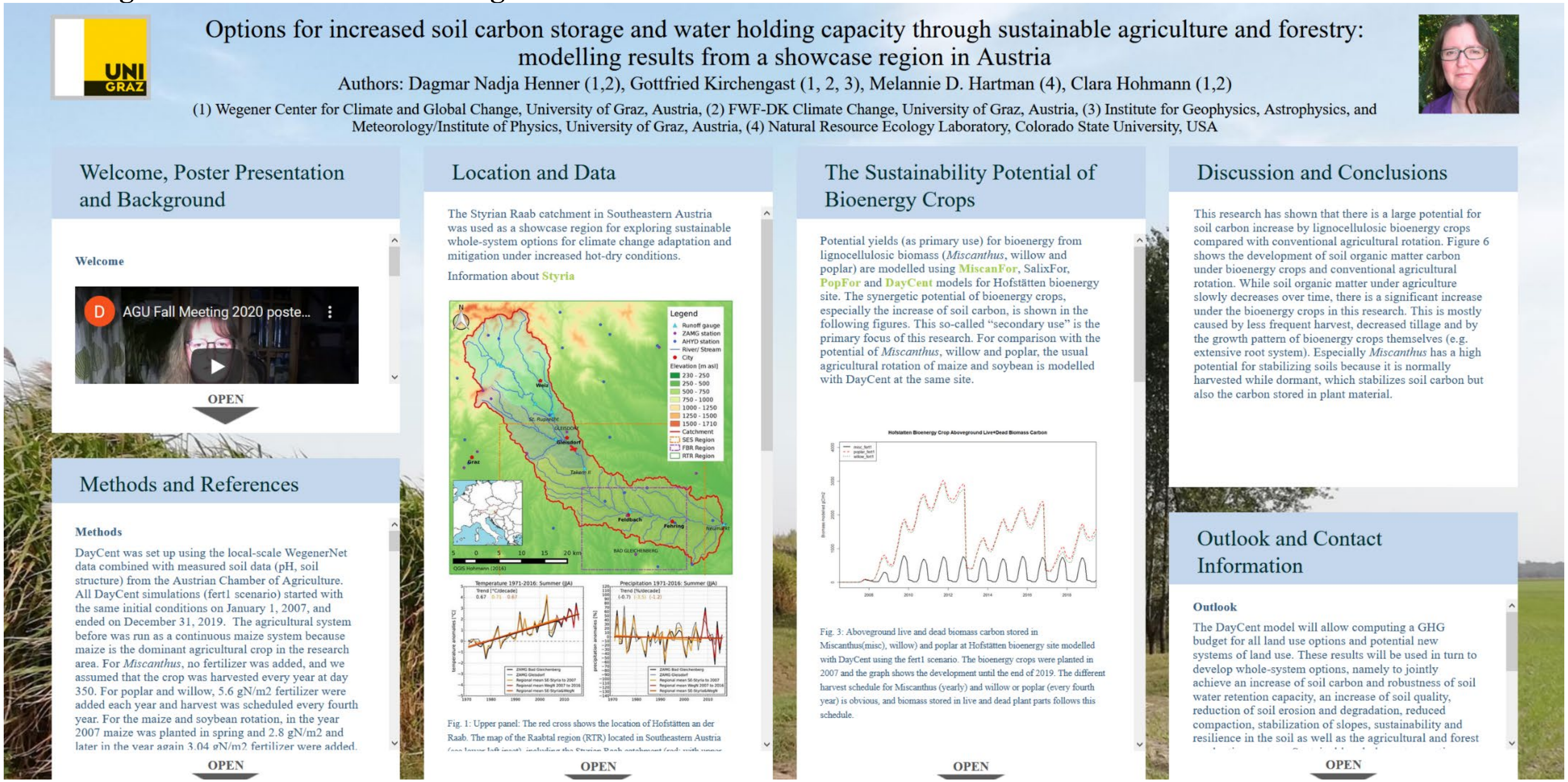
Options for increased soil carbon storage and water holding capacity through sustainable agriculture and forestry: modelling results from a showcase region in Austria



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Welcome, Poster Presentation and Background

