WASWAC

HOT NEWS

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WASWAC visited Inner Mongolia Academy of Agricultural & Animal Husbandry Sciences

On 29–30 July 2026, at the invitation of Academician Zhanyuan Lu, President of Inner Mongolia Academy of Agricultural & Animal Husbandry Sciences, Prof. Duihu Ning, President of WASWAC, led a delegation including Prof. Pengfei Du, Executive Deputy Secretary-General, Prof. Liqin Qu and Dr. Ying Zhao to Hohhot for academic exchanges. Centering on dry-farming, soil and water conservation, ecological agriculture and sustainable agricultural development, the team conducted field visits at research bases, held symposiums and gave presentations, to promote collaborative innovation between WASWAC and local research institutes.

On 29 July, accompanied by Prof. Ju Zhao, Vice-President of the Academy, Prof. Xingfu Zhang and Prof. Yahong Liu, Directors of the Center for Comprehensive Test and Demonstration, the delegation toured the Wuchuan Dry-Farming Experimental Station and the Siziwang Research Base. They viewed dry-farming technology demonstrations, experimental facilities for grassland and farmland

soil and water conservation, and germplasm resource cultivation of xeric forage for desert steppes. The delegation gained insights into local agricultural conditions, research layouts and practical ecological protection challenges across the arid and semi-arid regions of Inner Mongolia.

On 30 July, the WASWAC delegation visited the Academy history exhibition hall to learn about the development history, disciplinary layout and research achievements of the Academy. And they held a symposium with key researchers from different departments.

Academician Zhanyuan Lu gave an overview of the Academy, summarized progress made in agricultural animal husbandry development and ecological protection across Inner Mongolia, and highlighted practical needs and work priorities for promoting ecological agriculture and advancing sustainable agricultural development in the region.

Prof. Ning briefed the participants on the structure, operational activities and academic platform development of WASWAC. He noted that Inner Mongolia constitutes a key component of China's northern ecological security barrier. Great challenges remain for soil and water conservation in dry-farmland and grassland ecosystems. WASWAC looks forward to further communication with the Academy. Practical cooperation will be expanded in scientific research to joint projects, academic output and talent exchange, to jointly support ecological protection and high quality agricultural development in northern China. Participants had thorough exchanges on regional soil erosion prevention and control, degraded land rehabilitation, and technical models for ecological agriculture.

Then, the WASWAC delegation delivered 4 presentations to young researchers at the Academy.

Prof. Ning presented a report titled Soil Erosion in China and Discussion on Current Research Priorities, analyzing the status of soil erosion in China and cutting edge research directions.

Prof. Du shared experiences on gully erosion

control in black soil regions of China and practical practices for black land erosion management.

Prof. Qu addressed academic writing, standards, ideas and methods for preparing scientific manuscripts.

Dr. Zhao discussed frequent problems with figures and tables in academic manuscripts, and shared best practices for figure table making and standard formatting. These reports covered broad research trends, regional governance practices and practical skills for paper preparation. Young researchers asked many questions and gave positive feedback.

Moving forward, WASWAC will continue to leverage its academic platform to strengthen cooperation with research institutions, to integrate research resources and promote academic exchange, and to provide professional support for regional ecological conservation and sustainable agricultural development.

The GSP Plenary Endorses Proposal for a UN Decade on Soil Health and Adopts Key Decisions to Strengthen Global Soil Governance

The fourteenth session of the Plenary Assembly of FAO's Global Soil Partnership (GSP) concluded with a series of decisions that are set to strengthen global soil governance and reinforce international efforts to protect one of the planet's most important resources: soil.

Held from 17 to 19 June in a hybrid format at FAO headquarters in Rome and online, the Assembly and its side events brought together over 700 participants, representatives from 140 countries and 333 organizations and partners, reaffirming the GSP's role as the leading global platform for sustainable soil management.

