CLIMATE CHANGE AND WETLANDS

Study investigates dynamics of greenhouse gas emissions from wetland systems

A project funded by the Water Research Commission (WRC) investigated the dynamics of greenhouse gas emissions from wetland ecosystems. Article by Sue Matthews.

Althea Grundling

Tshifhiwa Malise records plant species in a sampling plot in the Waterkloofspruit peatland system at Kgaswane Mountain Reserve.

In June 1992, South Africa joined more than 150 other countries in signing the United Nations Framework Convention on Climate Change (UNFCCC), and subsequently ratified it in August 1997. The following year, the country's first national greenhouse gas (GHG) inventory was prepared, using 1990 data. Since then, the inventory has been revised and updated eight times, with the most recent version – reflecting data for 2022 and trends since 2000 – submitted to the UNFCCC Secretariat in December 2024.

At the same time, South Africa's First Biennial Transparency Report was submitted in accordance with the Paris Agreement, which aims to keep the global average temperature rise this century as close as possible to 1.5°C above pre-industrial levels. Apart from including a summary of the GHG inventory, the report covers South Africa's efforts over a two-year period from January 2021 to implement its Nationally Determined Contribution (NDC) – the climate action plan outlining the country's mitigation and adaptation contributions – as well as financial, technical and capacity matters.

In the latest inventory, considerably more attention is given to wetlands as a source of GHG emissions in the form of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). However, there is no distinction between coastal and inland wetlands, and all were assumed to be on mineral soils, because the area of organic soils is relatively small. This allowed emissions to be determined using the methodology for inland wetland mineral soils provided in the 2013 Wetland Supplement published by the

Intergovernmental Panel on Climate Change (IPCC). Since that does not include a method for estimating N_2O emissions from wetlands themselves, the inventory deals only with N_2O from nitrogen mineralisation or immobilisation associated with loss or gain of soil organic matter, as well as N_2O from biomass burning.

More importantly, the inventory uses the default CH_4 emission factor provided in the IPCC supplement for inland wetland mineral soils in temperate regions, derived from 20 studies primarily carried out in the northern hemisphere. The emission factor is three times higher than the country-specific one used in the previous inventory, for 2020. Admittedly, that was based on a 2012 study that measured methane emissions in only two southern Drakensberg wetlands a kilometre apart on a weekly basis over the early summer of 2010. Use of the IPCC's emission factor is the main reason why wetlands as a source of GHG emissions, expressed as gigagrams of carbon dioxide equivalents (Gg CO_2e), increased in South Africa's inventory submissions from 1 193 in 2020 to 9 678 in 2022.

In the IPCC's Sixth Assessment Report, the Working Group 1: Physical Science Basis noted that there is robust evidence and medium agreement that freshwater wetlands are the single largest global natural source of CH_4 in the atmosphere, accounting for about 26% of the total CH_4 source. There are still large uncertainties in emission estimates and how wetland GHG fluxes will respond to climate change, though, due to spatial and temporal variability in inundated land area, air temperature and microbial activity. While warmer temperatures may stimulate microbial activity, fluctuations in soil moisture caused by precipitation, evapotranspiration, permafrost melt and human-induced impacts on flooding or drying of wetlands also play a role. This is because methanogenesis – the production of methane by certain microorganisms during the decomposition of organic matter – is a strictly anaerobic process, taking place in the absence of oxygen. Inundation or saturation of soil creates such anaerobic conditions, hence increasing methane emissions from a wetland area, while drying aerates the soil and favours bacterial decomposition processes that release CO_2. Of course, CO_2 is also released through the respiration of wetland biota and taken up by photosynthetic biota, adding to the complexity of estimating GHG fluxes for the world's wetlands.

In an effort to increase understanding of such flux dynamics locally, the WRC funded a research project led by Dr Mokhele Moeletsi from the Soil, Climate and Water unit of the Agricultural Research Council's Natural Resources and Engineering division (ARC-NRE). The research team also included members representing the North West Parks & Tourism Board, and the Applied Behavioural Ecology and Ecosystem Research Unit at the University of South Africa. PhD student Mr Tlotlisang Nkhase was responsible for the main component of the project, in which CO_2, CH_4 and N_2O emissions were measured at two wetland study areas, one in the Colbyn Valley Nature Reserve in Pretoria and the other just over 100 km eastward in Kgaswane Mountain Reserve near Rustenburg. Both wetlands are also peatlands, a type of wetland in which partially decomposed plant material accumulates as organic matter called peat.

