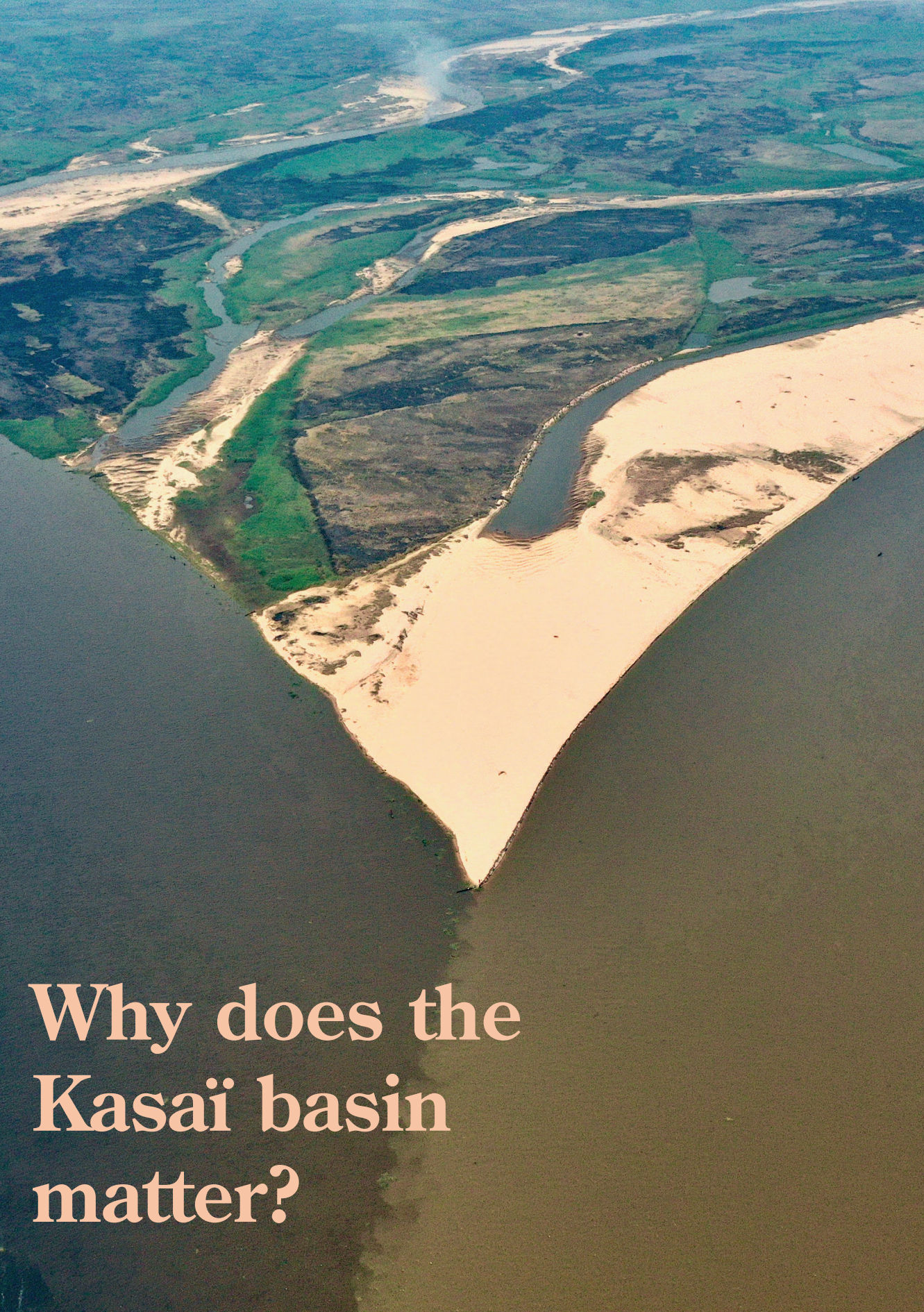




Why does the
Kasai basin
matter?

Why does the Kasai basin matter?

TropSEDs is a Swiss National Science Foundation (SNSF) funded project looking at soil erosion dynamics in the Kasai River Basin (DR Congo).

