Evapotranspiration of rewetted and drained fen soils with grass – long term lysimeter studies

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Abstract

In the context of reducing greenhouse gas (GHG) emissions to combat climate change, rewetting of peatlands is of particular importance. High groundwater levels covering organic matter in the soil prevent its oxidation to CO_2. The amount of water needed to allow the rewetting of peatlands can be determined in lysimeter studies.

The evapotranspiration in fens depends essentially on the groundwater table, the vegetation (transpirational active biomass) and the saturation deficit of the atmosphere. After rewetting, these factors can lead to an evapotranspiration of 1000 $l\ m^{-2}\ a^{-1}$ and even 2000 $l\ m^{-2}\ a^{-1}$ in dry years depending on the vegetation. In a long term experiment over 20 years, the lysimeters planted with *Phragmites australis* showed the highest evapotranspiration rates, followed by those covered with *Carex* species. Evaluation of these results for a large, flooded, rewetted fen area in the Havelländisches Luch in the federal state of Brandenburg, Germany, with *Phragmites* confirmed the high values of evapotranspiration measured at the groundwater lysimeter station of ZALF in Paulinenaue.

Introduction

About 10.9 % of the grassland in Germany is located on peatland (Roeder and Osterburg 2012).

Peatlands provide an important storage for carbon. While intact peatlands are carbon sinks, drained peatands often become CO_2 sources, due to the microbial turnover of the stored organic matter into e.g. CO_2 and CH_4.

In the context of climate change and the attempt to reach the goals of the Kyoto Protokoll, it is essential to reduce GHG emissions.

In North Eastern Germany the majority of peatland is fen (Statista 2012). There are efforts to reduce the water drainage and raise the water table again to limit GHG emissions. The rewetting of fens in combination with the reintroduction of peat-forming vegetation such as *Phragmites australis*, or *Carex spp.* species can reduce GHG emissions, and restart peat forming.

However, the peat-forming plant species need a relatively high water table in order to prevent the displacement of these species by other, more dry-adapted, plants. Furthermore, it is important to keep the water table as high as possible to prevent the aeration and with that, microbial turnover of the remaining organic matter in the soil into CO_2. Additionally, the water table needs to be kept as stable as possible to prevent high turnover and GHG emission peaks (cf. birch effect, see e.g. Jarvis *et al.* 2007)

The evapotranspiration (ET) is the amount of water evaporating from an area covered with vegetation. It can be predicted with lysimeter-setups as a function of in- and effluxes.

Approximately 15 % of the total peatland area in Germany are located in the federal state of Brandenburg (Drösler *et al.* 2013). The federal agency for the environment (LfU Brandenburg) expects an increase of the annual mean temperature and evaporation, while the annual precipitation is estimated to remain unchanged. The mean annual precipitation is 580 $l\ m^{-2}$ for the reference period between 1980 and 2010 (LfU Brandenburg).

Future rewetting efforts to sustainably reduce GHG emissions need to take the increasing water demand into account, since the change of vegetation after rewetting has also an effect on transpiration rates (Dietrich *et al.* 2019)

Methods

The Leibniz Center for Agricultural Landscape Research (ZALF) maintains a research station in Paulinenaue, Brandenburg, Germany, in the heart of a former vast fen area, called “Havelländisches Luch”. Here, 103 groundwater lysimeters containing various different types of soil are in operation. The fen soil lysimeters used for this study were installed as a monolithic, 1.5 m tall soil sample, with a circular surface area of 1 m². The monoliths originate from former fen landscapes from North East Germany and were all classified as eutric histosols. Origins were the Peenehaffmoor (Mecklenburg-West Pomerania), Haveländisches Luch and Rhinluch (both Brandenburg).

In 1997, *Phragmites australis,* was planted on lysimeters 12, 22, 24 and 97, *Carex acutiformes* was planted in 1992 on lysimeters 31, 99 and *Carex distichia* on lysimeter 103. On lysimeters 18 and 34 the naturally occurring vegetation was allowed to grow undisturbed, with *Typha sp.* as a dominant element. For *P. australis* in the lysimeters 12 and 22 the number of stalks was annually reduced to 50, for lysimeter 24 to 100.