The research team first identified four different zones in both study areas – the terrestrial zone and the temporary, seasonal and permanent wetland zones – according to the wetland hydrology and extent of saturation. Soil sampling was then conducted in each zone for physicochemical and bulk density analyses. Since GHG sampling would rely on the chamber method, four soil collars were pre-installed 30 m apart in each zone before the start of the growing season. This ensured that soil disturbance would be minimised during placement of the chamber, which was made from a transparent acrylic tube.

Initially the GHG sampling focused on CO_2, with data collected at two- to three-week intervals from June 2022 to May 2023. This entailed enclosing vegetation within the chamber for five to 15 minutes at a time, depending on the season, and measuring the concentration of CO_2 at 21 second intervals with a respiration meter. Additional CO_2 readings were taken after covering the chamber to exclude light, thereby preventing photosynthesis. This allowed for calculation of net ecosystem exchange (NEE) – essentially, CO_2 uptake through photosynthesis minus CO_2 release through ecosystem respiration. A negative NEE indicates that the ecosystem is a CO_2 sink, while a positive NEE indicates that it is a CO_2 source. The results showed that both wetlands are sinks when considered over all seasons, although there are periods during the year when certain zones act as sources because more CO_2 is being released through respiration than absorbed through photosynthesis.

Similar chambers were then deployed for CH_4 and N_2O sampling, using separate trace gas analysers that measure at one-second intervals, and with the chamber closure period being 25 minutes for CH_4 measurements and 45 minutes for N_2O measurements. Data was collected at two- to three-week intervals from June

Google Earth

The Colbyn Valley wetland, located in the heart of Pretoria, is surrounded by urban development.

The Waterkloofspruit peatland system lies in the Kgaswane Mountain Reserve, near Rustenburg in North West Province.

2023 to January 2024. The results showed that the permanent wetland zones of both the Kgaswane and Colbyn wetlands were CH_4 sources all year round, while the terrestrial zones were CH_4 sinks. The temporary and seasonal zones revealed more variation, as can be expected in response to seasonal climatic conditions and flooding. In the case of N_2O, all zones at both wetlands had fluctuating fluxes with very low emissions and no clear pattern.

The research team recognise the limitations of chamber measurements, which also have the disadvantage of requiring extensive time in the field.

"Fluxes change drastically diurnally, and since it is not feasible to have continuous chamber measurements, this is a major constraint for the evolution of fluxes," they note in the final report. "Instantaneous measurements can be misleading since changes in the weather can influence GHG fluxes."

They therefore investigated a machine learning approach to estimate NEE, using Artificial Neural Networks and Random Forest. Of the dataset collected for the permanent and seasonal wetland zones, 80% was used to train the model and the remainder for testing it. The inputs were photosynthetically active radiation (PAR), soil temperature, day length, air temperature and water level, and all were found to have a good correlation with NEE. A prototype of a web-based program, linked to the ARC climate database, was also developed so that the model can be used with weather station data to estimate NEE on a real-time basis. The research team recommended, however, that the two study sites be equipped with automatic weather stations, given that GHG fluxes are highly influenced by rainfall and temperature. The rainfall and temperature data used in the study were from weather stations 5 km and 20 km away from the Colbyn and Kgaswane wetlands, respectively.

"It is further recommended that static chamber measurements be complemented by an eddy covariance system for completeness," they added. Eddy covariance (EC) systems are instrumentation towers equipped with gas analysers and sonic anemometers to measure the vertical exchange of gases, water vapour and heat between the ecosystem and atmosphere. "The data from the two systems could be correlated and erroneous data could be patched to provide a complete overview of GHG fluxes within the wetland system."

Another aim of the research project was to estimate the distribution of sequestered carbon in a wetland ecosystem. It is widely reported that wetlands cover 6–9% of the Earth's land surface but store about a third of global terrestrial carbon. Of the various wetland types, peatlands are particularly impressive in this regard, having the highest carbon storage capacity per unit area of all terrestrial ecosystems. Indeed, it is said that they cover only 3% of land but contain more carbon than the world's entire forest biomass!

