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Organic matter cycling along geochemical, geomorphic and disturbance gradients in forests and cropland of the African Tropics - Project TropSOC Database Version 1.0

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Abstract

The African Tropics are hotspots of modern-day land-use change and are, at the same time, of great relevance for the cycling of carbon (C) and nutrients between plants, soils and the atmosphere. However, the consequences of land conversion on biogeochemical cycles are still largely unknown as they are not studied in a landscape context that defines the geomorphic, geochemically and pedological framework in which biological processes take place. Thus, the response of tropical soils to disturbance by erosion and land conversion is one of the great uncertainties in assessing the carrying capacity of tropical landscapes to grow food for future generations and in predicting greenhouse gas fluxes (GHG) from soils to the atmosphere and, hence, future earth system dynamics.

Here, we describe version 1.0 of an open access database created as part of the project **"Tropical soil organic carbon dynamics along erosional disturbance gradients in relation to variability in soil geochemistry and land use" (TropSOC).** TropSOC v1.0 contains spatial and temporal explicit data on soil, vegetation, environmental properties and land management collected from 136 pristine tropical forest and cropland plots between 2017 and 2020 as part of several monitoring and sampling campaigns in the Eastern Congo Basin and the East African Rift Valley System. The results of several laboratory experiments focusing on soil microbial activity, C cycling and C stabilization in soils complement the dataset to deliver one of the first landscape scale datasets to study the linkages and feedbacks between geology, geomorphology and pedogenesis as controls on biogeochemical cycles in a variety of natural and managed systems in the African Tropics.

The hierarchical and interdisciplinary structure of the TropSOC database allows for linking a wide range of parameters and observations on soil and vegetation dynamics along with other supporting information that may also be measured at one or more levels of the hierarchy. TropSOC's data marks a significant contribution to improve our understanding of the fate of biogeochemical cycles in dynamic and diverse tropical African (agro-)ecosystems. TropSOC v1.0 can be accessed through the supplementary material provided as part of this manuscript or as a separate download via the websites of the Congo Biogeochemistry observatory and the GFZ data repository where version updates to the database will be provided as the project develops.

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1. Rationale to project TropSOC

1.1 Changing tropical environments in Africa

Tropical ecosystems provide many services of global importance. Tropical forests are among the largest terrestrial carbon (C) reservoirs and show some of the highest levels of biodiversity (Losos and Leigh, 2004; Pan et al., 2014). At the same time, tropical landscapes are among the most dynamic regions worldwide and hotspots of modern day land-use change (Hansen et al., 2013) as they have to provide food for some of the poorest yet fastest growing populations on the planet. In particular, the African continent is facing huge environmental and societal challenges with a projected population growth of 400% by the end of this century (Gerland et al., 2014), much of it happening in (sub-)tropical sub-Saharan Africa. In consequence, forested landscapes in tropical Africa are currently facing unprecedented levels of land conversion and land degradation, accompanied by decreasing soil fertility (UNESCO and WHC, 2010). At the same time, unlike other tropical regions of the world, where deforestation are driven by the extension of commodity plantations and commercial logging, much of the deforestation in tropical African countries is driven by smallholder farms that apply slash and burn practices for subsistence farming with little alternatives to provide food for their families (Curtis et al., 2018; Tyukavina et al., 2018). As a result, deforestation and soil degradation have accelerated greatly since the second half of the 20th century with soil erosion, in particular, emerging as the main driver of soil degradation.

Today, erosion rates of tropical agricultural land globally are estimated at approx. 10.4 billion tons of soil per year and 0.2 billion tons of C per year. Tropical agricultural soil erosion represents therefore about half of the annual agricultural erosion globally, while only representing about one third of global cropland (Doetterl et al., 2012). An exemplary region to observe the consequences of land use change on soil resources and biogeochemical cycles in the tropical African region context is the African great lakes region along the East African Rift Valley System along the borders between the Democratic Republic of the Congo, Burundi, Rwanda and Uganda.

The region is a model for the complex interplay of socio-economic factors and their consequences for environmental systems in the Tropics. One of the highest human fertility rates globally (e.g. recent estimates for the last decade range from 7.3-7.7 children per woman in the province of South Kivu, Eastern DRC) (Dumbaugh et al., 2018) leads to massive population growth in the region, largely relying on local food and energy resources. Ridden by conflict and open warfare in the 1990s and early 2000s, population growth in the region is further aggravated

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as a result of refugees from remote areas settling nearby safer, larger cities in the region (Kuijrakginia et al., 2010). In consequence, massive deforestation of upland forests for fuel gathering and cropland expansion is taking place (Hansen et al., 2013), leading to large erosional soil fluxes and consequential soil degradation threatening soil quality (Karamage et al., 2016). Once conversion to agricultural land takes place, soil conservation measures could counteract the loss of soil quality (Veldkamp et al., 2020). But these measures are rare in the Eastern Congo Basin due to poverty of subsistence farmers, socio-economic instability and a lack of governmental intervention (Heri-Kazi Bisimwa and Bielders, 2020). Soil tillage and harvesting further degrade the nutrient containing litter and topsoil layers. In consequence, fields often have to be abandoned after only a few decades of use and recover only poorly (Carreño-Rocabado et al., 2012; Ewel et al., 1991; Hattori et al., 2019; Heinrich et al., 2020; Kleinman et al., 1996; Lawrence et al., 2010).

1.2 Tropical soils responding to disturbance

With the expansion of cropland into forested landscapes soil erosion rates are expected to continue to increase. Soil erosion will undoubtedly impact biogeochemical cycles and change the input, storage and exchange of C between soils and atmosphere as well as the flux of nutrients between plants and soils in tropical systems in the region. To understand how tropical soils and ecosystems respond to erosional disturbance, it is necessary to consider the combined effects of climate, geology, topography, soil formation, biological processes and human disturbance. To date, no study on the interrelationship of these controls on biogeochemical cycles has been carried out in tropical ecosystems. However, studies carried out in other regions have shown that controls on soil C dynamics, for example, are highly interlinked (Doetterl et al., 2015a; Hobley and Wilson, 2016; Nadeu et al., 2015).

Soil redistribution as a consequence of erosion also changes the functionality of landscape units. For example, soil degradation on hillslopes is matched by a rapid buildup of sediment deposits in valley bottoms, where C and nutrient rich soil is rapidly buried in subsoils under new sediments. While this consequence of deforestation can lead to an increase in the residence time of C due to slower microbial C turnover in buried soil (Doetterl et al., 2012; Alcantara et al., 2017), important nutrients are now lost to plants leading to biomass productivity (Veldkamp et al. 2020) and degraded tropical forests generally negative for microbial processes in soils (Sahani & Behera, 2001). Soil redistribution is also known to change the temporal and spatial patterns of soil weathering and affects C stabilization. In agricultural systems, the effects of this pressure can be

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observed very clearly: erosion removes weathered soil from eroding slopes but also brings the soil weathering front into closer contact with the C cycle (which occurs primarily in topsoils), thereby affecting CNP cycling and the stabilization of C with minerals in these systems (e.g. Berhe et al., 2012; Park et al., 2014; Doetterl et al., 2016).

Feedbacks on biogeochemical cycles between soil weathering, erosion will differ significantly not only between natural and disturbed systems, but also between systems with differing soil mineral reactivity. Recent advances have shown that mineral reactivity, constrained predominantly by soil weathering and the mineralogy of the soil parent material, has direct control over soil organic carbon, with climate exerting only indirect control through its impact on biogeochemical processes and matter fluxes (Doetterl et al., 2015a; Tang and Riley, 2015). However, the exact effects of mineralogy on the temperature sensitivity of microbial decomposer communities and the primary productivity of ecosystems have, to date, not been constrained (Hahm et al., 2014; Tang and Riley, 2015).

1.3 Importance and outlook of research on the future of tropical biogeochemical cycles

Tropical Africa is expected to experience great changes to both soil biogeochemical cycling and ecosystem level carbon (C) fluxes between soil, plants and the atmosphere, with unknown consequences for biogeochemical cycles. Despite decades of recognizing their importance, tropical soils remain among the least studied in the world (Mohr and van Baren, 1954; Mohr et al., 1972; Ssali et al., 1986; Juo and Franzluebbers, 2003). Although a more complete understanding on soil-plant coupling in tropical environments is critical, most of our process understanding on biogeochemical cycling between plant and soil is still derived from temperate regions. However, due to differences in their environmental setting and soil forming history, many tropical soil systems will likely react very differently to soil disturbance and land conversion than temperate soil systems. For example, temperate ecosystems can differ fundamentally in the way nutrients cycle and in the dominating and limiting factors for plant growth (Du et al., 2020). In contrast to soils in the temperate zone, long lasting chemical weathering has led to a massive depletion of mineral nutrients from soils in many tropical systems, although the remaining available nutrients are very efficiently re-cycled in natural tropical biospheres (Walker and Syers, 1976; Vitousek, 1984). Hence, any loss of nutrients is therefore a critical disturbance with direct effects on the functioning of tropical (agro-)ecosystems. Recent studies highlight the importance of soil degradation and the change in chemical soil properties that follows land conversion on plant communities in tropical systems (Bauters et al., 2021), organic matter turnover by microbial

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decomposers (Kidinda et al., 2020 in review; Bukombe et al., 2021 in review) and the stabilization of C and nutrients in soil of varying mineralogical properties (Reichenbach et al., 2021 in review).

Improving our process understanding on the consequences coupling between soil biogeochemistry and plant responses in the context of tropical land use changes of land use change on plant-soil interactions will help to better constrain plant-soil interactions in ecosystem and land surface models and to better inform policy makers and stakeholders in improving land management practices.

