Impact of short rotation forestry on soil ecological services

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Abstract
Increasing prices for fossil fuels and enhanced efforts to reduce the CO_2 emissions induced a growing demand for renewable energy sources. Within this context woody biomass from short rotation forestry (SRF) on fallow ground or degraded land is an interesting option. Broad application of SRF may significantly influence - positively and negatively - soil ecological issues and services such as nutrient cycling, C-Sequestration, soil erosion, bio-remediation, biodiversity and ground water supply. Soil related results of the NOVALIS project, which aims to investigate a broad range of ecological effects of SRF at several sites in northern Germany since 2006 are presented. Results indicate that water consumption of SRF is relatively high and thus ground water recharge might be significantly reduced. Especially in more continental and dry areas or in year with less rainfall than 600 mm the ground water recharge might turn to zero. It is concluded that landscape specific planning and management strategies have to be applied to minimize water consumption of SRF. However, nutrient cycling especially for N is closed and efficient in SRF.

Key Words
Renewable energy, woody biomass, short rotation forestry, nutrient cycling, ground water recharge.

Introduction
Cultivation of Short Rotation Forestry (SRF) with poplars (Populus sp.) and willows (Salix sp.) for energy production is energy effective and coincides with several environmental objectives (Dimitriou *et al.* 2009a). Since an increase of cultivation of poplar and willow SRC has been projected in Europe, the consequent implications on water and nutrient issues and other ecological aspects like species diversity and landscape ecology have arisen (Dimitriou *et al.* 2009b; Baum *et al.* 2009). The given paper will focus on the aspect of water budgets and nutrient (N) cycling. Results reported were gained from the NOVALIS-project, started in Sept. 2006 and funded by the Deutsche Bundesstiftung Umwelt (DBU; Lamersdorf *et al.* 2008). The project aims to evaluate ecological benefits of SRF and encompasses aspects of soil ecology, silviculture, phyto- and zoodiversity, economy and landscape ecology. Several existing and newly created sites planted with clones of poplar and willows in north-eastern Germany were considered.

Methods
Water budgets for two sites with different climatic background conditions (more oceanic *versus* more continental) and development stages (older poplar *versus* younger willow) are described: 1.) the Georgenhof site, located in the uplands of Northwest-Hesse on weathered sandstone material with mean annual rain fall of 677 mm and a mean temperature fall of 7,8 ^{o}C. Various poplar clones were planted in 1995/96 on a former cropland, which was extended in 1992; 2.) the Cahnsdorf site, located in the Oberspreewald-Lausitz district on relatively poor and sandy periglacial deposit with mean annual rainfall of 563 mm and a mean temperature of 8,6 ^{o}C. Here, various willow clones were newly cultivated in 2007. Water flux simulations (model Hydrus-1D; Simunek *et al.* 1998) were applied for the period of 2006 to 2008 (Georgenhof), whereas 2006 was particular dry and 2007 more warm/moist. For Cahnsdorf a pre-plantation stage with a leave area index (LAI) below 1 was considered separately (2007) and was compared to a later stage of the plantation (2008, management phase, LAI of > 6).

Element budgets are presented for nitrogen (N) and the Georgenhof site. Given values are means of two investigated clones. Whole above ground tree harvesting as well as litter and soil analysis were applied in 2006/07. The buried bag method was applied to determine the internal N-flux in 2008. N_2O-emissions and NO_3 concentrations in the soil solution were only controlled during late autumn 2008. Thus annual flux rates were adjusted to pervious measurements in comparable SRF.

Results

The water budget for the Georgehof site (Figure 1) indicates strong losses of precipitation input by transpiration (50 %), interception (24 %) and evaporation (14 %). Only 10 % of the precipitation input contributes to the groundwater recharge. Mean values of the water budget varied significantly. In more dry years (2006 = 594 mm) almost no seepage output occurred, while in more wet years (2007 = 918 mm) 136 mm were transferred to the groundwater layer.