Welcome

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Abstract

Sustainable agriculture and forestry is an important topic under climate change. This is a potential route for increasing long-term soil and biomass carbon storage, soil water retention capacity and for reducing water and wind erosion risks. This study uses the Styrian Raab and Enns catchment regions in Southeastern Austria as showcase regions for exploring sustainable whole-system options for climate change adaptation and mitigation under increased hot-dry conditions in agriculture and forestry. Based on dense data of the WegenerNet observing network and further hydrometeorological data, combined with hydrological modelling (WaSiM), the current hydrological disturbance potential in the Southeastern Austria focus regions is assessed. Furthermore, downscaled IPCC climate change scenarios are used for future projections and the results are evaluated for increasing heat and drought risks. This work provides the hydrological context for modelling the soil water and carbon storage enhancement options that farming, forestry and land-use practices might apply. A first key study aspect in this context is the sustainable potential of bioenergy crops. Using the local-scale WegenerNet data combined with Harmonized World Soil Database (HWSD) soil data, potential yields for bioenergy from lignocellulosic biomass (forest and Miscanthus, willow and poplar) is modelled using MiscanFor, SalixFor, PopFor and DAYCENT models for representative local areas in the showcase regions. Using DAYCENT biogeochemical modelling with different agricultural, forest management, and land use practices under climate change, sustainable system options under different future climate change scenarios are developed. These results will be used in turn to develop whole-system options, namely to jointly achieve increase of soil carbon and robustness of soil water retention capacity, increase of soil quality, reduction of soil erosion and degradation, reduced compaction, stabilisation of slopes, sustainability and resilience in the soil as well as the agricultural and forest production system. Sustainable whole-system options for farmers and forest managers are the major study focus and will supply data for local estimates in the chosen representative areas in the showcase regions as well as for upscaling to country level.

