The impact of Short Rotation Coppice (SRC) cultivation on the environment

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Introductory of the vTI series on SRC and environmental issues

The following six articles included in this series are describing potential effects and implications of the cultivation of Short Rotation Coppice (SRC) on the environment. The articles deal with the effects of SRC on water issues (Dimitriou et al., 2009), groundwater recharge with a spatial perspective (Busch, 2009), phytodiversity (Baum S. et al., 2009) and animal diversity (Schulz et al., 2009), as well as soil issues (Baum C. et al., 2009). Finally, the paper of Köhn (2009) deals with socioeconomic implications of SRC cultivation. The term SRC has prevailed to be referred to biomass productions systems cultivated for energy purposes using fast-growing tree species with the ability to resprout from the stumps after harvest, which occur in short intervals (i.e. 2 to 6 years). The management practices for SRC (soil preparation, weed control, planting, fertilization, harvest etc) are more similar to those of agricultural annual crops than forestry, although the species currently used in commercial SRC plantations in Europe are tree species such as willows (*Salix sp.*) and poplars (*Populus sp.*), i.e. fast-growing tree species with good coppice ability that produce much biomass even under very short harvest intervals. The reader should distinguish between SRC and Short Rotation Forestry (SRF), which is a broader term describing forest systems for biomass production (for energy purposes but also for others) using fast-growing tree species grown at denser spacing and elevated maintenance than in traditional forestry, typically harvested after 2 to 25 years depending on the desired end-product. We consider therefore that SRC falls within SRF and represents a more specialised and intense practice of SRF dedicated mainly for energy purposes. In the articles included in this series, we explicitly describe the effects of SRC on the environment, referring only in a few parts to effects of single stem trees used in SRF, since their use is currently broader than for SRC (e.g. poplars).

SRC for production of biomass for heat and/or electricity is considered as one of the promising means to contribute to meeting the European targets to increase the amount of renewable energy, and has been identified as the most energy efficient carbon conversion technology to reduce greenhouses gas emissions (Styles and Jones, 2007). Additionally, SRC cultivation in larger scale could help to meet social and economic targets of other EU policies (e.g. EU Rural Development, CAP reform). This combination of technological and political drivers has stimulated the interest in the growing and processing of biomass crops as a source of renewable energy. Different incentives for growing SRC have been introduced in several European countries. Currently, ca. 15 000 ha are being cultivated with willow SRC in Sweden, mostly in productive agricultural land. Smaller areas are cultivated in Italy (ca. 6 000 ha, mostly poplars), Poland (ca. 3 000, mostly willows), UK (c. 3 000 ha, mostly willows), Germany (ca. 1 500 ha, mostly poplars), and other European countries. Although these areas cannot be considered as extensive in comparison to

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other agricultural crops, a rapid increase of SRC in several European countries has been projected already in the short-term. For example, in Sweden the Swedish Board of Agriculture predicts a short-term increase of SRC to 30 000 ha (Jordbruksverket, 2006), the UK Biomass Strategy predicts that perennial energy crops will occupy some 350 000 ha by 2020 (DEFRA, 2007), and in Germany SRC cultivation areas may also increase markedly during next years due to a changing subsidise policy and the identification of high cultivation potentials for certain areas (e.g. 200 000 ha for the federal state of Brandenburg; Murach et al., 2008).

SRC is a perennial crop that differs from arable crops in a number of physical traits, and moreover, is managed quite differently. In particular, it is anticipated that SRC plantations will remain in place for a number of years (10 to 25 years depending on national regulation and market issues), thus taking the land out of arable rotations; harvest normally occurs in winter or early spring; the plants are deeper rooted and generally have a high water consumption compared to conventional crops; SRC is much taller (ca. 5 to 8 m at harvest) than other arable crops. Additionally, once established, SRC requires no annual soil cultivation and considerably less agrochemical inputs. Typically, much less nitrogen fertilizer is applied to SRC compared with arable crops. In fact, the vast majority of Swedish and UK SRC fields currently are not supplied with inorganic fertilizer at all. Minimal or no fungicides or insecticides are applied, although herbicides are needed during the establishment phase. As a result of the lower intensity, and particularly of the lower nitrogen fertilizer applications, SRC has a much lower carbon footprint compared with food or biofuel production from annual arable food crops (Heller et al., 2004).

