

Reduced groundwater recharge under SRC

May agroforestry help to lessen the enhanced water consumption?

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Project aims

Short rotation coppices (SRC) with mainly poplar and willow trees provide a high potential of energy supply and enable the substitution of fossil fuels. One negative effect that comes along with the establishment of SRC is a reduced groundwater recharge, as higher rates of transpiration and interception evaporation of poplar and willow plantations can be expected. Therefore it is very important to measure, analyze, and model the effects of SRC-planting on landscape water budgets, which are important aims of the joint research project BEST. To compare different land use types a plot model approach, using the hydrological model system WaSim, was set up to derive the water budget. The plot-level results presented here are a pre-study for the later landscape approach.

Measurement and model results from plot-level

To derive model sensitive parameters like the seasonal development of leaf area index (LAI) and stomata resistance (Rsc) for the land use SRC, measurements were made on the research plots. Furthermore soil hydrological properties are measured to validate the model at plot site. Fig. 1 (a) and (b) shows the interaction between the atmospheric conditions precipitation (Prec.) and vapour pressure deficit (VPD) and the plant-physiological parameters leaf area index (LAI) and stomatal resistance (Rsc). The year 2013 has an annual precipitation of 640 mm (German Weather Service (DWD) station Göttingen) which is similar to the long term mean of 676 mm (period of 1969-2013). The annual course of the LAI (Fig. 1 (b)) was measured with two optical devices (Li-Cor LAI2000 and LI1400). Both methods are based on the extinction of light determined by radiation measurements made above and below the canopy. Even these methods are quite similar differences in LAI up to 2 m²/m² occur, illustrating the difficulties and uncertainties of such measurements. Fig. 1 (b) also shows weekly surface resistance calculated from stomatal resistance of the well-illuminated leaf measured with the SC1 Leaf Porometer (Decagon Devices). This value correlates well with the VPD and the plant available water (PAW) shown in Fig. 1 (d). For high atmospheric demands and sufficient available soil water, Rsc is low.

In August PAW is significantly reduced and Rsc rises despite of high VPD – describing drought stress conditions, which also reduces plant growth (Fig. 1 (c)). The measurements show that the poplar SRC is able to reduce the soil water storage until drought stress occurs. So the assumption of a high water demand of poplar SRC can be confirmed with these observations as well as the link between sufficient water availability for optimal biomass growth. We used the measured plant-physiological parameters for LAI (mean of the two devices) and the minimum of Rsc (i.e. optimal transpiration) together with observations of meteorological and soil-physical properties to model the water budget of the research plot Reiffenhausen using the hydrological model system WaSim. Figure 1 (d) shows the comparison of the integrated value PAW between measurements and model, resulting in a Nash–Sutcliffe model efficiency coefficient is 0.9, which verifies a good model agreement.

