consumer co-operations. As the survey shows, farmers would select mainly marginal or maximal medium sites, of small size (< 2 ha) and located at often at larger distance from the farm. In contrast, 62% of the already existing SRC (50 ha in the survey) were planted on medium sites. However, the vast majority of these sites is also of small size and at a rather large distance from the farm. In the framework of the pilot co-operations, sites with both, marginal and medium soil conditions have been chosen for SRC production. Nevertheless, the choice for a site was always done according to a wide range of parameters. Besides the soil conditions, distance to the farm and the field size, very personal and individual arguments were taken into account for establishing SRC. As example for the latter: One of the poplar SRC in France has been planted on a plot of high quality soil. Nevertheless, it is located at about 10 kilometers from the farm, leading to a very time consuming management on case of traditional agriculture.

In Germany, SRC were mostly used in order to diversify the production and to value high quality pastures. One of the farmers is close to retirement and wants to change to a less time consuming production scheme than traditional agriculture. It can thus be concluded that the marginal sites indeed present a potential for SRC production. But it is not the exclusive argument for choice. Field size and the location are at least evenly important for the choice of a site as well as personal interests and reasons of a farmer to invest into a new production scheme.

The overall objective of WP5 has been the detection of the problems and chances as seen by farmers and consumers as well as to determine the reasons for the rather low implementation rate of SRC production in Germany and in France.

This lead to the **hypothesis that the low level of implementation of SRC is caused by:**

- **a lack of knowhow and information among farmers (1)**

A clear outcome of the survey among farmers was that there is a clear lack of know-how about. In total 52% of the participants wish to receive more information. The need for more information and knowledge transfer also explains the high proportion of farmers (54%) interested in joining SRC networks or co-operations.

Furthermore this lack of personal, technical knowledge is understood as one of the obstacles for a wider distribution of SRC. When asked for arguments against SRC production in general, the deficit of personal information was mentioned by nearly 30% of SRC owners and by 53% of farmers without SRC. Also, when asked for specific obstacles for an SRC establishment on the proper farm, it is again the lack of personal knowledge that is named by 55% of the farmers who are not willing to invest in SRC.

When questioned about the level of information about SRC service providers (harvest, planting), it became clear that farmers without SRC have a very low level of information, above all regarding biomass consumers. This emphasizes a rather substantial problem as, a positive decision for a SRC establishment will hardly take place if the commercialization options are unclear.

Within the framework of the pilot co-operations, the missing technical knowledge was an important issue for farmers at the beginning of the project. During the "feedback interviews" at the end of the project, most of them stressed that without the intensive technical assistance and advice from the project and the guaranteed market opportunities from the industry partners, they would not have made the step to invest. During the projects lifetime, beside of the knowledge transfer by CREFF, all of the participating farmers made strong personal efforts to gather further knowledge by attendance of fairs and information meetings and contacting diverse service providers. Nevertheless, despite of active information acquisition and consultancy by the project, harvest and logistics remains an important open question for all of the farmers.

Thus it can be concluded that the missing technical know-how as well as the lack of information regarding appropriate service providers and regional consumers inevitably lead to the current, hesitative position of many farmers about SRC. Farmers feel unable to evaluate the technical and economic risks and chances and prefer to remain in an expectant mood. The hypothesis seems thus confirmed.

- **a lack of knowledge about SRC products (chips/industrial wood) among industrial consumers (2),**

This hypothesis could not be tested by the survey among farmers. However, under WP3 a survey among industrial biomass consumers (heating (power) plants, pellet plants) had been organized in 2010 on this issue (Focke, 2011; see chapter 4.3.3.2.2). 93% of the participating biomass-buyers already have heard of SRC, but 66% have no yet used SRC material. However, 72% of the respondents planned to use SRC biomass in the future. With regard to the material quality, 45% of the companies believed that the SRC is suitable material for their plants and purposes. In so far the results of Focke (2010) seem to reject the hypothesis that a lack of knowledge about SRC products among industrial consumers does limit the implementation of SRC. However, a change in awareness among biomass consumers seemed to emerge during project lifetime 2009-2011. There is a strong evidence in this, due to the fact that most biomass consumer plan to use SRC material, but have no experience yet.

- **a lack of established markets, prices and unclear criteria for the quality of the end product (3)**

95% of SRC owners and 67% of farmers without SRC have answered the question what obstacles they see for SRC production with arguments of the category "uncertain business conditions”. Here, main arguments against SRC production have been “unclear marketing options”, a “low profitability” and ”low prices” for SRC material.

When asked about the specific reasons why certain farmers do not want to establish any SRC on their farm, “low profitability” and “lack of regional commercialization opportunities” was again mentioned by the majority. In combination with the lack of knowledge regarding appropriate SRC service providers and appropriate regional biomass consumers this seems to lead to uncertainties regarding marketing, delivery conditions, prices and finally profitability. This hypothesis can thus also be confirmed by the results of the survey. “Farmers without SRC” addressed a serious deficit of knowledge regarding marketing options, leading inevitably to uncertainties about the production and further on the product quality. Furthermore, asked for an expected profit margin, farmers seem to define it slightly higher than the margin currently achieved on existing, medium sites for market crops like grain or corn. From farmers perspective this expectation might cause to see SRC as relatively low profitable compared to standard market crops.

However, an important evolution could be observed concerning available commercialization opportunities between the beginning and the end of the project. When the project started in 2008, biomass power plants as well as private wood chips heating systems were still rather uncommon and possibilities to commercialize SRC biomass within a reasonable distance was still rather difficult in many regions. During these three years, biomass consuming power plants and heating systems have started to show interest in SRC biomass. Thus, the argument of lacking markets and commercialization opportunities is losing its importance nowadays and cannot be considered as a major reason for the low implementation rate of SRC in the project areas any longer.