At the Cahnsdorf site and during the pre-plantation phase (Figure 2), 70 % of the precipitation input was transferred to the seepage output, while during the management phase, when the leave area index was set to 6 (Figure 3), only 40 mm, respectively 6 % of the input was seen in the seepage output. Like for the Georgenhof site the transpiration (52 %) and the interception (24 %) terms were the most prominent pathways for loosing water out of the system.

A positive N-budget with a surplus of 36 to 78 kg/ha/a was calculated for the Georgenhof site (Figure 4). The annual input of atmospheric N (ammonium and nitrate deposition) compensated most of the fixation of N by trees, respectively the output by harvesting the aboveground biomass (wood + bark, exclusive leaves). About 100 kg of N is internally circulating by leaf litter, up to 70 kg/ha/a are released by the net-nitrification process in the upper 30 cm of the soil. Thus the site is well supplied with nitrogen and there is no need for any N-fertilisation so far. According to all available data there is almost no emission of N_2O or loss of nitrate via soil solution.

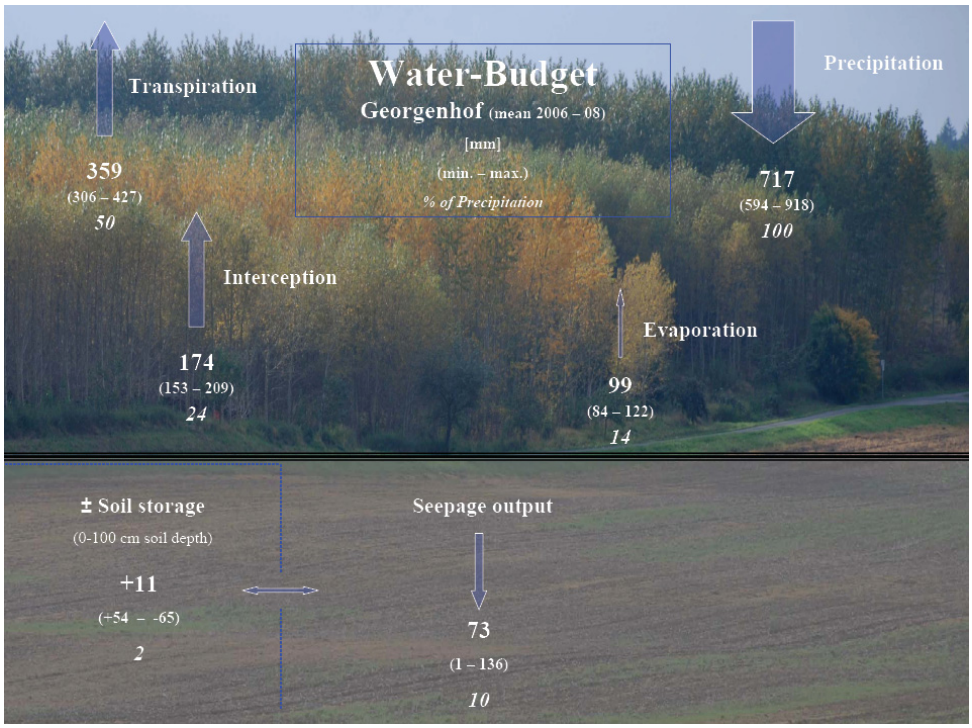

Figure 1. Water budget of the Georgenhof site (mean of 2006 to 2008).