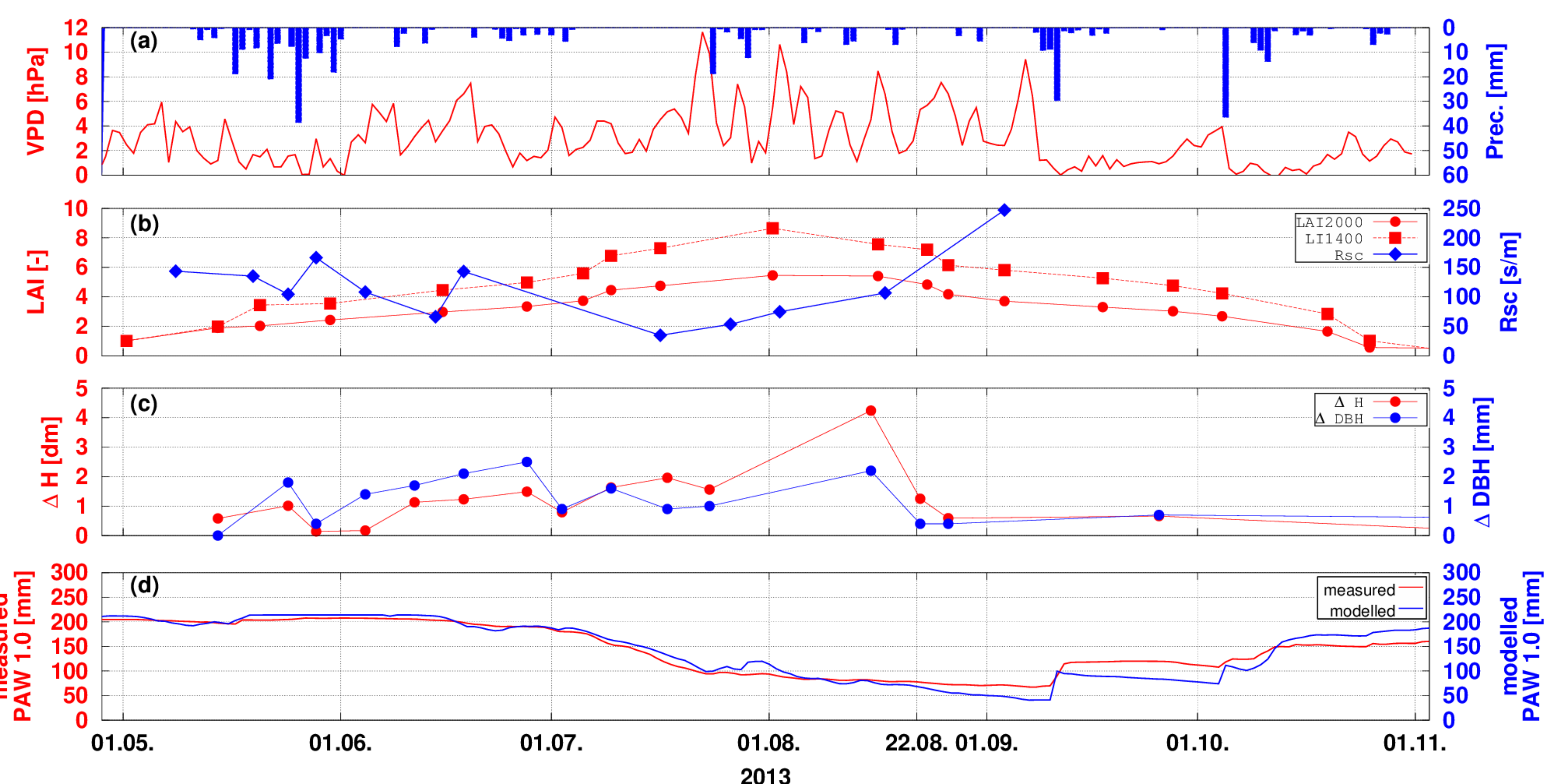


Fig. 1: Time series of atmospheric conditions, plant-physiological parameters, growth, and soil water changes of a Poplar SRC in Reiffenhausen (Lower Saxony) in 2013. (a) vapor pressure deficit (VPD) and precipitation (Prec.); (b) measured leaf area index (LAI) using optical devices LAI2000 (squares) and LI1400 (diamond) and stomatal resistance (Rsc); (c) increment of measured tree height (ΔH) and diameter breast height (ΔDBH); (d) measured and modelled course of plant available water, calculated until 1 m soil depth (PAW1.0).

Long term approach for different land use types

Based on these model-setup long term simulations were performed from 1969 to 2012 comparing three different land uses: (i) agriculture (AC), (ii) extensive grassland (GL) and (iii) poplar SRC. The parameterization for AC and GL were taken from literature, where AC is a mean agricultural summer crop. The climate forcing is taken from the DWD station Göttingen. Figure 2 compares the corresponding annual ground water recharge (GWR) of the research plot, assuming a constant soil and vegetation cover for poplar SRC as well as for AC and GL. Using AC as a reference, the GWR is lowered in average by 35% under poplar SRC, and even by 65% in dry years. Especially in succeeding dry years the GWR is very low or even missing for SRC compared to AC or GL. The increased occurrence of years with very low or even missing GWR under SRC has a negative impact, especially in regions with restricted groundwater availability. Table 1 summarizes the annual mean values of GWR.

Tab. 1: mean annual values of precipitation and ground water recharge.

	mean (1969-2012)	mean (5 driest years)	mean (5 wettest years)
precipitation	676 mm	500 mm	896 mm
GWR agriculture	142 mm	74 mm	235 mm
GWR grass land	116 mm	59 mm	199 mm
GWR poplar SRC	93 mm	33 mm	162 mm