- **a lack of regional business models and logistic co-operations that can develop adapted and optimized supply-chains and value chains between producers and consumers (4),**

which can be discussed in combination with the central project approach stating: The establishment of co-operations between producers and consumers has not only important effects for improving the efficiency of SRC-value-chains, but as well are preconditions to overcome obstacles and constraints for implementation of any SRC-value-chains.

According to the statements of the survey-participants regarding their choice for a business concept for SRC production, there is a clear desire for “co-operation with the consumer” (SRC owners 75% and farmers without SRC 58%). In addition 40% of the farmers without SRC have voted for ”long term supply contracts”. Both business concepts seem to provide the desired secure marketing conditions and economic perspective and thus can be interpreted as factors to reduce obstacles for SRC investment.

The increased interest for “production associations” especially among farmers without SRC (40%), goes in the same direction. The individual risk could be reduced and technical knowhow can be exchanged. Furthermore, production costs can be reduced by co-operative organized material and machinery, leading to an increased profitability of a SRC.

Within the CREFF pilot co-operations (see T.5.5 chapter 4.6.3.8), farmers repeatedly mentioned the importance of the co-operation for providing market security, enabling information exchange and know-transfer. Further on, they would like to increase collaboration among the participants by jointly investing in machinery (e.g. planting and/harvesting techniques) in order to become more independent from service providers and to lower the overall production costs. Unfortunately, these investments are currently difficult to realize due to the restricted number of participants within both of the established co-operation and the very low area of SRC in their region. Hopefully, the number of producer partners will increase in the near future to a critical mass so that common investments become possible and rewarding.

It can thus be concluded by confirming the hypothesis and claiming that the lack of regional business models and co-operation hinders the implementation of SRC. An intensified offer of co-operation initiated from regional consumers and thus a secured market with guaranteed prices as well as possible technical assistance for the establishment process, would certainly lead to a decrease of the obstacles and uncertainties of the SRC production.

Regarding the central project approach stating that producer – consumer co-operations can improve the efficiency of SRC-value-chains, seems partly confirmed. On the one side farmers in the survey complained about the lack of markets and prices, low price level and missing profitability and unclear harvesting options. Within the CREFF pilot co-operations (see T.5.5 chapter 4.6.3.8), farmers repeatedly mentioned the importance of the co-operation for providing market security, enabling information exchange and know-transfer. Further on, they would like to increase collaboration among the participants by jointly investing in machinery (eg. planting and/harvesting techniques) in order to become more independent from service providers and to lower the overall production costs. Nevertheless, in order to have truly positive effects on value chain optimization and cost reduction, the small number of producer partners within the existing co-operations are seen as limitation and has obviously influenced the engagement negatively at the end of the project, especially on the side of the consumer.

4.6.4.2 Further findings

Besides the discussion and test of the above hypothesis, the experiences gathered, lead to a certain number of observations that should be taken into consideration within future research and implementation projects.

- Within the initiation process of the pilot co-operations, it was very difficult to find sufficient farmers willing to participate in the project. Even at a later stage, and despite of repeatedly proposed information meetings and articles in agricultural journals, it was not possible to further increase the small group of farmers. Some more farmers showed interest, but could not participate due to a lack of fields or being located too far away (> 50 km) from the industrial partner. For these reasons, it is crucial that the services provided by both of the established co-operations further increase and contain professional assistance by incorporating SRC service providers. An improved availability of harvesting technologies will definitely reduce constraints and doubts regarding SRC production.
- The very low interest of farmers to attend SRC information events (several events in NRW and in France had to be cancelled due to insufficient participants) shows that so far, SRC is not a priority of concern among farmers.
- During the feedback workshops with producers and consumers, all stressed out that SRC will probably remain a secondary business field. So the will and the financial means to invest a lot of time and effort into know how and information acquisition seems rather limited among many of the participants.
- A clear disadvantage of the CREFF project design was that no financial incentives were planned for the support of industrial partners and the co-operating farmers. This was repeatedly mentioned by both counterparts and was seen as a obstacle to the general success of the project and a possible reason of the lacking interest in participation by farmers. Industrial partners invested a lot of time and effort in the mobilization of farmers without having any financial return so far and until the first harvest. Participating farmers felt like pioneers in a new business field that is still not entirely developed and where still many uncertainties remain. This made the high establishment costs difficult to bear. Furthermore, yields and the final financial return rate are difficult to precisely evaluate at this early stage.

- Due to repeated requests by COSYLVAL, the Region of Alsace confirmed financial incentives up to 50% of the establishment costs of new SRC in the region in 2012. This will undoubtedly have a boosting effect on SRC production and more farmers will join the co-operation.
  Thus, a certain financial support for lowering the costs of plantation establishment and thus the financial risks would have very beneficial effects and motivate further farmers to invest into this new field of business. This aspect should also be included into further research projects.
- A further important hindering factor of the development of SRC is the EU-wide prohibition of ploughing-up of grassland as it dramatically reduces the available sites. This topic should be re-discussed with the administrative bodies in agricultural- and nature protection in order to achieve that a case by case analysis of the sites is accepted. Environmental impacts of ploughing-up can be avoided by smart plantation design and specific establishment techniques on grassland.

4.7 Work package 0 - Coordination

The activities of coordination of the project have been carried out in association between INRA and UNIQUE. A convention has been signed between both institutes. The cooperation between both organisms for this task was very fruitful as all planned activities in this task have been successfully carried out: website, literature database, consortium agreement, organization of meetings, establishment of periodic mini-reports, etc. (see below for details).

4.7.1 Administration

4.7.1.1 Consortium agreement

A consortium agreement proposed by a lawyer of INRA Paris and amended by all partners has been adopted and signed by the five scientific partners. The agreement defines the rules of data and results sharing and publication among the five partners.