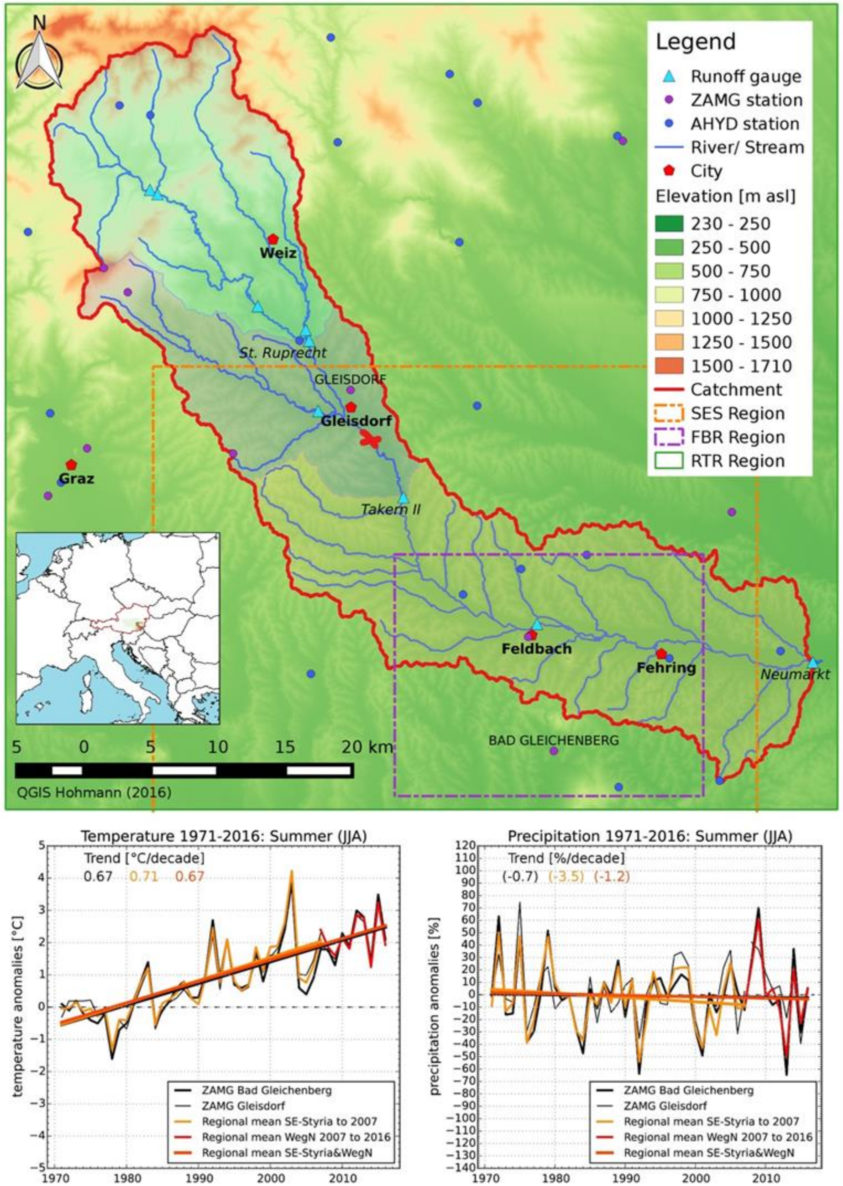
Background

Sustainable agriculture and forestry are important topics under climate change. This is a potential route for increasing long-term soil and biomass carbon storage, soil water retention capacity and for reducing water and wind erosion risks. Bioenergy crops, especially second-generation crops, like *Miscanthus*, willow and poplar, are considered to be a potential option for climate mitigation and for meeting the targets of the Paris Agreement in Europe.

Methods

Methods

DayCent was set up using the local-scale WegenerNet data combined with measured soil data (pH, soil structure) from the Austrian Chamber of Agriculture. All DayCent simulations (fert1 scenario) started with the same initial conditions on January 1, 2007, and ended on December 31, 2019. The agricultural system before was run as a continuous maize system because maize is the dominant agricultural crop in the research area. For *Miscanthus*, no fertilizer was added, and we assumed that the crop was harvested every year at day 350. For poplar and willow, 5.6 gN/m2 fertilizer were added each year and harvest was scheduled every fourth year. For the maize and soybean rotation, in the year 2007 maize was planted in spring and 2.8 gN/m2 and later in the year again 3.04 gN/m2 fertilizer were added. In 2008, maize was grown following the prescribed pattern. In 2009, soybean was planted, and no fertilizer added. This by-yearly pattern was followed until the end of the simulations.



Location and Data

The Styrian Raab catchment in Southeastern Austria was used as a showcase region for exploring sustainable whole-system options for climate change adaptation and mitigation under increased hot-dry conditions.

Information about **Styria**

Fig. 1: Upper panel: The red cross shows the location of Hofstätten an der Raab. The map of the Raabtal region (RTR) located in Southeastern Austria (see lower left inset), including the Styrian Raab catchment (red; with upper, middle, and lower sub-basins in different colors). Digital elevation model topography and other information elements such as station locations are shown as background and complementary information (see legend; Southeastern Styria (SES) and Feldbach region (FBR, WegenerNet) are intensively studied sub-regions; Kabas et al. 2011; Kirchengast et al. 2014). Lower panels: summer (JJA) temperature (left) and precipitation (right) anomaly time series (relative to the 1971–1990 average) and corresponding trends over 1971 to 2016, for different sub-regions and climate-quality stations in the catchment region. (Hohmann et al. 2018)