Among the most significant outcomes of the session was the Plenary's endorsement of the proposal for a United Nations Decade on Soil Health (2031–2040). With broad support from members and partners, the initiative moves forward for consideration and endorsement by FAO governing bodies (Committee on Agriculture, FAO Council and FAO Conference), paving the way for the development of an inclusive action plan aimed at mobilizing global action for healthy soils.

The Assembly also endorsed the revised Terms of Reference of the Global Soil Partnership, marking an important step in strengthening the partnership's institutional framework, and forwarded them for endorsement by FAO governing bodies. In parallel, the Assembly approved the establishment of the International Policy Panel on Soils (IPPS) and the GSP Bureau and likewise to be submitted to the same governing bodies for their endorsement, reinforcing the science–policy in-

terface and enhancing coordination among partners.

Another highlight of the session was the dynamic partner segment, which showcased experiences and perspectives from governments, research institutions, international organizations and civil society. Representatives from the European Commission, China, Canada, Madagascar, Colombia, Brazil, Senegal, Australia and many other partners shared initiatives and innovations supporting sustainable soil management worldwide, demonstrating the global reach and collaborative spirit of the GSP.

The Assembly welcomed the continued work of the Intergovernmental Technical Panel on Soils (ITPS), reaffirming its role in providing scientific guidance and producing global technical products. Future themes for Global Symposia and World Soil Day were also endorsed.

Recognizing the importance of digital technologies, the GSP partners supported the establishment of a working group on ethical issues related to soil information and data activities and the use of artificial intelligence, as well as a second working group tasked with reviewing and updating the GSOC-MRV Protocol.

The Assembly also acknowledged progress achieved under the GSP Action Framework and highlighted the need for stronger regional cooperation, improved coordination and increased resource mobilization across the 7 Regional Soil Partnerships.

On the financial front, the GSP partners recognized the critical support provided by resource partners and called for more diversified funding sources. They also requested a comparative assessment of in-person, hybrid and virtual meeting formats to inform future sessions.

As the session closed, participants confirmed that the GSP Plenary Assembly will continue to meet annually. The fifteenth session is scheduled to take place at FAO headquarters in Rome in June 2027.

News Source

https://www.fao.org/global-soil-partnership/resources/highlights/detail/es/c/1759762/

UNCCD COP17 Presidency & ENACT Partnership High-Level Dialogue: Transformation for Land, Climate and Biodiversity Resilience through Nature-based Solutions

As countries work to accelerate implementation of the Rio Conventions and achieve the Sustainable Development Goals, Nature-based Solutions (NbS) are emerging as one of the most effective approaches for delivering integrated outcomes across land restoration, climate action and biodiversity conservation.

Hosted as part of the official UNCCD COP17 Presidency Programme, this high-level dialogue will bring together ministers, senior government representatives, Rio Convention COP Presidencies, international organisations and non-state actors to explore practical pathways for scaling NbS and strengthening coherence across the land–climate–biodiversity nexus.

Building on the UNCCD COP17 theme, "Restoring Land, Restoring Hope," the dialogue will showcase how countries are integrating NbS into national policies, financing mechanisms and implementation strategies to advance Land Degradation Neutrality (LDN) while simultaneously contributing to climate resilience, biodiversity conservation and sustainable development.

The event will also feature the launch of key findings from the ENACT Partnership's 2026 State of Nature-based Solutions Report—the first global assessment of how NbS have been incorporated into LDN targets and other national planning instruments under the Rio Conventions. The report provides new insights into global progress, regional trends, implementation gaps and opportunities to strengthen NbS policy and practice in line with the UNEA definition of NbS and the IUCN Global Standard for Nature-based Solutions.

News Source

https://iucn.org/events/iucn-event/unccd-cop17-presidency-enact-partnership-high-level-dialogue-transformation-land

GEF-Funded Transboundary Water Management Project Launch

Three Southern African Development Community (SADC) member states – Eswatini, Mozambique and South Africa – have launched a six-year initiative to strengthen transboundary water management across the Incomati and Maputo river basins, which together support an estimated 3.4 million people.

