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Editorial: Disturbance, resilience, and restoration of wetlands

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Editorial on the Research Topic
Disturbance, resilience and restoration of wetlands

Wetlands, including peatlands, marshes, swamps, and coastal wetlands, contain more than 30% of terrestrial soil carbon on only 8% of the Earth's land surface (Mitsch and Gosselink, 2007). Due to their specific biodiversity and ecosystem function, and linking terrestrial and aquatic systems, wetlands are key players in the most important ecosystem services, especially water regulation, nutrient retention, and carbon cycling. The accumulation of peat in wetlands not only results in high carbon stocks in these systems but also provides invaluable archives of past wetland biomes and regional environmental conditions (Yu et al., 2010). However, in recent decades, the area of wetlands is decreasing due to land use change and the residual wetlands are prone to degradation globally (Davidson et al., 2018). The remaining wetland area is also sensitive to global climatic change and faces many natural and anthropogenic disturbances, such as drainage, global warming, fire, biological invasions, degradation, land use change, pollution impact, etc. (Battisti et al., 2016). However, the lack of clear definitions and limited data for the entire range of existing wetland ecosystems poses challenges to assessing ecosystem functions and biodiversity and thus limits our understanding of mitigating the numerous impacts. Thus, the purpose of this Research Topic is to bring together the latest research on wetland ecology and disturbance ecology to better understand wetland resilience, spanning over the entire range of possible wetland systems and allowing for an isolated view of individual systems.

Due to the high amount of carbon stored in wetlands, the ongoing degradation of wetlands causes an increased release of carbon into the atmosphere and further promotes global warming. In this Research Topic, Apori et al. present a scientometric analysis based on 522 documents to assess the status and the global trends of degraded peatlands and restoration research. Considering many countries have degraded more than half of their original peatland coverage for agriculture and energy use or peat harvest, the major aim of peatland restoration is to decrease greenhouse gas emissions and enhance biodiversity conservation. Great Britain and Germany are very active countries on this topic. Based on 12 sites in Zoige alpine wetlands with different degrees of degradation, Yang et al. found that the rate of carbon sequestration increased by 25.70% from natural wetlands to slightly degraded conditions. However, from slightly degraded wetlands to severely degraded wetlands, carbon accumulation sharply decreased by 81.67%. Returning systems to near-natural states will thus help to preserve their carbon sink function. Wetland degradation significantly reduced soil water content, soil organic carbon, microbial biomass carbon, and microbial biomass nitrogen, which were hypothesized as potential reasons that explain the decrease of carbon sequestration.

Climate, one of the direct driving factors of vegetation development, is expected to play a critical role in the spatiotemporal patterns of wetland vegetation communities and resulting carbon storage, especially in recent years under global warming. In this Research Topic, Yan focuses on revealing the association between climate factors and net primary productivity (NPP) of freshwater marsh wetlands in Sanjiang Plain, which is the largest freshwater marsh wetland distribution region in China. In the last 60 years, solar radiation had the largest explanatory power on the spatial distribution of NPP before 1985, and the temperature was the most important climate factor after 1985. Another study from Zong et al. aims to predict the distribution of suitable habitat areas for the *Deyeuxia angustifolia* community in the Tumen River Basin under the current and future BCC-CSM1-1 models combined with the MaxEnt model. They found that the areas of the high-fitness region are approximately 2,268.40 km^2 (10.03%) and that these areas are decreasing under both RCP2.6 and RCP8.5 scenarios and the center of the habitat will move to the eastern region of the Tumen River Basin.

Water-logged anoxic conditions are the most important factors that promote and sustain carbon accumulation in wetlands. Correspondingly, changes in the hydrological processes and dynamics under climate change and human activities have been attracting attention to these studies globally. In this Research Topic, Liu Y. et al. highlight the importance of hydrodynamic characteristics on the stability and self-maintenance of the inland saline-alkali wetland. The results show that water resources act as the major factor that affects the dynamic characteristics of the wetland surface water and groundwater. The observed differences in submerged areas of the studied wetland between the wet and dry seasons amounted to a total of 250 km^2. There are four papers that focus on evaluating the effects of the hydrological processes on delta wetlands in the Yellow River Delta, China. Wang X. et al. evaluate the effects of hydrological connectivity blocking on *Suaeda Salsa* development, and they found moderate burial was beneficial for seedling emergence; moderate salinity (10–20 g. kg^{-1}) and fluctuating water levels (0–10 cm water depth) were the most suitable conditions for seed germination and vegetation growth. The changes in hydrological gradients also caused differences in soil iron contents across different vegetation communities. Liu X. et al. found higher iron content in the *Spartina alterniflora* community in the upper intertidal zone and the *Phragmites australis* community in the lower intertidal zone. Sun et al. report that the soil quality decreased from inland areas to the coastline and from reclaimed wetlands to tidal flats along with the change in vegetation type. High hydrological connectivity and diverse micro-habitats in the tidal creek section of the river estuary was a driver of the structures of the bacterial communities in different habits. Wang Z. et al. found that the bacterial community diversities, as well as the dominant bacteria *Flavobacteriia* and *d-Proteobacteria* but in reverse to *Bacteroidetes* and *Gemmatimonadetes,* significantly decreased with distance away from tidal creeks.