Bioenergy test site Hofstätten an der Raab

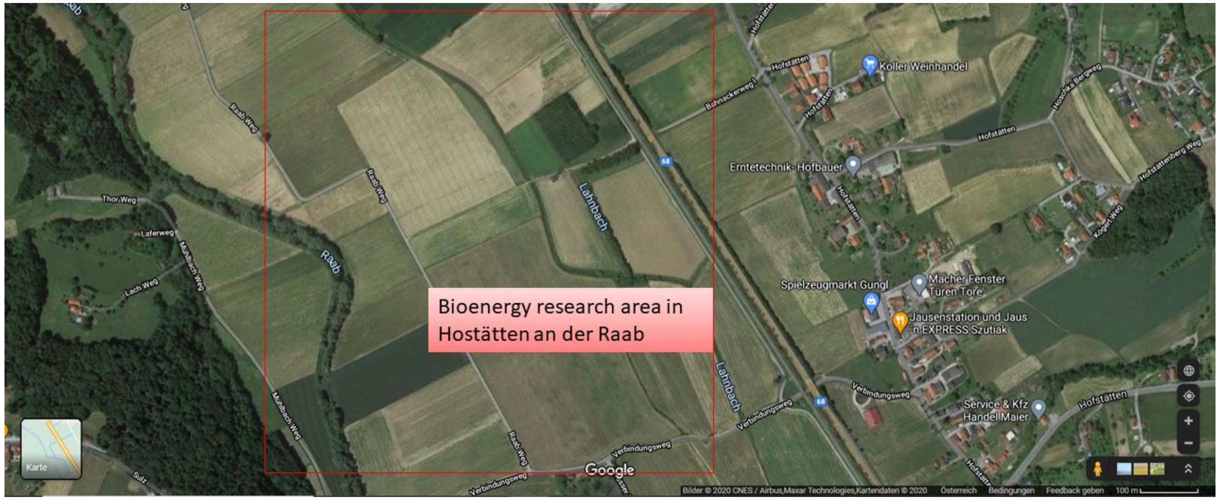


Fig- 2: Hofstätten bioenergy site (Google, CNES/Airbus, Maxar Technologies 2020)

WegenerNet data

Based on dense data of the WegenerNet observing network and further hydrometeorological data, combined with hydrological modelling (**WaSiM**), the current hydrological disturbance potential in the Southeastern Austria focus regions is assessed.

WegenerNet **home**

Wegenernet **data portal**

WegenerNet 3D - **Video** Installing Precipitation Radar FURUNO WR 2120 on ORS mast Stradnerkogel

The Sustainability Potential of Bioenergy Crops

Potential yields (as primary use) for bioenergy from lignocellulosic biomass (*Miscanthus*, willow and poplar) are modelled using **MiscanFor**, SalixFor, **PopFor** and **DayCent** models for Hofstätten bioenergy site. The synergetic potential of bioenergy crops, especially the increase of soil carbon, is shown in the following figures. This so-called "secondary use" is the primary focus of this research. For comparison with the potential of *Miscanthus*, willow and poplar, the usual agricultural rotation of maize and soybean is modelled with DayCent at the same site.

