

Global black soil distribution

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KEYWORDS

Black soils, distribution map, food security, soil organic carbon

HIGHLIGHTS

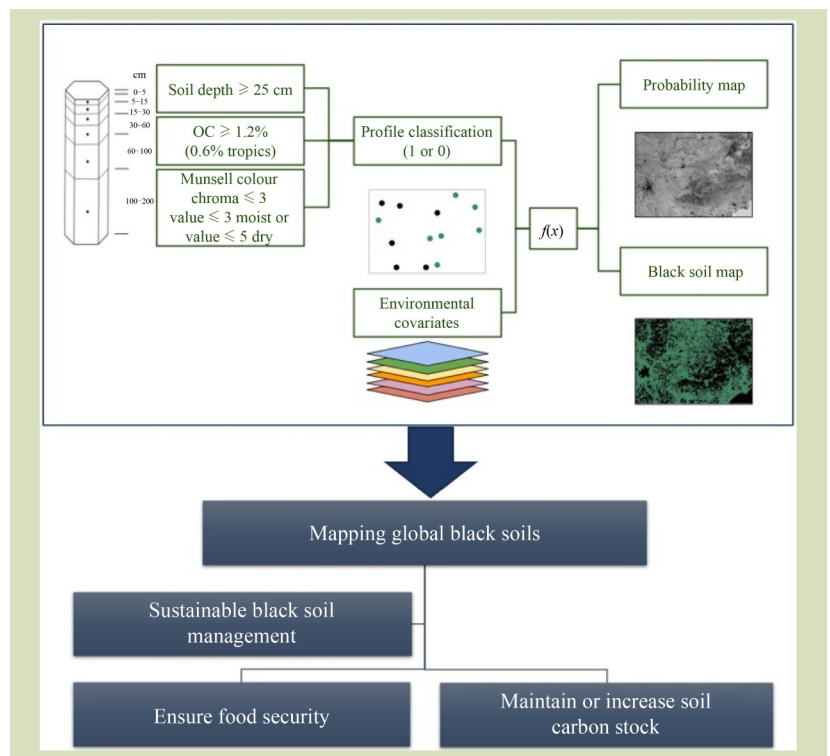
- Global black soil distribution map developed by using country-driven approach.
- Black soils are key to global food security and climate change mitigation and adaptation.
- Black soils form under various pedoenvironments at global level.
- Black soils predominantly occur in Eastern Europe, Central and Eastern Asia, and the northern and southern extremities of the Americas.
- Black soils hold a substantial global soil organic carbon stock, amounting to about 56 Gt.

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GRAPHICAL ABSTRACT



ABSTRACT

Black soils, characterized by their thick, dark horizons enriched with organic matter, epitomize highly fertile soils. However, their fertility precipitates intense land use, engendering challenges such as soil erosion, nutrient depletion, pollution, compaction, salinization, and acidification. Notably, these soils are significant contributors to global greenhouse gas emissions, primarily due to substantial losses in soil organic carbon. Despite these challenges, black soils are pivotal for global food production. This paper delineates the implementation of digital soil mapping for the global cartography of black soils and human interference on these soils. Predominantly distributed in Eastern Europe, Central and Eastern Asia, and North and South America, black soils cover an approximate area of 725 Mha, with the Russian Federation, Kazakhstan, and China collectively have over half of this area. Agriculturally, these soils underpin significant proportions of global crop yields, producing 66% of sunflower, 30% of wheat, and 26% of potato outputs. The organic

carbon content in the upper 30 cm of these soils is estimated at 56 Gt. Sustainable management of black soils is imperative for ensuring food security and addressing climate change on a global scale.

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1 Introduction

Black soils are mineral soils which have a black surface horizon that is rich in organic carbon to at least 25 cm deep^[1]. Their inherent high fertility often leads to intensive land use, resulting in a spectrum of environmental challenges. These include soil erosion, nutrient depletion, pollution, compaction, salinization, and acidification. Additionally, these soils are significant sources of greenhouse gas emissions, primarily due to the high losses of soil organic carbon (SOC). Despite these environmental impacts, black soils are crucial to global food production, contributing substantially to agricultural output^[2].