A rapid large-scale shift from “conventional” agricultural crops to SRC will certainly have positive and negative implications on a range of environmental issues. A concentrated increase of SRC grown on agricultural land is anticipated in areas neighbouring power stations using biomass as a fuel (with approximate radius from power stations of up to 100 km). In such areas, SRC might need to be cultivated on a substantial fraction of all available agricultural land to fulfill biomass needs for fuel in power stations, simultaneously being economically and energy efficient. Where SRC is grown to supply small local heat and/or power stations, plantations will be on a much smaller scale, although they may still be concentrated. This, coupled with the above-mentioned special features of SRC will surely alter the appearance of the landscape and have potential implications for the local water and soil quality, hydrology, carbon storage in soil, and biodiversity. The papers included in this series deal with the potential effect of SRC on all these issues, and speculate on the expected positive or negative impact of SRC cultivation at the micro- (field) and macro- (catchment and larger) scale based on the existing literature. Research results related in the above topics are presented, possible gaps in knowledge and future research aspects are identified, and assumptions for potential impacts of SRC cultivations are drawn.

For example, the paper of Dimitriou et al. (2009) examines the implications of SRC on water balances and water quality. The evapotranspiration (V_{ET}) rates reported in the literature for willow and poplar SRC seem to be somewhat higher than arable crops in most cases, but such values vary noticeably and are related to site-specific factors such as the local conditions in terms of soil type, temperature, groundwater level, the precipitation at the site, the planted species or clones, the age of the crop, and their interactions. Despite this, effects on water balances on catchment level have not been reported or justified. All these should be combined with the reported improved groundwater quality in terms of nutrient leaching when SRC is planted in a certain area. Therefore, if the identified potentially negative impacts would be considered and minimized, the average effect of SRC on water issues could be positive. To succeed in this, the authors suggest that the V_{ET} differences between SRC and arable crops should be better studied, comparing SRC fields grown for several years and respective arable fields in the same areas. Moreover, the relation of V_{ET} with local precipitation and other factors, i.e. root development and groundwater availability, should be closer examined and combined with positive effects of SRC on groundwater leaching compared to other arable crops.

To promote future decision-making processes with respect to the envisaged expansion of SRC on productive but also on marginal soils, the potential local impact of SRC on water needs to be extrapolated in the larger scale. This can be assessed within the framework of existing ecological and spatial planning as a tool for rapid qualitative assessments. Such an effort is conducted by Busch (2009) in his paper included in this series. He assessed the suitability of SRC for two municipalities in the district of Uelzen, Northern Germany, applying GIS analyses and based on the theoretical impact of SRC on groundwater recharge. The author calculates the ecological impact as a function of groundwater recharge for different SRC water use boundaries, but states that better and more precise data concerning SRC water use are needed to assess the ecological impact of SRC on water issues. Such impact assessments and ecological evaluations of landscape functions need to carefully consider site-specific conditions (soil type, climatic parameters etc) as well as existing environmental goals.

For this reason, it is interesting to consider the results of Baum S. et al. (2009) about the impact of SRC on phytodiversity, and the results of Schulz et al. (2009) on animal diversity, both included in this issue. In both papers it is suggested that there are indications about increased biodiversity in SRC in comparison with other arable crops. Protection and increase of biodiversity is a political commitment set by the European Union, and therefore it would be of key importance if biodiversity could be increased within the stand and/or in the surroundings when SRC replaces other crops in agricultural areas intensively managed. Concerning phytodiversity, and despite the lack of long-term studies that would enable better understanding on how SRC affects phytodiversity in time and space, there are indications that it would be increased if SRC is planted in areas dominated by agriculture or coniferous forest. Baum S. et al. (2009) identify also areas where SRC establishment might negatively affect phytodiversity, especially habitats of threatened species such as undisturbed peat land, forest wetlands, or areas adjacent to lakes or rivers. The authors present simple guidelines which favour biodiversity in SRC plantations, but they also underline that there are still a series of open questions to enable the best management of SRC in terms of increasing phytodiversity, which would be obtained if long-term studies can be initiated. Schulz et al. (2009) claim that research studies for animal diversity in SRC has been conducted mostly for birds and ground beetles, and that more research for invertebrates is needed. According to related literature, their diversity, equated with species richness, differs considerably in SRC in comparison to arable fields; whereas bird diversity in SRC is higher than in agricultural cropland, higher diversities of ground beetles have been found in arable fields. However, it has been found that animal diversity depends on a number of factors such as the age of the plantation, the tree species/clone, the plantation size, the habitat structures and the location of the plantation (surroundings and other uses). The authors, besides making recommendations for SRC management that will potentially increase animal biodiversity by encouraging habitat diversity, also point out that more studies in commercial SRC fields should be conducted. They add that the influence of the surrounding landscapes on the diversity of SRC and the influence of SRC on the diversity of the surrounding landscapes need to be considered, reminding as other authors do in this series, the importance of the decision for locating the plantations.