The project is led by an international research team based at ETH Zurich (Sustainable Agroecosystems group & Surface Earth Evolution group), Switzerland and UCLouvain (Earth and Life Institute), Belgium.



After sampling the Congo River from Lisala to Kisangani in 2009, I dreamed of a next expedition along the Kasai River to see the influence on the Congo River outlet by the Savannah region drained by the Kasai River. After more than a decade, this dream became reality due to efforts by many people and the trust of SNSF to fund this risky but very rewarding science.

Johan Six, Professor of Sustainable
Agroecosystems, ETH Zurich





Severe surface erosion led to deep channels in this maize field in Nkwadi, Mbuji-Mayi region. January 2023.

The Research

The Congo River Basin, located in Central Africa, is home to the world's second largest tropical forest after the Amazon. While both river basins are globally relevant due to their pivotal role in biogeochemical cycling, they present distinct climatic, ecological and socio-economic environments.

The Congo Basin is experiencing fast population growth, which exerts high pressure on its current ecosystems. For instance, the clearing and conversion of land for farming and charcoal production is accelerating. This conversion for farming results in higher soil erosion, which affects the overall soil health and leads to massive carbon and nutrient losses. Soils hold significant organic carbon and can either release or sequester carbon, impacting atmospheric CO₂ levels. In light of projected population increase, which goes hand in hand with agricultural conversion and deforestation, it is important to understand how these activities alter biogeochemical cycles in general and soil erosion in particular.

The Kasai Basin, covering an area of approximately 890,000 km² - about 22 times the size of Switzerland - is the largest tributary to the Congo River. Its watershed contains dense tropical lowland forests of central Congo in the north and drier woodland savannahs in the south. Besides this shift in vegetation, the Kasai Basin presents a range of climates, soils, land-uses and human activities. Because of these naturally and anthropogenically induced gradients, the basin represents an ideal location for studying the drivers of tropical soil erosion dynamics and its influence on the carbon cycle.

Soil erosion depletes soil fertility and degrades ecosystems. It also disturbs the soil and thereby releases organic carbon that can then be decomposed by microorganisms in the presence of oxygen, leading to potential local CO₂ emissions. But despite the importance of these negative consequences of soil erosion, they are not necessarily the end of the story when it comes to carbon biogeochemistry.