4.7.1.2 Staffing

Partner	Name	Starting date	Duration	What
Unique	Laura Van den Kerchove	2008		MSc forestry,, working on WP5 and coordination
IER	Stephanie Haid	December 2008	3 years	PhD thesis funded by FNR, working on WP4
INRA	Bénédicte Rollin	February 2009	12 months	Fields campaigns for WP1
FVA	Michael Nahm	February 2009	3 years	PostDoc, working on WP2
HFR	Jan Focke	January 2009	3 years	PhD student, working on WP3
Unique	Laureline Bes de Berc	June 2009	3 months	Student, working on WP5
INRA	Laetitia Callas	July 2009	6 months	Engineer assistant (WP1)
FVA	Felipe Ruiz Lorbacher	2009		
FVA	Patrick Wehrle	2009		
INRA	Julien Toillon	October 2009	3 years	PhD thesis funded by another project but also working on several WP1 CREFF sites
INRA	Erwin Dallé	March 2010	18 months	Prepared wood samples for analyses and site monitoring
INRA	Dramane Konate	June 2010	2 months	Master student, worked on monitoring of some sites in Vosges and Bourgogne
INRA	Charlotte Grossiord	June 2010	2 months	Master student
INRA	Claire Amory	June 2010	2 months	Master student
INRA	Keita Nsanoumi	June 2010	2 months	Master student
INRA	Laurent Roux	2010	3 months	Student co-supervised by INRA and AILE to work at the Brittany sites
Unique & IER	Martin Asen	March 2010	6 months	MSc geography and anthropology, assisted the planning, implementation and partly the evaluation of the survey among farmers
INRA	Romain Leray	September 2010	2 months	Growth and phenology monitoring at the Brittany sites
INRA & Unique	Laureline Bes de Berc	November 2010	5 months	Update and compilation of French SRC guidelines based on the experiences made in France and Germany
INRA	Viviane Sogni Tchichelle	June 2011	2 months	Master student
INRA	Cécilia Gana	June 2011	2 months	Master student

Table 19: Presentation of staffing during CREFF project time

4.7.2 Collaboration tools

4.7.2.1 Web tools

A website (free access) dedicated to the project (www.creff.eu) has been developed and regularly updated. Objectives and structure of the project, partnership, past and future meetings, calendar, picture galleries, links toward related websites or sites of the participating institutes and companies are presented. A "news" section presenting the forthcoming events related to SRC in Germany and in France is updated as often as possible. During year 2011, this section also presented the first results of CREFF partners.

In parallel, the Silverpeas platform (password requested) has also been regularly used and updated by all partners' contributions. All documents related to meetings (agendas, minutes, slideshows, etc.), administration (contracts, conventions, agreements, etc.), mini-reports, pictures, maps, protocols, itinerary, logos, templates, etc. are available. Silverpeas is above all used to transfer files and documents and to share literature and project outputs with all the project partners.

After the annual meeting 2010, an access password has been provided to FNR and ADEME. This allows them to have a regular insight into the activities and outputs of the project work.

4.7.2.2 Literature database

A common result by all the project partners of CREFF is the compilation of a SRC database, containing all SRC plantations in Germany and France that are known to the project partners. The goal is to develop a data base with abundant information on site characteristics, experiences, technical difficulties and plantation design of different SRC in order to serve as a base for further plantation establishment. The database can be found in Silverpeas. The database is still updated by all WPs as frequently as possible.

4.7.2.3 Meeting organization

A kick-off meeting of the project has been held in Champenoux (INRA Nancy) in February 2009. All partners (including research, industrial and producer partners) were present.

Then steering committee meetings were organized more or less every three months with the presence of representatives of the five leading partners. Every partner has successively organized these meetings in their places.

These gatherings were an opportunity for everyone to present the progress of its work and, possibly, its first results. On these occasions external speakers could also be invited, and visits of SRC fields were often part of the agenda.

Date	Place	Type
9th September 2008	Potsdam	ERA NET Kick-off meeting
February 2009	Champenoux	CREFF Kick-off meeting
26th May 2009	Stuttgart	SC Meeting
23rd June 2009	Champenoux	Coordination meeting
28th – 29th September 2009	Freiburg	SC Meeting
10th – 11th February 2010	Rottenburg	Annual meeting
1st – 2nd July 2010	Champenoux	SC Meeting
7th December 2010	Stuttgart	SC Meeting
26th May 2011	Freiburg	SC Meeting
6th – 7th October 2011	Rottenburg	SC Meeting
25th – 26-h January 2012	Freiburg	SC meeting
7th – 8th February 2012	Helsinki	ERA NET *Closure* meeting

Table 20: List and description of CREFF meetings

4.7.2.4 Activity reports

A periodic mini-report system has been established and adopted: each of the five partners had to report every three months (every two months the first year) a summary of its activities during the period (meetings, field works / visits, conferences, progresses, results, problems, new contacts, etc.). This system was applied in 2009 and 2010.

All the mini-reports are available on the Silverpeas area. Figure 117 above shows the classic structure of a mini report.