1.4 Objectives and framework

In the following we aim at providing an overview on the data collected by project TropSOC which is now available to the research community as an open access database. We give a brief description of the project's design before elaborating the structure of the database and its content. Note that beyond the overview information presented here, more details to methods and sampling designs for each assessed parameter is explained in great detail in the supplementary metadata files accompanying the database.

The main objective of project TropSOC was to develop a mechanistic understanding of plant and microbial process responses to changing soil properties in the African Tropics exemplified along land use, erosional and soil geochemical gradients studied in the Congo and the Albertine Rift. Trying to understand biogeochemical cycling affected by human activities in tropical (agro-)ecosystems as a whole, TropSOC had two main foci:

(i) investigate how nutrient fluxes and organic matter allocation between tropical soils, plants differ in relation to the controlling factors geochemistry, topography and land use.

(ii) investigate how the geochemistry of soils and their parent material control, interact with or mediate the severity of erosional disturbance on C cycling in tropical soils.

In order to address these objectives, project TropSOC investigates effects on tropical soil biogeochemical cycling and biological responses to variation in soil and environmental properties along three main vectors (Figure 1): (i) Mineralogy of parent material, since it may drive the the geochemical features of soils developed which control soil fertility and the potential of soils to stabilize organic matter and nutrients. (ii) Landform, since topography may influence water and soil fluxes, particularly erosional soil loss on slopes and soil deposition in valleys. (iii) Vegetation and land cover, since it may control the input to and extraction of organic matter from soil, and

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respond to variation in soil properties and hydrology, as well as mediate the impact of rainfall to induce soil erosion.

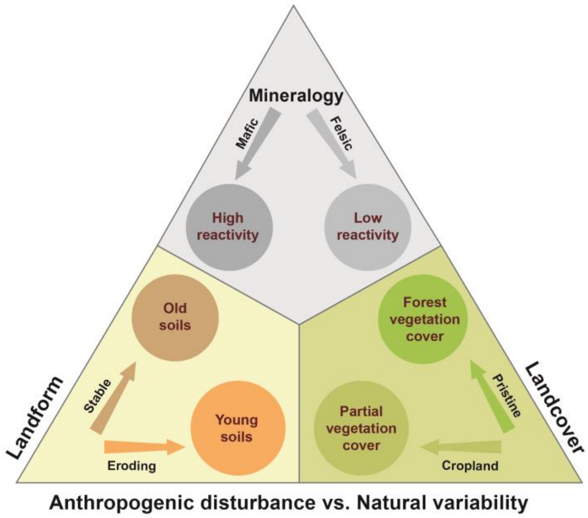

Figure 1. Factorial design of the project TropSOC studying biogeochemical cycles in Central African tropical forest and agricultural landscapes in relation to mineralogy, landform and land cover types.

Conducted in one of the hotspots of Global Change, the Central African Congo Basin and African Great Lakes region the database described here is the foundation for several manuscripts published as a part of the 2021 special issue “*Tropical biogeochemistry of soils in the Congo Basin and the African Great Lakes region”* in SOIL Journal (Bukombe et al. 2021, in review; Kidinda et al. 2020; Summerauer et al. 2021 in review; Reichenbach et al. 2021 in review; Wilken et al. 2020 in review).

2. Study and sampling design

2.1 Study area - Climate, topography, land use

The study area of TropSOC is located in the eastern part of the Democratic Republic of the Congo, Rwanda and Uganda, in the border region between the Congo and the Nile basin (Figure 2). It is yet largely understudied (Schimel et al., 2015) despite its great significance for the global climate system (Jobbágy and Jackson, 2000, Amundson et al., 2015) and being confronted with rapid land conversion (Hansen et al., 2013) and forest degradation). The Climate of the study region is classified as tropical humid with weak monsoonal dynamics (Köppen Af - Am) and mean annual temperatures (MAT) ranging between 15.3 and 19.3 °C and mean annual precipitation (MAP) between 1498 and 1924 mm (Fick & Hijmans, 2017) with high potential erosivity (Fenta et al. 2017) (Figure 2d).

As a part of the Eastern African Rift Mountain System, the active tectonism within the study region produced a hilly, patchy landscape with steep slopes up to 60% and soil parent material ranging from volcanic ashes to mafic and felsic magmatic rocks as well as a sedimentary rocks of varying geochemistry and texture (Schlüter 2006) (Figure 2a,b).

The study area is dominated by agricultural land use, with larger patches of protected, old growth closed canopy forest in highland areas (Figure 2c). Typical crops planted for subsistence farming are rotations of cassava (*Manihot esculenta*), maize (*Zea mays*) and a variety of legumes and vegetables. The dominant vegetation in all studied forests of the region is characterized as tropical mountain forest (Verhegghen et al. 2012; van Breugel et al. 2015). Note that while forest vegetation is thought to be largely spared from direct disturbance by human activities, large mammal populations (i.e. African forest elephants, Great Apes) became extinct or largely reduced due to hunting during the 20th century resulting in a massive increase in understory.

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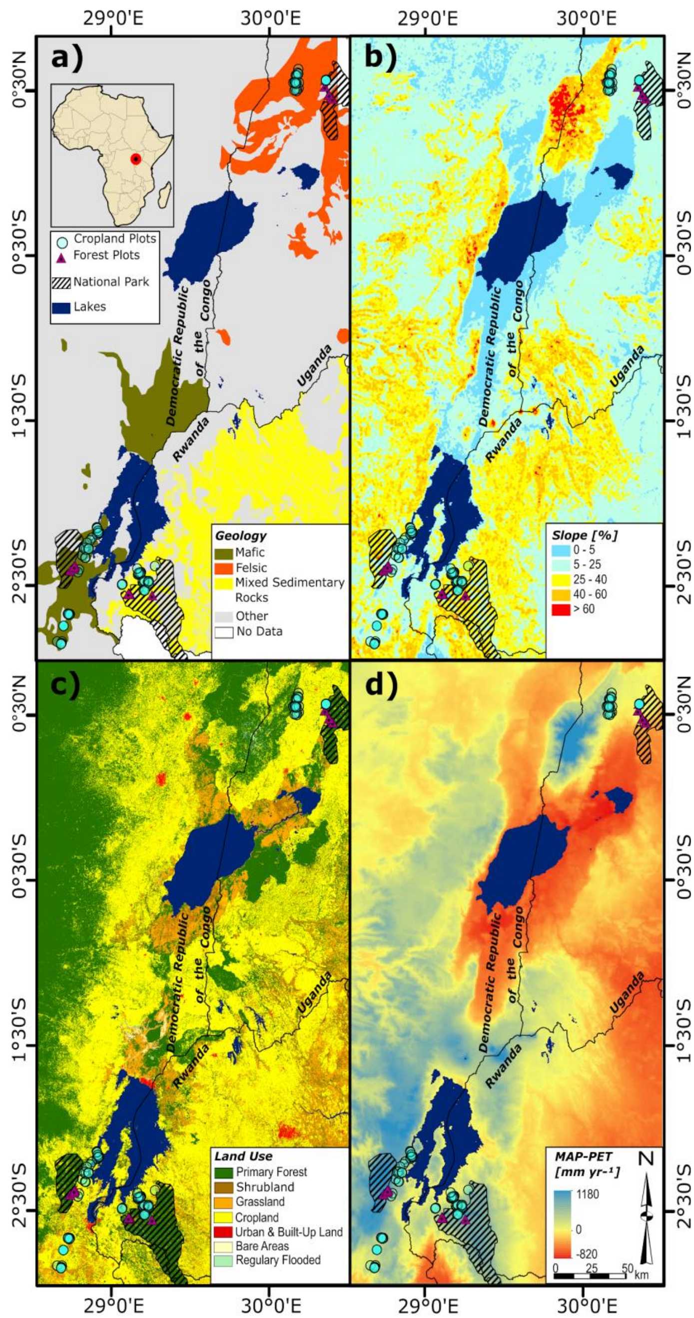

Figure 2. Overview of the study region with respect to major investigated factors: soil parent material geology and geochemical regions (a), slope steepness (b), land use (c) and climate d).

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2.2 Study area - Geochemistry and soil types

Within the study area three regions each representing a geochemical differing parent material for soil formation were determined. The first region (Figure 2a) is predominantly situated on mafic magmatic rocks, typically mafic alkali-basalts ranging in age between 9-13 Ma (Schlüter 2006), resulting from extinct (Mount Kahuzi) and active (Mount Nyiragongo) volcanic activities between the cities of Bukavu and Goma, Kivu, DRC. The second region is situated on felsic magmatic and metamorphic rocks typically consisting of gneissic granites ranging in age between 1600-2500 Ma (Schlüter 2006) near the city of Fort Portal on the foothill of the Rwenzori Mountain range, Uganda. The third region is situated on a mixture of sedimentary rocks of varying geochemistry consisting of alternate layers of quartz-rich sandstone, siltstone and dark clay schists ranging in age between 1000-1600 Ma (Schlüter 2006) and spread across the Western Province of Rwanda in and around the district of Rusizi.

The dominant soil types of the study region are various forms of deeply weathered tropical soils (FAO, 2015). Potential ash deposition through the region's active volcanism occurs frequently, re-fertilizing soils to various degrees. Following World Reference Base (WRB) soil classification (IUSS WRB, 2015), soils in the mafic region can be described as umbric, vetic and geric Ferralsol and ferralic vetic Nitisol. Soils in the mixed sedimentary rock region and the felsic region can be described as geric and vetic Ferralsol. Soils in valley bottoms can locally show gleyic features, where the dominating soil types are variations of fluvic Gleysol.

