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Environmental aspects of short rotation coppices – a literature survey

The renewable energy source wood is particularly for heat production of great importance. To cover the increasing demand for wood, more and more wood is produced in short rotation coppices (SRC). By applying SRC on arable land there is a change from the cultivation of agricultural crops to fast-growing trees. Potential ecological consequences of SRC are shown in an actual literature survey. The survey indicates that the cultivation of fast-growing trees in SRC can lead to a number of positive environmental effects on soil and water conditions as well as biological diversity and enables a sustainable contribution to climate protection.

Keywords
Short rotation coppice, environmental aspects, biodiversity, energy wood production

Abstract
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In 2011, the share of renewable energy sources in final energy consumption in Germany was just over 12 %, at which the largest share was contributed by biomass. Wood has great importance within the heating sector, e. g. in the thermal utilization. As a result of the energy transition this importance will increase in the following years. As the growing demand for wood cannot supply only by additional forest harvesting, wood from short rotation coppice (SRC) is becoming increasingly important as an alternative. Short rotation coppices are agricultural areas where fast-growing trees are grown for wood production. For cultivation in SRC the mainly used tree species are poplar, willow and robinia. On suitable sites these trees provide large biomass yield, have a simple proliferation and achieve a high planting success. Moreover they show rapid juvenile growth and tolerate high stocking densities [2–4].

Potential ecological consequences of an increased cultivation of SRC on the soil and water conditions as well as on biodiversity are summarised below in an actual literature survey. Because in general agricultural land is used for cultivation of fast growing trees, in the present study the SRC will be compared mainly with these agricultural landscapes and in particular with other cultures which can also serve the energy crop production. The in literature described potential pros and cons of SRC on the ecosystem are summarized in **Table 1**.

Impact on biodiversity

To assess the biodiversity in an ecosystem, according to [2], the different parameters like understory vegetation, soil fauna, soil microorganisms, spiders, beetles and avifauna should be considered and the densities of their respective individuals should be determined. In the following there is a precise description of the influence of SRC on these biodiversity parameters as well as on soil and water condition and greenhouse gases.

Among the rows of trees SRC offer potential habitation for speciose understory vegetation. By extensive farming and the abandonment of pesticides after the establishment of the plantation the understory vegetation can develop to a greater extent in comparison to agricultural sites. In willow plantations the understory is more speciose than in poplar plantations due to the smaller shape of the willow leafs more light reaches the soil and is available for vegetation. Speciose understory vegetation delivers a high quantity of seeds which serve the birds and insects with food and thus have a further positive impact on biodiversity. Overall, many studies show that the understory vegetation of SRC has significantly higher species diversity in relation to arable sites. However, these are almost exclusively common and widespread species, such as typical arable weeds.

The soil fauna is affected differently by the cultivation of SRC. Because of the reduced tillage intensity in SRC demanding species can colonize and find a habitat, which heavily used fields don't offer. Earthworms benefit from an extended soil regeneration period and were promoted by the cultivation of SRC. They enhance the bioturbation and optimize the aeration and infiltration of soil.

Spiders are eminently suitable as an indicator group for the evaluation of the biodiversity of habitats since they occur in

Table 1

Environmental aspects of short rotation coppices

	Positive Wirkungen ***Positive effects***	**Negative Wirkungen** ***Negative effects***
Naturschutz und Biologische Vielfalt *Nature protection and biological diversity*	• Artenreiche Begleitvegetation *Speciose understory vegetation [4–10]* • Neue Lebensräume für Webspinnen, Laufkäfer und Vögel *New habitats for spiders, beetles and birds [2; 6; 11–19]* • Geringerer Einsatz von Pflanzenschutz- und Düngemitteln *Reduced use of pesticides and fertilizers [4; 9; 15; 20–22]*	• Anbau von Invasiven *Cultivation of invasive species [2; 23–24]* • Monokulturen *Monocultures [4]* • Inkulturnahme von vorher nicht landwirtschaftlich genutzten Flächen *Cultivation of non-farmland [6; 25–26]* • Grünlandumbruch *Tilling of grasslands [6; 25–27]* • Verlust von Offenlandstrukturen *Loss of open land structures [14; 16; 28]*
Bodenhaushalt *Soil conditions*	• Längere Bodenruhe *Longer soil regeneration period [3; 4; 29]* • Geringere Bodenbearbeitung *Reduced tillage* • Humusanreicherung im Oberboden *Humus accumulation in the topsoil [6; 30–33]* • Intensivierung des Bodenlebens *Intensification of soil life [6; 9; 19; 34; 35]* • Schutz vor Bodenabtrag *Protection against erosion [6; 36–38]* • Bodenlockernde Wirkung *Soil loosening [39]*	
Wasserhaushalt *Water conditions*	• Hochwasserschutz *Flood protection [38]* • Weiniger Stoffausträge über das Sickerwasser *Less loaded seepage [9]*	• Erhöhter Wasserverbrauch *Increased water consumption [2; 21; 31; 38; 40–41]* • Geringere Grundwasserneubildung *Reduced groundwater recharge [9, 21; 36]*
Treibhausgase *Greenhouse gases*	• Geringere N_2O-Emissionen *Decreased N_2O-emissions [42; 43]* • Hohes CO_2-Vermeidungspotenzial *High CO_2 avoidance potential [27; 42]*	

all terrestrial and semi-terrestrial areas in a high number of species and individuals. Due to spiders specific habitat claims, changes in habitats or in intensity of use can be assessed. For spiders, a significant increase in individual density in SRC is detectable. However, with increasing rotation period the number of spider species, which are typical for forest areas, increase also. In addition, spiders with larger body sizes are found, which were characteristic of undisturbed habitats.