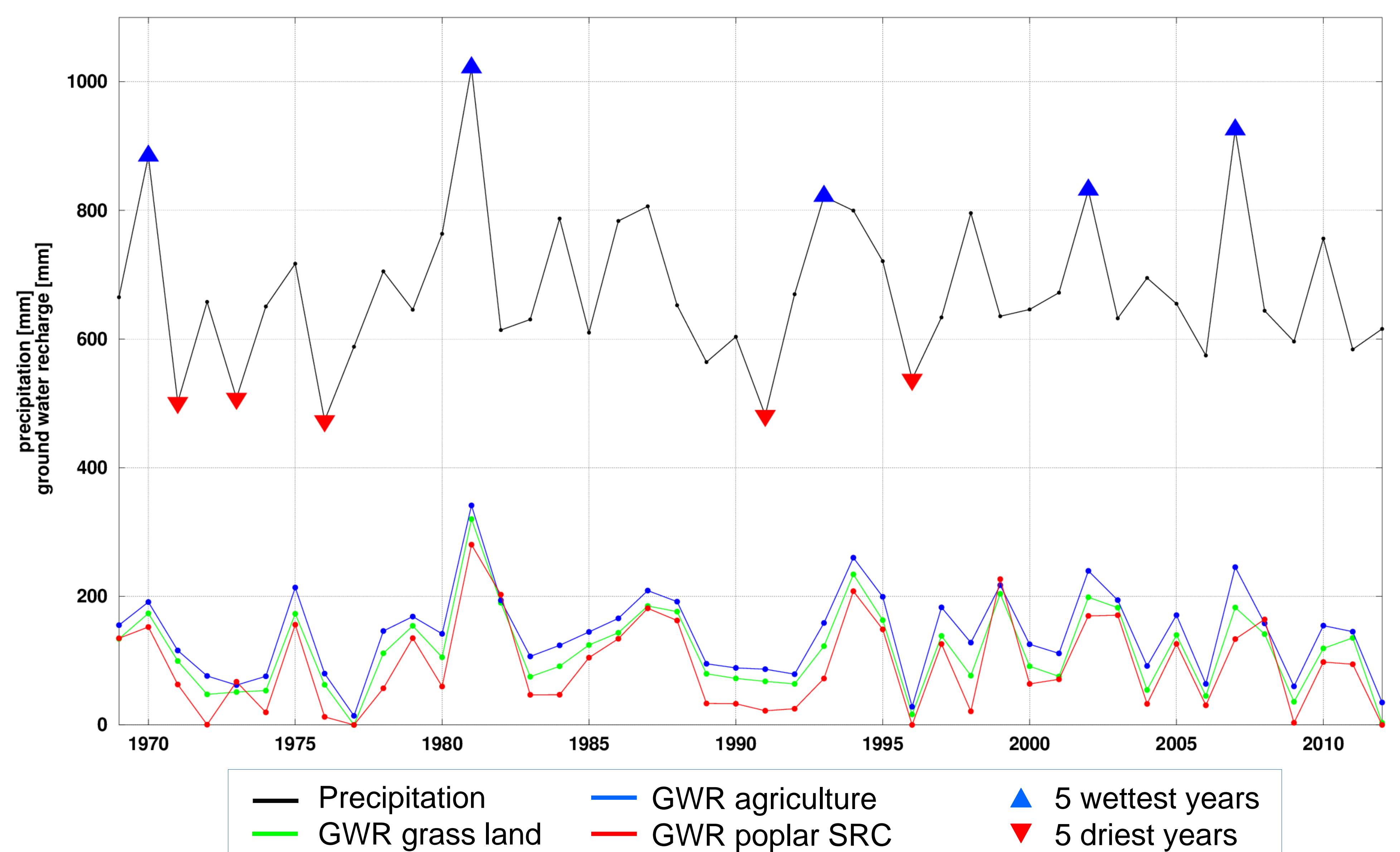


Fig. 2: Annual precipitation and ground water recharge of grass land, agriculture and poplar SRC, research plot Reiffenhausen, Germany. Blue and red marks indicating the 5 wettest and 5 driest years in the period 1969 to 2012, respectively.

Discussion

Agroforestry systems (AF) can be seen as an option to combine the benefits of woody biomass production by SRC and to reduce the negative effect on GWR by adding strips of grassland or other annual crops. However, further investigations and analyses are needed to study the effects of AF on the water budget. Interaction of trees and crops in AF are quite complex due to the differences in model sensitive parameters like leaf area index, transpiration, root distribution, root depth and effects on microclimate. A positive effect of AF alleviating the negative influence of SRC on GWR can be expected. Especially in regions with low water availability AF in an appropriate extend and design can be a tradeoff between biomass production and the protection of water resources.

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