Short Rotation Woody Crops (SRC) plantations for local supply chains and heat use

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Sustainability criteria and recommendations for short rotation woody crops

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1 Introduction

The project SRCplus promotes the sustainable production of short rotation woody crops (SRC) in the different target countries in Europe. Therefore, several aspects related to sustainability of SRC production, considering environmental and ecological, but also economic issues, are presented in this report. The aim of this report is to provide a general overview on the sustainability of SRC cultivation in order to inform plantation owners and interested stakeholders on how to set-up and manage SRC plantations in a best sustainable manner.

The report takes into account all the environmental benefits that can be achieved when growing SRC as well as management practices of SRC cultivation and their interaction with the obtained environmental benefits. As a result, a number of recommendations for SRC growing have been developed giving an overview of the things-to-consider to achieve and practice a sustainable SRC production. In the related literature, research results have been reported mostly for willow and poplar SRC, since these are the species that have been of most interest in Europe.

However, in this report, we have made an effort to include also research results concerning the impact on sustainability when other species were cultivated as SRC, such as alder, ash, birch, eucalyptus and robinia. Despite this, we present the results in such a way as to refer to general SRC impact and general recommendations that can be followed in a large panel of European areas.

Figure 1: A poplar SRC plantation grown in an agricultural landscape; differences in morphological and physiological features between SRC and agricultural crops result in variable impact of SRC on the surroundings (Photo: Nils-Erik Nordh)

1.1 General characteristics of SRC

Perennial SRCs are woody species such as willow, poplar, acacia, robinia and others. It is an excellent alternative to annual crops and can be complementary to the existing agricultural system.

In general, SRC cultivation is by definition a low-input agricultural practice that generally implies low GHG emissions due to limited applications of chemicals, but also because the crops are cultivated for a number of years which leads to limited management inputs. The use of pesticides is negligible and in most cases non-existent. This is not due to the absence of diseases or insects, but mostly because of the relative low economic value compared to conventional agricultural crops since the produced biomass is used for energy. The use of fertilizers is limited compared to conventional agricultural crops: fertilization of trees is not common practice, and the crops are perennial and grown for several years before harvest, using the nutrients recycled in the soil-plant system from descent leaves and root die-off. Even in the cases when N fertilization is recommended, as for willow SRC, the amounts recommended (ca 80 kg N per hectare and year) are significantly lower in comparison to other common agricultural crops.

Moreover, due to technical constraints and physiological reasons (e.g. the height of the trees), fertilization equipment does not allow for fertilization each year, when the density of the plantations is high, as in the case of willow and poplar SRC. Tillage is also carried out once in the establishment period, and no other soil management occurs until the termination of the plantations, which is usually several decades.

1.2 Sustainability of SRC

Despite the general advantages of SRC production compared to other conventional crops, SRC can also provide other specific important environmental and ecological advantages that can be optimized if certain actions and decisions are taken when planning an SRC project. In the report below, a summary of the impacts of SRC on the environment, i.e. biodiversity, soil and water, will be presented and a list of practices to consider proposed in order to ensure positive impacts on the environment.

Since it is important to consider that the term sustainability includes also the economic dimension, the actions suggested take always into account the short-term farmers' perspective for maximum profit, as well as the society perspective for long-term environmental gains.

Regarding the social impacts, this report takes into account the changes in the landscape that can occur when SRC plantations are introduced in a certain area. The morphological features of SRC plantations differ than other crops planted on agricultural land (where most of the SRC is anticipated to be established in the European context), since the fast-growing tree species used can get high rather fast (e.g. several meters after two-three years). This will have an effect on the perception of the public towards SRC as a new landscape element. This is even more important for areas planted near an end user such as a private boiler or a power plant, as SRC could become a dominant landscape feature in these areas. Therefore, this report takes into account such considerations and suggests ways to avoid negative and to enhance positive impacts from an SRC establishment in terms of landscape.

1.3 Synergies with agricultural and ecosystem services

If managed in a sustainable way, SRC can generate significant synergies with other agricultural practices, with ecosystem services and nature conservation measures.

