



Short rotation forestry (SRF) on agricultural land and its possibilities for sustainable energy supply

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for sustainable energy supply**

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Preface

The report documents the outcome of a project on environmental and landscape aspects of short rotation forestry (SRF) on agricultural land. The project was supported financially by the Nordic Council of Ministers, working group 'Environment strategies in Agriculture & Forestry (MJS)'. The point of departure for the project was a related project at a Swedish national scale, supported by the Swedish Natural Protection Agency¹.

The report includes a literature survey, a chapter on landscape aspects as well as a summary of attitude studies, which is based on questionnaires performed in various Nordic and Baltic countries. The results of the questionnaire were discussed on an international workshop held in autumn 2007 in Uppsala, Sweden. The Proceedings of the workshop, which was arranged in collaboration with the Nordic Association of Agricultural Scientists (NJF), contain short country reports on the results of the questionnaires and are published within the NJF report series². The workshop discussions resulted also in the development of best-practice guidelines for sustainable biomass production in SRF plantations on agricultural land in Nordic-Baltic regions. The guidelines are part of this report by means of an Appendix (Appendix 2), which also is meant to be circulated as a document by its own.

Uppsala, December 2007

Martin Weih
Project leader

¹ Weih, M. (2006). *Willow short rotation coppice grown on agricultural land – possibilities for improvement of biodiversity and landscape design*. Report to the Swedish Environmental Protection Agency (Dnr 802–114–04). Uppsala, Sweden: Swedish University of Agricultural Sciences (SLU). 36 p. (in Swedish, with English Summary) (<http://pub-epsilon.slu.se/75/>)

² Weih, M. (ed.). 2007. Proc. Workshop Environmental and landscape aspects in short rotation forestry on agricultural land: a Nordic perspective. Uppsala, Sweden, Sep 10–12, 2007. *NJF* [Nordic Association of Agricultural Scientists] *Report* 3(3). 52 p.

Summary

Abstract

The report summarizes the analyses and discussions of environmental and landscape design issues performed within the project Short rotation forestry (SRF) on agricultural land and its possibilities for sustainable energy production in a Nordic perspective. Major aims were to evaluate the possibilities of SRF plantations to improve the natural and cultural qualities of landscape under the conditions in different Nordic countries and to formulate recommendations for the sustainable localization and management of SRF plantations based on experiences in various Nordic countries. To reach the aims, a literature survey was performed and a report on landscape aspects was produced. In addition, questionnaires on attitudes towards SRF plantations and the involved risks and possibilities for environment and landscape were performed among public stakeholders and researchers in various Nordic and Baltic countries (Sweden, Denmark, Finland, Norway, Latvia, Lithuania, Poland). The results of the questionnaire were discussed on an international workshop held in autumn 2007 in Uppsala, Sweden.

Although the commercial practice of SRF on agricultural land might partly conflict with the goals of nature conservation and cultural heritage, SRF plantations imply new and unique possibilities for landscape improvement, amelioration of environmental problems (e.g. waste water cleaning) and increased biodiversity (e.g. in open landscape).

Opinions of central and local authorities, non-governmental organizations etc. regarding SRF plantations and their effects on environment and landscape are often strongly biased due to misconceptions and poor knowledge.

Guidelines for the sustainable localization and management of SRF plantations were developed within the project. The guidelines are complementary to existing manuals for SRF growers. The guidelines should facilitate an active dialogue between commercial growers and nature/culture conservation interests in particular regarding those aspects where conflicts of interest exist between the two sides.

Possibilities for SRF plantations vary greatly among different Nordic countries. In countries with few or no own examples of commercial SRF plantations, the awareness of environmental and landscape issues in relation to SRF plantations is low, because discussions mostly focus on basic questions related to establishment, management and economy.

Background and problem statement

There is an increasing demand for bio-energy crops, both in the energy sector, but increasingly also for fuel to the traffic sector. High-density plantations of fast-growing trees grown on fertile land for the production of bio-fuels are today realised at commercial scale in Sweden. In future, short rotation forestry (SRF) is likely to become increasingly important also in many other Nordic countries. For example, life cycle analysis of willow biomass production on agricultural land based on commercial clones and cultivation practices in Sweden revealed high energy efficiency of the production system: The produced biomass yields 20 times more energy compared to the energy input, a figure which is more than 3 times higher than the energy balance (i.e., energy output/energy input) of annual energy crops such as wheat and rape³. In addition, plantations of fast-growing trees require a reduced chemical input when compared to conventional arable crops, can provide an alternative use of agricultural land and can enhance the local environment through increased biodiversity.

Nevertheless, SRF plantations have raised concerns about environmental, biodiversity and landscape issues, and there are risks for conflicts between the interests of commercial willow growers and, e.g., environmentalists. The main focus of the project was on the possibilities and risks for environment, biodiversity and landscape associated with SRF agriculture under the conditions in Nordic and Baltic countries.

The project aimed at evaluating the following aspects:

- the possibilities of SRF plantations to improve the natural and cultural qualities of landscape under the conditions in different Nordic countries;
- the possibilities to direct localization, design and management of SRF plantations towards improved environmental quality and sustainable development in agriculture;
- to formulate recommendations for the sustainable localization and management of SRF plantations based on experiences in several Nordic countries.

In this context, the project also aimed at identifying possible conflicts between, e.g., economical, environmental and cultural considerations regarding the design and management of SRF plantations.

³ Börjesson P. 2006. *Life cycle assessment of willow production*. Lund, Sweden: Lund University, Dept. of Technology and Society, Report no. 60. 21 p. (In Swedish, with English Abstract)

Main conclusions

Environment, biodiversity and landscape issues in SRF on agricultural land (Chapter 1):

Tree (SRF) plantations can increase biodiversity in open agricultural landscapes and serve as tools for the amelioration of environmental problems at local (e.g., waste product contamination through phytoremediation) and global scale (e.g. increased greenhouse effect through carbon sequestration). Thus, SRF biomass plantations offer additional possibilities in terms of, e.g., wastewater cleaning and carbon sequestration. However, particularly with respect to plantation management, the commercial practice of SRF plantation culture might frequently conflict with the interests of nature and culture conservation. An active dialogue between commercial growers and nature/culture conservationists as well as the development of guidelines for the establishment and sustainable, environmentally friendly management of SRF plantations on agricultural land (e.g., Appendix 2 of this report) will facilitate feasible compromises between the two sides.

Possibilities and limitations of SRF on agricultural land across various Nordic and Baltic countries (Chapter 2 and Appendix 1):

Possibilities for SRF plantations vary greatly among different Nordic countries. In countries with few or no own examples of commercial SRF plantations, the awareness of environmental and landscape issues in relation to SRF plantations is low, because discussions mostly focus on basic questions related to establishment, management and economy. Appropriate measures, e.g., information campaigns, to increase awareness of environment and landscape issues should be considered especially in countries with poor tradition of commercial SRF plantations, in order to decrease the risk of negative developments arising from the potential conflicts of interest between, e.g., nature conservation and economic production goals.

Landscape perspective on energy forests (Chapter 3):

Energy forests (i.e., SRF plantations) can improve landscape quality by adding structure, form and colour. For the purpose of improving environmental quality and sustainable development in the localization, design and management of SRF plantations, there are several possibilities available. Energy forest cultivation competes best on low-lying land with relatively high soil humidity. This type of location has only a fairly low impact on the visual character of the landscape.

Best-practice guidelines for sustainable biomass production in SRF plantations on agricultural land in Nordic-baltic regions (Appendix 2):

- Avoid areas with protection status for nature conservation and/or cultural heritage.
- Avoid very large SRF plantation sizes – plant several smaller plantations instead.
- Locate the plantations close to existing native woodlands and/or incorporate ‘islands’ of native trees within large plantations.
- Leave buffer zones without any crop or with native vegetation in the edges of plantations.
- Plant several varieties (preferably of different gender) within the same plantation; different varieties may be planted in sections or parallel stripes in order to facilitate harvest actions.
- Apply chemical weed control only during plantation establishment.
- Do not apply more nutrient fertilizer than the biomass crops demand during a growing season.
- Try to plan harvest actions to be performed only during the period of frozen ground.
- Harvest parts of plantations in different years.
- Locate, design and manage SRF plantations in such a way that they maximize variation in landscape.

1. Environment, biodiversity and landscape issues in SRF on agricultural land – a short literature survey⁴

1.1 Introduction

High density plantations of fast-growing tree species grown on fertile land are today a viable alternative for the production of bio-fuels in many Nordic and Baltic countries (e.g. Verwijst 2001, Weih 2004, Weih & Nordh 2007). For example in Sweden, willow biomass plantations are commercially grown for energy purpose. Rapid development of sustainable production systems and infrastructure, along with recent progress in tree crop breeding resulted in high biomass production potential of SRF plantations on fertile agricultural land even under Nordic climate conditions. However, the establishment and large-scale implementation of woody biomass plantations is often controversial due to, for example, presumed negative influences on biodiversity and the cultural heritage landscape, along with negative public attitudes. Conflicting interests of different parts of society and socio-political issues (e.g. agricultural and energy policy, market developments, public attitudes) are therefore major barriers for the rapid development of SRF bio-fuel plantations in many Nordic countries, rather than climatic, technical or environmental constraints (IEA 2005). The development of guidelines for the establishment and sustainable, environmentally friendly management of woody biomass plantations could be a means to balance the conflicting interests of different parts of society (e.g., biomass production and nature conservation interests) (Weih 2006). The following literature survey will be a basis for the preparation of best-practice guidelines for the sustainable management of SRF plantations in Nordic and Baltic regions.