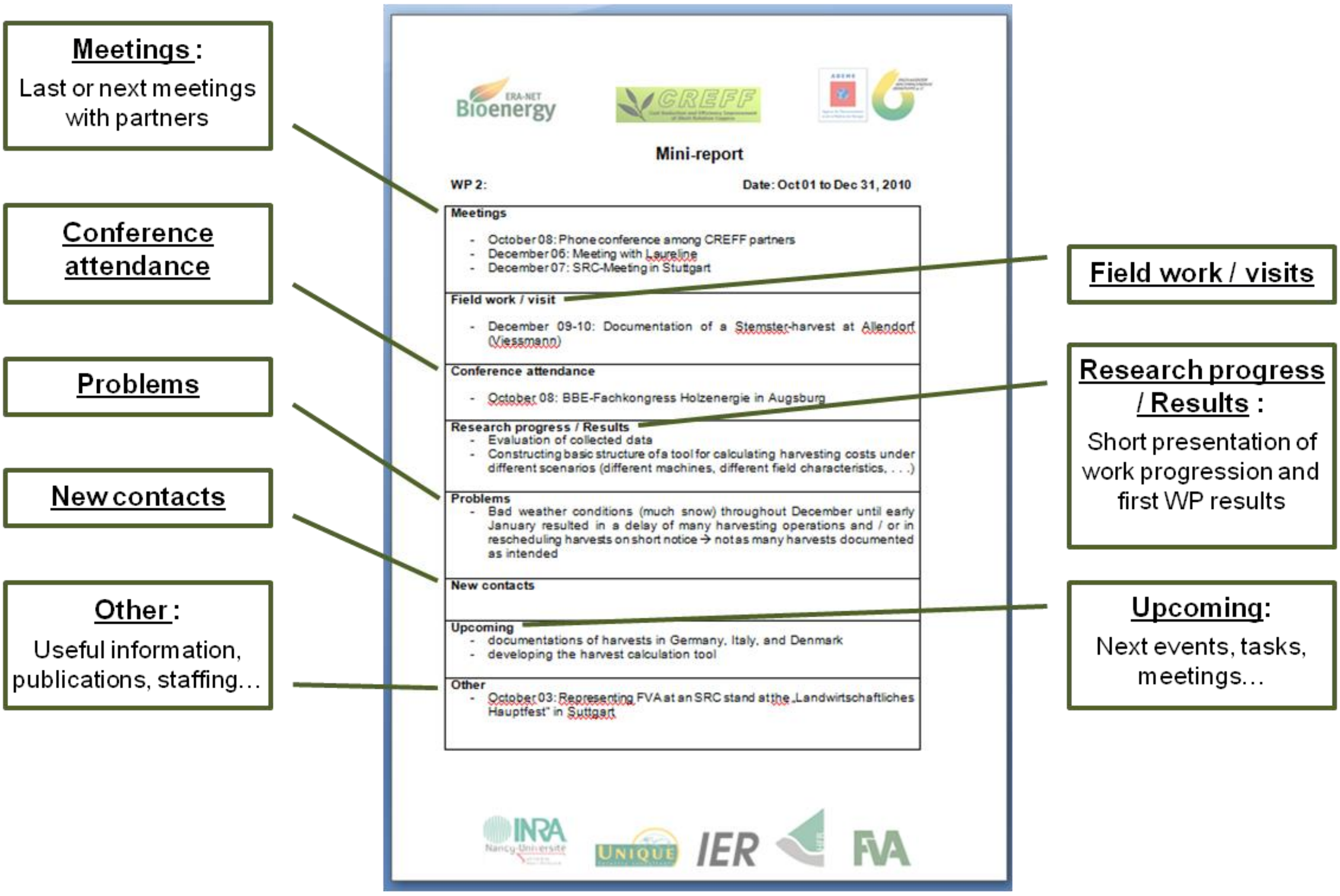


Figure 125: Structure of mini reports

4.7.3 Dissemination

In addition to the website, communication about the project has been actively carried out by all partners. The project has been presented in several occasions both in France and Germany:

- Forum ITADA (April 2009, Müllheim)
- REGEFOR workshop (June 2009, Nancy)
- FCBA meeting (June 2009, Paris)
- Congress "Energiepflantzen" (July 2009, Wiesbaden); WP2 presented by Michael Nahm
- Reichstof LWK/ZEBIO conference on SRC; presentation of CREFF by WP5 and WP3 on chips quality
- "Energietag Baden Württemberg 2009" (September 2009, Stuttgart); presentation of CREFF project by Frank Brodbeck
- Forum PNRB (Programme National de Recherche sur les Bioénergies) (January 2010, Paris) ; presentation of CREFF by Frank Brodbeck
- Annual meeting of Agricultural Association of Wesel (January 2010, Wesel)
- Conference "Long term business contracts in the wood sector" (February 2010, Freiburg)
- Biomass Conference (May 2010, Lyon). Poster presented
- Agrarholz 2010-FNR (May 2010, Berlin)
- Presentation of wood energy projects (July 2010, Freiburg); presentation of CREFF at FVA
- Presentation at CARMEN Forschungskolloquium: "Wie kann der Anbau von Kurzumtriebsplantagen (KUP)-Holz auf landwirtschaftlichen Flächen gesteigert werden? - Ergebnisse der ökonomischen Bewertung von Prozessketten sowie einer Befragung von Landwirten" (November 2010, Straubing)

All details about these meetings and the CREFF presentations can be found on the CREFF website and on the Silverpeas pages of the project.

A flyer and a poster have also been designed by UNIQUE (available on the website).

The table below shows the planned time frame of each work package.

Schedule — Year 1 (months 1–12), Year 2 (months 13–24), Year 3 (months 25–36)

	Tasks	Resources
WP 1 INRA	T 1.1 Checking of existing plantations	2.0 PM
	T 1.2 Selection and characterization of plantations	6.0 PM
	T 1.3 WUE / NUE estimations	10.0 PM
	T 1.4 Growth / Yield estimations	12.0 PM
WP 2 FVA	T 2.1 Check exitisting plantations	2 x 1.0 PM
	T 2.2 Select plantations for research	1 x 0.5 PM
	T 2.3a Select + analyse harvesting systems	9 x 1.0 PM
	T 2.3b Select + analyse logistic systems	30 x 0.5 PM
	T 2.4 Develop improved harvesting- and logistic systems	22 x 0.25 PM
WP 3 HFR	T 3.1 End product requirements and quality parameters	4 PM
	T 3.2 Design of simulation device and quality evaluation methods	6 PM
	T 3.3 Analysis of products and processes	4 PM
	T 3.4 Conditioning - process-oriented QM-System & DS-System	4 PM
WP 4 IER	T 4.1 Definition of Systems and Scenarios	3.5 PM
	T 4.2 Economic model calculations	8 PM
	T 4.3 Socio-economic estimations and values	5.5 PM
	T 4.4 Environmental impact calculations	8 PM
	T 4.5 Risk Analysis Model	5 PM
WP5 INRA & UNIQUE	T 5.1: Initialise pilot - co-operations	6 PM
	T 5.2: Analyse situation and set-up framework	8 PM
	T 5.3: Define optimised value-chains	4 PM
	T 5.4: Define improved business concepts	8 PM
	T 5.5: Establish pilot co-operations	8 PM
Coordination		12 PM