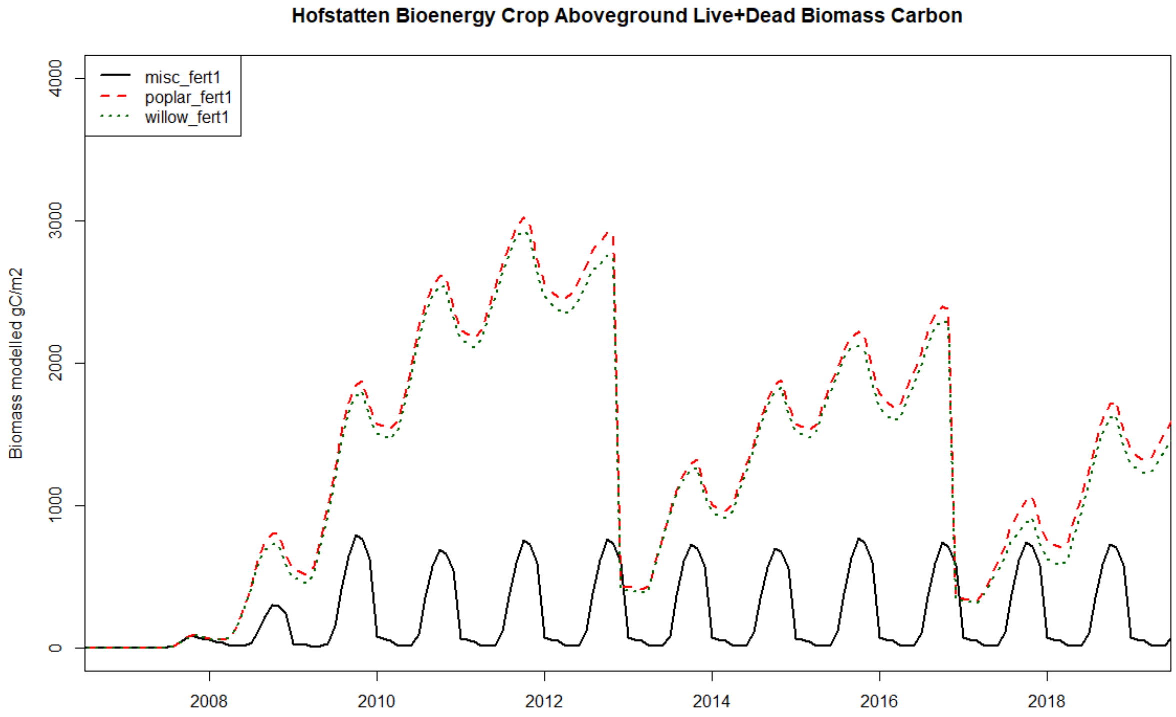


Fig. 3: Aboveground live and dead biomass carbon stored in Miscanthus(misc), willow) and poplar at Hofstätten bioenergy site modelled with DayCent using the fert1 scenario. The bioenergy crops were planted in 2007 and the graph shows the development until the end of 2019. The different harvest schedule for Miscanthus (yearly) and willow or poplar (every fourth year) is obvious, and biomass stored in live and dead plant parts follows this schedule.

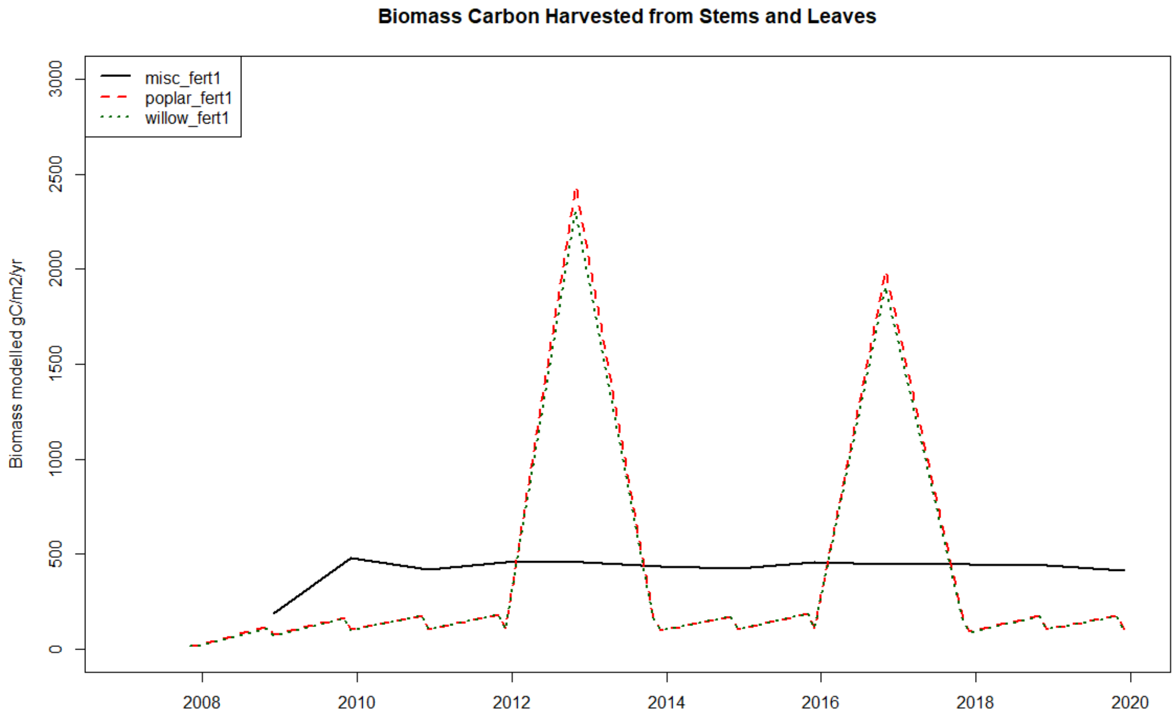


Fig. 4: Biomass carbon from stems and leaves harvested from Miscanthus, willow and poplar at Hofstätten bioenergy site modelled with DayCent using the fert1 scenario over the years 2007-2019. Miscanthus allows for a regular harvest of biomass carbon while willow and poplar harvest events are spiking events.