Aside from being harvested for energy production, the cultivation of SRCs has many benefits compared to annual crops. They help to improve water quality, enhance biodiversity, provide ecosystem services (hunting, beekeeping, water supply, fire protection), mitigate animal diseases between farms, prevent erosion, reduce artificial input materials (fertilizers, pesticides) and mitigate climate change due to carbon storage. These advantages have to be promoted to produce sustainable woodchips from SRC, enhancing the positive impacts of SRC to the environment. Thereby, sustainability aspects must be considered: SRC has most positive impacts on marginal soils and especially as structural elements in the landscape, bordering for instance fields, roads, and electricity lines.

2 Land use change

2.1 Impacts on land use changes

The impact of SRC on the environment is highly depended on the previous land use of the fields. The impacts of land use changes, classified into direct (dLUC) and indirect (iLUC), are among the most critical impacts in any crop-based bioenergy value chain, as in the future land use competition becomes an increasing limitation for any commodity. The objective of the present document is not to discuss all these impacts in detail, but rather to focus on specific issues of dLUC in relation to SRC cultivation. Indirect land use changes are not addressed here.

In order to develop recommendations on sustainable SRC cultivation, the former land use has a crucial role on the positive or negative impacts. A distinction is made whether the future SRC is planned to be grown on:

- **current agricultural land**: different types of agricultural land (ploughed land), depending on the soil quality and water availability
- **current grassland**: a distinction between intensively and extensively managed grassland needs to be done
- **current forest**: in many countries SRC shall not be grown on land that is classified as forests (both from the legal viewpoint, but also due to environmental issues).
- **marginal land**: Different definitions of “marginal land” are available. Some land that is economically classified as “marginal” has high ecological values. SRC may be well suited on steep slopes (to prevent erosion), on flood-prone areas, under power lines, etc.
- **protected land**: the cultivation of SRC on protected land depends on the protection status and goals.

To achieve a resource effective biomass production with SRC, the high fertility agricultural land is most appropriate, since it produces in such areas the highest biomass yields per unit area (and profit for the farmer) with proper management. As mentioned above, and will be further analyzed below, an introduction of SRC in such areas seems to offer positive impacts in terms of water and soil quality, and biodiversity, compared to conventional agricultural crops that are usually cultivated in fertile soils.

However, with the current wood and energy prices, SRC is less competitive in many regions compared to cropping systems on arable land, and thus farmers are often interested to establish SRC mainly on abandoned agricultural land or grassland. A change of land use from grass to SRC can be discussed controversially because of the efforts in European agriculture to preserve and avoid reductions of carbon-sequestering ecosystems or ecosystems with high biodiversity value such as grassland. Being a perennial crop with minimal pesticide inputs, SRC is more akin to grassland than to other arable crops in terms of management, and the consequent impacts on soil and water quality are not expected to differ much. In the following parts of this report, relevant comparisons are brought up and analyzed, since land use transformation must be performed in a careful way to ensure compliance with the environment protection.

In general, the impacts of SRC cultivated on forest land are rather negative. Thus, many countries have elaborated legislations that prevent the cultivation of SRC on forest land.

All three land-use types (agricultural land, grassland, forests) can be managed in different ways. Depending on these management practices, as well as on soil and climatic condition, “marginal land” can be applied to all three land use types. Thereby, different definitions of marginal land exist, depending on the focus of economic issues, fertility, risks, etc.

Marginal land could be e.g. moderate or highly contaminated soils, flood-prone areas, land under power lines, parallel to rail trails, and land on landslip prone areas. These land types create opportunities; mostly because SRC can tolerate and grow satisfactory under unfavourable conditions (e.g. heavy metal contaminated soils, anaerobic conditions, less fertile sites, flooded areas). On these areas often not many other crops than SRC can be grown and offer an income. Although the expected biomass production and therefore the land-use efficiency will be rather low, there can be sites of interest to grow SRC since competition to other crops is avoided and several environmental advantages are offered, if

SRC management is optimized. However, for certain areas, e.g. high biodiversity marginal land, there is an environmental risk to generate negative impacts through SRC cultivation.