Milestones: KickOff Meeting; Project WKS; Project WKS; Project WKS; Project WKS; Project WKS; Final report; Dissemination WKS; Presentation at ERA NET Joint

Table 21: Time table of WPs by tasks and milestones

5 CREFF Project results

5.1 Project results

First hypothesis, i.e. the assumption that farmers will preferably establish SRC plantations on sites characterized by unfavourable conditions, is generally confirmed by the answers to the questionnaires. However, many already existing plantations on which harvesting operations were documented had been established on sites that cannot be regarded as marginal. This reflects the pioneering motivation of those farmers who showed great interest in innovative land use concepts and who have regarded the establishment of their SRC plantations as an interesting experiment. Moreover, possibly due to different definitions of marginal sites, it is a subjective term and dependent on overall farmer land quality and conception by each farmer. Marginal sites can be good quality sites but far away from the farm... Unfavorable (far away from the farm, steep, etc.) is different from marginal (soil bad quality, wet, etc.). We are aware that a small group of farmers was interviewed (1%): the group may be not representative of the whole farmers.

Plantation management

At plantation level, the effects of (1) pedoclimate, (2) plantation management, and (3) plant material on yield and water-use efficiency have been studied. A weak link between yield and soil and climate conditions was observed for the first rotation when sites were analyzed together. So, a limited effect of pedoclimate on yield was found at the early stage of the plantation, meaning that plantation management (probably weed control in the first line) and plant material characteristics are of primary importance during the first rotation.

More precisely, high density can be preferred, at least for the first rotations, as competition among trees was not effective during the first years. The spreading of wastewater was shown to be more efficient as fertilizer than both chemical fertilization and sludge spreading. First year coppicing showed a good efficiency to stimulate regrowth, but the season during which the harvest was performed (fall vs. spring) had few effects on the regrowth of the following years.

In terms of plant material, black locust showed very promising potential under water limitation (drought episodes are likely to be more frequent in the future). Interestingly, the most productive sites were the ones where the trees were the least efficient to use water. So, at the least fertile sites (the less productive ones), the trees improved their efficiency to use water (more biomass was produced per unit of consumed water).

Harvesting and logistic systems

Our results have confirmed that SRC management is most profitable on sites with a high biomass productivity that allows for an economical harvest. This renders the establishment of profitable SRC plantations on marginal soils difficult, except for fields with a good water availability. Another option is to establish SRC plantations with longer rotation periods, and to exclude work performed by in-house efforts and of family members from cost calculations. However, due to the different parameters that can affect the management options of a given field site, general recommendations for managing and harvesting SRC plantations are difficult to give. Rather, each field needs an individual approach. Similarly, costs for transport and logistics are difficult to quantify because, again, there are no standard solutions and most farmers use their own and often very old equipment. Yet, we have frequently observed deficits in the organization of harvest operations, what resulted in raised costs. The planning of harvests can clearly be improved.

As a tool to support the farmers in planning, we have developed the “KUP-Ernteplaner” which allows for calculating different harvesting scenarios under the individual site conditions of a field. As for the available machinery, the forage harvesters are the most cost-efficient systems.

The average wood chip production costs amounted to 27,1 €/tdm and the woodchip quality matched the required quality standards. Tractor-mounted cutter chippers might reduce harvesting costs even more, but no recommendable system was available during the running time of Creff. To harvest whole SRC trees in short rotation cycles of up to five years, the cutter-collecter Stemster offers a practicable solution. However, the mean costs of the woodchip production of two harvests including the chipping was notably higher than the costs for forage harvesters and amounted to 60,3 €/tdm. Hence, if the Stemster is used for SRC harvesting, additional costs arising from transport should be avoided as much as possible. Another innovative harvesting technique documented in Creff consisted of a combination of a feller-bundler with a forwarder. The machine is useful to harvest SRC trees grown in long rotation periods, the production costs for woodchips were 59,6 €/tdm. Along with motor-manual harvesting, this aggregate can be utilized for harvesting SRC trees grown on marginal soils with reasonable water availability.

As our results indicate, the cutting technique used by different harvesting systems does not influence the regrowth performance of poplars in the rotation period following the harvest, and poplars vitality do not suffer even from severe destruction of the above-ground parts of the stocks.

In general, our results show that profitable management of SRC is possible under certain conditions such as low transport distances and the exclusion of in-house efforts from monetary calculations. Yet, such scenarios cannot be expected to be typical, and the SRC management on marginal soils remains economically critical even under these conditions. Other management costs need to be kept as low as possible. This includes the establishment and recultivation costs, the latter of which can be very cost-intensive. In sum, we consider it likely that SRC material from sites with unfavourable properties will only be of local significance under the current market conditions.

Consumer oriented production and conditioning

1. Material analysis:

SRC material can be harvested with special forage harvesters or screw and disk chippers. Produced material is comparable with residual forest wood chips but in with higher water content with a highly negative impact on net calorific value. Gross calorific value is comparably high. In regard to residual forest material ash content is at a equal level and lab results for the ash melting behaviour can be evaluated as non critical, which is supported by determined conversion indicators.

2. Design of storage simulation device:

Storage simulation device was developed, planned, constructed, and realised and is available as a prototype for lab scale storage trails under different microclimatic scenarios and for diverse chip materials.