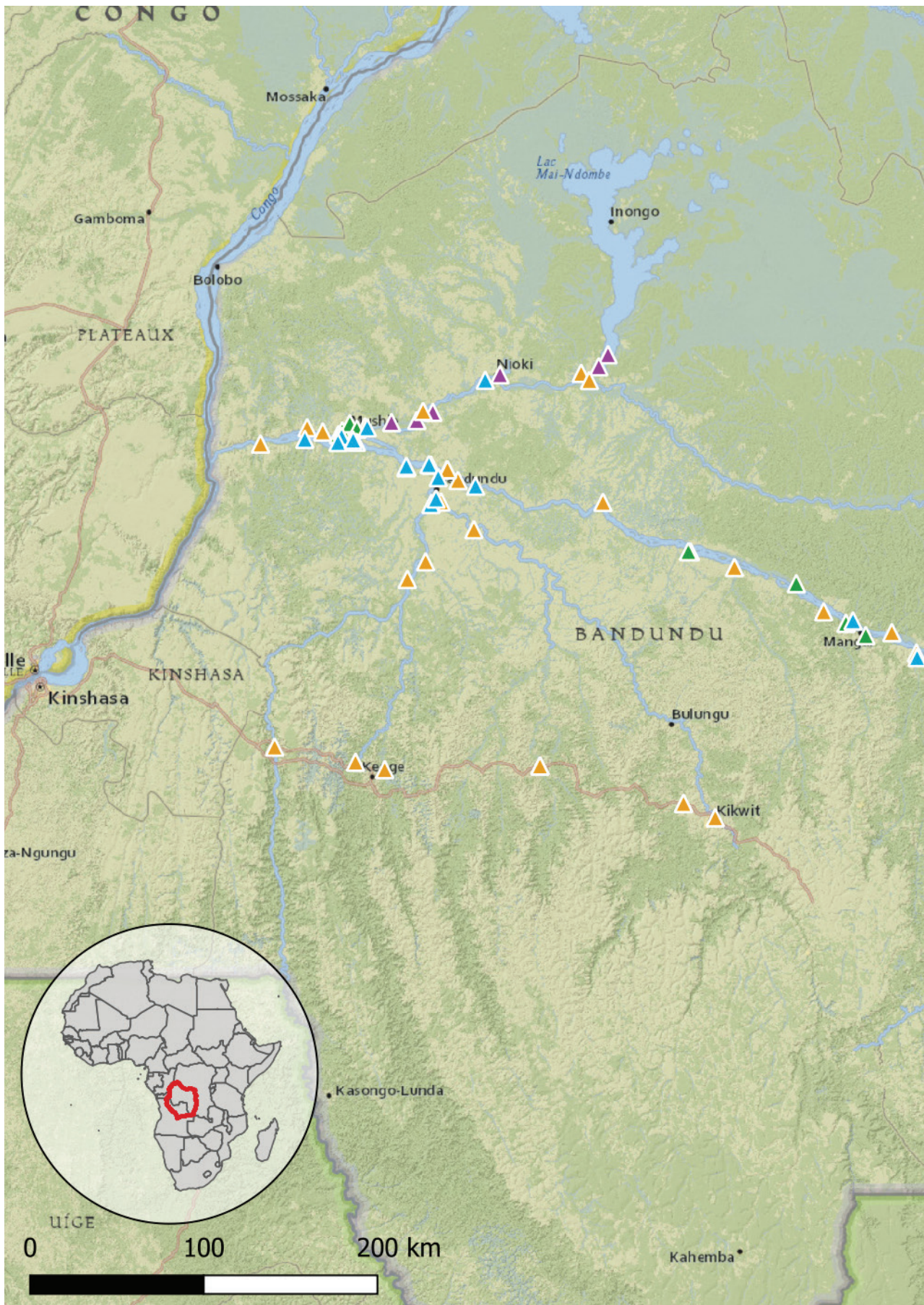
Eroded sediments and the organic carbon they contain can move variable distances, with some traveling only to the bottom of a hillslope while others are carried to streams and rivers which might ultimately reach the ocean. Along this cascade, organic carbon can be either decomposed to gaseous or aqueous species of inorganic carbon or stored long-term in depositional environments, like floodplains and lakes connected to the rivers.