1.2 Environmental risks associated with SRF plantations

Intensively managed plantations of fast-growing trees imply the risk of various negative effects on the environment in terms of, e.g., herbicide application, deteriorated soil properties and nutrient leakage. However,

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when compared to conventional arable crops, the perennial character of the crops used in tree plantations commonly leads to reduced herbicide application (i.e., herbicide treatment is required only during the establishment of the crop). Further, afforestation with fast-growing trees on former arable land has often positive effects on soil properties due to less frequent use of heavy machinery, especially when the use of harvesters is restricted to the period of frozen ground in winter-cold regions. For example, carbon sequestration and water holding capacity were found to increase in formerly arable soils that were planted with fast-growing willow and poplar for 6 to 10 years (Kahle et al. 2005). The perennial nature of tree plantations also leads to less nutrient leakage compared to conventional arable crops provided that the rate and timing of fertilization is adjusted to the nutrient delivery and nutrient holding capacity of the soil in relation to the uptake capacity of the trees (Ericsson et al. 1992). This may imply the application of repeated, small fertilizations throughout the growing season according to a scenario following tree growth, i.e., small amounts early and late in the season and larger amounts in mid-summer (Ingestad 1987, Alriksson et al. 1997). Particularly in plantations with wider tree spacing grown in single-tree systems (e.g., poplars), nutrient supply by placing close to the roots of individual trees is an option to prevent leakage to groundwater (van den Driessche 1999). If tree plantations are managed according to these principles, they are unlikely to endanger the environment by means of groundwater contamination even under the short periods of plant nutrient uptake that are typical under the cool climate of Nordic regions (Aronsson et al. 2000).

1.3 Environmental applications of SRF plantations

In contrast to the potential risks of nutrient leakage from fertilized plantations, plantations of fast-growing trees can offer great possibilities for environmental control at a local scale in terms of, e.g., phytoremediation. Thus, based on the large nutrient quantities taken up by fast-growing trees, the plantations can be used as recipients for municipal wastewater and industrial sludge and simultaneous biomass production (multifunctional biomass plantations, Perttu 1993, Isebrands and Karnosky 2001, Aronsson and Perttu 2001, Labrecque and Teodorescu 2003). A major problem occurs particularly in Nordic and Baltic regions with extended dormant periods during winter, where only very small quantities of nutrients are taken up by plants. This sort of wastewater treatment can therefore be accomplished in winter-cold regions only if the wastewater is stored in ponds or lagoons during the winter period (Dimitriou & Aronsson 2005).

1.4 Biodiversity aspects

In general, tree plantations can have positive or negative effects on biodiversity, depending on location, management and previous land use (Cossalter and Pye-Smith 2003) and studies on biodiversity in plantations of fast-growing trees often arrive at contradictory conclusions especially when different kinds of organisms are considered (Hartley 2002). Thus, the landscape context (forest or agricultural, Hanowski et al. 1997, Weih et al. 2003) along with the land-use type that the plantation replaces (Christian et al. 1994) and spatial scale aspects (e.g. size or shape of plantation; Christian et al. 1994, Berg 2002) influence the impact of establishment of tree plantations on biodiversity. In addition, many animals use multiple habitats and therefore depend on certain habitat combinations (With et al. 1997, Law and Dickman 1998) and the diversity of land use types in a given landscape can have large impacts on biodiversity.

Compared to natural mixed coniferous forests of the Pacific Northwest, Halpern and Spiess (1995) regarded large poplar plantations to decrease flora diversity in the long term. In comparison to managed coniferous forests and farmland in boreal Sweden, young poplar and willow plantations have however been concluded to increase vascular-plant diversity (Gustafsson 1987, Weih et al. 2003, Augustson et al. 2006).

Similar to the observations on floras, fauna diversity (birds and mammals) is frequently found to be higher in willow and hybrid poplar stands compared to agricultural croplands (Christian et al. 1998, Berg 2002). Thus, the more extensive management of tree plantations compared to intensively managed cereal crops can improve habitat quality for many organisms including plants, birds and arachnids (Berg 2002, Blick and Burger 2002, Dhondt and Wrege 2003, Weih et al. 2003). In addition, plantations of fast-growing trees appear to have a potential as important habitats for gamebirds (Sage and Robertson 1994). The location of tree plantations within the landscape context exerts a strong influence on their effect on biodiversity: A native wood nearby the tree plantation will facilitate the migration of birds, insects and plants and, thus, increase biodiversity. If no native woods are present, small groups of native trees can be planted nearby the fast-wood plantation. The native woods will serve as retreat area where animals and insects can survive during the periods of clear-cut in the fast-wood plantation. In large plantations, different parcels of the stand can be established and harvested in different years in order to enhance structural diversity and biodiversity. The same goal could be achieved by establishing a large number of smaller plantations, which are harvested in different years. Both alternatives can possibly improve the possibilities for biological control of herbivorous insects, which can be a serious problem in fast-wood plantations (Björkman et al. 2004). Mixtures of different species or varieties can be established either by planting them in different blocks across the field or random mixtures

within each row (e.g., Aronsson 1995, Volk et al. 2004). These mixtures increase structural and functional diversity and contribute to reduce the impact of pests and diseases (Ramstedt 1999, McCracken and Dawson 2001). Finally, a few meters wide stripes along the edges of tree plantations could be left without trees to support the development of a rich native flora and fauna.

It hence appears that intensively managed tree plantations, if not too large in size and if planned creatively, can increase the abundance and diversity of many organisms, particularly in landscapes dominated by either conventional agricultural fields or managed coniferous forests, by increasing structural diversity. However, plantations should be avoided close to open habitats of high conservation values such as certain types of wet meadows and buffer zones along streams, because such sites often have a conservation value linked to openness of the habitat (Berg 2002). With the above restrictions in mind, small-scale tree plantations (or subdivided larger plantations) grown on agricultural land may have the potential to positively affect biodiversity in many farmland regions, where the set-aside of agricultural land from food production suggests the development of alternative uses.

1.5 Effects of SRF plantations on landscape

Plantations of fast-growing trees may already after few years of growth be up to 6 or 8 m in height and it is important to consider the impact this will have on the landscape at the early planning stages of a fast-wood plantation. Many concerns are raised regarding the impact of plantations of fast-growing trees on the landscape (e.g., Skärbäck and Becht 2005): Will the open agricultural landscape be “darkened” by a new type of forest? How will the new crop be adapted to the traditional field crops of agricultural landscapes? Will we soon experience a total transformation of our ingrained cultural heritage? Studies regarding the effects of plantations of fast-growing trees on visual landscape perception usually arrive at different conclusions, e.g., the more open the landscape is, the larger can the size of the plantations be and particularly small plantations placed in open agricultural landscape can enrich landscape perception; small-scale undulating landscape only “tolerates” small plantations (Rode 2005, Skärbäck and Becht 2005). A general comment is often that plantations of fast-growing trees are an exciting new feature of the landscape, these plantations can enhance the aesthetic value of landscape by adding variation (e.g., autumn colors) and structure in homogeneous agricultural landscape (Skärbäck and Becht 2005, Blomqvist 2007). If used creatively as part of active landscape analysis and design, plantations of fast-growing trees can greatly improve the visual and recreational values of a landscape (e.g., Enberg 2002, Rode 2005, Blomqvist 2007). For example,

monotonous structures in blocks of tree plantations can be broken up by edge stripes of native herbs and woods, which are flowering and thereby can increase the aesthetic value of the landscape (Rode 2005).

1.6 Synergies and conflicts of interests

Localization, shape and management of commercial fast-wood plantations are partly conflicting with the primary interests of nature conservation and landscape design, whilst no serious conflicts of interest appear to exist between the interests of commercial growers, nature conservationists and landscape designers, if plantations are established outside areas of high nature conservation and cultural heritage values (Weih and Nordh 2007). Synergies between commercial and nature conservational interests could be achieved by localization of plantations nearby native woods, which favour biodiversity and also shelter the plantation from extremes in climate (e.g., frost) and, thereby, improve sustainable productivity of the plantation. No serious conflicts of interests are expected between nature conservation and landscape design principles of shaping and managing tree plantations (Weih and Nordh 2007). Possibly could synergies be achieved through the establishment of edge habitats consisting of attractive (flowering) plants that have high conservational value for plants and insects.

The report by Weih and Nordh (2007) has shown that there are potential negative impacts of commercial SRF plantations on environment and landscape, but these may be controlled and minimised by application of a creative and integrated attitude to ensure that establishment and management of SRF plantations operate in an optimal way to secure the positive impacts on rural economic activity, nature conservation (biodiversity) and cultural heritage.

1.7 Conclusions

Plantations of fast-growing trees (*Salix*, *Populus*) offer great possibilities for the efficient use of agricultural land in Nordic and Baltic regions. If the biomass produced is used as bio-fuel, the plantations have a great potential to contribute to carbon managed future economies, because they contribute only marginally to the production of atmospheric greenhouse gases. By combining biomass production and phytoremediation in tree plantations, waste products from society (waste water, sludge, ash) can be used as resources to improve tree growth and generate added values in terms of both environment and economy. Plantations of fast-growing trees grown on agricultural land can improve biodiversity at landscape level, in particular if the plantations are established instead of cultures of

cereals and spruce or fallow ground in homogeneous agricultural landscape. These tree plantations can also positively affect soil properties compared to conventional agriculture. Particularly plantations of relatively small size offer great possibilities for landscape design, because they are an exciting new feature in most regions and can enhance the aesthetic value of landscape by adding variation and structure.

Limitations for the localization, shape and management of fast-growing tree plantations are set by economic constraints, the landscape context and by environmental concerns. Regarding the localization of plantations, no serious conflicts between commercial and environmental interests are expected if the plantations are planned outside areas of high nature or culture conservation value. Synergy effects are possible if plantations are located nearby native woods. With respect to plantation management, the commercial practice of intensive tree culture might frequently conflict with the interests of nature and culture conservationists. An active dialogue between commercial growers and nature/culture conservationists as well as the development of guidelines for the establishment and sustainable, environmentally friendly management of SRF plantations on agricultural land will facilitate feasible compromises between the two sides.

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2. Possibilities and limitations of SRF on agricultural land across various Nordic and Baltic countries: an attitude study⁵

2.1 Introduction

Short rotation forestry (SRF), here synonymous to energy forestry, is a biomass cultivation system relatively recently introduced to the agricultural landscape. The search for renewable and CO₂ neutral energy sources has lead to the development of new growing systems for producing biomass. Weih (2004) concludes that SRF grown in boreal regions may have the potential for efficiently supplying biomass for energy purposes and in addition work as a tool for environmental control on a local scale.