For centuries, the black soil regions of Eurasia and North America have been extensively cultivated. Such cultivation, primarily focused on cereals, oilseeds, and pastures, coupled with land use change and the excessive use of fertilizers, has resulted in a substantial decline in the SOC content of these soils, with losses ranging from 20% to 50% of their original SOC levels^[3–8]. This decline has led to the release of significant amounts of carbon, predominantly in the form of CO₂, contributing to the intensification of global warming. Research by Lal in 2021^[9] highlighted the significant role of Chernozems soils in the global efforts for climate change adaptation and mitigation. These soils are capable of sequestering between 0.7 and 1.5 Mg·ha⁻¹·yr⁻¹ C when managed sustainably, thereby being crucial for lowering global greenhouse gas emissions.

The current military conflict in Eurasia presents a significant challenge to global agrifood production. This issue was a key topic during the 169th session of the FAO Council, where the link between ongoing conflicts and food insecurity was extensively discussed. Russia and Ukraine, known for their rich black soils, are major contributors to the global food supply, accounting for nearly 30% of global wheat exports and about 80% of sunflower oil exports^[10]. Additionally, this conflict has led to the deterioration of these fertile soils, contaminating them with various pollutants such as heavy metals, depleted uranium and napalm. This contamination has resulted in a marked decrease in the biodiversity of black soils^[11]. Therefore, understanding the geographical distribution and condition of black soils is crucial for evaluating their role in food security and their capacity for carbon sequestration.

Black soil distribution varies widely worldwide, with some countries including Argentina, Canada, China, Russia and the USA having extensive areas, whereas others, such as Ukraine, are known for their high organic matter content in black soils. The level of research and mapping of black soils also differs greatly, being well-advanced in some countries but still emerging in others.

Digital soil mapping (DSM) represents a structured approach for producing intricate mappings of soil varieties and features. This technique uses mathematical and statistical frameworks to blend soil observation data with environmental factors. DSM is extensively used for predicting distributions of soil types^[12–15], presenting numerous advantages compared to traditional approaches, such as the facility for documenting and updating the mapping procedure and the ability to gauge predictive uncertainty. To determine the worldwide distribution of black soils, each country is required to generate its black soil map, demanding a grassroots, country-driven method to determine the worldwide extent of black soils. This method proved effective in the development of the FAO Global Soil Organic Carbon Map (GSOCmap)^[16], indicating its usefulness for developing an all-encompassing global black soil map. Developing such a map would improve understanding of the role of black soils in enhancing food security and aiding in climate change mitigation.

This paper outlines the DSM methodology used for mapping black soils at both national and global levels, and to highlight the crucial role of black soils in global food security and carbon storage. Additionally, it presents an opportunity to explore the diversity of black soils worldwide, covering major types and their pedogenetic characteristics.

2 Materials and methods

The development of the global black soil map involved in two stages. During the first stage, the International Network of Black Soils (INBS) designed a process for its member countries to generate their own black soil maps. This phase included comprehensive training for these countries to guarantee uniformity and precision. Once trained, the maps from each

member country were collated and merged. The second stage involved a gap-filling technique using the data from these maps. A predictive model was developed using these data, aimed at identifying black soil distribution in INBS member countries that were unable to complete their own maps. This methodology, encompassing map development and aggregation as well as gap-filling through predictive modeling, allowed for the creation of a global map of black soil distribution.

2.1 Stage 1: the creation of national maps

Our research employed a four-step methodology targeting soil layers down to a depth of 25 cm, aligning with the FAO definition of black soils. This characterization defines black soils as mineral soils with a dark top layer, rich in organic carbon and extending at least 25 cm deep, distinguished by the main three properties listed below: Munsell color, topsoil depth and organic carbon content. The first step involved classifying the soil profiles into two categories: black soils (BS) (1) or non-BS (0). To this purpose, the following soil attributes were needed: profile identifier (ID); 1

- Profile identifier (ID)
- Latitude in geographical coordinates wgs84 (Y)
- Longitude in geographical coordinates wgs84 (X)
- Top boundary of the horizon/layer in cm (TOP)
- Bottom boundary of the horizon/layer in cm (BOTTOM)

- Wet Munsell color (in different columns)
 - Hue (W_hue)
 - Chroma (W_chroma)
 - Value (W_value)
- Dry Munsell color (in different columns)
 - Hue (D_hue)
 - Chroma (D_chroma)
 - Value (D_value)
- Organic carbon concentration in percentage (SOC)

To qualify as black soil (BS)^[1], these layers had to adhere to specific criteria illustrated in Fig. 1. The Munsell color needed to have a chroma (color intensity) of 3 or less and a value (lightness) of three or less when moist, or five or less when dry. The organic carbon content in these horizons had to be equal to or greater than 1.2% (or 0.6% in tropical soils). Profiles meeting these thresholds were classified as BS (1), and the others as non-BS (0). This classification resulted in a table containing the ID, X and Y, and a column indicating the BS class (0 or 1).