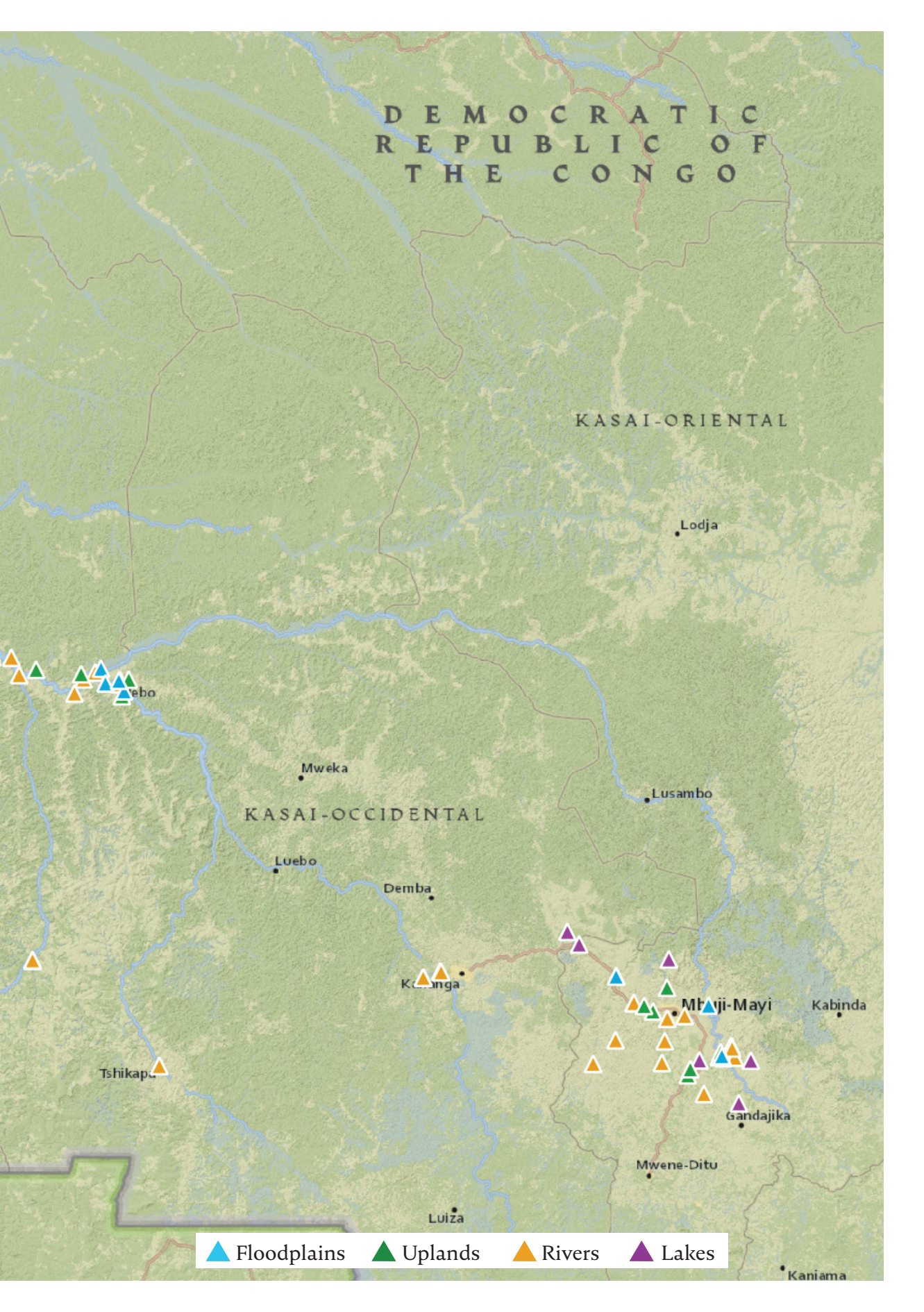
In addition, plant regrowth at erosion sites can resupply the eroding system with 'fresh' carbon pulled from the atmosphere via photosynthesis. Depending on the fate of this newly acquired plant carbon, this can counterbalance the CO₂ emissions from soil erosion. Recent work has shown that soil erosion generally appears to be a carbon source to the atmosphere over short timescales and small distances, but can shift to being an overall carbon sink when those timescales and distances are expanded.

Our research aims to enhance our understanding of the balance between the different soil erosion carbon fluxes in tropical environments and provide additional insights for completing carbon accounting at variable spatial and temporal scales.









DEMOCRATIC
REPUBLIC OF
THE CONGO

KASAI-ORIENTAL

Lodja

Luebo

Mweka

KASAI-OCCIDENTAL

Luebo

Demba

Lusambo

Kulonga

Tshikapa

Mwaji-Mayi

Kabinda

Gandajika

Mwene-Ditu

Luiza

Kaniama

- ▲ Floodplains
- ▲ Uplands
- ▲ Rivers
- ▲ Lakes

In order to cover the different aspects of this research, the group was divided into four complementary teams. Each team was assigned a specific landscape domain: uplands, floodplains, rivers and lakes.

The uplands and slopes are the sites of initial erosion. Floodplains along the rivers are depositional environments and transient storage sites for the sediments and their associated carbon. Rivers are sediment and carbon transport corridors, but during this transport the carbon can be transformed and potentially released to the atmosphere. Lakes are capable of long-term carbon storage and preserve records of past environmental conditions. Taken together, these sites allow us to investigate the fluxes of carbon across the landscape and through time.

The large distances and remoteness of the Kasai Basin required long field campaigns to collect samples at a meaningful spatial scale. To cover the ground between these sampling sites, our teams travelled by land and water in 4x4 cars and boats.