Finally, all three land-use types (agricultural land, grassland, forests) can also have a protection status, according to different local, national and EU protection classification. In case that this status is related to certain ecosystems, habitats and protected species, the cultivation of SRC is rather negative. For protection areas that are related to landscape protection, the cultivation of SRC may have positive or negative impact. In general, the site-specific protection goals have to be identified and the impact of SRC cultivation on the fulfilment of these goals assessed.

An overview on the different impacts of SRC implementation on the three land-use types is presented in Table 1.

Table 1: Impacts of SRC implementation on agricultural land, grassland and forests (Adapted from BUND 2010)

Criterion	Agricultural land	Grassland	Forest
Use of pesticides	During set-up and removal phases similar to conventional agricultural land use; During the short rotation phase not needed.	During set-up and removal phases similar to conventional grassland; During the short rotation phase not needed.	Higher
Use of fertilizers	Considerably lower	Considerably lower	Higher
Soil erosion	Considerably lower	During set-up and removal phases higher than grassland; During the short rotation phase similar to grassland.	Slightly higher
Biodiversity	Usually much higher than in intensively used agricultural land; On extensively used agricultural land it can be higher or lower.	Depends on the intensity of the used grassland as well as on species composition.	Depends on the forest type and the design of the SRC; Compared to natural forests, biodiversity in SRC is rather lower.
Climate and water	Higher evaporation, higher interception, higher wind protection and temperature balancing, reduction of dust and pollutants	Higher evaporation, higher wind protection and temperature balancing	Rather negative impacts
Carbon sequestration	Considerably higher	Higher or equal; depends on management practices.	CO_2 storage considerably lower, but annual sequestration higher

In important factor that influences the sustainability of the used land is the energetic output of SRC per ha in comparison to other crops, and thus, the potential to contribute to mitigate climate change. Although very site-specific, average figures are presented in Table 2. Furthermore, figures on the energy balance are shown in Table 3.

Table 2: Annual energetic output of SRC, energy crops and forest in kWh/ha

SRC	Corn (biogas)	Rapeseed (biodiesel)	Forest
16,000 – 60,000	37,000 – 55,000	11,000 – 21,000	10,000 – 27,000

Table 3: Energy balance as input/output ratio of selected crops (Börjesson & Tufvesson 2011)

SRC (willow)	Corn (whole plant)	Rapeseed (whole plant)	Wheat (including straw)
24	11	9	11

Besides the type of the cultivated land, also the shape and the size of the new SRC plantation have a large impact. In order to be economical viable and depending on the exact location (there may be differences in EU countries) minimum sizes of about 2-5 ha are needed to establish economic viable plantations.

2.2 Recommendations on land use changes

The following recommendations can be given to prevent negative and to increase positive impacts on land use changes:

- Goals of protected land need to be respected. SRC shall be avoided on land that is protected due to its endangered species habitats and biotopes.
- In general, poplar and willows grow better than many annual crops on marginal agricultural land that is characterised by very humid soils and frequent floods. These areas are suitable for SRC, as they have various environmental benefits.
- The cultivation of SRC on high valued wetlands and peatlands (with no agricultural use) shall be avoided. However, on wetlands and peatlands that are intensively used, SRC is a good measure to capture carbon.
- The land use change from forests to SRC shall be avoided, as impacts are usually rather negative.
- The cultivation of SRC in intensive agriculturally used landscapes with only few forest areas and structural elements (hedges) shall be promoted. In general the cultivation of SRC on this land is positive, as it adds a structural element; however, some species depend on the openness of the landscape (e.g. great bustard).
- Most appropriate areas for SRC are intensive agricultural land, but leads to displacement of other crops.
- Impacts of SRC cultivation on extensively used grassland are often rather negative. Thus the impacts need to be carefully assessed and in case that the impacts are negative these areas shall be avoided.
- The shape and the size of the plantation shall consider the overall characteristics of the landscape. In general, from the environmental viewpoint, smaller and heterogenic shaped plots are preferable.
- If cultivated on grassland, the set-up of SRC without previous ploughing (direct planting) shall be preferred.
- SRC is very suitable for the remediation of contaminated soils (e.g. landfills, excavation areas) as it “recycles” land.
- In water protection areas, the cultivation of SRC can contribute to increase the groundwater quality.