Short rotation forestry plantations are intended to be established on agricultural land and SRF has more characteristics in common with agriculture than with conventional forestry in the way plantations are managed. Soil preparation before planting, measures of weeding and fertilisation are all performed as in conventional agriculture, but less intensive.

In several Baltic and Nordic countries and especially in Sweden, SRF with different species and hybrids of *Salix* sp (L.) has been tested and developed as a crop with high potential for being a possible commercial alternative to non-renewable fossil fuels for heat and power production (Weih and Nordh, 2007).

Although the cultivation of salix has many similarities with conventional agricultural crops, there are important characteristics that differ significantly from other crops grown on agricultural land. Firstly, the crop is perennial and there are 3 to 4 years between harvests and, secondly, salix SRF plantations have a greater impact on landscape perception compared to other bioenergy crops on agricultural land (Rosenqvist, 2007). However, studies by Skärbäck (2005) and Blomqvist (2007) pointed out that SRF plantations can be located and managed in such a way that negative changes of the landscape are minimal.

When changing from conventional agriculture to the cultivation of dedicated bioenergy crops there are environmental and social issues that need to be considered in order to get a successful introduction and public acceptance for the new crops. A number of these issues have been listed by

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Fritsche *et al* (2007). These issues are land use, land availability and land-use conflicts; loss of biodiversity and deforestation; greenhouse gas emissions; soil erosion and other forms of soil degradation; water use and water contamination and, finally, socio-economic problems and standards.

Major barriers for full-scale implementation of SRF plantations are often non-technical, such as misconceptions by both the public and regulating authorities and lack of adequate information (Weih and Nordh, 2007). From the farmers' point of view, SRF is an unfamiliar crop and therefore regarded as a crop with a higher risk than conventional crops and, consequently, the farmer expects a higher profitability to be willing to start SRF cultivation (Rosenqvist, 2007). In addition, from an environmental point of view, the demands on SRF and other bioenergy crops are often higher than for conventional crops.

The aims of this study are to investigate the opinions about SRF plantations at regulating authorities and organisations influential for public attitudes in various Nordic and Baltic countries, and to identify possible conflicts of interests, e.g., between commercial and environmental interests, regarding the localisation, design and management of SRF plantations on agricultural land in the Nordic and Baltic countries.

2.2 Methods

The study is based on a questionnaire (Appendix 1–1), according to a method used by Weih (2006) and with questions based on the experiences of SRF in Sweden. The questionnaire was sent to 8 countries – Denmark, Estonia, Finland, Latvia, Lithuania, Norway, Poland and Sweden (Tab. 1) – and was presented to the recipients either as face to face interviews, phone interviews or sent out by e-mail. The amount of recipients varied from almost 1000 in Latvia to 18 in Norway. The amount of respondents varied from 10 to 74 among countries. Most of the country representatives had chosen to send the questionnaire by e-mail to the recipients (Tab. 1). The data collection was performed during 2005 (Sweden) and 2006 (all other countries). The original questionnaire sent out was in several cases modified and adapted to the background knowledge and conditions of different countries. The Finnish questionnaire was added with a number of specified subjects under each main question. The country reports were presented and discussed on a workshop performed in Uppsala, Sweden, in autumn 2007 (Proceedings of the workshop see Weih, 2007) and a discussion of the Swedish results is found in Weih (2006).

The stakeholder groups were divided in a different way in different countries (Tab. 2). Whereas Sweden had been the most detailed in their description of the different stakeholder groups, Estonia and Finland presented the collected data just as a summary of all the results. However, in Finland the questionnaire was sent out to recipients representing different

stakeholder groups, but no identification of different stakeholder groups was performed, in order to keep the respondents' identity confidential.

Table 1. Material and methods used for the attitude study in different Nordic and Baltic countries

Country	Material	Methods
Denmark	20 respondents	Telephone interview, survey sent by email
Estonia	?	?
Finland	246 recipients (39 respondents)	Survey sent by e-mail (September 2006)
Latvia	987 recipients (74 respondents)	Survey sent by e-mail (July 2006)
Lithuania	10 respondents	? (November 2006)
Norway	18 recipients (10 respondents)	Survey sent by mail or email
Poland	179 recipients (10 respondents) 25 interviewees (21 respondents)	Survey sent by e-mail (July 2006), interviews (2006)
Sweden	72 recipients (53 respondents)	Survey sent by e-mail (April 2005)

Table 2. Stakeholder groups in the different countries investigated

Country	Stakeholder groups
Denmark	Farmers association and advisory service, public authorities, researchers, suppliers of planting material; planting, harvesting and general management services, traders and heat and electricity producers
Estonia	No division to different stakeholder groups
Finland	No division to different stakeholder groups
Latvia	Municipalities, NGOs, state organisations,
Lithuania	NGOs, state organisations, researchers
Norway	County authorities, private industry, researchers
Poland	Farmers, NGOs, researchers
Sweden	Bioenergy and landscape architecture organisations, central authorities, county administration, enterprises, farmers' and local heritage interest organisations, municipalities, nature conservation organisations, universities

2.3 Results

2.3.1 Reputation of energy forest

The reputation of SRF in the different countries is in general good and there were more positive than negative attitudes associated with the term 'energy forest'. The most positive attitudes were found in Denmark, Lithuania and Poland. In Sweden the attitude was mainly positive or neutral while in Estonia there were equally many positive and negative answers. The Latvian respondents were all neutral and in Finland the attitude was either neutral or negative. The most reluctant attitudes towards the sound of 'energy forests' appeared to be in Norway – all the Norwegian replies were either neutral or negative.

2.3.2 Possibilities associated with energy forest on agricultural land

Possibilities for society and production (Appendix 1.2).

The possibilities for society and production that stakeholder groups in different countries expressed varied greatly. The biomass produced in a SRF plantation was considered as an energy source by several stakeholder groups in different countries. Several enterprises and farmers and also different authorities regarded energy forest plantations as a possible income source or employment possibility. The plantations were also in some cases considered to need little input of, e.g., investments or labour. Rural development and keeping the countryside active and living was often emphasised by different authorities and also by farmers, e.g., in Poland. Mainly in Sweden and Denmark, the plantations were considered to be favourable to recreation. The expressed possibilities were very focused on societal issues.

Possibilities for environment and landscape (Appendix 1.3).

Many stakeholder groups mentioned possibilities related to environment or landscape and these comments were focused on certain themes. Variation in landscape was considered an important possibility by several stakeholder groups, especially in Sweden and Denmark, but also researchers in, e.g., Lithuania mentioned it. Several Danish and Swedish stakeholder groups, including researchers and authorities, emphasised the positive effects of energy forest plantations to fauna, flora, insects and bird life. Different stakeholder groups especially in Denmark, Lithuania and Sweden considered the use of unused or set-aside agricultural land by SRF plantations as an interesting possibility.

2.3.3 Challenges and problems associated with energy forest

Society (Appendix 1.4)

Many of the challenges that different stakeholder groups mentioned were very concentrated on issues related to society. Issues such as lack of information, experience or knowledge was mentioned by different stakeholder groups, e.g., farmers in Poland and nature conservation organisations in Sweden. Some of the comments were focused on practical issues such as damages to drainage systems, and these comments were made by farmers and researchers both in Denmark and Sweden. Poor economy was also mentioned as a challenge by both farmers and researchers. Whereas farmers often mentioned very practical concerns such as unclear regulations and lack of markets for production, authorities emphasized challenges such as interest conflicts and (negative) public attitude.

Environmental and landscape (Appendix 1.5)

Unfavourable changes in landscape were mentioned as a concern by several stakeholder groups in Denmark, Latvia, Norway and Sweden. Leaching of mineral nutrients to ground water was considered to be a challenge by, e.g., nature conservation organisations in Sweden and researchers in Norway. Different authorities in Lithuania and Sweden were also concerned about the effects of SRF on biodiversity.

2.3.4 Localisation of energy forest plantations

Localisation of the plantations divided opinions between the different stakeholder groups and countries (Appendix 1.6). Several comments without detailed explanations on why plantations should be located in a certain way were given. One stakeholder group in Sweden preferred good quality land for the plantations, whereas many stakeholder groups in different countries, including Sweden, preferred to use poor-quality land for the cultivation. Landscape issues in relation to localisation were emphasised by several stakeholder groups in different countries. Comments considering cultural and nature values were given especially by authorities in Lithuania and Sweden.

2.3.5 Shape of energy forest plantations

Many stakeholder groups commented on the shape of plantations (Appendix 1.7). Homogenous plantations were recommended by few stakeholder groups in Lithuania and Sweden, whilst many stakeholder groups in, e.g., Denmark, Lithuania and Sweden preferred heterogeneous plantations. The preferred size of plantations also varied between different stakeholder groups; small plantations were most recommended by various stakeholder groups in Sweden. Landscape and economical issues in relation to shape were emphasised by several stakeholder groups in different countries.

2.3.6 Management actions to enhance environmental benefits

Only very few management actions to enhance environmental benefits of energy forest plantations were mentioned by the different stakeholder groups (Appendix 1.8). Species mix and borderline plantations with species other than the crop species were mentioned by stakeholder groups in Norway and Sweden. The use of native species and varieties was emphasised by stakeholder groups in, e.g., Latvia, Lithuania and Sweden. One stakeholder group in Sweden mentioned the localisation of plantations in order to gain positive effects on water quality. The comments given were often related to water protection, decreased nutrient leaching and phytoremediation.

2.4 Discussion

The formulation of the questionnaire was based on the experience in Sweden (Weih, 2006), but questions, target groups and the way of distributing the questionnaires had to be adjusted to the local conditions in the different Nordic and Baltic countries. For example, representatives of different countries selected different target (stakeholder) groups, and the data collection time varied between countries. In addition, representatives for the various countries put rather different effort into the attitude study, which additionally increased data heterogeneity. Results from the questionnaire must therefore be interpreted with care and specific for each country; a tabular summary of all results is found in Appendix 1 and additional country-specific information is presented by Weih (2007). The very heterogeneous data basis made it difficult to draw general conclusions, but some interesting observations of a more general character could still be made.