Several striking differences in the elemental composition of the three parent materials can be noted. In the mafic region, bedrock is characterized by high iron (Fe) and aluminum (Al) content as well as a comparably high content of rock-derived nutrients such as base cations and phosphorus (P). The felsic and the sedimentary rock regions are characterized by lower contents of Fe, Al as well as lower rock-derived nutrients contents and characterized by higher Si content (Figure 3). A specific feature of the sedimentary site is the presence of fossil organic C in the parent material of soils ranging between 1.29 - 4.03% C. Fossil organic C in these sediments is further characterized by a high CN ratio (mean ± standard deviation: 153.9 ± 68.5), depleted in N and free of ^{14}C (due to the high age of sedimentary rock formation). The elemental composition of soils at stable landscape position between the three regions retains the geochemical features of its parent material to some degree and illustrates the process of enrichment of metal oxy-hydroxides and the depletion of silica as a consequence of weathering. Generally, differences in the elemental concentrations between the three regions are less pronounced in soil (figure 4)

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compared to differences in parent material (figure 3). Remarkably, levels of rock-derived nutrients in soil, while overall depleted compared to the parent material, are comparably similar, potentially indicating biological mechanisms that keep these important nutrients in the plant-soil system against a general trend of leaching and depletion, typical for weathered, old and nutrient poor tropical soils (Grau et al., 2017 and references therein).

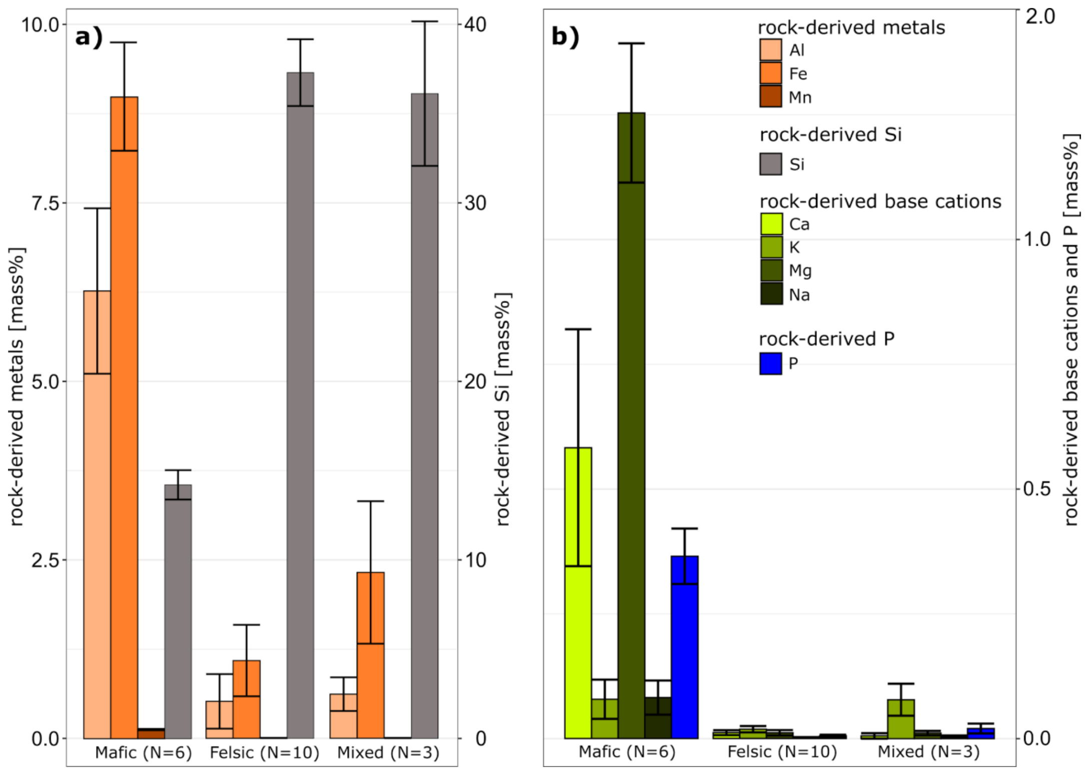

Figure 3. Chemical composition of unweathered rock samples representing the parent material for soil formation in three studied geochemical regions (mean +/- standard error). Panel 3a shows the distribution and concentration of rock derived aluminum (Al), iron (Fe) and manganese (Mn) and total silica content (Si). Panel 3b shows the distribution and concentration of rock derived calcium (Ca), potassium (K), magnesium (Mg), sodium (Na) and phosphorus (P). Note the difference in scale on y axis between panel 3a and 3b.

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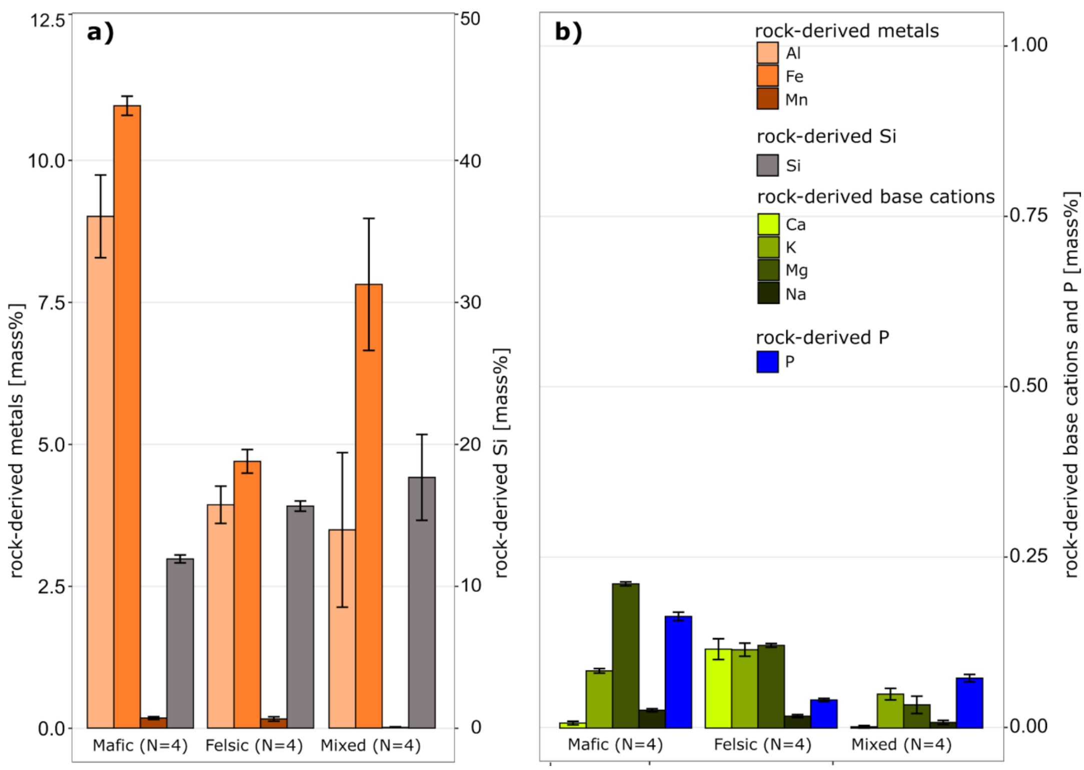

Figure 4. Soil chemical composition of subsoil in stable, old growth closed canopy forests (no erosion) in the three investigated geochemical regions (mean +/- standard error). The data illustrates the convergence of elemental concentrations between the three regions as a result of weathering and soil development. Abbreviations explained in figure 3. Note the difference in scale on y axis between panel 4a and 4b.

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In summary, the study region provides a unique combination of (i) near-pristine forest and agricultural land use, (ii) steep terrain and heavy tropical precipitation with high erosion potential and (iii) geologically diverse parent material for soil formation. These factors make the study region ideal for identifying the importance of various controls on tropical soil biogeochemical cycles.

2.3 Overview to plots and sampling design

Plots were established along geomorphic gradients in old-growth closed canopy forest as well as cropland in all three geochemical regions. Field campaigns to collect soil and plant samples at 136 forest and cropland plots along slope gradients (catena and stratified random approaches) and additionally within several cropped nearby micro-catchments were carried out between March 2018 and July 2020. A detailed description on data quantity and quality can be found in the metadata files accompanying the database and are briefly described in section 4.1 of this publication. In order to cover potentially stable, eroding and depositional landforms, topographic positions of plots ranged from plateaus (slope < 5%), over two slope positions (slopes between 9 and 60%) to valley positions (slopes < 5%) (Table 1).

Table 1. Topographic information of TropSOC plots across different geochemical regions and land use. Slope and altitude are displayed as minimum and maximum values. Each topographic position per geochemical region contains the range between 3-7 field replicate plots.

	felsic region (Uganda)					
	forest plots			**cropland plots**		
topographic position	*plateau*	*sloping*	*valley*	*plateau*	*sloping*	*valley*
slope [%]	3 - 5	9 - 55	3	1 - 5	7 - 50	1 - 5
altitude [m] a.s.l	1304 - 1306	1271 - 1420	1272-1277	1507 - 1797	1466 - 1830	1587 - 1768
	mafic region (DR Congo)					
	forest plots			**cropland plots**		
topographic position	*plateau*	*sloping*	*valley*	*plateau*	*sloping*	*valley*
slope [%]	3	11 - 60	1 - 2	0 - 5	8 - 43	0 - 3
altitude [m] a.s.l	2208 - 2227	2188 - 2248	2181 - 2310	1477 - 1731	1486 - 1774	1505 - 1708

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	mixed sedimentary region (Rwanda)					
	forest plots			cropland plots		
topographic position	*plateau*	*sloping*	*valley*	*plateau*	*sloping*	*valley*
slope [%]	3	9 - 60	1	3 - 5	8 - 50	2 - 5
altitude [m] a.s.l	1908 - 1939	1891 - 2395	1882 - 1889	1719 - 1837	1565 - 1952	1556 - 1758

2.4 Sampling design forest

2.4.1 Forest plot installation

Sampling in forests followed a strict catena approach and plots were established following an international, standardized protocol for tropical regions (Phillips et al. 2016). Within each geochemical region, three plots covered by old-growth closed canopy tropical forest vegetation (forest that developed a complex structure characterized by large, live and dead trees) were established per topographic position as field replicates representing an area of 40 m x 40 m per plot were established from February to June 2018. Each plot was subdivided in four 20 m x 20 m subplots and a total of 36 forest plots were established this way (four topographic positions with three replicate plots each in three geochemical regions). Note that three plots in the mafic region had to be relocated due to safety reasons after the sampling period. For an overview on forest plot sampling design see Figure 5a.