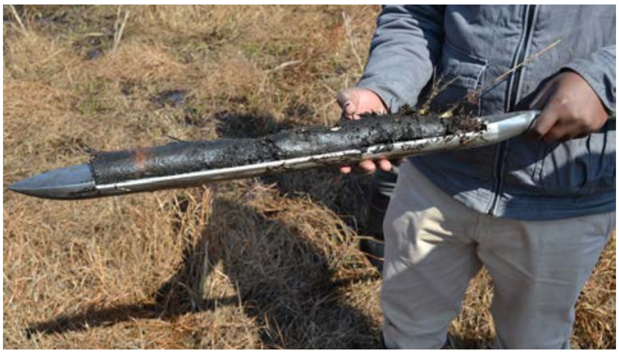
The Waterkloofspruit peatland system in the Kgaswane Mountain Reserve was therefore selected for a study on the relationship between vegetation, soil organic carbon and water levels, since it is the slow decomposition of plant matter under waterlogged, oxygen-poor conditions that accounts for the high carbon storage capacity of peatlands. This component of the project was the responsibility of master's student Ms Tshifhiwa

Althea Grundling

Key members of the research team included (from left to right) Jason le Roux, Tshifhiwa Malise, Tlotlisang Nkhase, Dr Mokhele Moeletsi and Prof Leslie Brown, as well as Althea Grundling, who took the photograph.

The research team identifies wetland zones at the Waterkloofspruit peatland system. (Photo by Althea Grundling)

Althea Grundling



Peat is extracted from the Wterkloofspruit peatland system using a peat auger.

Project team

Boardwalks were constructed to minimise disturbance of the wetland ecosystem during greenhouse gas sampling.

Malise, who was supervised by Prof Leslie Brown (UNISA) and Dr Althea Grundling (ARC-NRE). Ms Malise is a longtime employee of the North-West Parks and Tourism Board, the management authority for the Kgaswane Mountain Reserve.

Over the summer of 2022/23, a vegetation classification and mapping exercise was undertaken by plotting out quadrats of homogeneous vegetation within the various delineated units of the wetland. In a total of 53 plots, 107 plant species from 30 different families were recorded. Five plant communities with the following dominant species were identified: ***Verbena bonariensis*** (forb) – ***Imperata cylindrica*** (grass) along the channel wetland, ***Cyperus esculentus*** (sedge) – ***Pteridium aquilinum*** (bracken fern) on the seepage areas, ***Leersia hexandra*** (grass) – ***Bolboschoenus maritimus*** (sedge) at the valley bottom adjacent to central basin reeds, ***Hyparrhenia dregeana*** (grass) – ***Miscanthus junceus*** (grass) in the channel wetland and ***Thelypteris palustris*** (forb) – ***Phragmites australis*** (reed) in the unchanneled valley bottom.

Next, the focus shifted to soil organic carbon and water levels. Soil sampling, soil descriptions and water level measurements were done for each of the 53 plots during both the wet season in April 2023 and the dry season in August 2023. The results showed that soil organic carbon varied within the five plant communities, with higher values recorded where the water table is nearer to the surface and smaller fluctuations across the wet and dry seasons. While the soil organic carbon values ranged from 2–30% depending on the soil form, the water levels did not vary considerably between the wet and dry seasons, indicating a relatively stable system.

"Through the establishment of baseline data on the vegetation and distribution of soil carbon, subsequent monitoring will allow for the assessment of ecosystem health and effects of environmental changes," note the research team. "By monitoring changes in vegetation and carbon stocks over time, management authorities can identify areas at risk and implement appropriate management strategies to maintain or enhance carbon storage capacity."

Of course, quite apart from their carbon storage capacity, wetlands have a vital role in mitigation and adaptation to climate change impacts through the various other ecosystem services they provide. These include water retention and flow regulation that enhance water security during droughts and reduce the risks of flooding, water purification through filtration, as well as habitat provision that supports biodiversity and sustains human livelihoods.

Although South Africa's first NDC, updated and submitted to the UNFCCC in September 2021, does not specifically mention wetlands, the Biennial Transparency Report of December 2024 lists wetland protection and habitat restoration among South Africa's adaptation actions, and includes some existing efforts to rehabilitate wetlands, such as invasive alien plant removal projects.

The research team suggest, however, that a collective mindshift is needed if wetlands are to be given the protection they deserve.

"Practices and behaviours deeply rooted in people, communities and cultures must be changed to ensure sustainable use of wetlands," they conclude. "The information obtained from this study will provide a better understanding of wetland functioning and composition to enable scientifically sound management of these endangered ecosystems in the reserves as well as in similar systems elsewhere in the region."

Related report, ***Measurement of greenhouse gas emissions from wetland ecosystems*** (**WRC report no. 3168/1/24**) authored by ME Moeletsi ME, T Nkhase, T Malise, JP le Roux, AT Grundling, LR Brown, T Seloane and SM Mazibuko.