One of the most obvious observations that can be made from this study is that the experiences and knowledge concerning SRF cultivation vary a lot both between countries and between stakeholders within individual countries. This was reflected by many answers and comments given by the different stakeholder groups in various countries. Also in Sweden, where commercial SRF salix plantations have been increasingly common in parts of the country since the early 1990's and where much experience of the willow SRF cultivation systems is available, we frequently found misconceptions and lack of basic knowledge regarding SRF management and influence of SRF plantations on environment and landscape (Weih, 2006). For example, some of the answers and comments from regional authorities expressed a worry that the removal of salix plantations would need deep ploughing, beneath the existing plough pan, and thereby interfere with undisturbed archaeological contexts. Indeed, no deep ploughing is needed when removing salix plantations.

Poor knowledge on SRF culture was partly found at rather fundamental level, e.g., whether SRF is considered a forestry or agriculture issue. However, it should be kept in mind that most of the data were collected from people with little or no own experience from practical SRF cultivation, because farmers were mostly not included in the survey (except for Poland). If farmers had been included in the survey, the overall pattern of answers might have been different. The observation of frequently poor knowledge suggests that there is a great need for education and information dissemination to all sorts of stakeholder groups and across all investigated Nordic and Baltic countries, in order to improve communication and understanding with respect to SRF cultivation systems on agricultural land under Nordic conditions.

Comments on landscape, biodiversity, society, production, rural issues, bioenergy, nature and cultural issues varied between countries and

stakeholder groups. Landscape issues were a concern in most countries and the fear of closing an open landscape and blocking of scenic views was frequently mentioned as a major concern. In some cases (e.g., Denmark), however, SRF plantations were regarded as a possibility to increase the variation in an otherwise open and monotone landscape (cf. chapter 3; Blomqvist, 2007).

The comments on shape, size and location of SRF plantations indicate potential conflicts between maximising the economical outcome and landscape and environmental concerns (cf. Weih and Nordh, 2007). From an economic point of view, large and continuous plantations were mentioned to be most efficient to manage. In addition, plantations should be located close to roads, in order to reduce costs for transportation of the harvested biomass. However, especially large and homogeneous plantations are not desirable from a landscape and biodiversity point of view, which might cause conflicts of interest between commercial SRF growers and a society with enhanced environmental, landscape and recreation interests (cf. chapter 1). However, the awareness of landscape and environment issues and, thus, the associated potential conflicts of interest, was found to be rather low especially in countries with few or no own experience of commercial SRF plantations, because in these countries the focus was mainly on basic questions related to the establishment, management and economy of SRF plantations. Appropriate measures, e.g., information campaigns, to increase awareness of environment and landscape issues should therefore be considered especially in countries with poor tradition of commercial SRF plantations, in order to decrease the risk of negative developments arising from the potential conflicts of interest between, e.g., nature conservation and economic production goals. In accordance with the conclusions presented in chapter 1, we see a need for guidelines and recommendations especially concerning the sustainable and environmentally friendly localization, shaping and management of SRF plantations on agricultural land under Nordic conditions. The guidelines (cf. Appendix 2) could possibly be included in revised editions of available practical “SRF growers manuals” (e.g., Gustafsson *et al*, 2007) and supplied to farmers by advisory officers. The guidelines could also be disseminated to central and local authorities involved in the regulation of SRF plantations.

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3. Landscape perspective on energy forests⁶

3.1 Background

This chapter aims at evaluating the possibilities of SRF plantations to improve the natural and cultural qualities of landscape, and to comment on the possibilities to direct localization, design and management of SRF plantations.

A landscape analysis to that extent can be recommended in order to assess the *visual character* of the fields as a landscape element in interaction with their surroundings. The description, which I refer to as "Landscape experience" is based on a method that has its basic point of departure in another method, developed by Kevin Lynch (Lynch, 1960). With the aid of maps and field studies, analyses are made of the spatial divisions, directions and boundaries, viewing points and lines of sight, specially exposed landscape elements, i.e. landmarks, minor roads from which the landscape can be appreciated and major roads that screen off and divide up the landscape, and function as barriers.

The method has been used in order to be able to answer these questions, a study was made of the changes to the landscape caused by 'Storförsök syd' (Skärbäck and Becht, 1984). The appearance of the energy forests and their impact on the landscape were analysed and described on the basis of the *aesthetic character* of the plants and the forests, as well as the *visual character* of the forests as an element of the landscape in interplay with their surroundings (Skärbäck and Becht, 2005).

The Storförsök Syd project was also studied through photographic documentation. A total of twenty-five viewing points were identified within the area. The choice of viewing points was subjective. Primarily, viewing points were sought from which Storförsök Syd's energy forest fields were visible. In addition to these, the area contains a number of other viewing points from which it would not be possible to view energy forests to any significant extent. Such viewing points have not been included in this landscape analysis.

Throughout the entire project period, three years, the landscape was photographed from 35 photo points during the winter, spring, summer and autumn. Owing to the relatively short project period, it was only possible to study the phases from new facility up to fully-grown energy forest stage, i.e. not the felled forest stage.

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The results of this landscape analysis are that of the 25 viewing points, in part selected with a focus on the energy forest fields, only 2 viewing points ceased to exist completely. For 8 of the viewing points, the view was restricted to some extent in one or more directions.

This report contains photos from both the Storförsök Syd project during the 80th and from additional photos of different SRF crops in 2006.

Energy forest cultivation competes best on low-lying land with a relatively high soil humidity. This type of location has only a fairly low impact on the visual character of the landscape. The screening effects are limited since the surrounding roads are often elevated. The aesthetic character can be divided into the parameters of *form, colour and function*.

3.2 Aesthetic character

3.2.1 Form

The form of an energy forest is understood to be its *linear perspective* and its *sculptural* expression. The overall sculptural impression of the form of an energy forest depends partly on the *structure*, i.e. the skeleton of the forest and the plants that characterise the type of growth and the sculptural structure, and partly on the *texture*, i.e. the external impression, the pattern, that is created by the foliage, the density of the plants, etc.

3.2.2 Structure

The *Salix* plant has few branches and an upright growth structure. The foliage is substantial in relation to the wood for young plants. Consequently, newly planted *Salix* forests have many similarities with traditional field crops. The properties of the structure can therefore be described as *upright growing* (Figure 1) or *billowing* (Figure 2).



Figure 1. Upright growing structure



Figure 2. Billowing structure

3.2.3 Texture

The texture of an individual plant is elegant. This applies also to newly planted fields, which initially give an impression of perviousness. Then as the forest gradually grows, the impression becomes more compact and dense. The properties of the texture can therefore be described as *compact* or *dense* (Figure 3), or alternatively *elegant* or *pervious* (Figure 4). The feeling of compactness has very much to do with the direction of the sun light. When the observer is standing against the light the crop looks more compact.



Figure 3. Compact – dense texture



Figure 4. Elegant – pervious texture

3.2.4 Linear perspective

The linear perspective can be described in terms of *even* (Figure 5) or *uneven* (Figure 6). When newly planted, a field may appear irregular since different plants receive a different start. (Referring to Figure 6) However, after a few years the cultivation appears more compact and even (Figure 5).



Figure 5. Even linear perspective

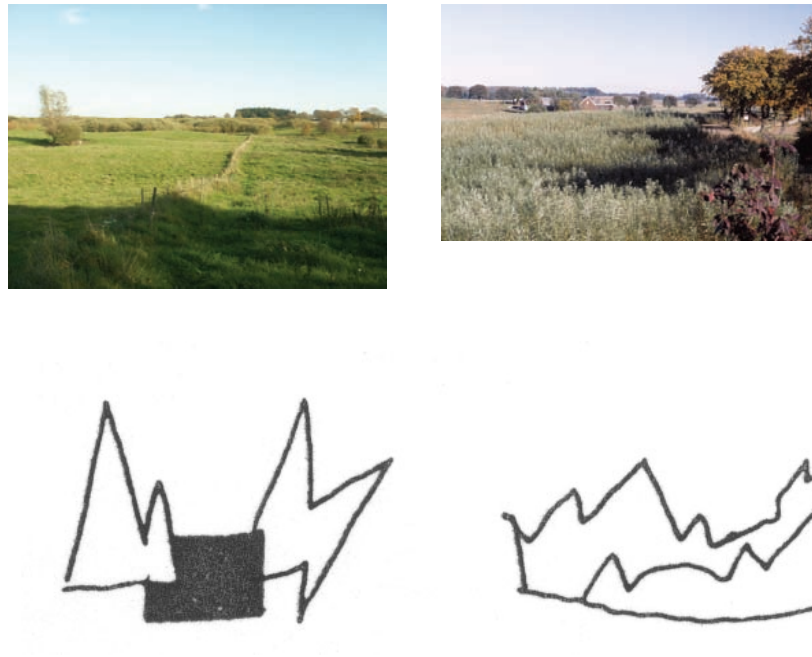


Figure 6. Uneven linear perspective

3.2.5 Varied topography

In varied topography, the linear perspective has an equalising effect (Figure 7). This is because the plants at low points often have greater access to water and grow faster than plants on higher, often drier terrain.



Figure 7. An equalising linear perspective in undulating terrain

3.3 Colour

Colour can be characterised on the basis of three parameters: lustre, grey scale and colour scale. Lustre ranges from matt to shiny, grey scale goes from dark via grey to light, and colour scale is defined on the basis of the composition of the colours blue, green, yellow and red.

The studies conducted in connection with Storförsök Syd produced the following results:

Lustre: Newly planted fields are experienced as shiny but change after 1–2 years to matt.

Colour scale: The colours are greenish blue – turquoise in all stages of growth from newly planted to felleable.

Grey scale: The grey scale is light-grey at all stages.

3.4 Function

The aesthetic character is influenced to a large extent by functional aspects, such as land use, upkeep and choice of crop.

3.4.1 Upkeep

In the case of newly planted fields, the soil has been weeded and exposed. The rows of plants are distinct. Surrounding the cultivation there is a 5 m-wide plant-free zone of open soil. In all, this gives an impression of a traditional agricultural crop (Figure 8).