With climate change and increasing human impact, more nutrients accumulate in wetland soils, which may increase carbon decomposition yet promote vegetation growth, thus altering the carbon turnover of wetlands. There are four studies that focus on evaluating changes in available nutrients in wetland soils and their effects on wetland vegetation growth or soil properties. Li, Zhang et al. evaluate changes in C/N/P stoichiometry and water use efficiency of *Messerschmidia sibirica* and the soil in the Yellow River Delta. They found that water use efficiency had a positive correlation with the leaf C and N content and a negative correlation with the leaf C/N ratio, which indicates that *M. sibirica* can compensate for the decline in N use efficiency through the improvement of water use efficiency. Li, Yuan et al. evaluate the short- (3 years) and long-term (10 years) effects of N and P fertilization on the physicochemical properties of peat and water in a bog-fen complex in northern China. They found that short-term fertilization increased *Sphagnum* moss cover, while the expansion of vascular plants was found owing to continuing long-term fertilization. However, the changes in carbon input and decomposition process constrained the variation in the soil C concentrations when the cumulative amount of external N and P increased. Changes in hydrogeochemical processes also control the salinity of water in specific saline-alkali wetlands. Cui et al. thus analyze the spatial distribution characteristics of water hydrochemistry and salinity in an inland saline-alkali wetland in northeast China. The results show that the water in the studied wetland is at a risk of salinization owing to a high rate of evaporation while the solutes in the water are primarily derived from aquifer leaching. Wetlands can also remove phosphorus from sewage, and constructed wetlands are widely used for water purification. Zhang J. et al. analyzed experimental data reported in 27 papers to evaluate the nitrogen and phosphorus removal characteristics of vegetated steel slag substrate-constructed wetlands. Combining steel slag with other substrate materials in constructed wetlands significantly increased the removal amount of total nitrogen and ammonium nitrogen but reduced the removal amount of total phosphorus. Moreover, changes in physicochemical parameters (e.g., temperature and pH) significantly affected the N and P removal capacity.

The increasing regional human activities not only cause changes in the hydrological dynamics and nutrient budgets but also cause direct effects on wetlands, such as reclaiming, burning, species invasion, and heavy metal pollution. In this Research Topic, Wei et al. aim to reveal the response of nutrient stoichiometry in helophyte species *Glyceria spiculosa* under agricultural intervention. They report the highest increase in plant leaf N/P ratio in nutrient-rich wetlands followed by that in drained and cultivated wetlands, but the N/P ratio in root and root hair showed no significant changes under different agricultural interventions. Gao et al. focus on evaluating the litter decomposition of *Calamagrostis angustifolia* and the loss of key elements from litters in burned wetland sites. They found that autumn burning promotes more mass loss and accelerates the decomposition of plant litter, whereas spring burning decreases the decomposition rates of plant litter. The N/P ratios in residual plant litter indicated that N acted as the limiting element for plant litter decomposition in *C. angustifolia* wetlands, and the limitation increased with increasing decomposition time. Jiang et al. focus on evaluating heavy metal pollution in lake sediments in Xingkai Lake and Xiaoxingkai Lake in hydrologically connected periods and disconnected periods in 2021. They found that the overall

contamination level and potential ecological risk of heavy metals in these two lakes were low but relatively higher in the small lake than those in the large lake based on the geo-accumulation index and potential ecological risk index, mainly driven by agricultural activities. Yuan et al. also focus on heavy metal pollution in a lake, and *in-situ* and high-resolution information on metals at the sediment-water interface under ice cover in Chagan Lake was obtained. The results show that the concentrations of Pb and As in Chagan Lake were a little higher even under the ice than in other freshwater rivers and lakes, and the diffusive fluxes showed that the sediments indeed acted as a sink for Pb and Cd, while Cu, Zn, Mn, and As were released from sediments into the overlying water.

Wetland restoration became a major task and mitigation measure to maintain or restore the ecological functions of wetlands in recent years. Therefore, developing a simple and effective strategy for wetland restoration has become an urgent global concern for ecologists. In this Research Topic, Zhang M. et al. focus on restoring salinized wetlands and evaluating the effects of Melatonin Priming on *Suaeda corniculata* seed germination, antioxidant defense, and reserve mobilization. They found the priming of *S. corniculata* seeds with 50 mM melatonin significantly improved the germination index, superoxide dismutase, and peroxidase activity. However, the stress tolerance ability of *S. corniculata* seeds was reduced by high melatonin concentrations. Kowal et al. evaluate the water clarity and submersed aquatic vegetation cover after the exclusion of invasive common carp from the Delta Marsh in Manitoba. They found that the exclusion of large carp from the delta wetland resulted in increased water clarity, higher submersed aquatic vegetation cover, and species richness. Besides large carp, the delta wetland was also threatened by other stressors (e.g., increasing nutrient loading, stabilized water levels, and invasive hybrid cattail), which will also necessitate an ongoing assessment of wetland conditions.

In summary, the Research Topic widely discusses the response of wetlands to both natural and anthropogenic disturbances. We recognize there were few contributions that evaluated the resilience of wetlands under disturbances. We thus want to encourage more research related to this topic and hope that this compilation of articles will stimulate further work and help researchers and government managers understand the response of wetland ecological functions to climate change and human activities.

Author contributions

CG wrote the first draft of the manuscript, which was edited by all co-authors and approved. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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