Funded by the Global Environment Facility (GEF) with a grant of USD7.1 million and co-financing of USD64 million from the participating countries, the project aims to enhance water, food, energy and environmental security while promoting sustainable livelihoods. It will also support basin-wide and coastal zone planning, alongside efforts to mobilise investment.

The Incomati and Maputo river basins face increasing pressure from climate change, altered hydrological flows, unsustainable land and water use, pollution, and ecosystem degradation. These challenges pose significant risks to ecosystems, economies and communities across the three countries.

The Strengthening Integrated Transboundary Management of the Incomati and Maputo River Basins Project seeks to address these issues by strengthening the capacity of the Incomati-Maputo Watercourse Commission (INMACOM) SADC's youngest river basin organisation while enhancing scientific knowledge and improving coordination among river basin, conservation and coastal management institutions.

The project is implemented by the Global Water Partnership Southern Africa, with the United Nations Development Programme (UNDP) serving as the GEF implementing agency, providing oversight and ensuring accountability throughout implementation.

News Source

https://www.undp.org/eswatini/news/gef-funded-transboundary-water-management-project-launch

Governor Hochul Announces More than $240 Million Have Been Dedicated to Support On-Farm Environmental Protection Projects and County Soil and Water Conservation District Capacity over Last Five Years

During Earth Week, Governor Kathy Hochul today announced that since 2021, New York State has dedicated more than $240 million to support on-farm environmental protection projects and County Soil and Water Conservation District capacity. This includes record funding for the Climate Resilient Farming (CRF) Program, the Agricultural Nonpoint Source Abatement and Control Program (AgNPS), the Enhanced Nutrient and Methane Management Program (ENMP), and state aid to County Soil and Water Conservation Districts, among others. The AgNPS Program was recently provided with a boost through the State's Clean Water, Clean Air, and Green Jobs Environmental Bond Act.

More than $240 million has been committed in the New York State Budget to help farms implement critical best management practices that improve soil health, protect water quality, sequester carbon, and reduce emissions. This includes:

- $65.3 million through the AgNPS Rounds 26 - 30.
- $82.9 million through the CRF Rounds 6 - 9.
- $15.8 million through the Enhanced Nutrient and Methane Management Program (ENMP) Round 1.
- $76.75 million to State Aid to SWCDs.

These best management practice systems are made possible through the State's strong partnerships with the 58 County Soil and Water Conservation Districts (SWCDs), which are recognized as local leaders in conservation and are working to address environmental concerns and conserve New York State's natural resources.

Since 2021, the State has invested more than $75 million in the SWCDs, who work with New York's farmers to plan for and implement CRF and AgNPS projects on the farm that help producers meet their business goals while conserving the state's natural resources. The SWCD teams have the technical abilities to assist farmers to adopt best practices, including planting cover crops, implementing manure and methane management systems, and installing riparian buffers, which can provide valuable crop nutrients, aid in the health of the soil that sustains those crops, reduce greenhouse gas emissions, and protect water

quality and stream habitat.

In addition to assisting farmers, SWCDs work with local communities to improve environmental resiliency and sustainability. SWCDs lend their technical expertise to municipalities to manage stormwater, implement green infrastructure projects, protect stream corridors, manage invasive species, and more.

Additional SWCD Program successes over the last five years include:

- 445 acres of wetland restoration projects to protect wildlife habitat, floodplains, and ecosystem services that directly benefit downstream water quality and community resiliency.
- 10,536 acres of residue and tillage management via mulch till, no till, strip till or direct seeding to control soil erosion, reduce run-off, and enhance soil health.
- 13,434 feet of streambank and shoreline protection projects and 80 stream crossings to stabilize and revegetate areas prone to flood damage and reduce livestock access to water resources.
- 30,080 feet of irrigation pipeline installed to support irrigation water management systems that control the rate, amount, placement, and timing of irrigation water to ensure efficient use of water and control runoff.