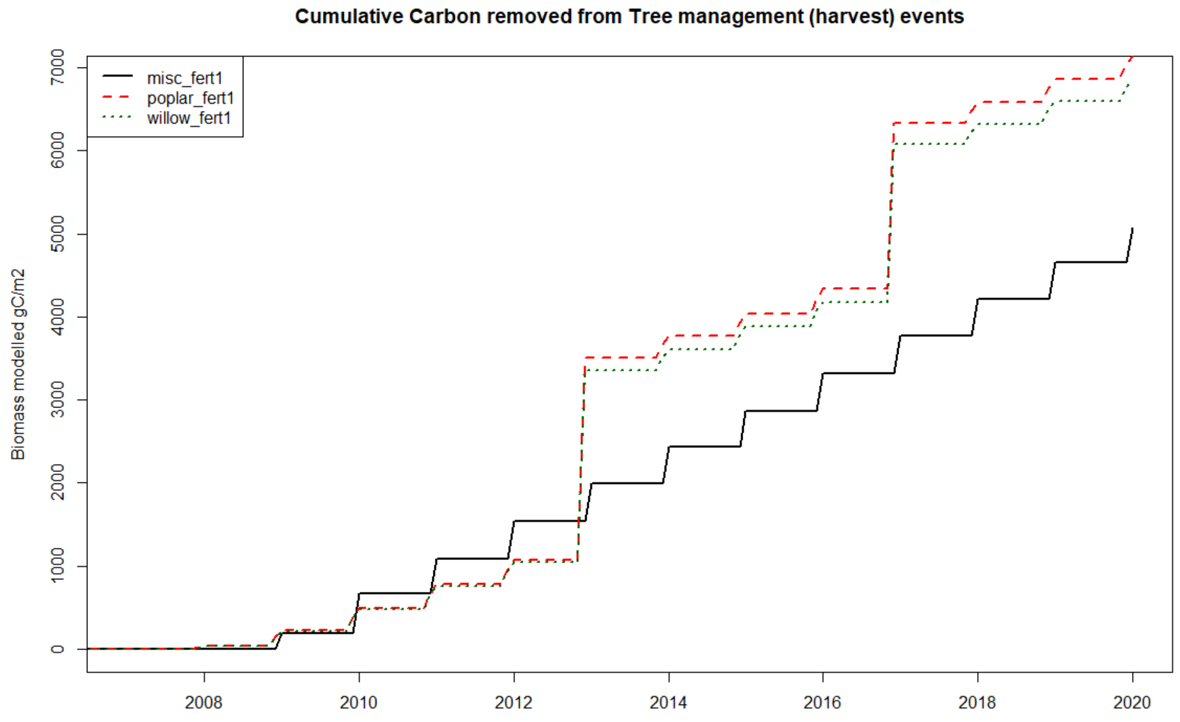


Fig. 5: Cumulative carbon removed during tree management events from Miscanthus, willow and poplar at Hofstätten bioenergy site modelled with DayCent using the fert1 scenario for the years 2007-2019.