The potential effects of SRC on soil issues are described in detail by Baum C. et al. (2009), illustrating the multiple function that SRC can have when planted in a certain area. For instance, SRC can play a positive role as a carbon sink, therefore contributing to mitigate global warming impacts, mainly due to the annual leaf litter stored in the soil and minimum tillage and other soil management practices compared to other arable crops. The authors report that increased carbon sequestration has been reported to occur when SRC is planted on former arable soils, however, the amounts of carbon stored seem to be governed by the initial soil properties, and therefore approaches for the selection of most promising sites for carbon sequestration must be developed. The nutrient cycling in/from soil planted with SRC can also be advantageous compared to arable crops due to management practices and the leaf litter biomass and rhizodeposits. Furthermore, willows and poplars can be colonized by ectomycorrhizal fungi, in contrast to other arable crops, and consequently positive changes in soil microbial diversity and activity can be achieved in arable soils. Other positive impacts due to the non-tillage management and the high litter supply as the abundance and diversity of the soil fauna are also reported, such as an increased abundance of earthworms and an increased diversity of carabids. Finally, SRC as multi-purpose plantations can be used for phytoremediation of contaminated soils (e.g. extraction of Cd, Zn and other heavy metals, and degradation of organic compounds) when biomass is produced in such sites and improve the soil quality of moderately contaminated arable land. This is also the case on marginal land that can be returned to agricultural production after SRC cultivation for a number of years. The authors conclude that all the positive effects on soil ecology can be maximized with proper site selection and management adjustments, but there should be a balance between such management "modifications" and the sustainable production of biomass from SRC, keeping in mind that SRC is a commercial crop for production of biomass for energy competing high value arable crops.

This balance between maximum environmental benefits and maximum attained biomass production from SRC is a big challenge that all stakeholders involved in SRC cultivation (farmers, decision-makers, researchers, and others) should deal with. Despite all the above-mentioned expected positive environmental impacts of SRC, farmers need to be convinced to cultivate the crop, and this is typically achieved when the economic profit from the cultivation of a new crop such as SRC is equal to or higher than that of other established or conventional crops. Such issues are addressed in the article of Köhn (2009) included in this series. To encourage farmers to grow SRC instead of other crops in order to achieve environmental benefits, decision-makers should be prepared to contribute with direct or indirect incentives to the farmers. For instance, a potential economic compensation to the farmers could be a form of reward for those helping to fulfill national and European environmental goals already set and simultaneously keeping agricultural land into production. A prerequisite for such incentives and decisions, however, is to have scientific evidence concerning the quantification of those environmental benefits after SRC cultivation compared to other crops, and to evaluate the extent of benefits for the society. Such issues concerning the added value of SRC cultivation, when at the same time important environmental goals are achieved, should be one of the drivers for SRC cultivation, besides or in combination with drivers for producing biomass for energy to achieve renewable energy commitments.

References

Baum C, Leinweber P, Weih M, Lamersdorf N, Dimitriou I (2009) Effects of short rotation coppice with willows and poplar on soil ecology. Landbauforschung 59(3):183-196

Baum S, Weih M, Busch G, Kroiher F, Bolte A (2009) The impact of short rotation coppice plantations on phytodiversity. Landbauforschung 59(3):163-170

Busch G (2009) The impact of short rotation coppice cultivation on groundwater recharge : a spatial (planning) perspective. Landbauforschung 59(3):207-222

DEFRA (2007) UK Biomass Strategy [online]. Zu finden in <http://www. defra.gov.uk/Environment/climatechange/uk/energy/renewablefuel/pdf/ukbiomassstrategy-0507.pdf> [zitiert am 06.08.2009]

Dimitriou I, Busch G, Jacobs S, Schmidt-Walter P, Lamersdorf N (2009) A review of the impacts of short rotation coppice cultivation on water issues. Landbauforschung 59(3):197-206

Heller MC, Keoleian GA, Mann MK, Volk TA (2004) Life cycle energy and environmental benefits of generating electricity from willow biomass. Renewable Energy 29(7):1023-1042

Jordbruksverket (2006) Bioenergi : ny energi för jordbruket [online] Zu finden in <http://www.sjv.se/download/18.1d56bbe108ae219d3980001660/ra06_1.pdf [zitiert am 06.08.2009]

Köhn J (2009) Socio economics in SRC : a review on concepts ans stakeholder interests. Landbauforschung 59(3):233-252

Murach D, Murn Y, Hartmann H (2008) Ertragsermittlung und Potenziale von Agrarholz. Forst Holz 6:18-23

Schulz U, Brauner O, Gruß H (2009) Animal diversity on short rotation coppices - a review. Landbauforschung 59(3):171-182

Styles D, Jones M (2007) Energy crops in Ireland : quantifying the potential life-cycle greenhouse gas reductions of energy-crop electricity. Biomass Bioenergy 31(11-12):759-772