2.4.2 Sampling mineral and organic soil layers

At the time of plot installation, four replicate soil cores per plot (one in each subplot) were taken in a depth-explicit way in 10 cm increments up to 1 m soil depth, and combined as composites per plot. In addition, one soil profile pit was dug to a depth of 100 cm in the center of one of three replicate plots (Figure 5) per topographic position in each geochemical region. These soil pits were dug and described according to FAO guidelines (FAO, 2006).

Leaf litter (L horizon) and partially decomposed organic material in O horizons were sampled at eight points along the border and in the center of each forest plot (Figure 5a) at the time of soil sampling. At each sampling point, the thickness of the L and O horizon layer were measured with a ruler and then sampled within a 5 cm x 5 cm square. When the litter layer was too thin (= no closed coverage of forest floor with litter), the sampling square was expanded to a 10 cm x 10 cm

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to retrieve enough sample material. The nine samples of each layer per plot were combined to one composite sample.

All collected composite samples were kept cooled until being brought to the laboratory (usually within 48 hours). In the laboratory, samples were oven-dried at 40°C for 48-96 hours and then weighed (accuracy: +/- 0.01 g). Derived soil parameters are detailed in section 2.7.

2.4.3 Forest inventory and aboveground standing biomass

In 2018, full inventories of the forest tree species and standing aboveground biomass (AGB) were conducted on all forest plots. The forest inventory followed an international, standardized protocol for tropical regions (Matthews et al., 2012). First, we identified the species of all living trees with a diameter at breast height (DBH, measured at 1.3 m above ground) greater than 10 cm in each plot. Second, these identified trees were classified into the following empirical DBH classes: 10 – 20 cm, 20 – 30 cm, 30 – 50 cm and > 50 cm. Third, to estimate the above-ground biomass (AGB), we constructed stand-specific height diameter (H–D) allometric relationships using a representative subset of the plot-specific trees (Méchain et al., 2017). For this, 20% of all measured, specific trees were selected for height measurement, across the DBH range that was recorded per plot. Depending on the tree abundance of each DBH class, the height of three to five individual trees were then measured using a hypsometer (Nikon Laser Rangefinder Forestry Pro II, Nikon, Japan). AGB for each individual tree was then estimated using the allometric equation as described by Chave et al. (2014) for moist tropical forests. To estimate wood density data, we used species averages from the DRYAD global wood density database (Zanne et al., 2009). To extrapolate this information for the entire plot for all our sites, we applied a stand-specific height-diameter regression model; modelHD, available within the R package BIOMASS (Méchain et al., 2017). In a last step, aboveground standing biomass carbon stock was estimated assuming that that all samples standing biomass has a 50 wt.% share of C (Chave et al., 2005). A re-census was carried out in 2020, in order to detect changes in above-ground standing biomass and to determine tree mortality. Tree mortality rate (λ) at each plot was assessed following Lewis et al. (2004), using inventories conducted in 2018 and 2020. Tree mortality rate was calculated for all tree stems with DBH>10cm in every plot.

2.4.4 Canopy leaves

To assess plant functional traits (leaf nitrogen, phosphorus, potassium, magnesium and calcium content) of living canopy leaves (see section 2.7), we sampled, at the beginning of the weak dry

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season (December-February), sun-exposed shoots from the outer canopy of selected tree species that collectively make up 80% of the standing basal area per plot with the help of trained tree climbers and following a sampling protocol described in Pérez-Harguindeguy et al. (2016). For every tree species, we selected at least 3 individual trees, and a minimum of five and maximum of 17 trees per plot were sampled for mature, healthy-looking (= without signs of herbivory) individual canopy leaves. Where sampling of outer canopy leaves was physically not feasible, partially shaded leaves situated below the uppermost canopy were sampled.

2.5. Sampling design cropland

2.5.1 Cropland plot installation

Plots on cropland were established following a stratified random approach using the same slope classification and selection criteria as for forest sites. However, cropland plots belonging to the same geochemical region and topographic position were not connected along a hillslope catena. On cropland only fields that were currently covered by cassava were sampled. Cassava fields were chosen since cassava is one of the most important food crops in the region, harvested for both tubers and leaves. Rotations of cassava, maize, pulses and vegetables are common throughout the area and two harvests are possible per year. The main varieties of cassava on our sites were Mwabailon, Nabiombo, Mwamizinzi, Sawasawa (in Eastern DRC), Bukalasa, Shayidire, Gitamisi, Amaduda (in Rwanda), Sambati, and Mubalaya (in Uganda). Only fields without soil protection measurements (i.e. terraced systems) were sampled. For an overview on forest plot sampling design see Figure 5b.

2.5.2 Soil sampling

Soil sampling was carried out in the same way as for forest soils with the exception that only two cores were combined per plot taken within a 3 m x 3 m area to create depth explicit composite samples. A total of 100 cropland plots were sampled this way (Figure 5) with 3-7 field replicate plots per topographic position (plateaus, slopes, valleys) in each geochemical region. No L and O horizons were present in cropland, and no soil profile description was carried out. Derived soil parameters are detailed in section 2.7.

2.5.3 Biomass and crop yield

As part of the regional stratified random sampling design for cropland plots (see cropland plot installation), biomass from different cassava varieties was collected for 65 plots out of the 100

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sampled cropland plots. Biomass was sampled shortly before harvest, approximately at the time of the plant tuber's maximum development. The timing of harvest differed between 12 - 24 months after planting depending on the variety and season. Within each plot, a 3 m x 3 m sampling area was chosen close to the center of each field and all cassava plants in this area were counted and harvested. The biomass of all plants was separated into leaves, stems and tubers. These parts were then weighed separately and individually at the time of sampling (i.e. in a field moist state).

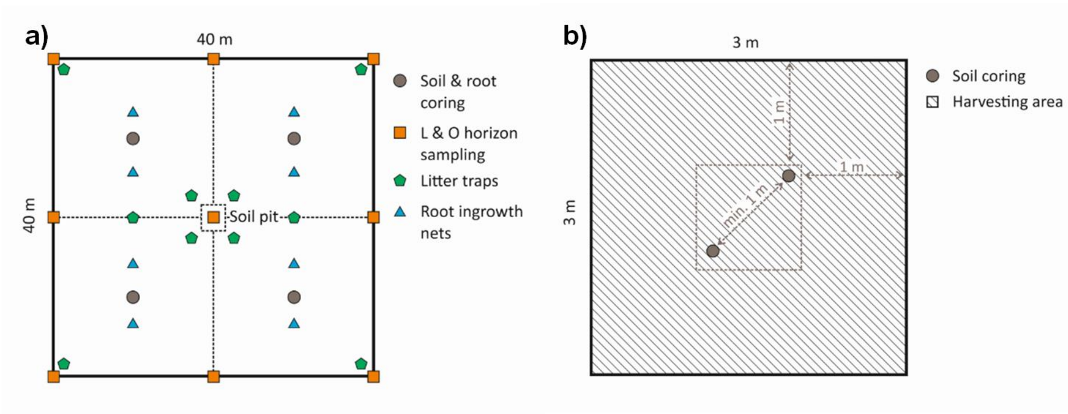

Figure 5. Overview on forest (a) and cropland (b) plot sampling design. Forest plots were subdivided into four 20 m x 20 m subplots and one soil profile pit was established per topographic position in each geochemical region for one of three replicate plots.

2.5.4 Land use history and management assessment

Farmers were sent a questionnaire to collect information on the land use and management history of sampled fields following McCarthy et al. (2018). This questionnaire was completed for a corresponding total count of 87 out of the 100 sampled cropland plots.

2.6 Monitoring design

2.6.1 Micrometeorological data

Three weather stations (ATMOS 41, Meter, Germany) were installed in August 2018 in each geochemical region of project TropSOC close to the investigated forest catenae (mafic: latitude: -2.324457° / longitude: 28.740818°; felsic: latitude: 0.561767° / longitude: 30.356808°, mixed sedimentary rocks: latitude: -2.460503° / longitude: 29.095251°). An additional weather station was installed in the mafic region near a cropland catchment, (latitude: -2.583984° / longitude: 28.715298°) which was selected for high-resolution erosion monitoring (see Wilken et al. 2021).

Furthermore, a meteorological station in the city of Bukavu (latitude: -2.499979°, longitude: 28.845009°) and Lukananda (latitude: -2.344073°, longitude: 28.750937°) were put into operation. All stations collected data at a temporal resolution of 5 minutes on precipitation, air temperature, relative humidity and air pressure. Additionally, global radiation and wind speed were measured at stations Bukavu and Lukananda.

2.6.2 Litterfall sampling

Litterfall was assessed following a standardized protocol to measure tropical forest carbon allocation and cycling (Matthews et al., 2012). At each of our 36 forest soil sampled plots, 10 litter traps were installed and distributed evenly and systematically per plot. These had a diameter of 60 cm each and were installed at a height of 1.0 m above ground. Litter samples were collected every two weeks for the period between August 2018 and February 2020 and later aggregated, to assess seasonal and annual variability in litter productivity and quality (see section 2.4). Collected litter included all organic residues collected by the traps. Larger, dead animals and woody material > 2 cm in diameter were discarded. After sampling, material from all 10 traps per plot was mixed to obtain a composite sample. These composite samples were taken to the laboratory the day of sampling, oven-dried at 70°C for 72 hours and subsequently weighed (dry weight, accuracy: +/- 0.01g). Data is provided as Mg ha^{-1} day^{-1} per plot and as the sum of total litter production per plot, aggregated at the seasonal level and annual level. The considered seasons were categorized based on the average precipitation for each period: weak dry season (December-February), strong rain season (March-May), strong dry season (June-August) and weak rain season (September-November).