The second step involved gathering environmental variables that covered the whole study area or country. These variables included climate, vegetation and terrain features along with potential additions like national geology and soil maps. The OpenLandMap project^[17] served as a key resource for these variables. All covariates were required to be in raster format, either as multi-band or single-band TIFF files, maintaining their original spatial resolution.

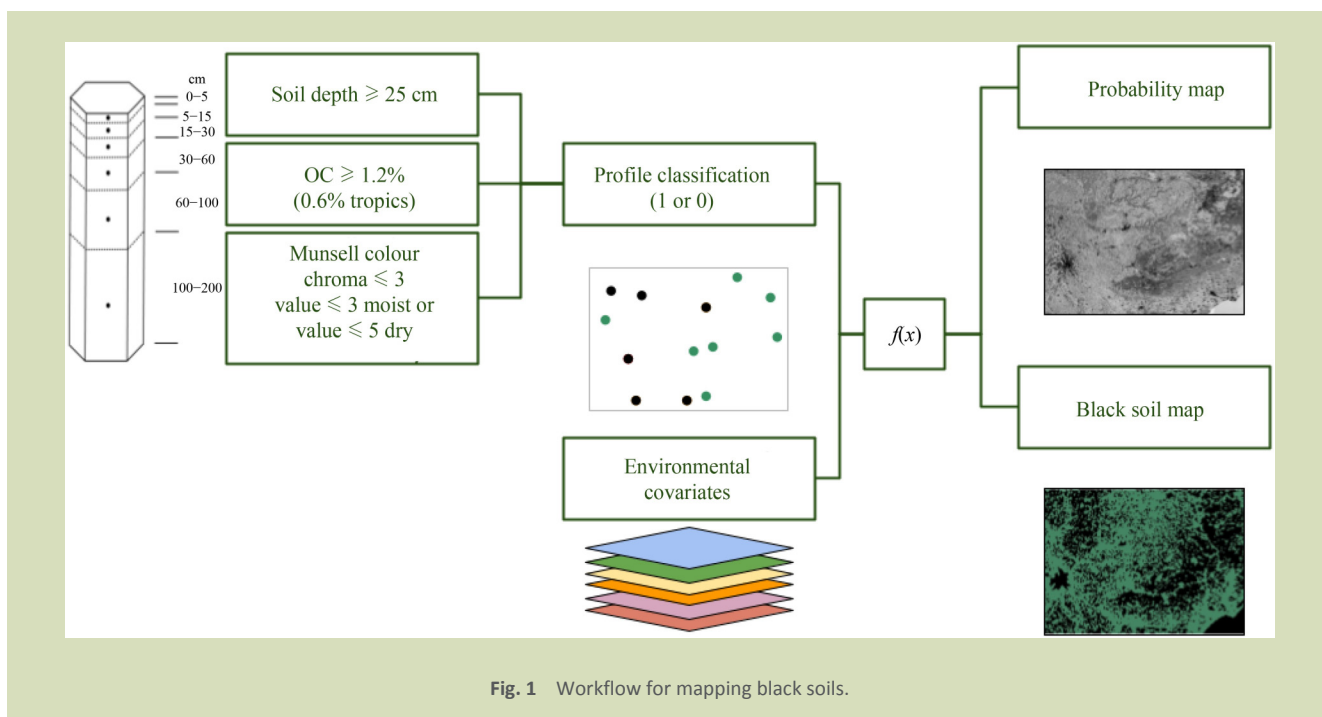


Fig. 1 Workflow for mapping black soils.

In the third step, we sampled these environmental variables using the soil profile coordinates. The goal was to integrate the soil data with the environmental covariate data at the specific locations of the soil profiles.