- On land that borders water bodies, SRC can contribute to mitigate soil erosion and to provide a structural element.

3 Phytodiversity

3.1 Impacts on phytodiversity

For phytodiversity, a series of experiments were conducted in SRC fields mostly in Sweden and Germany, but also in other countries, identifying, quantifying and evaluating the differences between SRC and alternative land uses such as cereal and grass production in agricultural land, but also differences between SRC and forest. An overview of the findings is presented below:

- SRC plantations can benefit phytodiversity of agricultural landscapes: as an additional structural landscape element.
- SRCs provide habitats with species compositions different from those of the surrounding land uses and can thus increase species diversity, especially in areas dominated by arable lands and coniferous forests.
- The species composition of the SRCs is a mixture of grassland, ruderal (species first to colonize disturbed sites) and woodland species, whereas arable lands contain predominantly ruderals and arable field species.
- SRCs have been quantified to be up to three-times richer in plant species than arable lands, and in some cases have been proved to be richer than coniferous forests and mixed-forests
- The contribution of SRCs to species diversity of an agricultural landscape changes over time. With decreasing irradiance for the ground vegetation the percentage of forest species increases. Thus, planted tree species, plant density, and plantation and rotation age influence species composition.
- Willow plantations are more suitable for supporting forest species than poplar plantations due to higher irradiance and irradiance variation in poplar SRC.

3.2 Recommendations on phytodiversity

The following recommendations to prevent negative impacts and to increase positive impacts on phytodiversity can be given:

- The establishment of SRCs in areas with high ecological status should be avoided (e.g. areas with protection status for nature conservation, areas with rare species, wetlands, peat bogs, swamps).
- High structural heterogeneity provides habitats for different plant requirements and thus increases diversity. High structural diversity at one SRC location can be achieved by:
  - Planting different tree species and clones
  - Harvesting at different times so that the trees have different rotation ages within one area
- Edges of SRCs have great species diversity, and planting several smaller plantations instead of one big SRC is advised because smaller plantations have longer edges for their size than larger ones. If that is not possible, planting long rectangular plantations can provide more benefits considering increased phytodiversity.

- An increase in forest ground species can be achieved by reducing the irradiance reaching the ground vegetation. This can be done by long rotation periods, high plant densities and planting willow instead of poplar. Another possibility is aligning planting rows in the east-west direction to reduce radiation reaching ground vegetation by shading the planted crop.
- The plantations edges needed to enable easier harvesting should be as wide as possible to allow e.g. indigenous flowering plants that attract insects. The mowing cycle of the headers should be adjusted in order to maximize environmental benefits.

Figure 2: A field with poplar SRC having different clones that develop differently adding variation in the landscape (Photo: Norbert Lamersdorf)

Figure 3: The edge of a willow SRC field neighbouring a winter wheat field; increased phytodiversity is evident (Photo: Nils-Erik Nordh)

Figure 4: Neighboring willow SRC fields with wide edges that allow several other species to grow (Photo: Nils-Erik Nordh)

Figure 5: A willow field planted with two different clones; the number of species in the plantation might increase (Photo: Martin Weih)

- Species composition in SRCs is influenced by irradiance (see above) and soil properties. High humus quality and plant nutrient availability supports nitrogen indicator species. Increasing soil acidity benefits indicator species for acidic soil reaction.
- The species coverage proportions in SRCs are more heterogeneous and higher than in arable lands.

- The more diverse the surrounding the lower is the species proportion of the SRC plantations on species number of the landscape (gamma-diversity, e.g. the total species diversity in a landscape).
- The higher the number of habitat types the higher the gamma-diversity and the lower the species proportion of SRC plantations on gamma-diversity.
- Species composition of the soil seed bank had low influence on the actual SRC vegetation and this influence decreased with increasing useful life as SRC plantations.