Figure 8. An impression of a traditional agricultural crop

3.4.2 Interim stage

At an interim stage, years 2–3, the amount of weeding decreases. The increasing volume of weeds is reminiscent of ditch vegetation or waste land, not of a natural field layer. The cultivation gives an unkempt and uncared-for impression (Figure 9).



6

Figure 9. An unkempt and uncared-for impression3.4.3 Fellable stage

By the fellable stage, the efforts aimed at upkeep have decreased still further. The texture becomes more compact and the impression of an agricultural crop is replaced by the impression of a thicket forest (Figure 10).



Figure 10. The impression of a thicket forest

As a ‘field of stubs’ (Figure 11), the felling stage has its own character with little similarity to other crops. The felling is carried out during the

winter, and after as little as six months new shoots have begun to appear, which improve the impression (Figure 12).



Figure 11. "Field of stubs" winter



Figure 12. "field of stubs" spring – autumn

The fact that energy forest cultivation is a relatively dynamic form of cultivation that varies over the course of time, and which is the subject of relatively intense upkeep, means that the land does not appear to be abandoned, like waste ground, and is therefore regarded in a relatively positive light (Figure 13).



Figure 13. Relatively intense upkeep – land does not appear to be abandoned

3.4.4 Land use function

In order to be able to discuss the appearance of an energy forest, we have to relate to the existing land uses that are to be found in the region. A suitable basis for division is then *forestry* (which can be subdivided into *thicket*, *deciduous forest*, *mixed forest* and *spruce forest*), *agriculture* (which can be subdivided into *field*, *meadow* and *pasture land*), and *waste land*.

Energy forest fields, when newly planted, are most similar to fields growing agricultural crops, i.e. agriculture. Then, as the fields gradually develop they begin to take on the appearance of overgrown land, or in other words waste land. When fully grown and felleable, the energy forest is reminiscent of a thicket forest, i.e. forestry.

3.4.5 Crop, type of plant – summary

When newly planted, the energy forest plant, *Salix viminalis*, displays similarities to cabbage and leguminous plants.

At the intermediate stage the energy forest crop is similar to no other plant form. It is by then too wispy to be confused with any other agricultural crop or thicket forest. At the felleable stage, the energy forest has a character which, in terms of both colour and form, can be likened to a thicket forest of birch or alder. However, the uncultivated peripheral zone around the field demonstrates clearly that it is not a question of any form of natural thicket forest. Here too, the topography is also very important.

Where energy forest grows on lowland fields that are surrounded by natural birch or alder, the forest blends fully into the landscape. On the other hand, in the case of energy forests growing in fields on higher land, which are often surrounded by hawthorn (*Crataegus*), oak (*Quercus*), and elm (*Ulmus*) with different colours and shapes, the energy forest will tend to stand out more.

3.5 Recommendations

For the purpose of improving environmental quality and sustainable development in the localization, designing and management of SRF plantations can give some possibilities.

- *To locate close to existing forests (Figure 14)*



Figure 14. Location close to existing forests

- To locate integrated with islands of other broadleaf trees (Figure 15)



Figure 15. Location integrated with islands of other broadleaf trees

- To harvest parts of the crop in different years (Figure 16).



Figure 16. Harvesting of parts of the crop in different years

- *To establish a number of small crops close to each other to be harvested different years rather than one big crop (Figure 17).*



Figure 17. Establishing of a number of small crops close to each other

- *To plant different species in the same field, but in different sections e.g parallel streams (Figure 18).*



Figure 18. Planting different species in the same field

- *To leave buffer zones without any crop at the outer boarder of the field (Figure 19).*



Figure 19. Leaving buffer zones without any crop at the outer boarder of the field

- *Not to plant in areas with protection for nature preservation or cultural heritage*

This is a statement that can be questioned as a general recommendation. Since the SRF plantations are not changing the landscape character very much, energy forests can many times be accepted as a new part of a living cultural landscape, thus a natural ingredient necessary for the maintenance of a living landscape. To prevent from the establishment of new groups for the future can in some cases be a problem for the survival of the farming.

There has been a lot of discussion whether SRF is an acceptable landscape element in Söderslätt, a too large extent protected landscape for its cultural heritage (Figure 20). If the SRF does not cover to large amount of the fields it rather seems to give an improvement of the landscape scenery.



Figure 20. SRF at Söderslätt, a landscape of high cultural heritage value

- *To harvest preferably on frozen ground (Figure 21).*



Figure 21. Harvesting on frozen ground

- *To locate, design and maintain crops so they improve the variation in Landscape (Figure 22)*



Figure 22 Try to improve the variation in Landscape

- *To plant along roads and railroads for snow protection*

Roads and railways that are built in cuttings in an open landscape experience problems every winter in connection with snow-drifts. The Swedish National Road Administration has begun to plant energy forests in broad belts alongside road cuttings (Figure 23), which has resulted in a significant decrease in traffic problems as a result of snow during the winter.



Figure 23. SRF as a wind shelter for snow protection along a motorway

Also railways can be protected by plantations of energy forests (Figure 24). The winter (2001–2002) the railways were affected by stoppages on several occasions as a consequence of snow problems. They were extensive stoppages that affected rail services all over the country, and led to substantial losses on the part of both transport operators and society in general.



Figure 24. SRF along the railroad Malmö-Ystad

- *To improve animal life*

Animal fauna have also been studied during the course of Storförsök (Göranson and Jeppsson, 1989). It was concluded that among the deer species, roe deer displayed the greatest increase, but fallow-deer and to a certain extent red deer have also increased in number. Field hare and wild rabbits have also increased. Other species that have increased include shrews and small weasels. Earthworms decreased initially when the fields were first planted, but then began to record considerably higher quantities than before cultivation once the forests had been harvested.

Studies of other energy forest fields in Sweden have also reported an increase in roe-deer and elk (Bergström, 2001; Figure 25).

Other impacts on animal life were summarized in Skärbäck and Becht (2005).



Figure 25. Deers can find shelter in SRF

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Swedish summary

Resumé

Rapporten sammanfattar de analyser och diskussioner kring miljö- och landskapsfrågor som genomförts inom projektet *Energiskogsodling på åkermark och dess möjligheter för uthållig energiframställning i ett nordiskt perspektiv*. De huvudsakliga målen inom projektet var att utvärdera möjligheterna att med hjälp av energiskogsodlingar förbättra landskapets natur- och kulturvärden under de rådande betingelserna i olika nordiska länder och att med utgångspunkt från erfarenheter i de olika nordiska länderna kunna formulera och sammanställa rekommendationer för uthållig skötsel och lokalisering av energiskogsodlingar. För att nå målen genomfördes en litteraturstudie och en rapport om landskapspåverkan sammanställdes. Dessutom gjordes en enkätundersökning i ett flertal nordiska och baltiska länder (Sverige, Danmark, Finland, Norge, Lettland, Litauen, Polen) bland intressenter och forskare om attityderna kring energiskogsodling samt vilka risker och möjligheter odlingen innebär för miljön och landskapet. Resultaten av enkäten diskuterades vid en internationell workshop som hölls i Uppsala, Sverige hösten 2007.

Trots att kommersiell energiskogsodling delvis kan komma i konflikt med natur- och kulturvård så ger denna typ av odling nya och unika möjligheter att förbättra landskapet och även lösa vissa miljöproblem (t.ex. rening av avloppsvatten) samt att öka biodiversiteten (t.ex. i ett öppet landskap). Åsikterna hos centrala och lokala myndigheter, intresseorganisationer m.fl. rörande energiskogsodling och dess inverkan på miljö och landskap är ofta grovt felaktiga på grund av missuppfattningar och brist på kunskap.

Riktlinjer för uthållig skötsel och lokalisering av energiskogsodlingar utarbetades inom projektet. Dessa riktlinjer utgör ett komplement till existerande odlarhandböcker för energiskogsodling. Syftet med riktlinjerna är att underlätta en aktiv dialog mellan kommersiella odlare och natur- och kulturvårdsintressen, särskilt för de områden där konflikter kan tänkas uppstå mellan de båda särintressena.

Möjligheterna för att odla energiskog varierar betydligt mellan de nordiska länderna. I länder med få eller inga egna kommersiella energiskogsodlingar är medvetenheten liten gällande om miljö- och landskapsaspekter i relation till energiskogsodling eftersom diskussionen oftast rör frågor kring etablering, skötsel och ekonomi.

Bakgrund och problemlidentifiering

Det finns en ökande efterfrågan på bioenergigrödor huvudsakligen inom värme- och kraftproduktion men efterfrågan ökar även i form av biobränslen inom transportsektorn. Täta planteringar av snabbväxande träd på god åkermark med syfte att producera biobränslen är idag verklighet i kommersiell skala i Sverige. I framtiden är det sannolikt att energiskogsodling kommer att få en ökad betydelse även i många andra nordiska länder. Till exempel har livscykelanalyser av biomassaproduktionen i kommersiella salixodlingar med högavkastande sorter visat att odlingssystemet har hög energieffektivitet: energiinnehållet i den biomassa som produceras är 20 gånger högre än den energi som åtgår vid odlingen, ett förhållande som är cirka 3 gånger högre än den energibalans (erhållen energi/insatt energi) som fås vid odling av ettåriga energigrödor som vete och raps. Odling av snabbväxande lövträd innebär att insatsen av kemikalier minskar i jämförelse med odling av konventionella jordbruksgrödor och odlingen erbjuder en alternativ användning av jordbruksmarken och kan dessutom förbättra de lokala miljöförhållandena genom ökad biodiversitet. Trots detta har energiskogsodlingarna medfört oro kring odlingens inverkan på miljö, biodiversitet och landskapet och det finns risk för att det uppstår intressekonflikter mellan kommersiella energiskogsodlare och t.ex. miljöaktivister. Projektets huvudsakliga fokus har varit att belysa de möjligheter och risker som finns för miljö, biodiversitet och landskap i samband med energiskogsodling under de förutsättningar som råder i de nordiska och baltiska länderna.