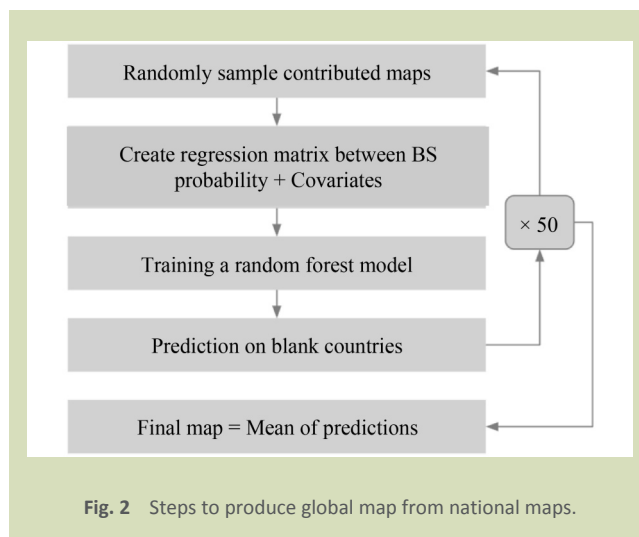
In the fourth step, we developed an inference model (Fig. 1). Since our target variable represented the presence or absence of BS, we treated it as a species distribution. In our case study, we focused on the occurrence of BS and aimed to delineate the area and the probability of BS occurrence. There is a range of models suited for species distribution, and the choice among them depended on the type of data input we had^[18]. Given the data we had on the presence and absence of black soil, we chose to use a random forest model. This method is popular for its combination of regression and classification decision trees in species distribution modeling. While a classification tree might seem more fitting for our study, we decided on a regression tree approach based on the findings of Hijmans and Elith^[19], who indicated superior results with regression models. Prior to calibrating the random forest model, we fine-tuned its hyperparameters^[20]. To assess the precision of the model, we conducted a 20 times 10-fold cross-validation and used confusion matrices, focusing on the overall accuracy of the model.

For making predictions, we used the calibrated model with a resolution of 1 km. This model generated a probability map that displayed the chances of finding BS in each pixel, with a scale from 0 (low probability) to 1 (high probability). Additionally, it created a categorical map that detailed the distribution of BS. The information gleaned from these maps was instrumental in understanding the probable locations and probabilities of BS presence.

To facilitate this process, access to a national soil profile database was crucial. In instances where such a database was unavailable, we considered alternative approaches like polygon-based soil mapping to gather necessary soil data.

2.2 Stage 2: steps for generating the global black soil map distribution

Country-specific black soil maps were used to infer global probability values. The methodology initiated with a stratified simple random sampling from these national maps (Fig. 2). A selection of 30,000 random points was made, distributed equally across three probability intervals: 10,000 samples in regions with a probability below 0.2, between 0.2 and 0.7, and over 0.7. Following this, 41 environmental variables of global relevance were retrieved from the OpenLandMap initiative^[18].



These encompassed the GSOCmap^[16] (equivalent to USDA soil categories, such as Mollisols, Vertisols, and Andosols), clay levels at a depth of 10 cm, pH at the same depth, snow cover, peak monthly temperatures, yearly average rainfall, agricultural land coverage and topographical attributes like slope and moisture index. Additional variables, including land cover, seasonal land surface temperature averages and variability and NDVI, were obtained from Google Earth Engine^[21]. The MERIT DEM^[22] was also employed to assess altitude with a 1 km precision.

For the prediction task, a Random Forest algorithm with recursive feature elimination was developed and iterated 50 times to derive an average probability prediction from these iterations. The primary predictors determined included GSOCmap, topographical moisture index, land surface temperature, NDVI, clay content at 10 cm depth, annual rainfall and peak yearly temperature.

The creation of the global black soil map involved using national maps from various countries, which fell into two categories. First, there were probability maps provided for Argentina, Brazil, Canada, China, Colombia, Mexico, Poland, Ukraine, Uruguay, and the USA. These maps used the prescribed methodology for determining black soil distribution. However, some countries, due to data limitations, could not adhere to the proposed method. Instead, they submitted polygon-based soil maps showing areas with black soils, derived either from extensive soil surveys or expert assessments. The maps for Bulgaria, Indonesia, and Slovakia followed this approach. The map for the Russian Federation was also a polygon map, but with an added layer of expert knowledge indicating the likelihood of black soil presence in each mapped unit. The maps submitted for Thailand and the

Syrian Arab Republic were also polygon maps but these were not included in the global map due to their overly coarse scale.

3 Results and discussion

3.1 Global map of black soils

The global map produced from this initiative represents a comprehensive depiction of the distribution of black soils across nations within the FAO INBS. Black soils predominantly occur in Eastern Europe, Central and Eastern Asia, and North and South America. Table 1 outlines the top 10 countries with the most significant areas of black soils, together accounting for 93.4% of global black soil estimated at 725 Mha in total. The Russian Federation, Kazakhstan, and China are notable for comprising more than half of this total area, with Russia alone having the largest share of black soil at about 327 Mha, equating to 45% of the global total. The FAO released the Global Black Soil Distribution Map (GBSmap) in 2023, featuring (A) categorical map showing areas with more than 50% probability of being black soils and (B) continuous map showing the probability distribution of soils being black soils^[1].