3. Survey:

The term "SRC" is well known under active and potential consumers. SRC material is not used in a high extent, nevertheless with a willingness of a future utilisation.

Thereby following results are found:

- Rather older material with higher diameters
- Chips delivered directly after harvest from short haul distance
- Knowledge of water content is high, for ash content rather low
- No frequent technical problems
- Storage is done under roof or open, with high effects on water content and dry matter
- In some cases material is technically dries (containers, belt dryers)
- Price is affected by wood chip market and energy prices
- SRC price level is equal to comparable materials with slightly lower price tendency
- Companies use own quality standards and national norms (e.g., ÖNORM)

➔ Overall future estimation for SRC material is neutral/positive

4. **Pilot storage studies:**

On a quality perspective, whole shoot drying is most efficient followed by covered chip heap storage. Uncovered chip storage is unfavourable.

- Quality parameters are positive influenced (water content, net calorific values)
- Mostly negative overall energy balance, ash content of chip heap storages ca. 10-15 % higher, whole shoot storages values between 25-140 % higher, ash melting slightly negative after storage)
- Under the overall energy balance, an instant material use is preferred but storage can be necessary for small burners e.g. for in farmer under economical aspects with higher prices for dryer material.

Economic analyses of value chains

Within work package 4 an economic evaluation and integrated assessment of SRC cultivation was carried out taking into account the conditions of small scale and marginal land, as it is often the case in Germany and particularly in the test regions of Baden-Württemberg or France. For the economic evaluation a calculation tool was developed which can be used to test variations of parameters and conditions for SRC cultivation. The following main results were achieved:

- The economic assessment of various process chains, representing the small scale and marginal land conditions showed that the largest share of costs is caused by the rent (24%) for agricultural land and by the establishment of the cultivation (21% of total cost). Also fixed and indirect costs determine (20%) the overall costs to a large extent.
- The effect of field size on costs was demonstrated. On a five hectare field the cultivation costs (about 850 €/ha/a) were about 5% lower than on a one hectare field (about 895 €/ha/a).
- The specific cultivation costs per hectare were clearly lower for willow (732 €/ha a) (- 15%) compared to poplar (865 €/ha a). However, the yield is also lower (8 vs. 10 t/ha x a) (-20%).
- The choice of harvesting technique and the mode and distance of transport have clear effects on the costs. Regarding different harvesting techniques the total costs for SRC cultivation vary from about 865 €/ha/a using a cutter chipper to about 780 €/ha/a using a cutter collector for harvesting. However, it has to be regarded that the choice for the appropriate harvesting technique depends on the type and quality of wood demanded by the consumer e.g. size of wood chips or water content. The transport costs are highly influenced by the distance from field/storage to the consumer. For cost optimal solutions the combination of technologies and processes of SRC cultivation have to be identified with regard to the site and the quality requirements of the consumer.
- The socio-economic background and motivations of stakeholders for SRC cultivation were evaluated through a questionnaire survey in Germany and France (together with WP5). The results show that additional offers for information and consultation should be provided, but should concentrate on giving a deeper understanding of the whole process chain and the long term character of the crop cultivations. Research is needed especially for cost-efficient and feasible harvesting technologies for small and marginal sites.
- A SWOT-analysis was performed to evaluate the environmental effects and the chances and risks of SRC cultivation on marginal sites compared to the conditions of good/medium site. It became clear that the cultivation of SRC may contribute to the diversification of cleared landscapes and may increase the biological diversity. However, the site specific conditions and the reference value/system determine to a large degree the balance of the environmental impact of SRC cultivation.

New business concepts

- Result 1: Survey and experience from both pilot co-operations: Farmers would and have selected mainly marginal (Bodenzahl 0-34[1]) or medium sites (Bodenzahl 35-59), but of small size (<2ha) and located at great distance from the farm. Among the farmers in the co-operations often also very personal and specific arguments to set a focus on SRC or more general bioenergy production could be detected.
- Result 2: A lack of knowhow and information among farmers is clearly stated by farmers, especially on harvest techniques and services (3.1)
- Result 3: Farmers see a lack of established markets and clear market prices as among most important problems, but the consumer side has changed during project duration giving more opportunities for SRC. Criteria for the quality of the end product are not seen as a very critical problem for farmers, but are seen from consumer side (refer to survey among consumers: long rotation, minimum > 3 years).
- Result 4: The lack of regional co-operative business models and co-operations hinders a further spread of SRC. An intensified offer of co-operation initiated from regional consumers and thus a secured market with guaranteed prices as well as possible technical assistance for the establishment process, is said to reduce obstacles and uncertainties of farmers regarding the SRC production.
- The hypothesis, that producer consumer co-operations can improve the efficiency of SRC-value-chains, can be partly confirmed. On the one side farmers in the survey complained about the lack of markets and prices, low price level and missing profitability and unclear harvesting options. Within the CREFF pilot co-operations (see T.5.5 chapter xx), farmers repeatedly mentioned the importance of the co-operation for providing market security, enabling information exchange and know-transfer. Further on, they would like to increase collaboration among the participants by jointly investing in machinery (eg. planting and/harvesting techniques) in order to become more independent from service providers and to lower the overall production costs. Nevertheless, in order to have truly positive effects on value chain optimization and cost reduction, the small number of producer partners within the existing co-operations is seen as limitation and has obviously influenced the engagement negatively at the end of the project, especially on the side of the consumer.

5.2 Final project conclusions

Unfavorable sites are defined as scattered, small, far away from the farm, bad soil conditions, wet, etc. sites.