The New York Department of Agriculture and Markets, in coordination with the New York State Soil and Water Conservation Committee, administers the CRF, AgNPS, and ENMP Programs through its Land and Water Division, which works to protect New York's land and water resources through farmland protection, farmland conservation, and proactive environmental stewardship. The CRF and AgNPS Programs function as part of the Agricultural Environmental Management (AEM) framework, a broader effort that helps farmers achieve higher levels of environmental stewardship and more efficient, cost-effective farming systems.

News Source

https://www.governor.ny.gov/news/during-earth-week-governor-hochul-announces-more-240-million-have-been-dedicated-support-farm

Tech Breakthroughs Boost China's Black Soil Protection Endeavors

Chinese scientists have released research results documenting technological breakthroughs in combating black soil degradation and boosting modern agricultural development through the use of modern precision practices.

Referred to as the "giant panda of cultivated land" thanks to its fertility and scarcity, black soil in China's Heilongjiang, Jilin and Liaoning provinces, all located in the country's northeast, and in some parts of north China's Inner Mongolia Autonomous Region, covers a total area of 1.09 million square kilometers. It produces about a quarter of China's total grain output.

However, black soil has experienced varying degrees of degradation due to factors such as excessive exploitation and climate change. The Chinese Academy of Sciences (CAS), together with authorities in the four provincial-level regions mentioned earlier, launched the "Black Soil Granary" program in 2021 to provide sci-tech support to the fight against soil degradation.

The CAS published the project's latest achievements, covering theories, technologies, models and smart equipment, on Monday in Nanjing, capital of east China's Jiangsu Province.

Jiang Ming, chief commander of the project and director of the Northeast Institute of Geography and Agroecology of the CAS, said that after five years of collaborative research, the project has established seven core demonstration zones, covering a total area of roughly 12,900 hectares. This project has increased soil organic matter content by 0.25 to 0.7 percent, reduced the soil erosion rate by 80 percent, and boosted grain yield by over 5.2 percent.

The research team made breakthroughs in integrating multi-source data from satellite, aerial and ground-based platforms, systematically mapping the current state of black soil degradation. They constructed the first-ever 10-meter spatial resolution information map of organic matter content in the black soil regions.

Their research reveals the spatial and temporal changes in black soil degradation over the past four decades, elucidates the degradation mechanisms and regulatory mechanisms for fertility improvement, and develops key conservation technologies tailored to different regions.

Jiang noted that the black soil information map serves as the core data foundation for digital management and precision production, addressing long-standing challenges such as fragmented data and delayed monitoring. Leveraging ground-sky-space integrated multi-scale sensing technology, it enables precise assessment of black soil resources, degradation types and severity for each plot, facilitating dynamic monitoring and targeted treatment.

"We are moving away from the past one-size-fits-all, experience-based management model, making black soil conservation evidence-based, precise and efficient," Jiang explained.

The information map also provides decision-making support for agricultural activities like straw incorporation, fertilization, soil improvement and agricultural machinery scheduling, enabling tailored measures based on local conditions.

Zhang Yucheng, a senior engineer at the Institute of Computing Technology of the CAS, said that Honghu new-energy unmanned smart tractors and supporting equipment have been widely deployed.

The research team completed independent development of this third-generation Honghu smart agricultural machinery technology system, with more than 90 percent of key components domestically produced. To date, 375 units of various smart agricultural machines have been manufactured, including 140 soil-testing robots and 5 unmanned soil-testing transport vehicles.

Zhang said the third-generation Honghu series is customized for the operational characteristics of black soil in northeast China, adapted to conservation tillage and large-scale, standardized operations. Equipped with an unmanned driving system, the series covers the entire process of plowing, planting, managing and harvesting. This effectively alleviates challenges in northeast China, including operating in the short frost-free period, tight farming windows and low manual labor efficiency.

Smart machinery enables uniform seeding, precise fertilization and variable rate pesticide application, reducing resource waste and supporting soil quality improvement and fertility preservation. In demonstration zones, the application of these machines has led to significant cost savings and efficiency gains for major grain crops such as corn and soybeans. The series has now entered mass production and

large-scale promotion, Zhang said.