3.2 Human use of black soils

Population distribution in black soil regions was analyzed using the gridded world population map^[23] (Table 2). The Russian Federation, with the most extensive black soil area, also had the largest population living on these soils, totaling 68 million inhabitants. Kazakhstan, despite having the second-largest black soil area of about 108 Mha, had a relatively small population of 8 million residing in these areas. China and Colombia, each with around 30 million inhabitants, follow as the countries with the next highest populations living on black soils. While this constitutes a minor fraction of the overall population of China, it represents a significant portion for Colombia, nearly half of its total population.

In terms of land cover, black soils globally encompass 227 Mha of cropland, 267 Mha of grasslands, and 212 Mha of forests (Table 2). Black soils, constituting 0.63% of the global land surface, are inhabited by 2.86% of the world's population and contain 17.4% of all cropland. However, these proportions vary across different FAO regions. For example, about 50% of black soils in Asia are grasslands whereas in North America, 54% of black soils are cropland.

Table 1 Top 10 countries with the largest areas of black soils

Country	Black soil area (Mha)	Country area (Mha)	Black soil proportion (%)
Russian Federation	327.0	1700	19.2
Kazakhstan	108.0	284	38.0
China	50.0	935	5.4
Argentina	39.7	278	14.3
Mongolia	38.6	157	24.6
Ukraine	34.2	60	57.0
USA	31.2	950	3.3
Colombia	24.5	114	21.5
Canada	13.0	998	1.3
Mexico	11.9	196	6.1

Table 2 Areas and population in black soils zones

	Black soil	World	Percentage
Area (Mha)	725	12,995	5.58
Population (million people)	223	7788	2.86
Cropland area (Mha)	227	1308	17.4
Forest area (million km ²)	212	4496	4.72
Grassland area (million km ²)	267	3129	8.52

Globally, around one-third of black soil areas are used for crop production, accounting for 17.4% of total cropland^[24]. This distribution, however, varies by region. Europe and Asia together make up 80% of the cropland on black soils, whereas North and South America each have about 10%. This is particularly significant for agriculture in Eurasia, where it represents 160 Mha.

Based on the ESA WorldCover land cover map^[24], there are 212 Mha of forests on black soils, representing 4.7% of global forested areas. The Russian Federation has the largest portion of these forested areas on black soils, with 143 Mha, which is 15% of its forest lands. Following Russia, Colombia, China and the USA have the next highest forested areas on black soils, with 18.5, 12.7, and 7.1 Mha, respectively.

The updated version of Hansen Global Forest Change v1.9^[25] revealed that the depletion of forests on black soils was 27.9 Mha from 2000 to 2021^[26]. The bulk of this deforestation, a substantial 20 Mha, has occurred in the Russian Federation whereas the USA, Brazil, and Argentina have also seen considerable reductions in forest cover. Collectively, these three nations have experienced a loss of 4.6 Mha, with the decline evenly spread among them mainly due to the transformation from forestry to farmland.

Despite their relatively small global area, black soils are crucial

for feeding the world. They support not only the populations residing on them but also contribute to global food supplies through exports. They are vital for food security and the global economy, particularly in the production of oilseeds, cereals and tubers. In 2010, for example, 66% of the sunflower, 30% of wheat, and 26% of potatoes were harvested globally from black soils (Fig. 3).

3.3 SOC content of black soils

The global estimation of SOC to 30 cm deep is around 677 Gt (Table 3)^[25]. Of this total, 9% is contained within black soils. It is noteworthy that in Europe, black soils account for about 23.9% of the SOC stock, whereas in Latin America and the Caribbean it is 9.7%. In North America, black soils comprise 3.9% of the SOC, and in Asia, they make up 8.7%.

In Europe, black soils hold a considerable portion of the total capacity for SOC sequestration. Countries such as the Russian Federation, Ukraine and Kazakhstan are estimated to have the capability to sequester about 14 Mt-yr⁻¹ C in their black soils. Similarly, in the South American countries of Argentina, Colombia, and Uruguay, a significant share of their SOC sequestration potential is attributed to black soils. In Asia, Mongolia is notable for having 80% of its total SOC sequestration potential within black soils, whereas, in China, this proportion is lower at about 10%^[28].