Projektet syftade till att utvärdera följande:

- möjligheterna att, med hjälp av energiskogsodlingar, förbättra landskapets natur- och kulturvärden under rådande förutsättningar i olika nordiska länder;
- möjligheterna att styra lokalisering, utformning och skötsel av energiskogsodlingar för att uppnå förbättrad miljö och uthållig utveckling inom jordbruket;
- utformning av riktlinjer för uthållig skötsel och lokalisering av energiskogsodlingar baserat på erfarenheter i flera nordiska länder.

Projektets syfte var också att identifiera möjliga konflikter t.ex. mellan ekonomiska intressen och miljö- och kulturvårdshänsyn i förhållande till utformning och skötsel av energiskogsodlingar.

Huvudsakliga slutsatser

Miljö-, biodiversitets- och landskapsaspekter kring energiskogsodling på jordbruksmark – en litteraturstudie (kapitel 1):

Planteringar av snabbväxande träd på jordbruksmark kan öka biodiversiteten i öppna jordbrukslandskap och bidra till att lösa vissa miljöproblem både lokalt (t.ex. som vegetationsfilter på förorenad mark) och globalt (t.ex. minskad växthuseffekt genom upptag av koldioxid). Odling av snabbväxande lövträd kan följaktligen erbjuda mervärden i form av t.ex. rening av avloppsvatten och bindning av kol. Det finns dock en risk, speciellt när det gäller skötseln av energiskogsodlingar, att det uppstår konflikter mellan natur- och kulturvårdsintressen och den kommersiella odlingen. För att åstadkomma genomförbara kompromisser mellan dessa intressen är det viktigt att det förs en aktiv dialog mellan kommersiella odlare och natur- och kulturvårdare samt att det sammanställs riktlinjer för etablering och uthållig miljövänlig skötsel av energiskogsodlingar på jordbruksmark (t.ex. Appendix 2 i denna rapport).

Möjligheter och begränsningar vid energiskogsodling på jordbruksmark i olika nordiska och baltiska länder (kapitel 2 och Appendix 1):

Förutsättningarna för att odla energiskog varierar betydligt mellan de nordiska länderna. I länder med få eller inga egna kommersiella energiskogsodlingar är medvetenheten liten gällande om miljö- och landskapsaspekter i relation till energiskogsodling eftersom diskussionen oftast rör frågor kring etablering, skötsel och ekonomi. Speciellt i länder där det inte finns någon erfarenhet av att odla energiskog är det viktigt att vidtaga ändamålsenliga åtgärder för att öka medvetenheten om miljö- och landskapsaspekter och för att på så sätt minska risken för de negativa effekterna som kan uppstå i samband med potentiella konflikter mellan naturvård och produktionsmål i odlingen.

Landskapsperspektiv i samband med energiskogsodling (kapitel 3):

Energiskogsodlingar (salixodlingar) kan förbättra landskapets kvalitéer genom att bidra med struktur, form och färg. Vid lokalisering, utformning och skötsel av energiskogsodlingar finns det många tillgängliga möjligheter att utföra dessa för att öka odlingarnas miljövärde så att de bidrar till en hållbar utveckling. Energiskogsodlingar kommer bäst till sin rätt i låglänta delar av landskapet där vattentillgången är god. I det läget är också energiskogsodlingens visuella inverkan på landskapsbilden som minst.

Riktlinjer för bästa möjliga skötsel av energiskogsodlingar för uthållig biomassaproduktion i den nordisk-baltiska regionen (Appendix 2):

- Undvik områden som är skyddsvärda för sina natur- och/eller kulturvärden.
- Undvik mycket stora odlingar – plantera flera mindre odlingar istället.
- Etablera odlingarna intill befintliga naturliga skogsbestånd och/eller inneslut 'öar' av naturliga träd i större planteringar
- Lämna buffertzoner, antingen utan gröda eller med naturlig vegetation, i kanten av odlingen.
- Plantera flera olika sorter (gärna av olika kön) i samma odling; sorterna kan planteras i sektioner eller i radavsnitt för att underlätta skörden.
- Använd kemiska bekämpningsmedel enbart vid etableringen av beståndet.
- Gödsla inte mer än grödan kan tillgodogöra sig under växtsäsongen.
- Försök att planera så att all skörd sker då det är tjäle i marken
- Skörda delar av beståndet under olika år.
- Genomför lokaliseringen, utformningen och skötseln av energiskogsodlingen så att variationen i landskapet blir så stor som möjligt.

Appendices

Appendix 1

Appendix 1-1.

Attitude study: List of questions used as a starting point for the questionnaire performed in various Nordic and Baltic countries. The list of questions was modified for the different conditions in the involved countries.

Questionnaire*:

Please answer the following questions as a representative for your organization.

- 1) Is the term “energy forest” held in good, neutral or bad reputation for you / your organization?
- 2) Which (positive) possibilities do you / does your organization associate with the culture of fast-growing trees on agricultural land?
- 3) Which problems can arise with the culture of fast-growing trees on agricultural land?
- 4) Where should plantations of fast-growing trees be located (landscape context) and where should they be avoided? Please motivate your answer!
- 5) How should plantations of fast-growing trees be formed (e.g., shape, size of plantation, mixture of species/varieties)? Please motivate your answer!
- 6) Which, if any, specific management actions (apart from purely yield-related) should be considered to enhance the environmental benefits of plantations of fast-growing trees? Please motivate your answer!
- 7) Comments? To be sent to organizations, which might have an interest in, or are influential for, the subjects “energy forest” and/or “environmental issues”; e.g. central and local authorities, non-governmental organizations, companies and university researchers specialized within a relevant topic.

Appendix 1.2. Attitude study: Possibilities for society and production.

Statement	Stakeholder groups
Substitution of fossil fuels	Bioenergy and landscape architecture organisations, farmers and local heritage interest organisations, universities (Sweden)
Energy self-sufficiency	Municipalities (Latvia), biofuel producers' and suppliers organisation (Lithuania); county administration (Sweden)
Energy source	Farmers' association and advisory service, public authorities, researchers, suppliers of planting material; planting, harvesting and general management services; traders and heat and electricity producers (Denmark); municipalities (Latvia); state organisations (Lithuania); researchers (Norway); central authorities, nature conservation organisations, universities (Sweden)
Biomass production	ENGO, researchers (Lithuania); universities (Sweden)
Local renewable energy production	Municipalities (Latvia); biofuel producers' and suppliers organisation, ENGO, state organisations (Lithuania); county administration, enterprises, universities (Sweden)
Meeting obligations under Kyoto protocol	Biofuel producers' and suppliers organisation, researchers (Lithuania)
Binding carbon dioxide	Researchers (Lithuania); central authorities (Sweden)
Employment or income	Municipalities (Latvia); state organisations, researchers (Lithuania); farmers (Poland); bioenergy and landscape architecture organisations, central authorities, county administration, enterprises, farmers' and local heritage interest organisations, county administration, universities (Sweden)
Little input needed	Farmers' association and advisory service, public authorities, researchers, suppliers of planting material; planting, harvesting and general management services (Denmark); farmers (Poland); bioenergy and landscape architecture organisations, central authorities, county administration, universities (Sweden)
Alternative agricultural production	Researchers (Lithuania); central authorities, universities (Sweden)
Diversification of agricultural activities	Farmers' association and advisory service, researchers, suppliers of planting material; planting, harvesting and general management services (Denmark); state organisations (Lithuania), farmers (Poland)
Preservation of living countryside	Public authorities (Denmark), farmers and local heritage interest organisations, central authorities, county administration, nature conservation organisations, universities (Sweden)
Using as a protection or buffer zone	County authorities (Norway); bioenergy and landscape architecture organisations, enterprises, universities (Sweden)
Favourable for recreation	Farmers' association and advisory service, researchers, suppliers of planting material; planting, harvesting and general management services (Denmark); bioenergy and landscape architecture organisations, county administration, nature conservation organisations (Sweden)
Examples for other comments	Good energy balance (bioenergy and landscape architecture organisations, Sweden); Sustainable energy use (municipalities, Sweden); Storable energy form (universities, Sweden); Long-term energy production (bioenergy and landscape architecture organisations, Sweden); Contribution in building sustainable society (county administration, Sweden); Reduction in intensive agriculture (ENGO, Lithuania); Poor soils not suitable to common agriculture can be used (NGOs, researchers, Poland); Additional agricultural land can be used for biomass production (universities, Sweden); Reversible land use (bioenergy and landscape architecture organisations, Sweden); Energy forest can be harvested at need (enterprises, Sweden); Better use of existing infrastructure (researchers, Lithuania); Better yields with "bred" Salix (central authorities, Sweden); Ensuring long term supply and planning (traders and heat and electricity producers, Denmark); Increased competition on land (enterprises, Sweden); Positive political signs (enterprises, Sweden); Increased availability of local resources (biofuel producers and suppliers' organisation (Lithuania); No possibilities due to state agricultural policy (municipalities, Latvia), Delivery security (enterprises, Sweden); Possibility to use field area for agricultural purposes (enterprises, Sweden); Good for soil quality (universities, Sweden); More flexibility (universities, Sweden)

Appendix 1.3. Attitude study: Possibilities for environment and landscape.

Statement	Stakeholder groups
Favourable to fauna, flora, insects or birdlife	Farmers' association and advisory service, researchers, suppliers of planting material; planting, harvesting and general management services (Denmark); bioenergy and landscape architecture organisations, central authorities, municipalities, nature conservation organisations, universities (Sweden)
Favourable to biodiversity	ENGO (Lithuania), enterprises, nature conservation organisations, universities (Sweden)
Less leaching	Farmers' association and advisory service, researchers, suppliers of planting material; planting, harvesting and general management services (Denmark); central authorities, enterprises, nature conservation organisations, universities (Sweden)
Phytoremediation	Researchers (Lithuania); central authorities, enterprises, nature conservation organisations (Sweden)
Reduced pollution	ENGO, state organisations (Lithuania)
Reduced pressure to environment	ENGO, state organisations (Lithuania); bioenergy and landscape architecture organisations, universities (Sweden)
Use of unused or set-aside agricultural land	Farmers' association and advisory service, researchers, suppliers of planting material; planting, harvesting and general management services (Denmark); biofuel producers and suppliers' organisation, ENGO, researchers, state organisations (Lithuania); central authorities, county administration, enterprises, municipalities, universities (Sweden)
Variation in landscape	Farmers' association and advisory service, researchers, suppliers of planting material; planting, harvesting and general management services (Denmark); researchers (Lithuania); county administration, bioenergy and landscape architecture organisations, enterprises, farmers' and local heritage interest organisations, municipalities, nature conservation organisations, universities (Sweden)
Examples for other comments	Water purification (universities, Sweden); Binding dust along roads (universities, Sweden); Ground water protection (farmers' association and advisory service, researchers, suppliers of planting material; planting, harvesting and general management services, Denmark); Not normally in conflict with other biological values (county administration, Sweden); Erosion reduction (researchers, Lithuania)

Appendix 1.4. Attitude study: Challenges and problems regarding society aspects.