- Currently, SRC in its standard form (2-5 year rotation length with willow and poplar) can not economically compete with crops on medium to good sites.
- On unfavorable sites, where there is less competition with other crops, SRC can be an opportunity to valorize unused lands.
- On unfavorable sites, where the profit margin is lower or zero, SRC can be an opportunity but it needs to be done in the right way/has therefore to be optimized:
  1. It is recommended to establish producer – consumer pilot co-operations in order to improve the efficiency of SRC-value-chains and to overcome obstacles and constraints for implementation of any SRC-value-chains. A second possibility is to exploit the material on one’s own.
  2. To define from the beginning the end use (energetic or non energetic) of the produced biomass, and the quality requirements by consumers.

[1] The Bodenzahl or Bodenwertzahl: German standard classification for agri-soils mostly based on substrate. It is determined by the data and estimation of soil ranges from 0 (very low) to 100 (very high).

3. To adapt the plantation design (density, rotation lengths, spacing, etc.) and management to the requirements and to the site conditions. Spacing has to make mechanical weed control possible. Moreover, denser plantations are likely to be more sensitive to drought episodes.
4. To use plant material using efficiently resources especially when they are limited. For instance, black locust has proved to be well suited for dry sites.
5. To valorize residual products where it is possible and allowed, to stimulate yields. If chemical fertilization is often inefficient and sludge spreading is sometimes constraining, the use of wastewater has shown its efficiency.
6. To choose mixture of species and clones rather than monocultures. It is important to avoid pathogen development. The use of species able to fix atmospheric nitrogen such as alder or black locust, in mixture or not with other species, can be interesting to enrich the nitrogen status of the plantation.
7. To plan harvest and logistic operations well in advance and in a professional way. This includes setting the timing for the harvest. For example, woodchips that are to be used in the same harvesting season should be harvested when the demand for them is high, such as in November and December. Material that is to be used in the next winter season should be harvested in February or early March to avoid biomass and wood quality loss during the preceding winter months. The machines to be used should be chosen well in advance, and cooperation with other producers should be sought for to reduce the machine transport costs. Special attention should be given to the biomass transport units used during the harvest. For example, the time required for one transportation cycle should be determined and the number of required transport units should be calculated well in advance. As a helpful tool, the KUP-Ernteplaner can be used.
8. To decide which kind of conditioning method is advisable according to the planned end use. Different kinds of conversion technologies have certain material requirements e.g., on water content and particle size. Whilst bigger burners have a higher range of tolerance for both mentioned values, smaller burners need specifically adjusted wood fuels. Therefore a natural storage process for SRC material is necessary, as active drying is not economically reasonable in many cases. Under material quality perspective, a rougher chip size with breathable coverage or even whole shoot storage is indicated, allowing a higher rate of inner heap air exchange with substantial reduction rates of water content. In consideration of an overall energy balance, a direct material use after harvest shows the highest energy efficiency and, but definitely a quite low material quality in terms of water content and net calorific value. In this case harvest should be done in November to January, in order to provide the material in the midterm of the heating season. As prices for dry chip assortments are higher and dry chips can be used for multiple energetic purposes and subsequent storage after harvest can be more valuable. In these cases, harvest in March is sufficient. Martial can be stored between six to eight month. After that the material can be used in the subsequent heating season.

- There are some other arguments than profit for the establishment of SRC on medium to good sites, such as environmental considerations (biodiversity, bioenergy production, carbon balance, etc.), extensive culture as compared with crops.
- However, financial support is needed.

5.3 Utilization of the results/Outlook

5.3.1 Utilization of the results/Outlook

5.3.1.1 Tools

- The SRC guideline for France is freely available on the project website (www.creff.eu) in .pdf format (Annex 0.1). It has been developed in collaboration among the five partners, by asking for experiences to SRC specialists (FCBA, AILE, nurseries, Agricultural Chambers, etc.), and by compiling international literature. It can be used in order to provide an overall introduction in SRC production to potential producer or, for SRC owners, the guideline can help to answer occurring questions on any aspect of SRC production.

It offers a detailed overview on the legal and financial framework of SRC and on techniques of soil preparation, weed control, planting and maintenance and harvest of SRC plantations. Furthermore, it provides information on environmental issues. It has been updated throughout the project in order to become as complete as possible at the end of the running period.

- A practical calculation tool for an optimized harvest planning has been developed by FVA.
- The producer-consumer model as tested by WP5 during CREFF has been repeatedly approved by the co-operating producer and consumer partners. Both case studies serve as examples for other initiatives striving to develop co-operations between producer and consumers of SRC biomass in order to lowering the hindering constraints.
- The survey that has been carried out conjointly by WP4 and WP5 among farmers in 2010 provided important insight into the chances and obstacles of SRC production as perceived by the farmers. It would be interesting to repeat the survey in different areas of Germany and France in order to make a comparison possible and to possibly stress out further regionally or locally influencing factors (i.e. agricultural structure, legal and political framework, regional financial incentive programs etc). Furthermore, the repetition of the survey in the current project area after some years' time would enable to analyze the evolution of the farmers' attitude towards biomass for energy production in general and especially on SRC.

5.3.2 Unsolved problems and further scientific needs

With regard to harvesting operations, a number of unsolved problems and scientific needs was identified. For example, it would be desirable to document more harvesting operations on slopes and other critical site conditions typical for marginal field sites to substantiate the few data available. In addition, new harvesting systems as well as currently used aggregates should be documented. The market for harvesting technology is very dynamic and new harvesting systems need to be documented to adapt the tool *KUP-Ernteplaner* to these developments and to assess their efficiency and practicability. The ongoing documentation of harvesting operations performed with already existing machines is important to determine the exact amount of biomass stocking on a field, and thus, to validate the biomass productivity model for SRC plantations developed in the BMBF-funded project ProBioPa at the FVA. Most notably, documentations of harvests of the second rotation period will be important. Until now, almost all available data on harvests concern harvest of the first rotation period. Yet, it can be assumed that the biomass productivity will be enhanced on at least some plantations after the first cut, so that financial calculations for managing a plantation have to be actualized. These developments need to be integrated into the *KUP-Ernteplaner* as well.