Figure 6: A poplar SRC plantation used for wood biomass production but also for livestock grazing (Photo: Ioannis Dimitriou)

Figure 7: A willow SRC field placed in the middle of an agricultural landscape; by this way SRC adds more to the total species diversity in a landscape (Photo: Nils-Erik Nordh)

4 Zoodiversity

4.1 Impacts on zoodiversity

For zoodiversity (diversity of animals), similar information as the above-mentioned for phytodiversity has been collected and analyzed. SRC with willow in Sweden is a well-known means to attract raw deer and plenty of plantations in Sweden have been established for hunting. Moreover, wild pigs have been reported to find habitat in agriculture landscapes, which is indicative of increases of mammals. Deer, hare and rabbit can cause problems to SRC plantations, and sometimes the increase of their numbers can be negative and can cause the loss of the plantation. However, hare numbers could decline further if planting of SRC were to become widespread, since this species favours mixed farmland and is unlikely to thrive in densely planted coppice stands.

Figure 8: Roe deer entering a willow SRC plantation for feeding and refuge (Photo: Nils-Erik Nordh)

There have been several discussions on the increase of birds into landscapes introduced with SRC plantations. A detailed list of the most important findings for related research is listed below.

- SRCs are in general richer in avian species diversity and abundance compared to other arable land but contain hardly any specialized breeding bird species.
- Regularly breeding birds on SRCs are mainly common and hence not endangered.
- Endangered breeding bird species occur on a small scale and they are predominantly limited to young SRCs or to the margins of SRC plantations.
- The habitat suitability of SRCs for breeding birds is in general strongly dependent on the age and structure of the planted willows/poplars, and different bird species are associated with different age classes of SRC.
- As the plantation ages and growth height increases, the breeding bird composition shifts from open land species to shrub-nesting birds and then to species originally inhabiting forest habitats.
- The highest species richness and abundance was found in 2-5 year old coppice stocks.
- The avian diversity and abundance is also linked with planting density of coppice stems and with increased number of weeds.
- The different numbers of breeding bird species are due to many further factors, such as variety of areal sizes, intensities of management, landscape context and regional species pool. The landscape context is also crucial for the impact of SRCs on the breeding bird diversity of agricultural areas.
- The overall effect on the zoodiversity will depend to a large extent on what the SRCs are replacing and how the surrounding landscape is.

If a substantial amount of a homogenous and intensively managed landscape (e.g. 20%) will be introduced with SRC, then there would be more:

- breeding bird species, because the SRCs provide new habitat structures.

- breeding bird species associated with forests, if some areas of SRCs would grow into the tree-like-stadium (height of poplars/willows > ca. 8 m).
- scrub breeding bird species, if some SRC areas are in a shrub-like stadium with large increase in vegetation height and density (height of poplars/willows > ca. 1 m).
- no qualitative difference to cropland for birds requiring open-field habitats for nesting and foraging.
- breeding bird species which need ecotones and benefit from edge effects (trees or shrubs to open land), increasing with small and oblong SRCs.
- more breeding bird species which profit from small areas of unmanaged grassland, not mowed areas with high grasses and herbs at the border of a SRC.
- slightly more endangered species, because of some SRC-associated structures (e. g. tall herb vegetation, ecotones) or rather a higher amount of structural richness.

Another positive impact of SRC is the diversity of invertebrates, such as earthworms, web-spinning spiders, beetles and butterflies that have been found in SRCs, both in the above-ground biomass and in the soil. An increase of earthworms in established SRC plantations for a number of years is recorded (compared to arable fields), however, on the whole, and despite the increased number of individuals in SRCs, intensively managed SRC are unlikely to provide botanically rich sites and consequently are unlikely to be of great value as habitats for ground dwelling invertebrates This is supported by the general low-input (pesticides) of SRC cultivation practices.

As s special ecosystem service, honey bee keeping should be mentioned, as SRC provides the following benefits for bees (honey, solitary and communal bees):

- As a low-input crop in comparison to annual crops, bees, which are sensitive to agrochemicals, benefit from less pesticide inputs.
- Especially willows provide the early-spring pollen for bees which is important for the bees after the winter break of bee activity.
- Resins from poplar and alder buds are an important source of propolis. Propolis is a resinous mixture that honey bees collect from tree buds, sap flows, or other botanical sources. It is used by the bees as antiseptic material to keep the hygiene in the hive as well as a sealant for unwanted open spaces in the hive.
- Accompanying vegetation on the ground level of the plantations provide important sources of nectar.
- The robinia flowers produce large quantities of nectar, thus providing a valuable source of feed for bees.
- Most SRC plantations require areas (called headers) for the harvest machinery which are not planted with SRC, but could be planted with indigenous wild flowers that would provide feed for the bees.