2.6.3 Belowground standing root biomass

For all soil sampled forest plots, standing root biomass and fine root production were assessed from September 2018 to December 2019. Sampling took place once per season within this period (one coring every three months) and a total of three rain seasons and three dry seasons) in 2018 and 2019 were covered. Each plot was divided into four equally sized subplots of 20 m x 20 m. Prior to deciding the root sampling strategy and size of depth intervals, root distribution was assessed using soil profiles that were dug in the plot centers for soil classification purposes. This assessment revealed that roots mostly dominated the organic horizons and the upper 50 cm of mineral soil (data not shown).

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Belowground standing root biomass was sampled using a soil core sampler (Vienna Scientific Instruments, Austria). Two cores were sampled per subplot where undisturbed soil cores were divided into five depth layers: one organic soil layer (O horizon), and four mineral soil layers from 0 – 10 cm, 10 – 20 cm, 20 – 30 cm, 30 – 50 cm. After transport to the laboratory, each sample was rinsed inside a 2 mm sieve; roots were separated into fine roots (<= 2 mm diameter) coarse (> 2 mm diameter) using calipers. In addition, fine and coarse roots were separated into living and dead roots based on criteria such as color, root elasticity and the degree of cohesion of cortex, periderm and stele; i.a. roots were considered living when root steles were bright and resilient (Ostonen et al., 2005). The dry mass of isolated roots per plot was assessed after previously having dried the root samples at 70 °C for 72 hours. Data is provided as mg cm^{-3} per plot per sampling date and is also aggregated at the seasonal and annual level.

2.6.4 Fine root net primary production

Fine root net primary productivity was assessed using the ingrowth net method following (Ohashi et al., 2016). Two net sheets (polyester mesh aperture size 2 mm, 10 cm wide, 20 cm high) were installed per subplot in a regular pattern with a distance of approximately 1 m between the two nets. Each net was vertically inserted in the top 20 cm of soil starting from the surface of the mineral layer. Nets were sampled every three months after installation and seasonally four times a year, from September 2018 to December 2019. Data is provided as g m^{-2} and g m^{-2} day^{-1} of total fine root production per plot over a certain period of time, and also provided aggregated at the seasonal and annual level.

2.7 Chemical and physical analyses

A wide range of chemical and physical parameters were assessed for the sampled soil and plant material with the aim to (i) characterize indicators of soil redistribution, (ii) the degree of soil weathering, (iii) the physical structure of soil as well as (iv) soil fertility and (v) soil organic carbon characteristics in order to link them to (vi) functional traits of the sampled biomass, (vii) biomass production and (viii) land management. For a full overview of all assessed parameters including their assessment methods, please consult the metadata accompanying the database.

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Among others, key measured parameters encompass:

Basic physical parameters

- Soil bulk density
- Soil texture
- Soil water holding capacity

Basic chemical parameters

- Soil pH (KCl)
- Soil potential cation exchange capacity and its base saturation
- Soil effective cation exchange capacity and its base saturation
- Main elemental composition of bulk soil (Al, Fe, Mn, Si, Ti, Zr, P) and the total reserve in base cations (Ca, Mg, Na, K) in rock parent material, soil, litter and vegetation samples
- Pedogenic oxides concentration (Al, Fe, Mn)

Available nutrients

- Dissolvable soil organic nitrogen and carbon
- Plant available phosphorus in soil

Organic matter characteristics

- Total and organic carbon and nitrogen content in rock parent material, soil, litter and vegetation samples
- Bulk soil radiocarbon signature
- CN ratio in soil, litter and vegetation samples
- Soil carbon stabilization mechanisms

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Microbial activity

- Heterotrophic soil respiration (including isotopic signature of respired gas)
- Microbial biomass during incubation
- Extracellular enzyme activity during incubation

Soil redistribution

- 239+240 Pu activity

All of the parameters listed above have been measured in soil for three depth layers (0-10 cm, 30-40 cm, 60-70 cm) representing distinct sections of the soil profile. Physico-chemical key properties of the remainder of soil samples in other soil layers have been assessed using mid-infrared spectroscopy and predicted following the workflow of Summerauer et al., 2021 in review). An overview of chemical and physical key soil parameters is provided in Appendix Table A1. Note that all physico-chemical soil properties and the corresponding mid-infrared data are part of the central African spectral library (Summerauer et al., 2021 in review) and minimize the need for future traditional soil analyses.

2.8 Milestones reached

Overall a total of approximately 2100 soil and rock samples were collected, of which about 10 - 30% were used yet for detailed analyses in different experiments by our group (see below). Additionally, 6000 above- and belowground biomass and litter samples were taken during several sampling and monitoring campaigns at forest and cropland sites. Several thousand and mid-infrared (NIR-MIR) spectra in the wavenumber range 600 cm^{-1} to 7500^{-1} (wavelength 1333.7 nm - 16666.7 nm) were collected across the sampled plant and soil samples and were used to train calibration models for each property to predict spatially and depth explicit soil parameters in relation to soil fertility, carbon stocks and carbon stabilization using partial least square regressions following the workflow of Summerauer et al., (2021 in review). Furthermore, since 2018, continuous monitoring has been carried out for the installed weather stations and vegetation dynamics in tropical forests have been assessed from August 2018 until December 2019. Water

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and heat fluxes between soil and atmosphere are monitored using several weather stations and soil probes to monitor heat and water transfer into soil.

Analyses conducted on collected samples, so far, contributed to scientific advances realized through

- the creation of a data frame of reference samples for calibration used in the newly developed soil spectral library for central Africa (Summerauer et al., 2021 in review).
- an investigation on the role of geochemistry and geomorphic position for soil organic matter stabilization mechanism and patterns of SOC stocks in tropical rainforests (Reichenbach et al., 2021 in review).
- an investigation of the role of geochemistry and geomorphic position on the heterotrophic soil respiration (Bukombe et al., 2021 in review) as well as the role of adaptations of microbial communities and their strategies to access nutrients along the investigated forest gradients (Kidinda et al., 2020 in review).
- an assessment of the suitability and the application of radioisotope $^{239+240}$Pu inventories for studying soil erosion processes in tropical forests and cropland (Wilken et al., 2020 in review)
- soil fractionation and incubation experiments encompassing cropland soils along geomorphic and geochemical gradients (unpublished).
- as part of this manuscript, the entirety of TropSOC's data is available as an open-access database with extensive metadata documenting experimental approaches, framing of the analyses, data quality and methodology. An overview of all datasets presented in this database is given in Appendix Table A2.

In summary, TropSOC's first results demonstrate that even in deeply weathered tropical soils, parent material has a long-lasting effect on soil chemistry that can influence and control microbial activity, the size of subsoil C stocks, and the turnover of C in soil. Soil parent material and the resulting soil chemistry need to be taken into account in understanding and predicting C stabilization and turnover in tropical forest soils. Given the investigated rates of erosion on cropland, our findings confirm the threat of large losses or organic matter leading to sharp decline in soil fertility with little potential of soils to recover from nutrient losses naturally on decadal or

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centennial timescales. TropSOC highlights that considering feedbacks between geochemistry and topography to understand the development of soil fertility in the Afrcan Great Lakes Region regions can significantly improve our insights into the role of tropical soils for reaching several key sustainable development goals such as climate mitigation and zero hunger and help to raise awareness for the need to maintain limited soil resources for future generations. Future work realized in project TropSOC based on the database will provide further insights into biomass and plant trait responses to soil geochemistry in forests, as well as cassava yield responses and SOC dynamics in cropland along the investigated geomorphic and geochemical gradients across the region.

3. Structure of TropSOC project database (TropSOC v1.0)

3.1 Database hierarchy

Datasets are given as tab-delimited .csv files. For each .csv file the metadata describing data structure and assessment methods are given in a .pdf file of the same name. Moreover, additional .pdf files for each main section of the database (basic information, forest, cropland, and microscale meteorology) are given, providing an overview of the structure within each section. Note that the '**basic information**' section of the database provides the linkages between individual data, e.g. from soil analysis and the location and/or soil depths where these samples were acquired (for linkages see also Figure 6).