Jiang said the next step is to move the achievements from "demonstration effectiveness" to "long-term, region-wide effectiveness," continuously optimizing the protection models adapted to different sub-regions and expanding the reach of technology promotion.

Meanwhile, leveraging the black soil information map and intelligent agricultural machinery, they will build an intelligent, digital, full-chain black soil health management system.

Zhang said future efforts will continue to iterate the intelligent agricultural machinery, enriching the full range of large, medium and small equipment to adapt to different plot sizes and black soil types, and driving intelligent agricultural machinery from demonstration pilots to normalized, region-wide adoption.

Nora Berrahmouni, deputy director of the Land and Water Division, Food and Agriculture Organization (FAO) of the United Nations, said China has made great commitments, including its national legislation and research program on black soils. Specifically, the CAS has effectively mobilized its strong research capacity to implement a science and technology campaign, delivering notable progress and tangible results in advancing sustainable black soil management and innovation.

The FAO is also actively supporting black soil countries. For example, an FAO-China South-South cooperation program was launched last year to promote optimized black soil management practices, support the establishment of soil analysis laboratories, and develop national digital soil maps, said Berrahmouni.

In addition to on-the-ground actions, the FAO, in collaboration with black soil member countries, launched the Global Status of Black Soils report in 2022 to understand the status and challenges of black soils at global level, she said.

News Source

https://english.cas.cn/newsroom/cas-in-media/202606/t20260609_1161405.shtml

Land Degradation Is Associated with Larger Crop Yield Gaps across Global Croplands

Abstract

There is a long-standing concern that land degradation reduces agricultural productivity, particularly in the long run. However, the empirical evidence on this issue remains inconclusive. Here, we present a global quantification of the link between land degradation, measured as the difference between current and historical conditions, and crop yield gaps, defined as the difference between attainable and attained yields. Our analysis establishes that, on average, a 10% increase in land degradation is associated with a roughly 2% increase in average crop yield gaps. Regionally, the loss can reach up to 6% for a 10% increase in land degradation in the globally most affected hotspots. These include northern and southern India, northeastern China, the US Midwest, as well as parts of Central and South America, particularly northern Argentina. Aggregated across the world's croplands, this translates into estimated losses of 20 million tonnes in crop production, corresponding to 52 trillion kcal, roughly the annual food calorie supply for 71 million people, and 4 billion USD in annual crop revenues.