Statement	Stakeholder groups
Low energy efficiency	Farmers' and local heritage interest organisations, nature conservation organisations (Sweden)
Avoiding unnecessary regulations	State organisations (Lithuania); bioenergy and landscape architecture organisations, universities (Sweden)
Public attitude	County administration, universities (Sweden)
Lack of information, experience or knowledge	Farmers' association and advisory service, researchers, suppliers of planting material; planting, harvesting and general management services (Denmark); NGOs, municipalities, state organisations (Latvia); farmers (Poland), nature conservation organisations (Sweden)
Lack of support or assistance	Municipalities, NGOs, state organisations (Latvia); biofuel producers and suppliers' organisation, researchers (Lithuania)
Interest conflicts	Public authorities (Denmark); ENGO (Lithuania); universities (Sweden)
Shortage of land to food production in future	Municipalities (Latvia); biofuel producers and suppliers' organisation (Lithuania)
Unsuccessful cultivation	Enterprises, farmers' and local heritage interest organisations, universities (Sweden);
Environmental requirements have to be the same as in agriculture	Bioenergy and landscape architecture organisations, nature conservation organisations (Sweden)
Better organisational structure needed	Biofuel producers and suppliers' organisation, ENGO, researchers (Lithuania)
Damages to drainage system	Farmers' association, researchers (Denmark); state organisations (Lithuania); county administration, farmers' and local heritage interest organisations, municipalities, universities (Sweden)
Poor economy	Farmers' association and advisory service, researchers, suppliers of planting material; planting, harvesting and general management services (Denmark); state organisations (Lithuania); farmers (Poland), universities (Sweden)
Difficulties in changing land use	Researchers, state organisations (Lithuania); county administration (Sweden)
Lower quality of soil	Researchers (Lithuania); farmers and local heritage interest organisations (Sweden)
Less flexibility	Farmers' association and advisory service, researchers (Denmark); county administration (Sweden)
Examples for other comments	Large use of non-renewable energy in production (universities, Sweden); Smell when spreading sludge (municipalities, Sweden); Readily accessible ground water or regular irrigation needed (researchers, Lithuania); Lacking benefit on genetic improvements due to long rotation period (suppliers of planting material; planting, harvesting and general management services, Denmark); Selection of unsuitable species (state organisations, Latvia) Soils not good for energy crops (farmers, Poland); Scarcity on nutrients (researchers, Norway); Weeds as a result of applying sludge (researchers, Lithuania); Fear of changing traditional system in agriculture (farmers, Poland); Different culture and social life in rural districts (researchers, Norway); Managing assistance program as a forestry project (researchers, Lithuania); Unsuccessful test plantations (farmers, Poland); Damages to game (municipalities, Sweden); Diseases (universities, Sweden); Combustion technical problems (enterprises, Sweden); Storing of chips (enterprises, Sweden); <i>To be continued</i> Subsidies often needed for profitable production (researchers, Lithuania); Economic efficiency (enterprises, Sweden); Limitations on subsidies only for low-yielding lands (researchers, Lithuania); Subsidies increase converting agricultural lands needed for food production to forest lands (NGOs, Latvia); Ignoring interests of agriculture in a case of intense support (state organisations, Latvia); Unclear regulations (farmers, Poland); Lack of markets for production (farmers, Poland)

Appendix 1.6. Attitude study: Localisation of plantations.

Statement	Stakeholder groups
Poor quality land preferred	NGOs, state organisations (Latvia); biofuel producers and suppliers' organisation, researchers, state organisations (Lithuania); county administration (Sweden)
Good quality land preferred	Bioenergy and landscape architecture organisations (Sweden)
Abandoned, disturbed, marginal land, or land outside agriculture preferred	Municipalities (Latvia); biofuel producers and suppliers' organisation, state organisations (Lithuania); county administration, farmers and local heritage interest organisations (Sweden)
Not in areas with significant nature values	Farmers' association and advisory service, public authorities, researchers, suppliers of planting material; planting, harvesting and general management services, traders and heat and electricity producers (Denmark)
Not in forested areas	ENGO (Lithuania); County administration, universities (Sweden)
Avoiding plantations in cultural landscape	Researchers (Lithuania), bioenergy and landscape architecture organisations, central authorities, county administration, farmers' and local heritage interest organisations, municipalities, nature conservation organisations (Sweden)
Minimising disturbance to or dominance in landscape	ENGO, researchers (Lithuania); bioenergy and landscape architecture organisations, central authorities, county administration, municipalities, universities (Sweden),
Plantations close to consumption	Researchers (Norway); enterprises (Sweden)
Considering nature values	Researchers, state organisations (Lithuania); county administration, farmers' and local heritage interest organisations, nature conservation organisations (Sweden)
Considering cultural values	Researchers (Lithuania); central authorities, county administration, farmers and local heritage interest organisations, nature conservation organisations (Sweden),
Examples for other comments	Considering neighbours (bioenergy and landscape architecture organisations, Sweden); Next to forest (county administration, municipalities, Sweden); Close to water (nature conservation organisations, Sweden); Avoiding areas susceptible to frost (universities, Sweden); In smaller fertile places (bioenergy and landscape architecture organisations, Sweden); On moist soils (bioenergy and landscape architecture organisations, Sweden); In valleys (bioenergy and landscape architecture organisations, Sweden); In monotonous landscape (universities, Sweden); In the areas where the alternative is "hopeless spruce forest" (bioenergy and landscape architecture organisations, Sweden); In areas with low ecological value (state organisations, Lithuania); On traditional field (municipalities, Sweden); Not in national parks and other protected areas (ENGO, Lithuania); Not close to principal drainage pipes (researchers, Lithuania); Not close to river valleys and beaches (researchers, Lithuania); Not on moist and wet areas (nature conservation organisations, Sweden); Not near to valuable open environments (universities, Sweden); Not close to rivers or lakes of a certain size (researchers, Lithuania); Not in northern Sweden (universities, Sweden); Not close to dwellings (farmers' association and advisory service, public authorities, researchers, suppliers of planting material; planting, harvesting and general management services; traders and heat and electricity producers, Denmark); Not in open land (farmers' association and advisory service, public authorities, researchers, suppliers of planting material; planting, harvesting and general management services; traders and heat and electricity producers, Denmark); Not in mosaic landscape with a great amount of forest (universities, Sweden); Not hiding favourable landscapes (municipalities, Latvia); Avoiding planting on scenic routes (farmers' association and advisory service, public authorities, researchers, suppliers of planting material; planting, harvesting and general management services; traders and heat and electricity producers, Denmark); Plantations spread in landscape (nature conservation organisations, Sweden); Diverse localisation (universities, Sweden); Shaping of plantations by landscape experts in recreational areas (universities, Sweden); Localisation so that landscape is affected in most positive direction (universities, Sweden); Localisation considering minimising smell-problems (municipalities, Latvia); Local species and well-managed stands do not make landscape worse (state organisations, Latvia); Avoiding excessive cultivation (biofuel producers and suppliers' organisation, Lithuania); Considering landscape issues before planting (farmers' association and advisory service, public authorities, researchers, suppliers of planting material; planting, harvesting and general management services; traders and heat and electricity producers, Denmark); Antiquarian competence has to be used in placing (farmers and local heritage interest organisations, Sweden)

Appendix 1.7. Attitude study: Shape of plantations.

Statement	Stakeholder groups
Heterogeneous plantations preferred	Farmers' association and advisory service, researchers, suppliers of planting material; planting, harvesting and general management services (Denmark); researchers, state organisations (Lithuania); county administration, farmers' and local heritage organisations, municipalities, nature conservation organisations, universities (Sweden)
Homogenous plantations preferred	State organisations (Lithuania); enterprises (Sweden)
Small plantations preferred	Bioenergy and landscape architecture organisations, county administration, farmers and local heritage interest organisations (Sweden);
Large plantations or certain minimum size preferred	Farmers' association and advisory service, researchers, suppliers of planting material; planting, harvesting and general management services (Denmark); researchers (Lithuania); enterprises (Sweden)
Considering landscape	Farmers' association and advisory service, researchers, suppliers of planting material; planting, harvesting and general management services (Denmark); municipalities (Latvia); biofuel producers and suppliers' organisation, researchers, state organisations (Lithuania); bioenergy and landscape architecture organisations, enterprises, farmers' and local heritage interest organisations, nature conservation organisations, universities, (Sweden)
Considering cultural history	Central authorities, farmers' and local heritage interest organisations, universities (Sweden)
Considering economical efficiency	Farmers' association and advisory service, researchers, suppliers of planting material; planting, harvesting and general management services; traders and heat and electricity producers (Denmark); municipalities, state organisations (Latvia); researchers, state organisations (Lithuania); researchers (Norway); enterprises, universities (Sweden)
Decisions based on mechanical concerns	Traders and heat and electricity producers (Denmark); state organisations (Latvia); researchers (Lithuania); central authorities, farmers' and local heritage interest organisations, universities (Sweden)
Good quality land should be saved for food production	Researchers, state organisations (Sweden)
Cooperation between farmers	Researchers (Lithuania); enterprises (Sweden)
Examples on other comments	Crops attractive to game preferred (nature conservation organisations, Sweden); Species similar to grain in their growing preferred (central authorities, Sweden); Successful varieties should be used (researchers, Lithuania); GMO-free varieties should be used (nature conservation organisations, Sweden); Varieties that do not hybridise with natural species should be used (nature conservation organisations, Sweden); Edge zones should be used (farmers and local heritage interest organisations, Sweden) Respect to landowner initiative (NGOs, Latvia); Total heating value of the end product the main indicator (ENGO, Lithuania); Control substances against insects and diseases not a current issue (universities, Sweden); Avoiding square shaped plantations (biofuel producers and suppliers organisation, Sweden); Plots compact and symmetrical, not scattered (researchers, Lithuania); Only ecological management methods should be used ("ecological farmers" - farmers and local heritage interest organisations, Sweden); Considering the effects of machines to soil structure (farmers' and local heritage interest organisations, Sweden); Forming and management based on life cycle analysis (enterprises, Sweden); Evaluation of all the aspects needed (ENGO, Lithuania); Securing sufficient delivery as a guide (researchers, Norway); More important to encourage to cultivation than to discourage with regulations at this point (state organisations, Lithuania)

Appendix 1.8. Attitude study: Management actions to enhance environmental benefits.