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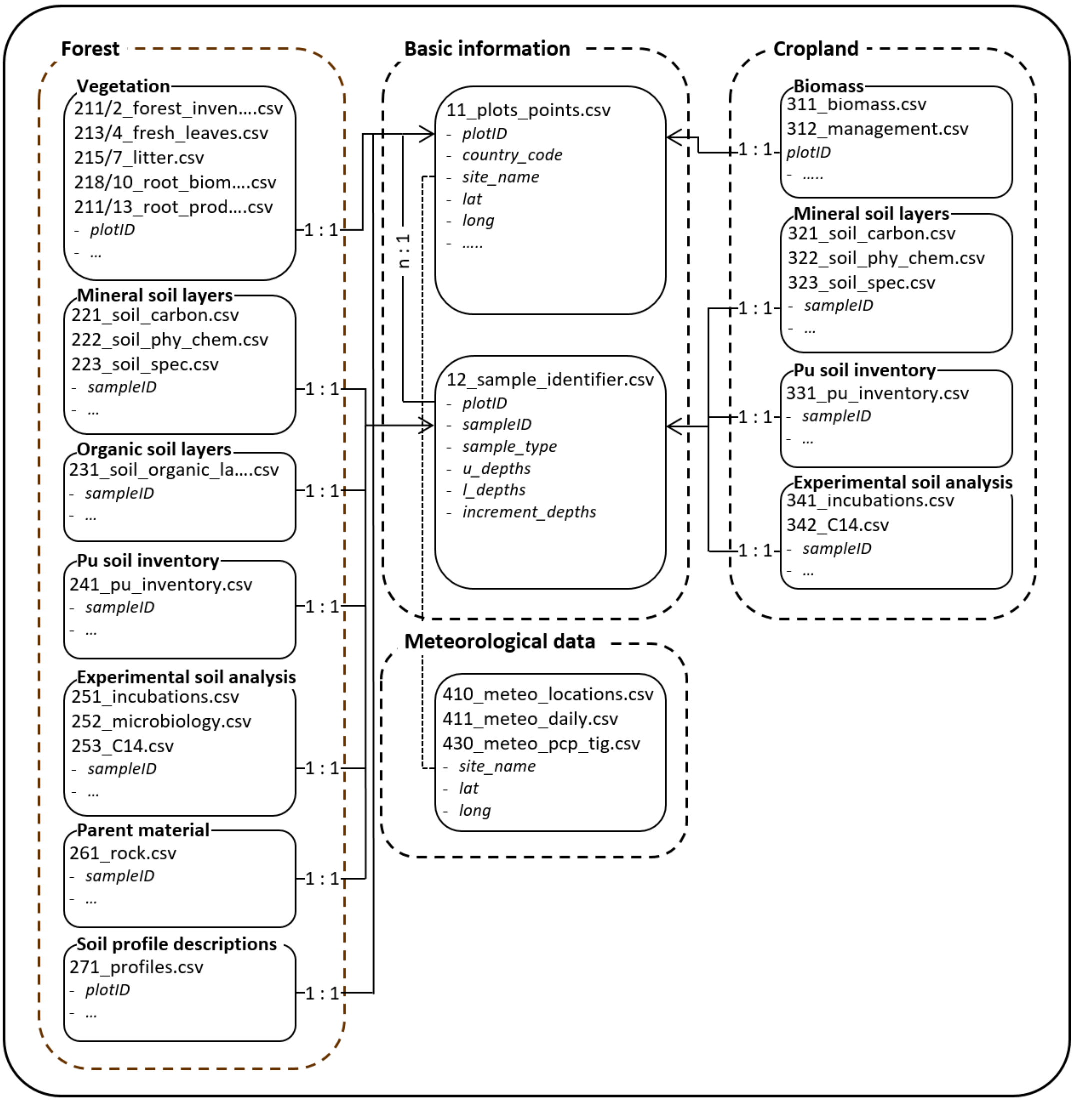

Figure 6. Overview of linkages between datasets in the TropSOC database v1.0. Note that for each data .csv-file an .pdf-file is given detailing the metadata of the respective data sheet.

3.2 Database infrastructure

3.2.1 Basic information

The database comprises basic information of all plots and single point sampling positions where data were collected during project TropSOC. An overview of the structure of the database is presented in Appendix Table A2. The basic information of the database is structured in the following way:

Part 1 – Location and basic background information for all plots and points where data were collected. Data can be found in file *11_plots_points.csv,* with description given in *11_plots_points.pdf*.

Part 2 – Sample identifier for the database' internal connection between location of plots, points and soil data from different soils depths as well as vegetation data. Data is stored in *12_sample_identifier.csv*, with description given in *12_sample_identifier.pdf*.

The key element to link all datatables for which data was collected and samples analyzed is the plot ID and its derivative the sample ID. This identifier allows to link the results from sample analysis with the locations given in *11_plots_points.csv*. This results in a n:1 connection between *12_sample_identifier.csv* and *11_plots_points.csv*. See metadata file 11_plots_points.pdf for an overview on the structure of the plots ID and 12_sample_identifier.pdf for an overview on the structure of the sample ID.

3.2.2 Forest

TropSOC's forest data consists of seven parts (Table A2 for overview) structured as paired .csv / .pdf files, containing the data (.csv) and accompanying metadata (.pdf) describing parameters and methods. Additionally, an overview to all collected forest data is given in file *2_forest.pdf.*

Part 1 – Above and belowground vegetation data acquired in 2018, 2019 and 2020 at all forest plots, comprising 13 data sets (Dataset files 2.1.1 - 2.1.13).

Part 2 – Mineral soil layer data acquired in 2018 at all forest plots, comprising 3 data sets (Dataset files 2.2.1 - 2.2.3).

Part 3 – Organic soil layer data acquired in 2018 at all forest plots, comprising 1 data set (Dataset file 2.3).

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Part 4 – $^{239+240}$Pu soil inventory carried out in 2018. In contrast to part 1 to 3 of the forest data, Pu data represents individual points and does not follow the plot concept in a strict manner (Dataset file 2.4).

Part 5 – Soil experiments carried out from 2018 to 2020, comprising 3 data sets with results from laboratory soil incubation and fractionation experiments and additional data from soil sample analyses (Dataset files 2.5.1 - 2.5.3).

Part 6 – Parent material elemental composition analysed based on unweathered rock samples taken within plots or from nearby road cuts and mines surrounding the study sites (Dataset file 2.6).

Part 7 – Soil profile descriptions done in soil pits at the centre of plots following WRB-FAO soil description (Dataset file 2.7).

3.2.3 Cropland

TropSOC's cropland data consists of the following seven parts (Table A2 for overview) structured as paired .csv / .pdf files, containing the data (.csv) and accompanying metadata (.pdf) describing parameters and methods. Additionally, an overview to all collected cropland data is given in file *3_cropland.pdf*.

Part 1 – Biomass and management data acquired in 65 and 87 out of 100 sampled cropland plots respectively, comprising 2 datasets (Dataset files 3.1.1 - 3.1.2).

Part 2 – Data on mineral soil layers was acquired in 2018 for 100 cropland plots and comprising 3 datasets (Dataset files 3.2.1 - 3.2.3).

Part 3 – Pu soil inventory carried out in 2018. In contrast to part 1 and 2 of the cropland data, Pu data represents individual points and not plots and was sampled across several catchments (Dataset file 3.3).

Part 4 – Soil experiments. This part of the database comprises 2 datasets with results from laboratory soil incubation and fractionation experiments and additional data from soil sample analyses (Dataset files 3.4.1 - 3.4.2).

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3.2.4 Meteorological data

The meteorological data comprises 4 parts (Table A2 for overview) structured as paired .csv / .pdf files containing the data (.csv) and accompanying metadata (.pdf) describing parameters and methods:

Part 1: Locations of meteorological stations: Coordinates, elevations and contact addresses for the respective data (Dataset file 4.1).

Part 2: Daily meteorological data: six meteorological stations recording precipitation, air temperature, relative humidity, air pressure, solar radiation, wind speed (Dataset file 4.2).

Part 3: High resolution five-minute triggered precipitation data: Precipitation recorded at the time of tipping bucket tilt at a resolution of five-minutes resolution (Dataset file 4.3).

4. Database status

4.1 TropSOC v1.0

The current version, v1.0, of TropSOC includes several thousand individual plant and soil samples collected across 136 sites spanning cropland and forests in the East African Rift Valley System and a large variety of parameters. A total of 36 .csv datasheets is available that gives all analyses done for specific samples. Datasheets are structured according to the descriptions given in section 3 and described and elaborated on in the accompanying metadata files. The current distribution of data points across the various levels of the database hierarchy is shown in Table 2. All individual data entries present in the database have passed quality control done by experts that were involved in the creation of the data. Where applicable, reports on the quality assessment of each parameter can be found in the metadata .pdf files accompanying the .csv files.

Table 2. Overview on the current number of data points in TropSOC v1.0 on plant, soil and meteorological and their affiliation to the hierarchical levels forest and cropland. Numbers in tables refer to the number of data entries at the lowest available aggregation level (= highest resolution of data). For details on parameters, see the according metadata descriptions. Note that in the felsic (Uganda) and mixed sediment region (Rwanda) collected weather station data represents both cropland and forest while separate stations were available for the two land cover classes in the mafic region (DRC). Abbreviations: SOM = Soil organic matter.

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Plant-Soil observations	**Plots**	**Bulk soil samples (0-100 cm soil depth, 10cm increments)**	**Bulk Vegetation samples (above/ belowground)**	**Incubated soil layers**	**SOM fractionated soil layers**	**Plots with vegetation assessments**
Forest	36	916	1437/4374	112	145	40
Cropland	100	1190	132/66	131	159	65
Total	**136**	**2106**	**1569/4400**	**243**	**304**	**105**
Meteorological observations	**Stations**	**Precipitation**	**Air temperature**	**Relative humidity**	**Global Radiation**	**Wind speed**
Felsic region	1	541	541	541	0	0
Mafic region (forest)	1	674	858	860	860	644
Mafic region (cropland)	3	1310	1310	1312	709	650
Mixed sediment region	1	90	520	565	0	0
Total	**6**	**2615**	**3229**	**3278**	**1569**	**1294**

4.2 Accessing TropSOC v1.0 and reporting issues/ask questions to its hosting platform CBO

Users may access the TropSOC database v1.0 and its supporting information through the supplementary material provided as part of this submission. Version v1.0 of the database is also available through the data download section of the Congo Biogeochemistry Observatory (CBO) (https://www.congo-biogeochem.com/data) and the PANGEA open access environmental data repository. CBO is a consortium of researchers who study biogeochemical cycles and atmosphere-plant-soil interactions in tropical Africa with a focus on the Congo Basin and the African Great Lakes region (Doetterl et al. 2020). Within CBO's framework, a multinational group of young scientists from Africa, Europe and the United States conducts cross-disciplinary environmental research across tropical Africa but with focus on the Congo basin. The dedication of young African researchers to understand and preserve the threatened natural resources of their home countries is paired with the resources of some of the most experienced and largest research groups focusing on African tropical forest and agroecosystems. Founded in 2018 by scientists of several African and European institutions and support by multinational organization such as CGIAR-IITA and CGIAR-ICRAF, CBO has become an important scientific network in tropical Africa for studying biogeochemistry in soils and sediments creating synergies between local key institutions and international researchers, crucial for the implementation of research in remote and difficult to access environments. Research at CBO is funded and supported by German, Belgian, US and Swiss Research foundations and linked to research institutes at Ghent University, Augsburg University, Florida State University, ETH Zurich, the University of Louvain and the Max Planck Society.