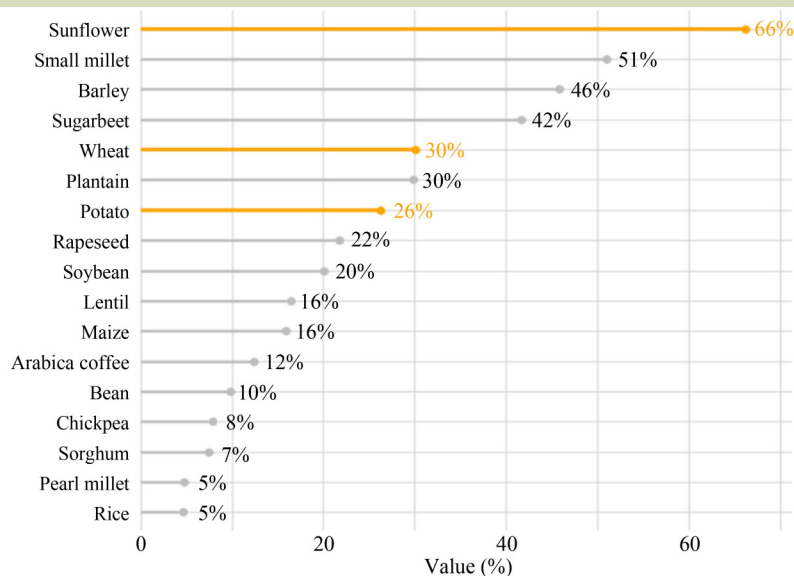


Fig. 3 Global contribution of crop yields originating from black soils was assessed by overlaying the GBSmap on the “Global Spatially-Disaggregated Crop Production Statistics Data for 2010 Version 2.0” from the International Food Policy Research Institute, 2019. The study showed results for crop proportions below 5% and for combined categories of crops from the evaluation.

Table 3 Total and cropland soil organic carbon (SOC) stocks and potential carbon sequestration rates associated with black soils (BS)

	BS	Global total	BS%
Total SOC stock (Gt C) ¹	56.0	677	8.3
Cropland SOC stock (Gt C) ²	18.9	62.8	30.1
Potential SOC sequestration (Gt·yr ⁻¹ C) ³	0.029	0.29	10.0

Note: ¹GSOmap^[16]; ²Based on WorldCover map^[24]; ³Based on GSOCseq product^[27], scenario of 10% increase in potential SOC sequestration differs significantly among countries according to the Global Soil Organic Carbon Sequestration Map^[27].

3.4 The diversity of black soils

3.4.1 Black soils of midlatitude grasslands

Deep black soils, predominantly found in midlatitude grasslands, are the most widespread type of black soils globally. This group encompasses Chernozems, Phaeozems, and Kastanozems characterized by a dark soil layer and elevated organic carbon, as classified in the World Reference Base for soil resources. These soils typically develop in regions with temperate or subtropical climates, characterized by fairly even distribution of rainfall throughout the year. The distinct black color of these soils is due to the accumulation of organic matter from the decaying roots of grasses, a process termed melanization^[29–31]. Additionally, black soils are not limited to just open grasslands; they can extend into more humid and cooler areas where grasslands are interspersed with forests. Found in various landscapes such as steppes, prairies and pampas, these black soils are the most extensively cultivated soil types in the world. Compared to other region-specific black soils, such as Andosols and tropical black soils, the midlatitude grassland black soils boast significant amounts of SOC and are rich in soil nutrients, including phosphorus and potassium. These black soils areas are recognized as the global food basket, thus ensuring international food security^[26].

3.4.2 Black soils of floodplains and wetlands

Another commonly found type of black soils occurs in floodplains and wetlands. In floodplain areas, their dark color is a result of excessive moisture, which slows down the breakdown of organic material and is further influenced by the continual deposit of fine organic particles transported with water. In wetland environments, the black topsoil layer is indicative of the presence of partially decomposed plant matter in oxygen-deprived conditions, similar in nature to dispersed peat or mud. These soils typically contain a high level of moisture, complicating their management and necessitating drainage for agricultural use. However, draining these soils can adversely impact essential ecosystem services, including the preservation of carbon stocks, biodiversity, and the quality and

filtration of water^[29]. These soils are predominantly classified as Mollic Gleysols. Soils in floodplains and tidal marshes may also be termed Fluvic, and those with a high organic content may be classified as Histic Gleysols, characterized more by clayey mud than distinct plant debris.