Statement	Stakeholder groups
Use of native varieties	State organisations (Latvia); state organisations (Lithuania); municipalities (Sweden)
Mix of species, or borderline plantations with other species	Researchers (Norway); county administration, universities (Sweden)
Growing with low or no fertilisation, or chemicals	Farmers' association and advisory service, researchers, suppliers of planting material; planting, harvesting and general management services (Denmark)
Using sludge as a fertiliser	Researchers (Lithuania), central authorities, enterprises, municipalities (Sweden)
Localisation in a land which has low nutrient retention capacity	Farmers' association and advisory service, researchers, suppliers of planting material; planting, harvesting and general management services (Denmark)
Examples on the other comments	Localisation near major highways for phytoremediation (researchers, Lithuania); Letting part of the plantation to grow old (universities, Sweden); Handling of ashes (central authorities, Sweden); Localisation in order to enhance water quality (universities, Sweden); Localisation along water systems to reduce leaching (nature conservation organisations, Sweden); Fertilisation adapted to the actual need (municipalities, Sweden); Considering game management (municipalities, Latvia); Localisation on certain environmentally sensitive areas (public authorities, Denmark); Considering habitat establishment (municipalities, Latvia); Management actions supporting not only production should be paid attention to (universities, Sweden)

Appendix 2

Best-practice guidelines for sustainable biomass production in SRF plantations on agricultural land in Nordic-Baltic regions

M. Weih & N-E. Nordh

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1. Preface

Sustainability standards for agricultural energy crop production are today a key issue from an environmental and nature protection viewpoint and are highlighted also internationally [1, 2]. In this project, we focused on aspects of sustainability issues related to SRF on agricultural land particularly in Nordic and Baltic countries, where this kind of agricultural biomass production has a great potential for the future [3, 4].

Plantations of fast-growing trees are economic enterprises in most cases and economic profit arguments (i.e., maximised biomass yield after shortest possible time) usually guide their localization, shape and management in the first place. Therefore, close-to-practice manuals for growers usually contain few or no considerations from an environmental or sustainability point of view. However, localization, shape and management of commercial SRF plantations might partly conflict with the primary interests of nature conservation and landscape design [4, 5]. For example, large monoclonal, block-shaped and very fast growing tree stands that are harvested frequently as a whole are desirable from a purely commercial perspective, whereas many small-sized, irregularly shaped stands consisting of several species and/or clones and harvested in different years would be preferred by nature conservation and landscape design interests [4]. Among all the Nordic-Baltic countries, nature conservation and landscape aspect considerations are mostly recognised in Sweden, where large areas of commercial SRF plantations exist. Most of the other countries have little or no own experience in SRF plantations, and nature conservation and landscape design aspects are of minor interest compared to the economic and practical aspects of SRF plantations, see Chapter 2 of this report.

There is indeed a large body of knowledge available since many years on how SRF plantations should be localized and managed in order to favor environmental and landscape qualities [6, 7, 8], see Chapters 1 and

3 of this report. However, this knowledge is rarely applied in commercial SRF plantations of Nordic and Baltic countries. In addition, lack of correct information, ignorance of best-practice advice and misconceptions often generate negative public attitudes and biased decisions of authorities that are directly or indirectly involved in the formal regulation process regarding these plantations [5].

The best-practice guidelines very briefly summarize the available knowledge on environmental and landscape aspects of SRF plantations on agricultural land in a Nordic-Baltic perspective; see Chapter 1 of this report and [9] for additional information. The guidelines should be seen as a complement to existing manuals for SRF growers [10, 11]. It is our hope that the guidelines will contribute to increase the awareness of environmental and landscape aspects among SRF growers in the Nordic-Baltic region and to facilitate an active dialogue between commercial growers and nature/culture conservation interests in particular regarding those aspects where conflicts of interest exist between the two sides.

Uppsala, December 2007

Martin Weih
Project leader

2. Guidelines

1. Avoid areas with protection status for nature conservation and/or cultural heritage.

Plantations should be avoided close to open habitats of high conservation values such as certain types of wet meadows and buffer zones along streams, because such sites often have a conservation value linked to openness of the habitat (Fig. 1). Particular attention should also be paid to the potential impact of SRF plantations on the conservation of historic, designed landscape and it is important to consider these aspects at the early planning stages of SRF plantations.



Figure 1. Avoid planting SRF along buffer zones close to streams, because the plantations may block the openness of the habitat.

2. Avoid very large SRF plantation sizes – plant several smaller plantations instead.

Intensively managed tree plantations, if not too large in size and if planned creatively, can increase the abundance and diversity of many organisms, particularly in landscapes dominated by either conventional agricultural fields or managed coniferous forests, by increasing structural diversity. The establishment of a large number of smaller plantations will, in particular if harvested in different years, enhance structural diversity and biodiversity.

3. Locate the plantations close to existing native woodlands and/or incorporate 'islands' of native trees within large plantations.

The landscape context (forest or agricultural) along with the land-use type that the plantation replaces and spatial scale aspects (e.g. size or shape of plantation) influence the impact that SRF plantations will have on biodiversity. Thus, the location of SRF plantations within the landscape context exerts a strong influence on their effect on biodiversity: A native wood nearby the tree plantation will facilitate the migration of birds, insects and plants and, thus, increase biodiversity (Fig. 2). Especially if no native woods are present, small groups of native trees can be planted nearby or within the tree plantation. The native woods will serve as retreat area where animals and insects can survive during the periods of clear-cut in the SRF plantation.



Figure 2. *Locate SRF plantations close to native woodlands.*

4. Leave buffer zones without any crop or with native vegetation in the edges of plantations.

A few meters wide stripes along the edges of tree plantations could be left without trees to support the development of a rich native flora and fauna (Fig. 3).



Figure 3. A willow SRF plantation with unplanted buffer zone.

5. Plant several varieties (preferably of different gender) within the same plantation; different varieties may be planted in sections or parallel stripes in order to facilitate harvest actions.

Mixtures of different species or varieties can be established either by planting them in different blocks or stripes across the field or random mixtures within each row. These mixtures increase structural and functional diversity and contribute to reduce the impact of pests and diseases. Especially in tree stands with random variety mixtures, the choice of varieties with similar growth characteristics at a given site is very important to avoid different varieties outcompeting each other and to ensure the long-term sustainability of the stand.

6. Apply chemical weed control only during plantation establishment.

When compared to conventional arable crops, the perennial character of the crops used in SRF plantations commonly leads to reduced herbicide application, because herbicide treatment is required only during the establishment of the crop. As soon as the stand has developed a more or less closed canopy, no further weed control will be needed and no chemical weed control should be applied after the establishment year.

7. Do not apply more nutrient fertilizer than the biomass crops demand during a growing season.

The availability of mineral nutrients (particularly N, P and K) usually is among the most important limiting factors for tree growth in SRF plantations grown in Nordic and Baltic countries. Compared to conventional agricultural crops, the perennial nature of tree plantations generally leads to less nutrient leakage provided that the rate and timing of fertilization is adjusted to the nutrient delivery and nutrient holding capacity of the soil

in relation to the uptake capacity of the tree crop. The nutrient demand of the crop depends on the growth dynamics of the stand, but is high compared to traditional forest trees (e.g. spruce). The addition of mineral nutrients to a plantation should compensate for the amount of nutrients removed by the harvested biomass (i.e., c. 60-80 kg/ha/yr). Especially for environmental reasons, the application of fertilizers should be spread over two or more occasions during one growing season. The choice of fertilizer amount depends on various factors, among them climate and soil conditions as well as planting distance.

Based on the large nutrient quantities taken up by fast-growing trees, SRF plantations can be used as recipients for municipal wastewater and industrial sludge and simultaneous biomass production. A major problem occurs in Nordic-Baltic regions with extended dormant periods during winter, where only very small quantities of nutrients are taken up by the trees. This kind of wastewater treatment can therefore be accomplished only if the wastewater is stored in ponds or lagoons during the winter period [12].

8. Try to plan harvest actions to be performed only during the period of frozen ground.

Afforestation with fast-growing trees on agricultural land has often positive effects on soil properties due to less frequent use of heavy machinery compared to conventional crops, especially when the use of harvesters is restricted to the period of frozen ground in winter-cold regions. For example, carbon sequestration and water holding capacity were found to increase in formerly arable soils that were planted with fast-growing willow and poplar for 6 to 10 years.

9. Harvest parts of plantations in different years.

Particularly in large plantations, different parcels of the stand can be harvested in different years in order to enhance structural diversity and biodiversity (Fig. 4). This might require that different parcels of the stand are also planted in different years.

10. Locate, design and manage SRF plantations in such a way that they maximize variation in landscape.

This general best-practice advice summarizes many of the above points. If used creatively as part of active landscape analysis and design, SRF plantations can greatly improve the visual and recreational values of a landscape. For example, monotonous structures in blocks of tree plantations can be broken up by edge stripes of native herbs and woods, which are flowering and thereby can increase the aesthetic value of the landscape.



Figure 4. Biomass harvests performed in different years may enhance the structural diversity of a SRF stand. A stand with one-year old shoots is seen to the left and three-year old shoots to the right.

3. Further reading

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