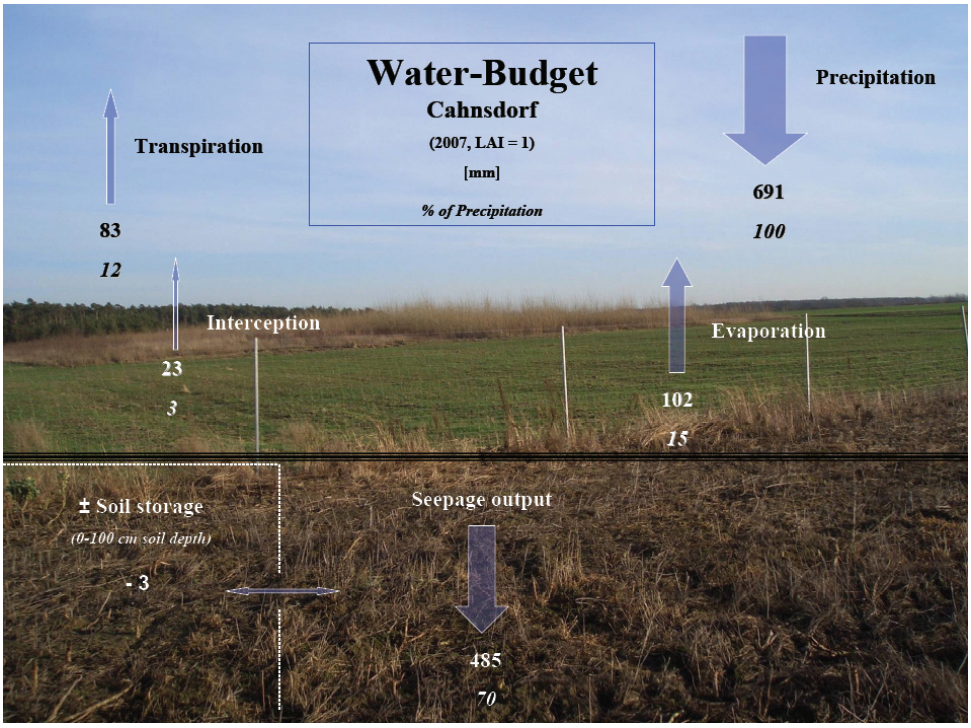

Figure 2. Water budget of the Cahnsdorf site, pre-plantations stage, i.e. the leaf area index (LAI) was set to 1.