3.4.3 Swelling black soils

Swelling black soils, an abundant soil group, are found from tropical to temperate regions, especially in areas experiencing alternating dry and wet conditions. These soils are characterized by their shrinkage during dry periods and swelling during the wet periods, a property attributed to their unique clay composition, which is rich in smectites. Although these soils are predominantly black, their organic carbon content is not particularly high. The dark color results from humus-clay complexes, which range in color from gray to black. Known as Vertisols, these soils are recognized globally, with almost every soil classification system having a specific name for them, reflecting their distinctive physical characteristics. The array of local names for these compacted black soils extends to nearly 100 different terms worldwide^[32].

3.4.4 Volcanic black soils

Volcanic black soils form a unique and enigmatic group where their dark color does not align clearly with the prevailing climate. These soils, found on volcanic ash, support both both grassland and forest ecosystems. Contrary to earlier theories, recent research has shown that their black color is not necessarily indicative of past soil development under grasslands^[33]. The deep black color of these soils is encapsulated in their name, Andosols (derived from the Japanese words *an* and *do* meaning dark soil). Rich in humus, particularly humic acids, these soils also contain complex mixtures of aluminosilicates like allophane and imogolite, which are not fully crystallized. While most volcanic soils are dark, this is not the case for those formed on recent ash deposits or in arid climates.

3.4.5 Black soils in tropics

Black soils in tropical regions, while uncommon, occur in specific locales characterized by highly weathered soils with dark mollic or umbric top layers. These soils generally develop from basic igneous rocks under stable, warm climate conditions. They fall into several categories, such as Ferralsols, Nitisols, Acrisols, and notably Lixisols, with the dark surface horizons described as mollic, umbric or hyperhumic^[33]. Compared to other tropical soils, these black soils are typically more fertile but occupy a limited geographic area, primarily in humid savannas and semi-deciduous forests. Their use for agriculture is largely influenced by local population densities and the stage of agricultural development. Carbon sequestration in these soils is constrained, with organic matter rapidly decomposing once disturbed by plowing. Also, they are subject to threats from various forms of degradation, such as water erosion, soil compaction and the loss of nutrients.

3.4.6 Black soils in highlands

In highland regions, black soils occur across a variety of ecosystems at diverse elevations. Commonly, these soils are found beneath alpine meadows in temperate zones and under páramo vegetation in tropical mountainous areas. The extensive root residues produced by these highland grasslands lead to the accumulation of dark humus in the soil. The composition of these soils can vary based on the amount of precipitation they receive. Soils that are rich in exchangeable bases due to higher precipitation are classified as Phaeozems whereas those that are heavily leached in wetter conditions are as Umbrisols^[34].

3.4.7 Anthropogenic black soils

Anthropic black soils, a unique category, owe their dark color to both organic matter and charcoal particles from human activity. These soils developed as humans settled and engaged in prolonged agricultural activities, leading to the accumulation of organic materials. Initially, these organic materials were simply incorporated into the soil, slightly increasing the levels of soil organic matter. However, the impact on SOC was generally minimal, as a new balance was quickly established. This was particularly true in tropical regions, where high temperatures and ample moisture accelerate organic matter decomposition. However, in certain scenarios, the continuous addition of organic materials significantly altered the properties of these soils. The soil gradually darkened, eventually becoming almost black and substantially richer in carbon and nutrients. In these contexts, human activity contribute substantively to soil formation, giving rise to what is known as anthropic black soils or Anthrosols^[33].

3.4.8 Black soils in miscellaneous environments

Black soils can develop in various other contexts, often covering small areas. Particularly noteworthy are those that form over limestone, commonly referred to as Rendzinas in many soil classifications. The World Reference Base for Soil Resources^[31] calls these Rendzic Leptosols and Rendzic Phaeozems. Originating from limestone, which is rich in calcium carbonate, these soils have a distinctively thick, black topsoil but often a limited overall depth. They typically form under the moist and semi-moist conditions found in a range of climates, from tropical to taiga zones. While these soils can sometimes cover substantial areas in some regions, their shallow nature imposes limitations for agricultural use. Despite this, they are effectively used in some areas for both crop and animal production.