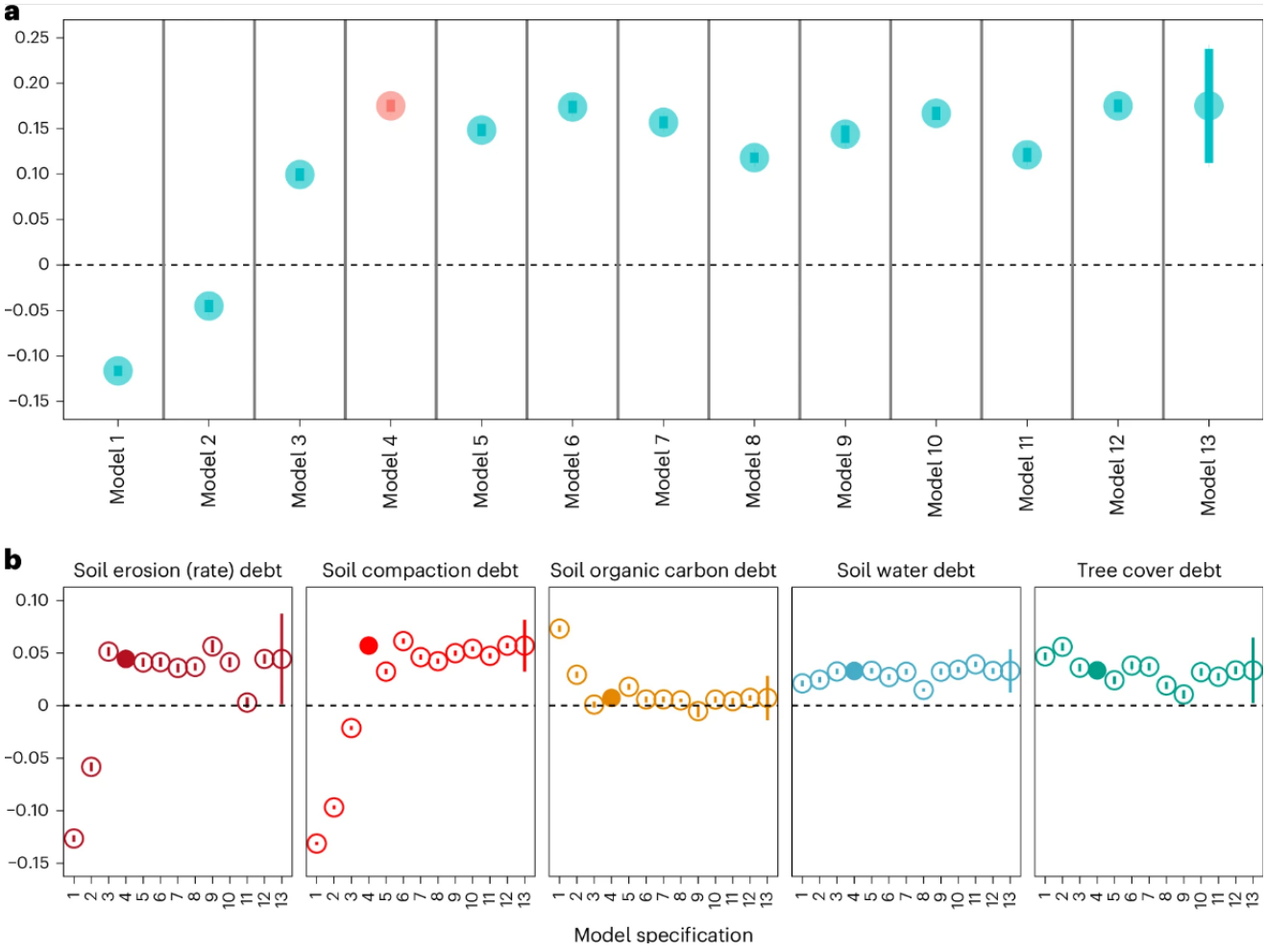
Results

Our empirical analysis shows that, after controlling for confounding factors, a significant positive association emerges between land degradation and crop yield gaps (that is, a negative association between land degradation and yield attainment). In other words, globally, on average, cropland areas with higher magnitude of historical land degradation, with other spatial heterogeneity controlled in the model being equal, correspond to areas presently having higher yield gaps. Our preferred model specification 4 includes controls for environmental, management (agricultural inputs) and socio-economic confounding factors. The association between crop yield gaps and the individual land degradation variables is that, for each 10% change in a land degradation variable, yield gaps change by 0.44% (95% confidence interval (CI) 0.40–0.49%; $P < 0.01$) for soil erosion debt, 0.57% (0.55–0.59%; $P < 0.01$) for soil compaction debt, 0.07% (0.05–0.10%; $P < 0.01$) for soil organic carbon debt, 0.33% (0.31–0.36%; $P < 0.01$) for soil water debt and 0.34% (0.30–0.37%; $P < 0.01$) for tree cover debt. To illustrate this magnitude, a 10% increase in land

degradation corresponds to relatively modest changes in the underlying indicators when evaluated at their global means, ranging from 0.04 to 0.14 standard deviations across degradation dimensions. By comparison, heavily degraded grid cells (75–90th percentile of the global distribution) exhibit substantially higher degradation levels than the global median (for example, 3.4–6.9 times higher for soil erosion debt).