The water table can be adjusted for every lysimeter, and is held constant from start of April to end of October. The water supply is provided via a water filled glass containers above the lysimeter, that are passively refilling water, when water has been taken up by plants, or has evaporated. The water influx is measured every day during the vegetation period. Excess water from e.g. rainfall, passes the soil and is collected in another, below-ground container measured daily. The lysimeters described here all were set to a water table at surface level.

Weather data, i.e. air temperature in 2 m, 5 cm above surface, on surface level and 5 cm below surface, as well as, relative humidity, global irradiance, sunshine duration, wind speed and evaporation is measured with a permanent weather station.

Mean annual temperature from 2001-2021 in Paulinenaue was 9.9 °C, with an annual precipitation of 560.1 l m^{-2}. The vegetation period April – October had a mean air temperature of 14.8 °C and 358.2 l m^{-2} of precipitation.

And the end of the vegetation period biomass for each lysimeter was harvested and weighted for the respective fresh and dry mass.

The evapotranspiration is calculated as the difference between the sum of water influx plus precipitation minus the efflux. Since the water table is set to be at surface level, it is assumed that the soil in the monoliths is saturated with water and hence the soil water buffer capacity can be neglected.

Results and Discussion

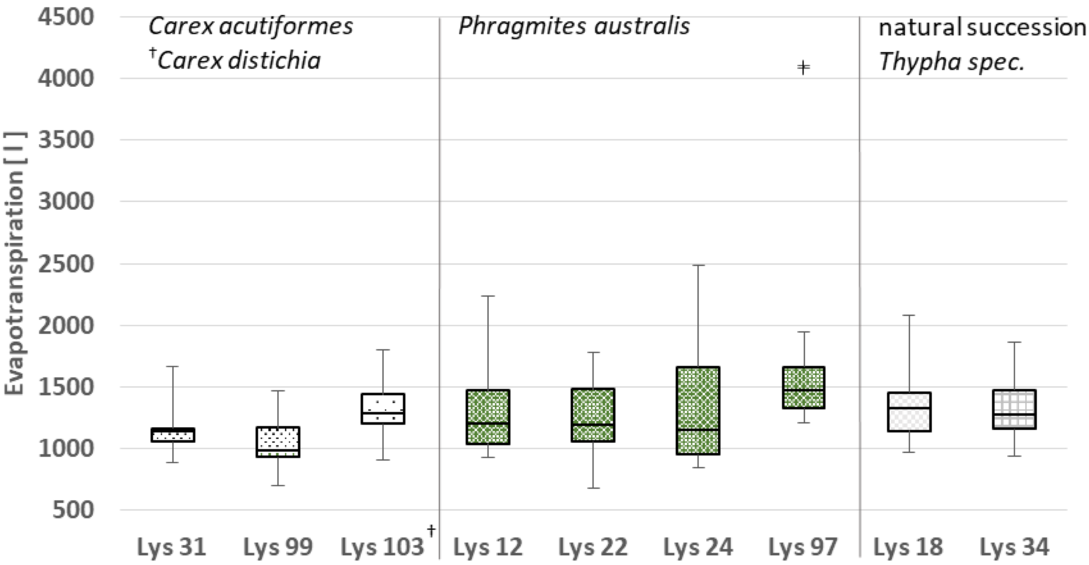

Figure *1* shows the range of ET values in the last 20 years and therefore amounts of water required to keep up the water table at surface level of grasslands on former fen soils. Lysimeters with *P. australis* showed the highest variation of ET. This can be explained by the varying biomass over the years (data not shown), as the transpiration-active biomass is part of the ET. Median ET values ranged from 984 l m^{-2} to 1475.5 l m^{-2}, with extreme values of 682 l m^{-2} and 2489 l m^{-2}. These values might, however be influenced to a certain extend by the effects and factors described by Allen *et al.* (2011), since the lysimeters are, for example, not placed within an area with a similar water table at surface level. Also, although a similarly high vegetation (i.a. *Zea mays*) was planted around the lysemeters every year, neighboring structures and other lysimeters with their vegetation might influence the measurements.