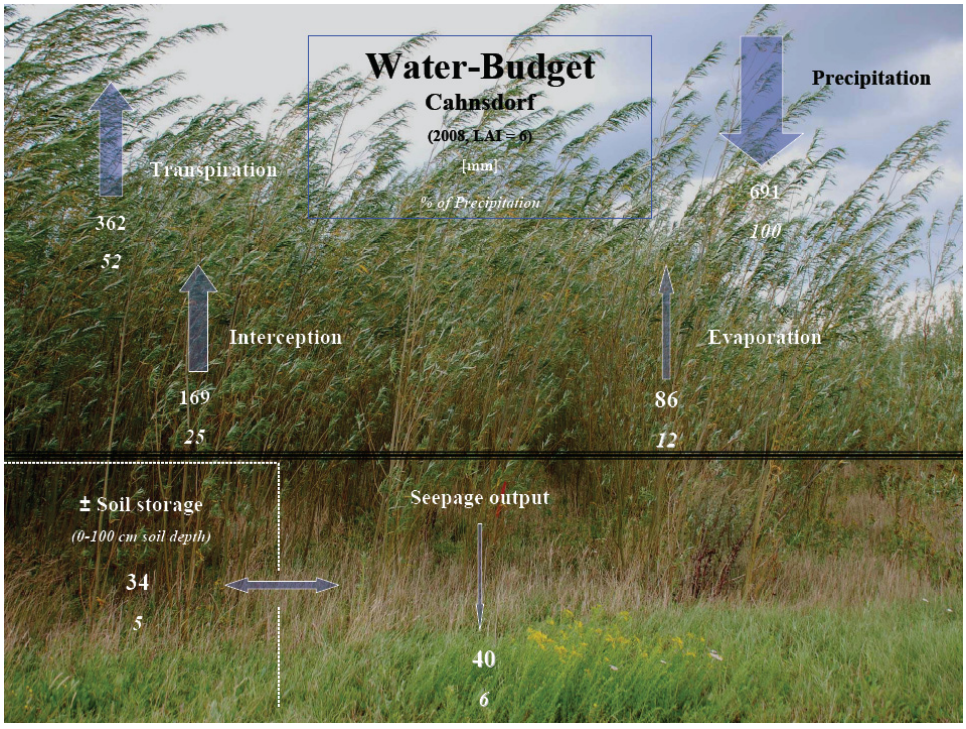

Figure 3. Water budget of the Cahnsdorf site, management phase, i.e. the leaf area index (LAI) was set to 6.

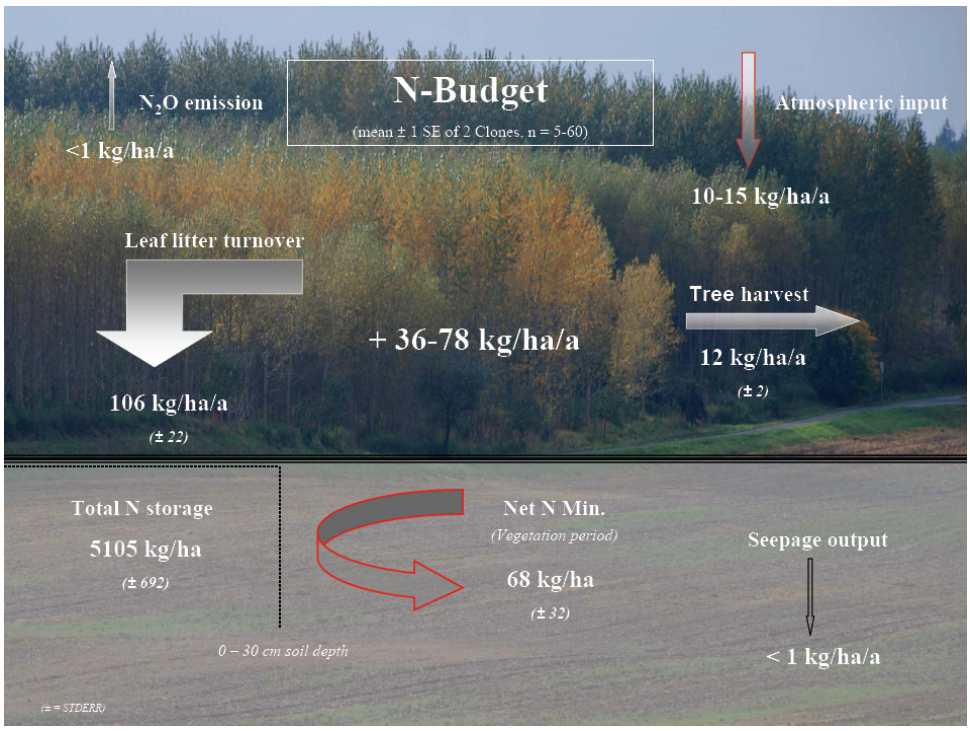

Figure 4. N-budget for the Georgenhof site.

Conclusions

Even under more favourable conditions (Georgehof 2007) the cultivation of SRF led to a significant reduction of the seepage and thus to an impaired ground water recharge. For relative dry years (2006) or more continental site conditions (Cahnsdorf site) results indicate an almost complete loss of seepage under SRF. It is claimed that before SRF will be installed the respective function of ground water recharge should be considered by a specific landscape planning and certain management strategies have to be applied to minimize the water consumption of SRF (e.g., reducing the rotation periods and minimizing edge effects to reduce the interception losses). The applied element budget for the Georgenhof site indicated a closed N cycling. According to all available data additionally mobilised (net-N-mineralisation, atmospheric input) is kept in the system and not transferred to the atmosphere (N_2O) or the ground water layer (NO_3). Furthermore there is obviously no need for any N-fertilisation so far.

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