Overall, we estimate that, globally, on average, a 10% increase in overall land degradation is associated with a 1.75% (1.69–1.82%) increase in the average yield gap. The estimated relationship between land degradation and crop yield gaps remains significant with the alternative use of standard errors that take into account spatial autocorrelation.

Our estimates are robust across a wide range of alternative. Across models, the overall association between land degradation and yield gaps remains consistently positive and statistically significant under alternative control variables, spatial adjustments and model function-



al forms. Across models, the associations between the overall land degradation and yield gaps are always significant and positive, with point estimates ranging between 1.18 and 1.88, meaning that a 1.18–1.88% increase in yield gaps is associated with a 10% increase in land degradation.

Beyond examining yield gaps, we can also decompose the estimated elasticity by separately estimating the elasticity for actual yields and attainable yields. The estimated elasticity for the yield gap is +0.18, and this is indicated to be the result of an elasticity of −0.12 for the actual yield and −0.07 for the attainable yield; that is, the association is substantially more negative for actual yields (−0.12) than for attainable yields (−0.07), but both are affected.

Beyond the global averages, the mapped heterogeneity of the land degradation–yield gaps association obtained from the machine learning model (Methods and Supplementary Note 6) indicates that, at a local (grid-cell) level, a 10% increase in land degradation can correspond to yield gaps that are higher by up to 4.4–22.7% (97.5th, 99th, 99.9th and maximum of 4.4%, 6.2%, 11.0% and 22.7%). The map shows that the higher yield gaps (linked to higher land degradation) are particularly pronounced in India (northern and southern parts), China (dispersed throughout, but particularly the northeastern part), the USA (especially the Midwest33) and parts of Central and South America (northern part of Argentina). In terms of absolute percentage point (pp) increases in yield gaps, intensive farming regions in the USA exhibit moderate absolute pp increases, while regions in Europe show small absolute pp increases, reflecting their low baseline yield gaps. Regions in South Asia, China, and some parts of sub-Saharan Africa show comparable or higher absolute pp increases despite lower elasticities, driven by their higher baseline yield gaps. The hotspots of strong land degradation role in yield gaps are not as identifiable in sub-Saharan Africa.

Article Source

https://www.nature.com/articles/s43016-026-01382-5

Geospatial Modeling of Soil Erodibility for Sustainable Land Management Planning in Ethiopia