Figure 9: Pollination is an important ecosystem service provided by willow flowers (Photo: Nils Erik-Nordh)

4.2 Recommendations on zoodiversity

The following recommendations to prevent negative impacts and to increase positive impacts on zoodiversity can be given:

- Where possible SRCs should be designed with a large edge to interior ratio.
- A mix of varieties and clones should be used.

Figure 10: A willow SRC plantation with two different clones; the differences in morphology can imply different impact on zoodiversity and for a more dynamic landscape (Photo: Nils-Erik Nordh)

Figure 11: A willow SRC field harvested in different ages can offer certain advantages concerning zoodiversity (Photo: Pär Aronsson)

- Rotational harvesting in mixed age-class blocks should be preferred.
- Huge blocks of SRC should be separated, e.g. by rides and hedges.
- Where possible, and in case of growing willow, planting of willow hybrids (Salix sp.) with a range of different flowering times should be preferred.
- The use of pesticides should be generally avoided. Biological measures may help to mitigate the risks of pests.

- A percentage of the SRC area should be reserved for small habitats like strips of grass and stepped wood boundaries.
- New SRC plantations should not be established in high wildlife-value habitats like wetlands, wet meadows, set asides, dry fallows, semi-natural grassland.

Figure 12: A hunting tower placed at the edge and an opening of a willow field; wild game such as row deer and moose is attracted to the willow fields (Photo: Ioannis Dimitriou)

5 Soil

5.1 Impacts on soil

The positive effects on soil quality when SRC is cultivated instead of agricultural crops have been mentioned as one of the great advantages of SRC when implemented in agricultural landscapes. A detailed list quantifying the advantages of SRC is presented below, when looking at cases when SRC plantations have been established for several years in an agricultural landscape (e.g. over 15 years).

- Carbon (C) storage in soil organic matter is higher under SRC than under conventional agricultural crops such as cereals or grass.
- Soil organic matter stability is higher under SRC than under conventional agricultural crops and supports C sequestration in the soil.
- Soil erosion is lower under SRC than under conventional agricultural crops.
- Total soil N content is higher and the proportional nitrogen (N) availability for plant growth is lower caused by an increased C/N ratio of soil organic matter under SRC than under conventional agricultural crops.
- Phosphorus (P) availability to the plants is lower under SRC than under conventional agricultural crops.
- The bulk density is slightly higher under SRC than under conventional agricultural crops.
- The soil pH can be slightly lower under SRC than under conventional agricultural crops.
- The microbial activity is slightly lower under SRC and contributes to the accumulation of organic matter compared to the soil under conventional agricultural.

- Cadmium (Cd) concentrations in the soil under SRC are lower than under conventional agricultural crops.

Figure 13: Willow SRC fields (in the background) next to tilled arable fields (photo taken in autumn). (Photo: Nils-Erik Nordh)

Additionally, and in general, soil compaction can be lower in SRC than other crops since harvest occurs much more often in the latter. Furthermore, soil compaction can be avoided if harvest occurs when soil is frozen in winter, when also the demands for wood for energy are highest. Also, an increased number of mycorrhiza (usually between the between the fungus and the plant roots – ectomycorrhiza) under poplar, willow, birch and eucalyptus SRC, compared to neighbouring arable soils, which is beneficial for nutrient cycling.

5.2 Recommendations related to soil

The following recommendations to prevent negative impacts and to increase positive impacts on soil can be given:

- SRC could be cultivated in fields with low initial soil organic matter content to increase this content and with this the fertility and C storage of the soil.
- SRC should be cultivated especially in areas with a high risk of erosion (wind or soil), e.g. with relief, to lower the loss of fertile topsoil and nutrients by water and wind.
- Application of municipal residues such as sewage sludge for recycling of nutrients to SRC can be encouraged, since SRC can contribute to prevent nutrient losses and can extract heavy metals efficiently.
- SRC should be used to remediate soils with increased Cd concentrations caused e.g. by the long-term use of Cd-containing P-fertilizers or other sources of environmental pollution.
- SRC fields should be established at the same location for at least three cutting cycles to achieve soil quality improvements concerning C storage and Cd uptake.
- SRC should be harvested in winter in countries when soil is frozen to avoid soil compaction.