Studies on the presence of beetles show that the individual density on agricultural landscapes is tendential higher in contrast to SRC. It is remarkable that more beetles were found in the centre of the SRC. For other species, especially birds, the contrary tendency is observed and the plantation centre is poorer in individuals. A significant decline in beetle species in SRC has not been established, but even here there was a shift to species, which were typical for forest areas, and a loss of species, which prefer a sunny meadow.

With respect to the avifauna it is reported that the cultivation of SRC lead to an increased number of species. Due to the harvest in winter, the reproductive success is significantly higher on SRC than on field locations. Furthermore also the food supply for the birds is improved. A change in the species composition from birds, which prefer open land structures, to those, which were characteristic for hedges and copse, is described. The highest density of species was found in a willow plantation with a rotation period of 2 to 5 years. From an ornithological point of view a cultivation of different varieties and clones with short rotation period as well as a division into subplantations with different rotation times is recommended.

To promote zoo diversity, in principle the cultivation native species and in particular of willows instead of poplars should be preferred. Due to their high growth rates and drought tolerance the cultivation of paulownia or robinia as an alternative is attractive especially for regions with poor nutrient and water supply. From an ecological point of view there are scruple to cultivate these introduced species because of the risk of an uncontrolled spread to other ecosystems and unforeseeable consequences for sensitive biocenosis. That's why these species, especially the very reproductive paulownia, should not be cultivated close to sensitive biotopes. Breeding of sterile varieties could solve the invasion-problems but could not enrich the low biodiversity in such plantations.

Effects on water and soil conditions

With regard to the hydrologic balance the significantly increased water consumption of SRC compared with conventional crops has to be considered. In order to achieve adequate results poplars and willows need an accumulated precipitation of over 600 mm per year. Due to high evaporation rates and deep root systems, SRC on areas with less than 500 mm rainfall p.a. could lead to reduced groundwater recharge. On sites close to sensitive wetland habitats SRC should not be cultivated. However, a positive effect of the reduced amount of seepage water is the reduced risk of leaching of nutrients such as nitrate to groundwater. Therefore, the cultivation of fast-growing trees on nutrient-rich sites with high rainfall and much leachate can lead to an improvement of groundwater quality with regard to the nutrient load. Another positive effect of SRC is the delay of rain water discharge which results in some flood protection. For the use along rivers the waterlogging tolerant willows are more suitable than poplars; also black alder represent a good alternative.

The soil benefits from the longer regeneration period and the input of organic matter, especially if the rotation period is longer. Through intense rooting, high humus content and reduced tillage a stable crumb structure as well as higher soil porosity can be achieved. The topsoil is protected against erosion by wind and water, what is additionally supported by the perennial soil cover. Furthermore, the cultivation of SRC on compressed and heavy soils can contribute to an improvement of soil conditions.

Contribution to climate protection

Regarding to greenhouse gases also the avoidance potential and associated costs should be considered for the cultivation of energy crops. CO_2 emissions are mainly caused by machinery used for soil preparation and harvest as well as fertilization. Since SRC are perennial plants which were harvested only every 3–15 years, less CO_2 is induced by the use of machinery in comparison to annual energy crops such as maize and rapeseed. The greatest effect on CO_2 emissions comes from fertilizer, whereas the use in SRC is significantly lower compared to other energy crops. This results in decreased N_2O emissions, which were directly correlated to the rate of applied nitrogen fertilizer. Overall, by use of woodchips from SRC a CO_2 avoidance potential of more than 12 t CO_2eq./ha with low costs of 50 €/t CO_2eq. can be realised. Other bio energy process chains most result in lower values. For example, CO2 avoidance potential for bio ethanol from wheat is 3 t CO_2eq./ha with costs of 400 €/t CO_2eq.

Conclusions

Short rotation coppices are novel ecosystems. The change from the cultivation of agricultural crops to fast-growing trees can lead to specific changes. Positive aspects from an environmental point of view are creation of new habitats, development of speciose understory vegetation and reduced use of pesticides and fertilizers. More benefits from SRC are the long soil regeneration period, humus accumulation in the topsoil, intensification of soil life and protection against erosion. But the higher water consumption of SRC compared with conventional crops has to be considered. So the cultivation of SRC on areas with low level of rainfall over the year could result in a reduced groundwater recharge. The high CO_2 avoidance potential at low costs from the cultivation of fast growing trees enables a sustainable contribution to climate protection. The cultivation of SRC allows the production of the renewable energy source wood and can have many environmental benefits on soil and water conditions as well as on biodiversity.

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