Uplands

Hillslopes are the starting point in the eroding journey of soil organic carbon. The Upland team sought to understand how carbon dynamics respond to land use and climate change across topographical gradients.

To capture a representative array of sample sites, the team collected soil cores from 24 hillslopes along the Kasai River, comparing paired slopes: one undisturbed and one impacted by human activities. Despite the challenges posed by the region's dynamic landscape, where the slash-and-burn agriculture often leaves only the most inaccessible slopes undisturbed, a diverse range of land-use types, including forests, grasslands, and croplands, were successfully sampled.



Fieldwork in the tropics, particularly soil sampling on steep slopes, can be demanding.

The team faced various challenges, such as equipment failures, difficult terrain, and harsh temperatures. However, the stunning landscapes and interactions with the local communities helped overcome those challenges and enrich the work.





*Each collected soil core is
cut into 5 cm sub-sections.
Mushie, August 2022.*



*Enjoying the walk
through the fields.
Mokele, August 2022.*



*The soils of the Kasai are old and deeply weathered, and often red because of the iron oxides they contain.
Mabenga, February 2024.*





Air drying of soil samples in the common room of the research vessel, named Kauka. February, 2024.

During three expeditions, the team collected over 6,500 soil samples. These samples are now being analyzed in the lab to measure soil organic carbon, mineralogy, grain size, carbon isotopes, and fallout radionuclides to investigate the interactions between erosion, soil characteristics and carbon stabilization versus losses. These analyses will provide deeper understanding of the dynamics of soil organic carbon in the eroding uplands of the Kasai Basin.





Drone imaging was used to obtain precise digital elevation models of the investigated floodplains.



Floodplains

During the tropical wet season, rivers can swell dramatically by as much as 3 meters! When this occurs, lowlands adjacent to the river are flooded, which gives these specific landforms the name of floodplains. Once the water recedes, the sediments and carbon that were transported by the river become trapped in the floodplain and are stored in the soil for a longer time. However, it is generally thought that sediment and carbon are in transient storage, which means that this material will be transported back into the river at a later date. Furthermore, the idea that carbon remains untouched and unchanged during storage is challenged because decomposition most likely occurs during storage. As a consequence of this, floodplains emit CO₂ to the atmosphere.

To determine whether tropical floodplains are sources or sinks of carbon (i.e., whether they are more efficient at decomposing or storing) the sampling campaign focused on coring floodplain soils. Through this sampling scheme, the depositional history of the floodplain will be reconstructed, which will ultimately answer the question of whether floodplains are sources or sinks of carbon.







Soil coring is a low-tech sampling method. Put simply, a metal cylinder is hammered into the soil, then extracted, along with the soil within the tube.

However, this is easier said than done sometimes... The soil within the tube is a soil sequence which represents a historical record of deposition events. Indeed, for every flood, a layer of sediment is added to the surface of the floodplain. As the years go by, more and more sediment accumulates, such that a 1-meter deep core can constitute a depositional archive of up to several decades.

The above is an example of a core where the surface (right side) is remarkably darker and more carbon-rich than the deeper soil (left side) which is light gray. This might be evidence for carbon being decomposed over time, as deeper, older layers contain a lower amount of carbon.



Since floodplains are very wet, one can easily get stuck waist-down in the mud; the lush vegetation and lack of man-made trails also make progress through the floodplain slow and arduous.



However, these exact conditions make the floodplains particularly unique and interesting. Indeed, the wet conditions are favorable conditions for protecting carbon against decomposition, while the low level of human occupation leaves the environment in an almost pristine condition.

While coring is the main component of the floodplain sampling scheme, drones can supplement soil data with extra information, such as topography and plant biomass.

Drones are a very flexible tool, as they can be used anywhere and with little constraints. Moreover, they work very fast, covering large areas in minutes.

Of course, this conspicuous piece of technology attracts a lot of attention, so kids invariably come look and have fun spotting the drone's flight.







BALISEUR
KAUKA



Rivers

Rivers are important conduits in the landscape which transport sediment and organic matter from the land to the ocean. Along the way, eroded material can either be carried downstream, redeposited in floodplains, or consumed by microbes that live in the river.