Figure 14: Inside a willow SRC field; soil is enriched with carbon from the consecutive leaf falls (Photo: Ioannis Dimitriou)

Figure 15: Newly established willow SRC plantation for restoration of a peat extraction field used also for protection of wind erosion (Photo: Ioannis Dimitriou)

Figure 16: Spreading of sewage sludge (here in mixture with wood-ash) is a common practice in Sweden (Photo: Ioannis Dimitriou)

Figure 17: Recently established poplar trees for soil phytoremediation and site restoration in waste-beds (Photo: Ioannis Dimitriou)

Figure 18: Winter harvest of willow SRC avoiding soil compaction, nutrient extraction from fresh parts while satisfying the peak for heating fuel needs (Photo: Ioannis Dimitriou)

6 Water

6.1 Impacts on water

When investigating the impact of SRC on water, research has been focused on quality issues such as nutrient leaching to groundwater (which the expected impact is usually positive) but also on the amounts of water that is percolating to the groundwater and to nearby surface waters ((which the expected impact is usually negative, especially in areas where water can be scarce in summer). Detailed conclusions from experiments conducted in SRC plantations comparing SRC with other agricultural uses in terms of water quality and quantity are presented below:

- Leaching of NO_3-N to the groundwater is substantially lower from SRC than that from traditional agricultural crops.
- Leaching of PO_4-P to the groundwater is almost equal or in some cases slightly higher from SRC than from agricultural crops.
- The slightly increased leaching of PO4-P to the groundwater was not correlated to sewage sludge applications to SRC.
- SRC as shelterbelts are shown to reduce diffuse pesticide pollution.
- Substantially less groundwater is drained from a willow stand compared to grassland, but translating this effect on a catchment area with 20% SRC, the negative impact on the water table is moderate.
- Harvesting of a willow SRC stand leads to a higher groundwater recharge in the first year of regrowth, because less water is lost through transpiration and interception.

Figure 19: A willow SRC field planted near a lake in a heavily intensive agricultural area, preventing nutrient and pesticide leaching from the arable fields to the river acting as a buffer zone (Photo: Ioannis Dimitriou)

Figure 20: A willow field in central Sweden (background) irrigated with wastewater from a local treatment plant (Photo: Pär Aronsson)

6.2 Recommendations on water

The following recommendations can be given to prevent negative and to increase positive impacts on water:

- SRC could be cultivated in fields located close to N sources (e.g. animal farms, N vulnerable zones, wastewater treatment plants etc.) to decrease N outflow to adjacent water bodies.
- SRC should be cultivated in areas where low groundwater level is anticipated (potentially flooded areas and areas near water bodies which can potentially flood).
- Application of solid municipal residues such as sewage sludge for recycling of nutrients does not affect water quality, and should therefore be encouraged.
- More frequent harvests lead to a higher average groundwater recharge, and therefore should be encouraged to ameliorate possible negative impact of groundwater recharge reductions.

7 Landscape change

7.1 Impacts on landscape change

It is important to consider the landscape changes that a potential implementation of SRC fields will bring, especially if many SRC fields will be planted close together in order to deliver the biomass to a larger end user. This can be proved important for the general acceptance of SRC as a crop in agricultural landscapes, despite the several above-mentioned positive impacts on other environmental issues.

7.2 Recommendations on landscape change

In the next part, a number of factors that an SRC project developer needs to consider are presented in order to avoid great disturbances in the landscape due to SRC planting, but also taking into consideration the criteria concerning the above-mentioned environmental impact.