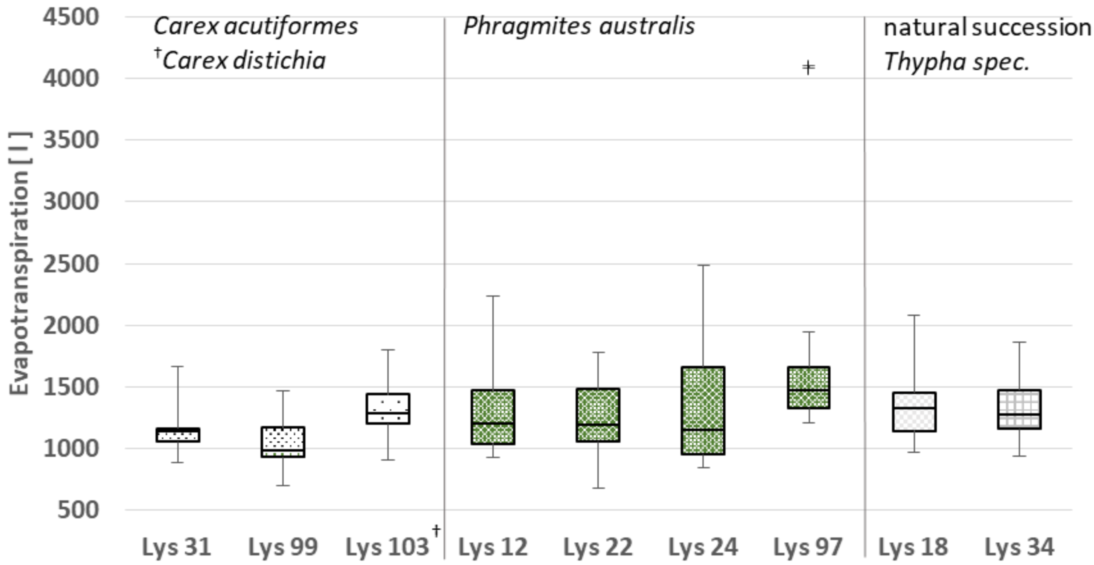

Figure 1: Total ET values during the vegetation period from all considered lysimeters from the year 2001 to 2021. The value of lysimeter 97 with ca. 4000 l was treated as an outlier. Whiskers show highest and lowest values.

The ET shows the tendency to increase over the course of the past 20 years (

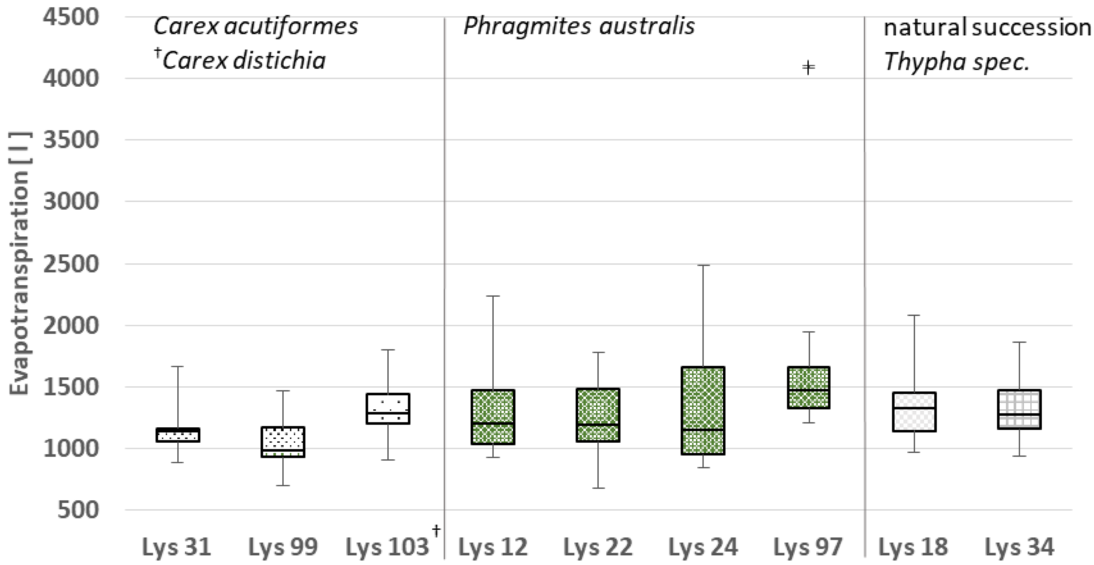

Figure *1*Figure *2*) similar to with the mean annual and vegetation period temperature in Paulinenaue, when comparing the mean air temperatures from the two 30-year timeframes of 1981–2010 and 1991–2021 (own weather station). This is in line with the increasing annual temperatures worldwide (NOAA 2022).