In the central African tropics, particularly in the Democratic Republic of the Congo (DRC), few studies have explored the processes of sediment and carbon movement in river systems.



By analyzing the physical and chemical composition of river sediments, it is possible to trace the drivers and sources of sediment transported by erosion to the river. Of particular interest is the age of sediment and which land-cover and climate contribute to high sediment loads.

From a multitude of analyses, it is then possible to draw a clearer picture of the physical, chemical, and biological processes that control erosion at the watershed scale.



Dramatic impression of two rivers originating from different biomes. Rivers draining forests tend to be dark in color due to their high organic carbon load.



Acoustic current doppler profiler (ADCP) is used to measure discharge from a stream draining a pristine forest.

At each river, various measurements were conducted. Apart from collecting approximately 100 liters of water for filtration and later analysis in the laboratory, in-situ measurements of discharge, pH, temperature, dissolved oxygen, and greenhouse gas fluxes were conducted.

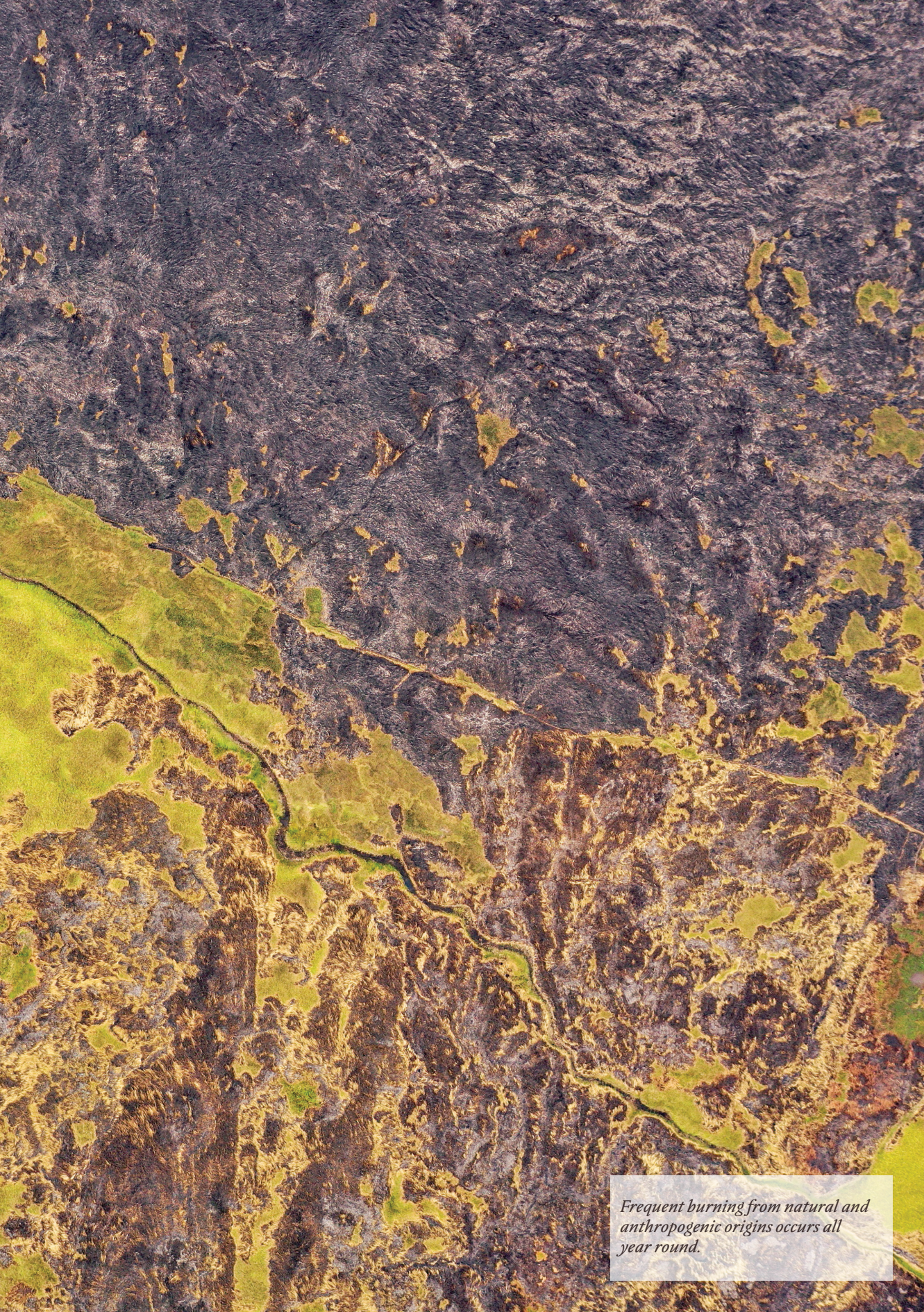


Dinghies or local pirogues were used to access small tributaries

Fieldwork often required travel by dinghy boats or pirogues, which were beautifully carved and sturdy enough to carry our equipment. These boats allowed us to reach remote and sometimes well-hidden river sampling locations.







Frequent burning from natural and anthropogenic origins occurs all year round.





Once at the field lab, most of the collected water was filtered using pressurized filter towers. By applying high pressure with a compressor, it was possible to quickly filter large volumes of water through filters with small pores ($0.2\ \mu\text{m}$). After five expeditions, an impressive total of 6,000 litres of water from 44 different rivers were filtered.

Despite filtering 80 L of water for each river, sediment yield was only a few grams.





Filtered sediments varied in color depending on the biome drained by the river.





*Coring sediments on Lake Nzailembo.
August 2022.*



Lakes

Lake sediments serve as windows to the past. Over centuries and millennia, sediment layers accumulate, protected from environmental disturbances by the lake water. These layers preserve information about surrounding vegetation, such as pollen, while climate conditions can be inferred from oxygen isotopes in clay minerals.



The coring platform ashore of Lake Mukamba. June 2023.