Users are encouraged to provide feedback and corrections to existing data if problems are discovered by contacting CBO (contact@congo-biogeochem.com) or the corresponding author of this manuscript (sdoetterl@usys.ethz.ch). Corrections will be implemented in consecutive versions of the database that can be downloaded via the CBO site.

4.3 Consecutive database versioning and archiving

Updated versions of the database will be periodically released following either substantial changes or new peer-reviewed publications, leveraging the dataset. Versioning of these official releases are tracked using an associated version number, e.g. TropSOC v1.0, and so on. These official releases will be archived at ETH Zurich's Research collection via ETH's Soil Resources Group (https://soilres.ethz.ch/) and the CBO data storage (https://www.congo-biogeochem.com/data) with a dataset DOI issued for each release via ETH Zurich so that users may revert back to the earlier version if so required. These archived releases will be maintained into perpetuity to facilitate reproduction of any analyses conducted using a past version of the database. When accessing the dataset and using it for own research, users commit to cite the original manuscript provided here in addition to the version number, DOI and any description provided to future versions of the database (see section 6 for details).

5. Database governance and participation

TropSOC is a community effort with multiple contributors operating at different levels (Figure 7). Governance of TropSOC is required in order to ensure continuity of services and to plan for the future evolution of this data repository. Studying the rapid environmental changes to the African Tropics is a central research objective for the scientists of the Congo Biogeochemistry Observatory (CBO) making it the ideal body to govern future versions of TropSOC. The governance structure of TropSOC is briefly described in Figure 7. While the TropSOC core team is responsible for the original version of the database, its maintenance, management and archiving, scientists involved in the Congo Biogeochemistry Observatory (CBO) oversee the establishment of cooperative agreements on the long term and act as a steering committee for modifications on TropSOC suggested by the research community. The main role of the steering committee is to determine the feasibility of major changes to TropSOC proposed by the community and to coordinate activities that would like to build upon TropSOC or continue similar research work within the framework of CBO. Although the structure of TropSOC is oriented around individual and research projects, the nature of scientific research is often more group-

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focused. For example, teams of researchers generally work together to seek out funding and to conduct research. Thus, in some cases a group or team of individuals may seek to utilize or modify TropSOC for their purposes. Such groups can petition the scientific steering committee to be formally designated a CBO member group. Approved organizations should nominate a member to serve on the steering committee.

Interested researchers are also invited to contribute data to future versions of TropSOC in order to grow the database. Anyone can be a data contributor provided they agree to the terms of use and follow the proper steps for contributing data to TropSOC. If such suggestions arise, the CBO steering committee together with the TropSOC core team are responsible for approving the suggested changes and additions to the database. Upon approval, the TropSOC core team will interact with the new data contributors to implement the suggested data additions. In the case of organizations or individuals making larger changes or additions to TropSOC, a designated data maintainer from new contributor groups is required to coordinate the technical aspects of the implementation of changes together with the TropSOC core team. Within the pool of data contributors, individuals with significant experience working with TropSOC may be designated, either by the steering committee or database maintainers, as expert reviewers. These individuals are tasked to assist maintainers and oversee peer review and quality assessment of contributed new entries.

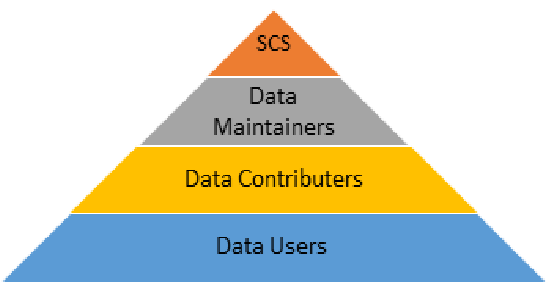

Figure 7. A simplified depiction of the TropSOC governance. The scientific steering committee (SCS) is responsible for approving major management decisions. The TropSOC core team as data maintainers are responsible for implementing broader changes together with new data contributors. All interested scientists are welcome to contribute data to future versions of the data base or access the data for their own research.

6. Data Availability and User Guidelines

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All data presented in this study is part of the publication and added as a supplement consisting of datatables (.csv) and accompanying metadata descriptions (.pdf files). In addition, the database and its metadata is archived and published in the open access environmental and geoscience data repository at the German Research Centre for Geosciences (GFZ), accessible at: https://doi.org/10.5880/fidgeo.2021.009. Please note that the database DOI is currently in preparation and will be released as soon as the review process is completed. In the meanwhile, please use the following link to access the database (version 1.0) or consult the supplement added to this submission:

https://dataservices.gfz-potsdam.de/panmetaworks/review/efed3d5f6035ca261a95aaab45704c2d7d69ac1219d4abd3773d5f104a4900d3/

Additionally the database is accessible via the website of the Congo Biogeochemistry Repository (https://www.congo-biogeochem.com/data). Updated versions of the database will be made available as version updates at both repository.

As detailed above, TropSOC is an open source project that provides several ways for participation. Anyone may share the TropSOC dataset provided they do so in accordance with the Creative Commons Attribution 4.0 International Public License (https://creativecommons.org/licenses/by/4.0/legalcode) and by citing the according references of the original database description and future modifications under their separate DOI.

In addition, we strongly encourage TropSOC users to follow these simple guidelines for use:

(1) TropSOC users must agree not to manipulate the original source data without permission of the TropSOC governance team described in section 5. This process should be followed in particular when groups or individuals seek to use the TropSOC database beyond the scope of its original objectives (see section 1.1).

(2) When utilizing TropSOC data, including the complete dataset, individually curated entries, or value-added calculations, users should cite this publication and reference the version of TropSOC that was used for their work under its specific DOI.

When using the database, please cite TropSOC v1.0 as:

Doetterl, S.; Bukombe, B.; Cooper, M.; Kidinda, L.; Muhindo, D.; Reichenbach, M.; Stegmann, A.; Summerauer, L.; Wilken, F.; Fiener, P. TropSOC Database. Version 1.0. GFZ Data Services. https://doi.org/10.5880/fidgeo.2021.009, 2021.

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Additionally, please cite this publication here where the data is first described as:

Doetterl S., Asifiwe R.K., Baert G., Bamba F., Bauters M., Boeckx P., Bukombe B., Cadisch G., Cizungu L.N., Cooper M., Hoyt A., Kabaseke C., Kalbitz K., Kidinda L., Maier A., Mainka M., Mayrock J., Muhindo D., Mujinya B.B., Mukotanyi, S.M., Nabahungu L., Reichenbach M., Rewald B., Six J., Stegmann A., Summerauer L., Unseld R., Vanlauwe B., Van Oost K., Verheyen K., Vogel C., Wilken F., Fiener P. Organic matter cycling along geochemical, geomorphic and disturbance gradients in forests and cropland of the African Tropics - TropSOC Database Version 1.0. *Earth System Science* XXX, DOI XXX, 2021.

(3) If users leverage individual data entries from the database, they should also cite the original research studies in which this particular data has been used for its first time (e.g. Bukombe et al., 2021, Kidinda et al., 2021; Reichenbach et al., 2021; Summerauer et al., 2021; Wilken et al., 2021)

(4) When users interpret their own data in the context of data accessed from TropSOC, they should submit those new data for inclusion in TropSOC after they have published their results and/or obtained a DOI for their dataset (Details of contributing process see section 5).

7. Conclusions and Outreach

The TropSOC database is an attempt to gather the data used in individual studies in one place and in the same format to facilitate comparisons and synthesis activities. TropSOC is unique in that it includes measurements and monitoring data of bulk soil and vegetation responses in the African tropical context for the first time on carefully selected and comparable land use, geomorphic and geochemical gradients at the landscape scale. Building on the data gathered along these gradients during several years of field activities and carrying out numerous lab experiments to investigate the impact of soil geochemistry and land degradation on biogeochemical cycles in tropical plant-soil systems, TropSOC is the largest integrative project database on plant-microbial-soil systems in the Congo basin to date. TropSOC's open-access database structure and participatory approach makes it a suitable tool for scientists to study experimentally defined soil disturbance and plant responses, as well as to test some of the assumptions behind modelling biogeochemical cycles in land surface models. Furthermore, we hope to encourage the community to increase the effectiveness of that investment, and to use the TropSOC database as a repository to increase the impact of your own research results. As such, TropSOC is an interactive database that is open for contributions. In addition, TropSOC now manages one of the largest topically structured soil and plant sample archives for tropical eastern

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Africa with several thousand samples and more than three tons of plant and soil material stored at ETH Zurich. Subsamples of all the above are available upon request to interested researchers.

Finally, we hope that work based on the TropSOC database can help to provide answers on the role and magnitude of geochemistry, as well as soil mobilization, in controlling biological processes and fluxes of carbon and nutrients in the Tropics in order to better constrain soil processes in models ranging from profile to global scales (Todd-Brown et al. 2013). Reducing the uncertainties associated with our understanding of tropical (agro-) ecosystems in diverse but rapidly changing landscapes is one of the most pressing issued for securing the future well being of hundreds of millions of people and to constrain land loss in an area that is home to some of the last and most fragile populations of great apes in the wild. Elucidating the gravity of the consequences for soil functioning that can be observed in the TropSOC's study area can contribute to reducing the large uncertainty associated with terrestrial biogeochemical processes in models and raise awareness for the necessity of pressing for and creating socio-economic fundament for sustainable land management in tropical Africa.