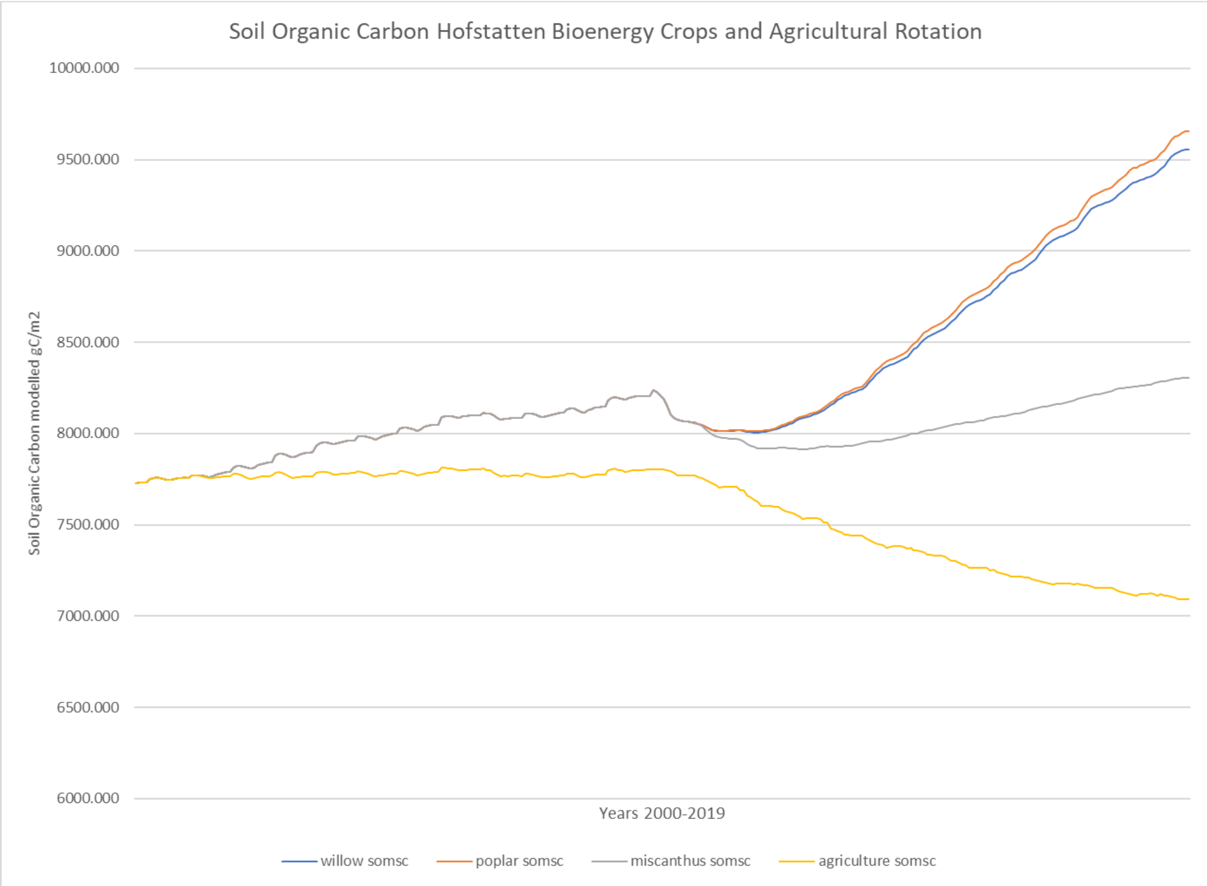


Fig. 6: Soil organic matter carbon (SOMC) stored under Miscanthus, willow and poplar at Hofstätten bioenergy site modelled with DayCent. The bioenergy crops were planted in 2007 and the graph shows the development until the end of 2019. The situation at the beginning of the graph represents the historic agricultural rotation before the establishment of bioenergy crops. SOMC slowly decreases over time in the agricultural rotation and increases with bioenergy crops.