4 Perspectives and summary

Significant areas of black soils occur across many regions globally. In Eurasia, the largest areas occur in the Russian Federation (327 Mha), Kazakhstan (108 Mha), China (50 Mha), Mongolia (39 Mha), and Ukraine (34 Mha). In North and South America, large black soil areas occur in Argentina (40 Mha), the USA (31 Mha), Colombia (25 Mha), Canada (13 Mha), and Mexico (12 Mha). In many of these regions, black soils are a key component of major midlatitude grasslands, such as the pampas in Argentina, the Great Plains in North America, the northeast black soil region in China, and the forest-steppe and steppe regions in Ukraine and the Russian Federation^[29,34–39]. These soils were originally inhabited by diverse burrowing soil fauna, whose activity mixed organic matter from grasses into the upper mineral soil, creating a thick, black topsoil layer. Although grasslands in these areas have been largely converted to cropland, about 37% of black soil areas globally are still grasslands. Also, the INBS GBSmap indicates a significant occurrence of black soils in forested areas. These forest-associated black soils are most extensive in the Russian Federation and Canada, with about 29% of all black soils globally under forest cover^[25].

Black soils have also developed in smaller areas under specific conditions. For example, they have developed over volcanic ash deposits as in Japan, in wetlands where water slows down the decomposition of organic matter, and in high alpine regions where cold temperatures similarly retard decomposition, allowing for an accumulation of soil organic matter^[40]. Additionally, there are significant areas where human activities have led to the formation of black soils over extended periods. These soils were enriched by indigenous groups through the

addition of charcoal and other organic materials over centuries. In Europe, plaggen soils have been created through consistent additions of manure and straw. Both the Amazonian dark earth and plaggen soils are excellent examples of how human management practices can beneficially transform soil properties^[41].

For generations, black soils have been highly valued for their abundant organic matter and resulting natural fertility. This richness has led to the transformation of about one-third of these soils into cropland, making them a vital component of the global food supply. Despite comprising only around 17% of global cropland, black soils are significant for agricultural production. For example, they are used globally to produce 66% of sunflower, 51% of small millet, 42% of sugar beet, 30% of wheat, and 26% of potatoes^[26]. The critical role of black soils in crop production has been further highlighted by disruptions in the global food supply chain due to conflicts in regions rich in these soils.

The growing concern over human-induced climate change has brought into sharp focus the significance of the carbon stored in the organic matter of black soils. Covering 725 Mha and comprising 5.6% of soil globally, black soils hold a substantial 8.2% of the global SOC stocks, amounting to about 56 Gt C^[27]. The concept of carbon sequestration—the process by which soils absorb carbon from the atmosphere and store it in persistent organic matter—has been recognized as a crucial natural mechanism useful for counteracting human-induced climate change. The Global Soil Organic Carbon Sequestration Potential Map (GSOCseq) indicates that black soils could contribute to about 10% of the total SOC sequestration potential of soils worldwide^[27].

This study emphasizes two primary objectives: conserving the natural vegetation cover of black soils in grasslands, forests and

wetlands, and implementing sustainable soil management practices on black soils used for agriculture. Preserving natural cover is crucial for maintaining high levels of organic matter in these soils, preventing decomposition and the subsequent release of significant amounts of CO₂ into the atmosphere. Also, adopting sustainable management approaches, such as reduced tillage and no-till farming, helps stabilize and potentially increase soil organic matter levels. Even though improved management practices are often implemented at the individual farm level, protecting natural landscapes usually necessitates the development of systems to monitor the status and changes in the condition of black soils. This protection also requires governance and oversight at both sub-national and national levels. Currently, China is the only country with a national law specifically designed to protect, conserve, and promote the sustainable management of black soils^[42].

The imperative to consistently identify and advocate for black soils motivated the formation of the INBS under the auspices of the FAO Global Soil Partnership in 2017. Efforts undertaken by the INBS have culminated in the establishment of a uniform definition of black soils and the first ever Global Black Soil Distribution Map (GBSmap). Such endeavors have been pivotal in delineating where black soils are found and evaluating both the threats to these soils and the potentially efficacious management strategies to mitigate these threats.

Through this research, the FAO INBS has documented the global distribution of black soils and their significance in agricultural production and addressing the climate change. It is anticipated that sustainable soil management and governance can enhance management methodologies across the global black soil regions. Advocacy for the sustainable management of black soils is instrumental in advancing the achievement of the UN Sustainable Development Goals (SDGs), particularly SDG 2: end hunger, achieve food security and improved nutrition, and promote sustainable agriculture.

Compliance with ethics guidelines

Yuxin Tong, Marcos E. AngelinI, Yusuf Yigini, and Isabel Luotto declare that they have no conflicts of interest or financial conflicts to disclose. This article does not contain any studies with human or animal subjects performed by any of the authors.

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