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8. Appendix

Appendix Table A1. Basic chemical and physical soil parameters aggregated at land use and geochemical regions. Displayed are average values and standard deviation taken over ten soil increments á 10 cm taken from 0 - 100 cm soil depth derived from NIR-MIR spectral data, calibrated on samples from three depth increments (0 – 10 cm; 30 – 40 cm; 60 – 70 cm). See metadata files 223_soil_spec.pdf and 323_soil_spec.pdf for details. Abbreviations: CEC = potential cation exchange capacity; ECEC = effective cation exchange capacity; Si = Silica; Al = Aluminum; Fe = Iron; Mn = Manganese; SOC = Soil organic carbon; SON = Soil organic nitrogen; P = Phosphorus; TRB = Total reserve in base cations; BD = Bulk density. All assessment methods are explained in the according .pdf metadata files accompanying the database.

Geochemical region	**Mafic**		**Felsic**		**Mixed sedimentary rocks**	
Land use	*Forest n = 169*	*Cropland n = 370*	*Forest n = 201*	*Cropland n = 239*	*Forest n = 174*	*Cropland n = 305*
Soil Chemistry						
pH (KCl)	3.92 ± 0.45	4.21 ± 0.32	4.96 ± 0.64	5.00 ± 0.44	3.48 ± 0.35	4.14 ± 0.42
CEC [me/100 g]	34.14 ± 4.89	21.26 ± 7.46	15.24 ± 5.37	26.33 ± 6.69	14.71 ± 11.50	19.02 ± 9.17
share of bases in CEC [%]	13.21 ± 14.16	13.90 ± 10.04	59.92 ± 20.87	52.72 ± 12.75	5.66 ± 11.68	18.58 ± 17.65
ECEC [me/100g]	9.12 ± 3.55	4.90 ± 3.00	10.43 ± 5.40	13.74 ± 3.93	5.53 ± 2.49	6.49 ± 4.63
share of bases in ECEC [%]	46.08 ± 18.66	48.69 ± 15.67	81.72 ± 20.67	91.74 ± 16.45	9.94 ± 15.83	41.36 ± 23.13
Si [%]	12.41 ± 1.36	11.88 ± 2.18	19.35 ± 2.83	16.35 ± 1.88	18.99 ± 5.46	15.59 ± 1.84
Al [%]	9.02 ± 1.11	6.37 ± 2.39	2.81 ± 1.11	4.08 ± 1.29	3.10 ± 2.92	3.20 ± 1.97
Fe [%]	10.32 ± 1.67	10.98 ± 2.58	3.50 ± 1.84	5.05 ± 1.68	5.65 ± 3.54	5.77 ± 1.71
Mn [%]	0.25 ± 0.07	0.19 ± 0.10	0.14 ± 0.11	0.26 ± 0.10	0.25 ± 0.09	0.08 ± 0.12
SOC [%]	2.79 ± 1.55	2.12 ± 1.24	1.17 ± 1.25	2.14 ± 1.45	2.87 ± 1.82	2.49 ± 1.42
SON [%]	0.28 ± 0.14	0.18 ± 0.10	0.12 ± 0.12	0.22 ± 0.12	0.15 ± 0.14	0.20 ± 0.12
SOC/SON [-]	9.09 ± 6.94	15.2 ± 7.89	12.30 ± 8.78	11.67 ± 14.07	38.13 ± 46.07	20.52 ± 9.07
Total P [%]	0.20 ± 0.07	0.12 ± 0.06	0.12 ± 0.06	0.30 ± 0.10	0.07 ± 0.07	0.10 ± 0.08
TRB [%]	0.56 ± 0.22	0.18 ± 0.19	0.60 ± 0.27	1.03 ± 0.30	0.09 ± 0.17	0.21 ± 0.30
Soil Physics						
BD [g/cm^3]	1.20 ± 0.14	1.28 ± 0.16	1.64 ± 0.16	1.41 ± 0.16	1.43 ± 0.34	1.42 ± 0.19
clay [%]	54.79 ± 11.79	64.76 ± 13.00	41.45 ± 11.44	35.17 ± 11.26	39.60 ± 14.77	43.12 ± 11.40
silt [%]	13.94 ± 2.29	11.01 ± 3.28	10.23 ± 3.70	14.42 ± 3.76	21.73 ± 13.03	14.45 ± 5.20
sand [%]	31.39 ± 10.20	24.84 ± 9.55	51.08 ± 10.52	48.81 ± 8.11	39.10 ± 18.69	41.50 ± 9.15

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Appendix Table A2. Structure of the TropSOC database. For each topic a .pdf file is given that entails an overview for the available data on soil, vegetation and weather data collected for the investigated forest and cropland plots. Each dataset then comprises a data-containing .csv file and an additional metadata-containing .pdf file of the same name.

	Introduction & structure of the data base	0_intro_structure.pdf
1.	**Basic information**	**1_basic_information.pdf**
1.1.	Location and basic background information for all plots and points where data were collected	11_plots_points.csv/pdf
1.2.	Data base internal connection between location of plots and points and soil data from different soil depths	12_sample_identifier.csv/pdf
2.	**Forest**	2_forest.pdf
2.1.	Vegetation	
2.1.1.	Forest inventory	211_forest_invent.csv/pdf
2.1.2.	Forest inventory aggregated	212_forest_invent_agg.csv/pdf
2.1.3.	Fresh leaves chemistry	213_fresh_leaves.csv/pdf
2.1.4.	Fresh leaves chemistry aggregated at species level	214_fresh_leaves_agg.csv/pdf
2.1.5.	Litter fall	215_litter.csv/pdf
2.1.6.	Litter fall aggregated to seasonal values	216_litter_seasonal.csv/pdf
2.1.7.	Litter fall aggregated to annual values	217_litter_annual.csv/pdf
2.1.8.	Root biomass	218_root_biomass.csv/pdf
2.1.9.	Root biomass aggregated to seasonal values	219_root_biomass_seasonal.csv/pdf
2.1.10.	Root biomass aggregated to annual values	2110_root_biomass_annual.csv/pdf
2.1.11.	Root productivity	2111_root_prod.csv/pdf
2.1.12.	Root productivity aggregated to seasonal values	2112_root_prod_seasonal.csv/pdf
2.1.13.	Root productivity aggregated to annual values	2113_root_prod_annual.csv/pdf
2.2.	Mineral soil layers	
2.2.1.	Soil carbon and nitrogen including different organic matter fractions	221_soil_carbon.csv/pdf
2.2.2.	Physical and chemical soil properties from traditional laboratory analyses.	222_soil_phy_chem.csv/pdf
2.2.3.	Physicochemical soil properties from NIR-MIR spectroscopy	224_soil_spec.csv/pdf
2.3.	Organic soil layers	231_soil_organic_layer.csv/pdf
2.4.	Pu soil inventory	241_pu_inventory.csv/pdf
2.5.	Soil experiments	
2.5.1.	Incubation experiments	251_incubation.csv/pdf
2.5.2.	Microbial biomass and enzyme experiments	252_microbiology.csv/pdf
2.5.3.	^{14}C data from bulk soil and CO_2 measurements	253_c14.csv/pdf
2.6.	Parent material	261_rocks.csv/pdf
2.7.	Soil profile descriptions	271_profiles.csv/pdf
3.	**Cropland**	3_cropland.pdf
3.1.	Biomass & management	
3.1.1.	Biomass yield based on plot data	311_biomass.csv/pdf
3.1.2.	Land management data	312_management.csv/pdf
3.2.	Mineral soil layer characterization	
3.2.1.	Soil carbon and nitrogen including different organic m atter fractions	321_soil_carbon.csv/pdf
3.2.2.	Physicochemical soil properties from traditional laboratory methods	322_soil_phy_chem.csv/pdf
3.2.3.	Physicochemical soil properties from NIR-MIR spectroscopy	323_soil_spec.csv/pdf
3.3.	$^{239+240}Pu$ soil inventory	331_pu_inventory.csv/pdf
3.4.	Soil experiments	
3.4.1.	Incubation experiments	341_incubation.csv/pdf
3.4.2.	^{14}C data from bulk soil and CO_2 measurements	342_c14.csv/pdf
4.	**Meteorological data**	4_meteo.pdf
4.1.	Locations of meteorological stations	410_meteo_locations.csv/pdf
4.2.	Daily meteorological data from six meteorological stations	420_meteo_daily.csv/pdf
4.3.	High resolution 5 min triggered precipitation data	430_meteo_pcp_tig.csv/pdf
4.4.	Meteorological data aggregated to monthly and seasonal values	440_meteo_monthseas.csv/pdf

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9. Sample availability

Remaining soil and plant samples are logged and barcoded at the Department of Environmental Science at ETH Zurich, Switzerland.

10. Team list

See acknowledgements and author list.

11. Author contribution statement

SD functioned as the project leader. SD and PF were lead coordinators for compiling the data base, responsible for data analysis and designed the metadata. BB, MC, LK, DM, MR, LS and FW were collecting and creating datasets and also analyzed these data before inclusion into the database. RKA, FB, MC, CB, AM, MM, JM, SMM, LN, AS, RU and CV were technical contributors and participated via data collection. GB, MB, PB, GC, LNC, AH, KK, BBM, BR, JS, BV, KVO and KV were conceptual contributors and participated in the design of the study as well as by giving advice and feedback during the campaign. SD and PF wrote the paper. All authors supported data analysis and gave feedback during the writing process.

12. Competing interests

All other authors declare that they have no conflict of interest.

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13. Special issue statement

Data presented in this article is the fundament for several research articles published as part of the Copernicus Special Issue in SOIL with the title: *Tropical biogeochemistry of soils in the Congo Basin and the African Great Lakes region*.

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