This makes it possible to reconstruct historical vegetation and climate patterns. By connecting these factors, potential drivers of rainforest extent can be identified and offer insights into how these drivers may impact the rainforest in the future.





Preparing the tip of the core for the next coring.

To collect short sediment cores from several lakes, coring was initially conducted from a small platform suspended between two pirogues or dinghies. Later on, a custom-made platform was built, allowing for the recovery of longer, continuous sediment cores.

Lake coring was done through a hole in the center of the platform.



As the rainforest plays an important role for atmospheric carbon uptake, so does carbon storage to balance CO₂ levels in the atmosphere. The potential carbon storage capacity of lake sediments can be estimated by analyzing their carbon content, stability and transport times. This knowledge can also be linked to the soil, floodplain and river carbon analyses, providing a better understanding of carbon cycling in the Kasai Basin.



Coring is required to sample sediments from lake bottoms. Sediments are collected in long PVC tubes so the chronology is preserved – the deeper sediments are often deposited earlier and therefore older. Changes of past environmental conditions may then be reconstructed by quantifying the physical and chemical properties of these sediments.



The Kasai is beautiful, especially in the morning when the sun rises, causing the surface of the water to sparkle. I thoroughly enjoyed the field sampling—except for the 40-degree heat! Now, I need to return to my office to continue programing and numerical simulations, contributing to TropSEDs by understanding the lateral carbon fluxes along the land-ocean continuum in the Kasai Basin.

Pengzhi Zhao, Researcher







TropSEDs fieldwork has come to an end. The teams have returned home. The ships and boats have made their way back to port. The collected samples are being processed in the laboratories and field gear is stored and packed away. As we transition to the next phase of the project - data analysis and publication - we would like to acknowledge and thank all those who made this fieldwork possible.

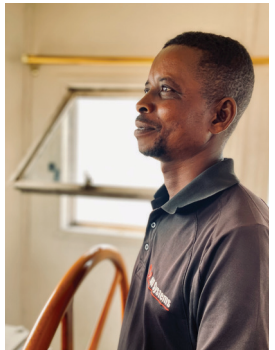
Our five expeditions across the Kasai Basin went about as smoothly as one could have hoped for, thanks in large part to the efforts of the innumerable collaborators that we have met along the way. Countless individuals played a crucial role, already from the initial planning stages in Zurich, Louvain-la-Neuve, and Kinshasa. Some were with us for the entire journey, while others joined for a fleeting chapter. Together, they helped us turning our ambitious project into a successful reality.