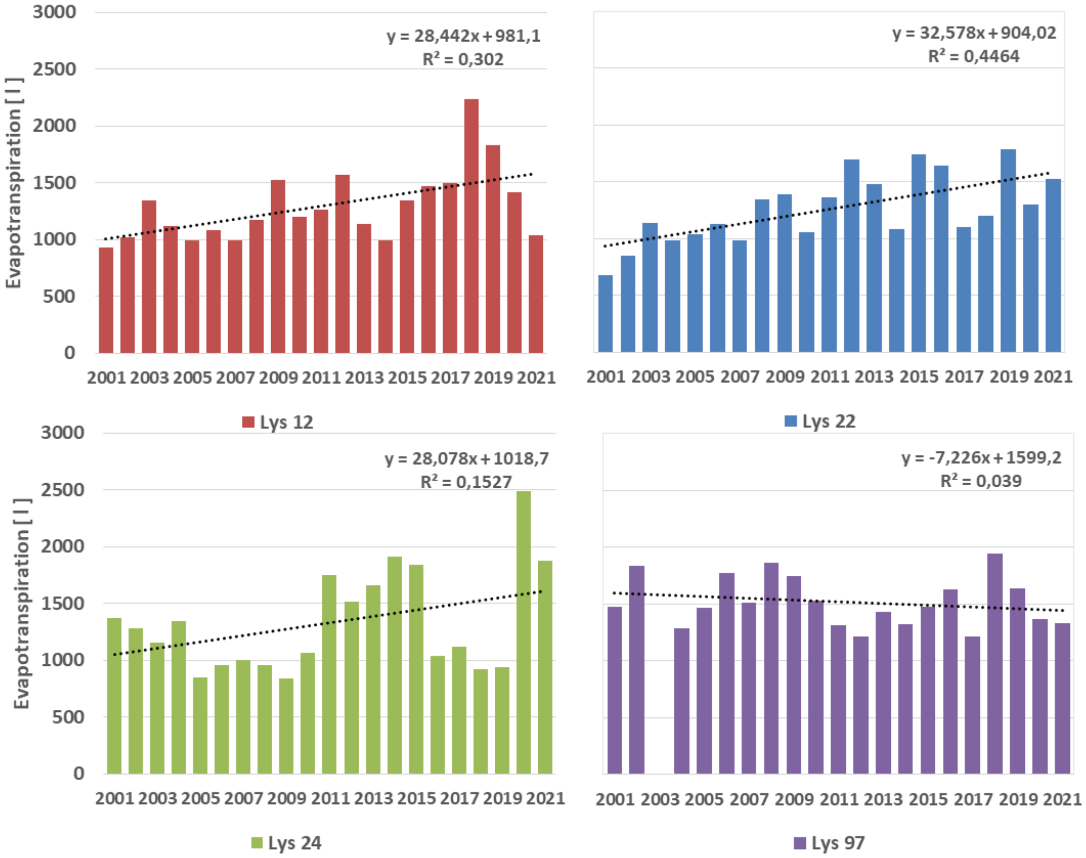

Figure 2: Mean yearly ET in liters (dotted line = trend) during the vegetation periods exemplarily for *Phragmites autrali*s lysimeters over a 20 year period. Increasing trends were found for all other lysimeters.

Conclusions and/or Implications

Although the ET depends on biomass and setup of the lysimeter installation, the measured values provide valuable insights on the water demand in relation to the vegetation, given a constant water table over the vegetation period. This allows to estimate the efficiency of a rewetting procedure, especially when considering the negative effect on GHG emissions after water table fluctuations (cf. birch effect).

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