- Planting SRC in agricultural fields close to forest stands gives a feeling of a natural continuation in the landscape and should be preferred. However, planting in only forest areas should be avoided since the landscape would become very forest-homogenous.
- When SRC is harvested, a more diverse landscape is achieved, which gives also a dynamic character to the landscape when SRC starts growing fast.
- Planting of SRC near cultural sites of importance should be avoided.
- Clusters of SRC fields are preferred for economic reasons enabling lower prices for management activities. The farmer can choose planting different clones that usually grow differently in terms of vigorousness and have different colours especially during autumn. Broad openings between fields also give opportunities for recreation in the area (e.g. walking).
- SRC is very suitable to be grown alongside roads with heavy traffic, as this land is often not used. However, it must be considered, that, depending on the given road, safety issues need to be considered. In order to allow drivers to have a good view e.g. at bends and crossings, SRC fields edges in these cases needs to be broader.
- On roads were traffic is not heavy, e.g. in rural areas, the impact of SRC plantations on driving is rather small, however, a field edge is still needed to allow easier

management (e.g. turning of the harvesting machines) therefore the overall impact on open views is not high.

- SRC fields should be planted close to the end users to achieve better economy due to low transport costs. Especially when the user is a large power plant for heat and/or power, SRC establishment in adjacent areas is welcome since it offers a greener tone in the surroundings which is usually absent from such areas.
- In open landscapes and areas where common agricultural crops are grown, SRC can offer a variation in the landscape but also protection from winds which in many cases can increase the total production on a farm basis.
- SRC should be in general planted in areas with the less perceived landscape impact (e.g. close to forest, in hilly areas, away from culturally important sites) and in a way that will fit to the surroundings (e.g. smaller patches in forest areas, bigger fields in open agricultural areas, adjusted to the hill variation in hilly areas).

Figure 21: A rectangular willow SRC field established in an agricultural area but close to the existing forest allowing a smooth change of the landscape (Photo: Nils-Erik Nordh)

Figure 22: A recent harvested willow SRC field placed in between of two forest stands. When grown after some years of harvest, landscape changes will be minimal; when harvested, diversity of landscape (and the positive impacts of this) increase (Photo: Nils-Erik Nordh)

Figure 23: Willow SRC field of different ages and planted with different clones give a diverse character in the landscape with different heights and different colours that are appreciated by neighbours (Photo: Nils-Erik Nordh)

Figure 24: SRC fields close to bigger roads should be left with wider edges to allow drivers with open views (Photo: Nils-Erik Nordh)

Figure 25: A willow SRC field planted parallel to a rural road; despite being a long field, the sight impact is not high since any SRC field must have relatively broad edges that allow easier management (e.g. harvesting) (Photo: Nils-Erik Nordh)

Figure 26: A willow SRC plantation close to a power plant that uses willow chips for energy offers better logistics but also a natural tone in the landscape since power plants are usually located in industrial zones not having extensive green areas (Photo: Nils-Erik Nordh)

Figure 27: Willow SRC plantation planted between arable fields and forest for landscape variation and wind protection (Photo: Nils-Erik Nordh)

Figure 28: A two year old willow SRC field (in the background) in an agricultural landscape. In the same picture, a wind power generator established in the area (Photo: Ioannis Dimitriou)

8 Conclusion

The cultivation and use of SRC source can be generally valuated positively, as it presents a renewable energy source with a relatively short and closed life cycle, in comparison to fossil fuels.

However, the main constraint is the potential conflicts with other land uses, either for the production of other agricultural commodities or for nature protection goals. Thus, the impact of the land use change is an important issue that needs to be assessed individually for each new planned SRC plantation and can be optimised following the presented recommendations in this document. Often, the result will be very positive, especially when SRC is cultivated on highly intensive agricultural land and landscapes. However, on several locations and in several situations, the establishment of SRC may have also negative impacts and these shall be avoided or minimised.

It has to be recognised that any new SRC plantation (as any cultivation change) is confronted with trade-offs. The challenge is to identify those areas that have the smallest negative impacts and that maximise the positive ones.

The present report did not aim to provide answers to individual cases ant to offer single solutions. It rather presents various recommendations and criteria that will allow any interested person, that wants to establish new SRC plantations, to build his/her own opinion on the issue and finally to decide whether to continue with a new SRC project.

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