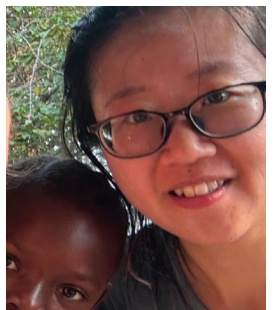
The Kauka's crew, from the engine room to the bridge, worked tirelessly to navigate the waterways and maintain the vessels. The galley staff kept everyone well-fed, the military personnel kept everyone safe, the scientists guided the research, and most importantly, the local communities allowed access to their land.

In the background, this was all only possible due to the administrative effort of various institutions, including the Régie des Voies Fluviales (DRC), the Ministère de l'Environnement et Développement Durable (DRC), the International Institute for Tropical Agriculture (DRC), ETH Zürich (Switzerland), the Université Catholique de Louvain (Belgium) and the Congo Atomic Energy Commission (DRC).

TropSEDs is a science-focused project, rooted in human connections and collaboration. This mosaic of faces, likely incomplete, is our best testament to this adventure!







Ce sont les réalités du terrain

Desami Brainto, Scientific collaborator

Indeed, our floodplain team has an important turnover. After Joseph fell 7 times in the swamp, John lost both shoes in the mud, we had difficulties convincing them to come back.

Nathan Carlier, Researcher

...a couple of goats, chikwange, pili-pili, beers, and music. Great recipe to spend a good night!

Antoine de Clippele, Project coordinator

We are finally steaming full speed ahead and are reaching 11.3 km/h, with an average of 7-8 km/h. Nice!

Kristof Van Oost, P.I.

Yes, we were nicely cramped...

Lissie De Groot, Researcher

I was really dreading the heat, the mosquitoes, and the lack of sleep. In the end, we got plenty of those, but...

Gaëlle Wanlin, Researcher

If I have to work in floodplains again, I'll be sure to lose a few pounds first, so I'll don't sink so deep in the mud!

Alfred Ludjwera, Scientific collaborator

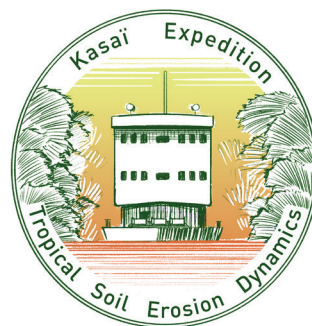
...many fun moments: when the Kauka turned into Noah's Ark with pigs, goats, and even a cow on board, cooking a pizza under a wheelbarrow in Mbuji-Mayi, the rat incident in the bathroom at Pili Pili, eating caterpillars...

Gaëlle Wanlin, Researcher

I'd love to go again!

Michelle Engelhardt, Researcher

TropSEDs is a Swiss National Science Foundation (SNSF) funded project. It was possible with the support of ETH Zurich (Sustainable Agroecosystems group & Surface Earth Evolution group), Switzerland and UCLouvain (Earth and Life Institute), Belgium.



– Research team

Matti Barthel
Kristof Van Oost
Johan Six
Travis Drake
Antoine de Clippele
Lissie de Groot
Pengzhi Zhao
Nathan Carlier
Michelle Engelhardt
Jordon Hemingway
Gaëlle Wanlin
Yi Hou
Laura Summerauer
José Nlandu
Joseph Zambo

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Alfred Ludjwera
Desami Brainto
Carlos Kabanga Beya
Papy Mukadi wa Mambula
Nixon Mayala
Blarro Elombe Ifubu
Kenza Benabderrazik

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– Photography credits

Matti Barthel
Kristof Van Oost
Johan Six
Travis Drake
Antoine de Clippele
Lissie de Groot
Pengzhi Zhao
Nathan Carlier
Michelle Engelhardt
Jordon Hemingway
Gaëlle Wanlin
Yi Hou
Laura Summerauer

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