In addition, it is of great importance to interview the farmers who had harvested SRC plantations during the last seasons with regard to their experiences and opinions about SRC management and the applied harvesting operation. It is of great importance for a practice-orientated evaluation of SRC management to find out how the opinions of the farmers regarding their SRC plantation have developed after these experiences. Such information would complement the now existing data in crucial respects and might yield important clues for the future development of SRC management.

6 Publications

Scientific articles in French peer-reviewed journals

Bastien, J.-C., **N. Marron**, A. Berthelot and A. Leplus. **2011**. Les systèmes dédiés à la production de bois énergie en France – Travaux de recherché et projets en cours. **Revue Forestière Française**.

Marron, N. 2011. Réduction des coûts et amélioration de l'efficacité de la filière Taillis à courte rotation : le Projet franco-allemand « CREFF ». **Revue Forestière Française**. (**Annex 0.2**)

Oral communications during international congresses and symposiums

Toillon, J., B Rollin, E Dallé, J-C Bastien, F Brignolas and **N Marron**. **2011**. Optimization of wood production in bioenergy plantations: 1. through the use of adequate plant material in terms of resource use efficiencies. Poplar Council of Canada Conference & Annual Meeting 'Poplars and Willows on the Prairies: Traditional Practices meet Innovative Applications', **EDMONTON**, Canada, September 18-22.

Poster presentations during international congresses and symposiums

Toillon J., B. Rollin, E. Dallé, L. Roux, L. BesDeBerc, R. Leray and **N. Marron**. **2012**. Optimization of wood production in bioenergy plantations. 4th WoodWisdom-Net Research Programme Seminar in collaboration with ERA-Net Bioenergy. **HELSINKI**, Finland. February 7-8. (**Annex 1.5**)

Toillon J., E. Kartner, B. Rollin, E. Dallé, L. Roux, L. BesDeBerc, R. Leray and **N. Marron**. **2011**. Optimization of wood production in bioenergy plantations. 2. through adapted plantation management practices. 26th New Phytologist Symposium: Bioenergy Trees. **NANCY**, France. May 17-19. (**Annex 1.4**)

Toillon, J., B. Rollin, G. Bodineau, J. Gauvin, A. Berthelot, J.-C. Bastien, F. Brignolas and **N. Marron**. **2010**. Wood production determinants in poplar: where are we going? 5th International Poplar Symposium, **ORVIETO**, Italy, September 20-25.

Marron, N., B. Rollin, M. Nahm, F. Brodbeck, J. Focke, T. Beimgraben, S. Haid, A. König, L. Eltrop, L. Van den Kerchove and A. Weinreich. **2010**. Cost reduction and efficiency improvement of Short Rotation Coppice (CREFF): A German-French ERA-Net project. 18th European Biomass Conference and Exhibition from Research to Industry and Markets, **LYON**, France, May 3-7.

Communications during French conferences

Marron N. 2009. Réduction des coûts et amélioration de l'efficacité de la filière TCR – Projet franco-allemand issu de l'ERA-Net Bioénergie. Les ateliers du Regefor 2009 : la forêt face aux défis énergétiques, **CHAMPENOUX**, France, June 8-10.

Toillon J., F. Brignolas and **N. Marron**. **2010**. Productivité, efficiences d'utilisation de l'eau et des nutriments chez le peuplier, le saule et le robinier en fonction du système de culture et du contexte pédoclimatique. Séminaire ANR - ADEME : « Bioénergies de 3ème génération » - Forum scientifique du Programme National de Recherche sur les Bioénergies (PNRB) et du programme Bioénergies (BIO-E), **PARIS**, France, January 21-22.

7 Feedback on collaboration within CREFF

No major problem was encountered during the duration of the project in terms of relationships among partners and with the funding agencies, FNR and ADEME.

The main difficulty for the project partners during the entire duration of CREFF was the juggling with three different languages: German, French, and English. Communication among the scientific partners of the project was almost exclusively done in English. The presence in the project coordination team of a person from Luxemburg (Laura Van den Kerchove) speaking perfectly the three languages was an asset. However, communication with German and French farmers was impossible in English, and most documents for them (guidelines, invitations, agendas, mails, etc.) had to be translated either from German into French, or from French into German. This translation work was very time consuming. The hiring of Laureline Bes de Berc by UNIQUE and then by INRA during several months was also very helpful for this purpose as she was able to communicate in French, in English, and in German.

The different ways to proceed of the two funding agencies (FNR and ADEME) concerning the reporting dates (during spring for FNR or during fall for ADEME) and format (either in German or in English, and either for each partner independently or for all partners together) was sometimes confusing, difficult to handle, and time consuming when the partners had to translate their activity reports. In spite of these difficulties, reports were always delivered in due time to the two funding agencies. For future project calls implicating several funding agencies (especially if they are from different countries), an harmonization, from the beginning of the projects, of rules, dates, format, etc. among the agencies would be helpful for the project partners (even if we are aware that it could be difficult to modify the internal ways to proceed of institutions).

In spite of these inconveniences, collaboration was smooth and the contact with the funding agencies was quite easy. The scientific partners were quite free to manage their activities and the overall outline of the periodic reports as they liked. Phone meetings among project coordinators and the funding agencies were organized periodically during the entire duration of the project in order to discuss about the progresses of the project.

Steering committee meetings (twice a year on an average), mini-reports of the activities of each partner (every three months on an average), document sharing via Silverpeas, organizations of phone conferences among project partners when necessary, etc. (see WP0. Coordination section (4.7) for more details) were established in order to make the communication among project partners easier.

To conclude, the CREFF experience was very positive: the ERA-Net Bioenergy call SRC 2008 was the occasion to develop relationships and collaborations among scientific teams working on complementary domains in France and Germany, and to bring together forest and agriculture experts of SRC in France as well as in Germany to reach the objectives of the project.

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