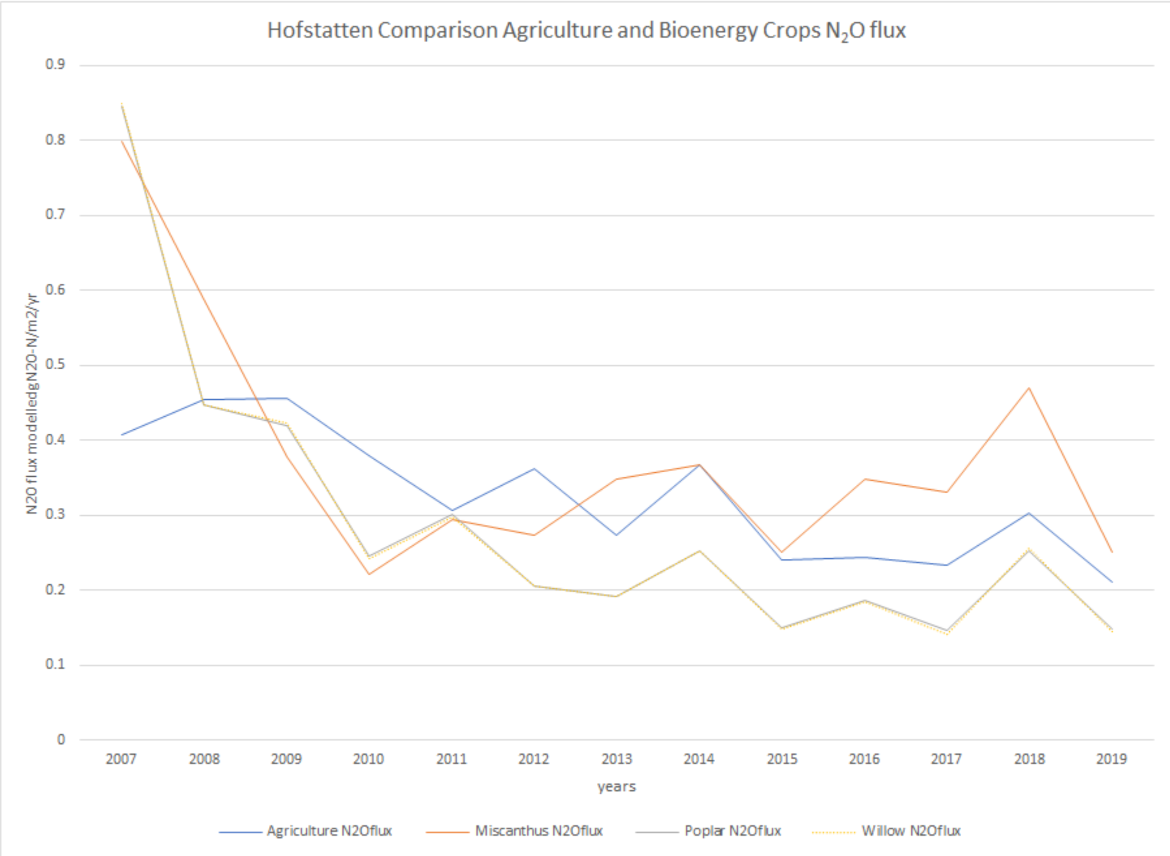


Fig. 7: Comparison of the N_2O fluxes from agricultural crops, Miscanthus, willow and poplar at Hofstätten bioenergy site modelled with DayCent for the years 2007-2019. Agricultural N_2O fluxes are intermediate while fluxes from Miscanthus are sometimes higher. This corresponds with larger rain events (2018). Willow ad poplar stabilizes the N_2O fluxes most effectively which may correspond with the fact that they need larger amounts of water.

Discussion and Conclusions

This research has shown that there is a large potential for soil carbon increase by lignocellulosic bioenergy crops compared with conventional agricultural rotation. Figure 6 shows the development of soil organic matter carbon under bioenergy crops and conventional agricultural rotation. While soil organic matter under agriculture slowly decreases over time, there is a significant increase under the bioenergy crops in this research. This is mostly caused by less frequent harvest, decreased tillage and by the growth pattern of bioenergy crops themselves (e.g. extensive root system). Especially *Miscanthus* has a high potential for stabilizing soils because it is normally harvested while dormant, which stabilizes soil carbon but also the carbon stored in plant material.

Outlook and Contact Information

Outlook

The DayCent model will allow computing a GHG budget for all land use options and potential new systems of land use. These results will be used in turn to develop whole-system options, namely to jointly achieve an increase of soil carbon and robustness of soil water retention capacity, an increase of soil quality, reduction of soil erosion and degradation, reduced compaction, stabilization of slopes, sustainability and resilience in the soil as well as the agricultural and forest production system. Sustainable whole-system options for farmers and forest managers are the major study focus. These will supply data for local estimates in the chosen representative areas in the showcase regions as well as for upscaling to country and European level.

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