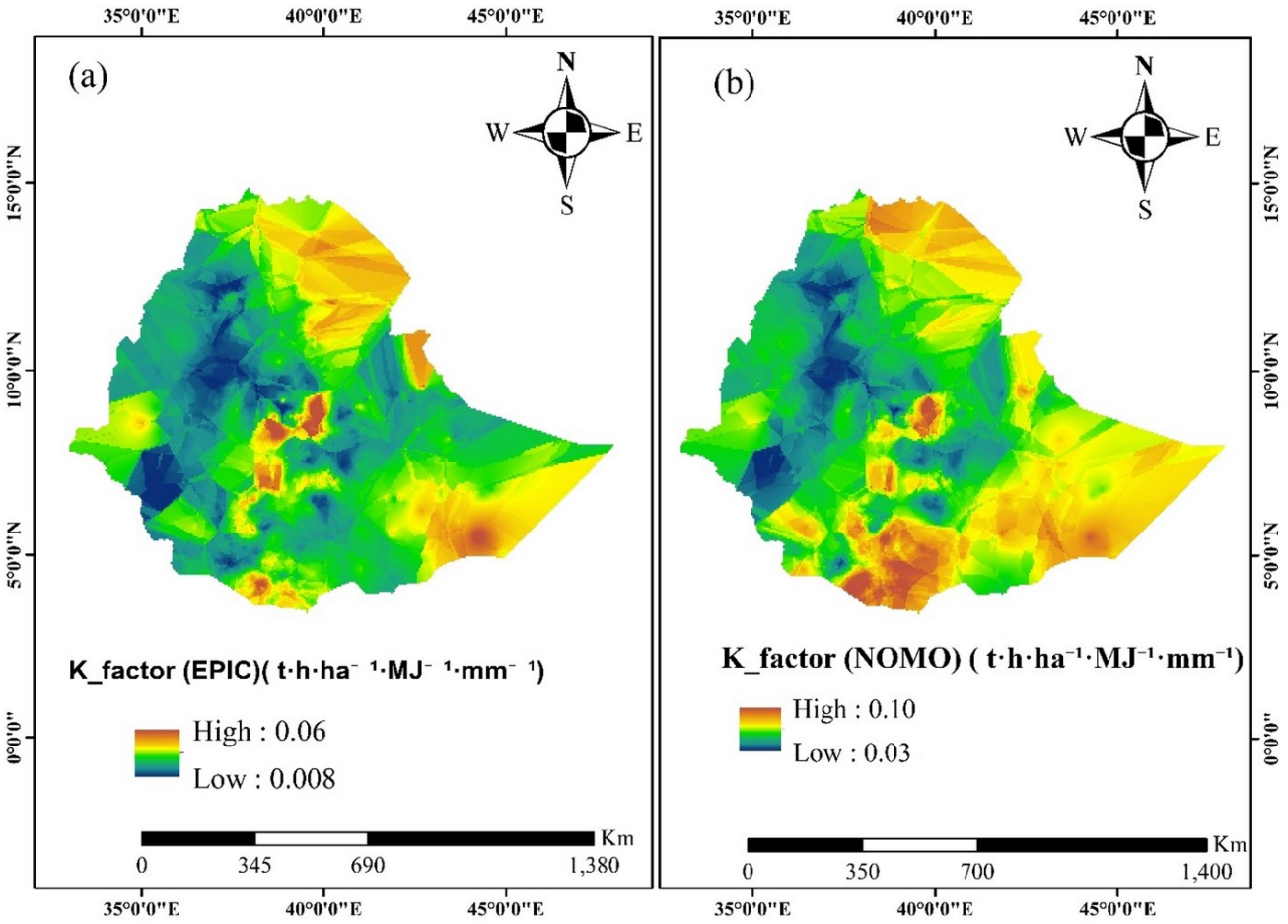
Abstract

Soil erosion is a serious environmental problem worldwide, with over 80% of Ethiopia's land highly vulnerable to erosion. The Revised Universal Soil Loss Equation (RUSLE) is widely used to estimate soil erosion, and the soil erodibility factor (K-factor) is one of its key components. While past studies in Ethiopia have evaluated soil erodibility, they were mostly focused on small or local areas like watersheds, districts, etc. A national-scale assessment is missing but is important for better understanding and managing soil erosion in the country. This study estimated soil erodibility factors across Ethiopia using the RUSLE Nomograph and Erosion-Productivity Impact Calculatormodel methods, combined with Empirical Bayesian Kriging at a 250 m resolution. The Nomograph method provided more accurate K-factor estimates compared to observed data. We also developed indices, including the Clay Ratio (CR), Modified Clay Ratio (MCR), and Critical Level of Organic Matter (CLOM), to analyze their sensitivity to soil erodibility. Using the CLOM index, we produced a digital map showing the variation of erosion susceptibility across Ethiopia. The national average K-factor value for Ethiopia was estimated to be 0.04 t-ha-h/ha/MJ/mm. In addition, among soil types, Nitisols were the least susceptible to erosion, while Solonetz soils were the most vulnerable. This is the first study to map soil erodibility across Ethiopia nationally, providing valuable information for soil conservation and erosion management efforts.

Results and Discussions

Some physicochemical parameters (percentage of sand, silt, clay, structure code, permeability code, SOC, SOM, and very fine sand) were used to estimate K-factors using Nomograph and EPIC model approaches.

The national average soil erodibility value for Ethiopia was calculated as 0.02 and 0.06 t-ha-h/ha/MJ/mm using EPIC and Nomograph model approaches, respectively. These findings highlight the sensitivity of erodibility estimation to model selection and the importance of including soil structure and permeability parameters. Similar observations have been reported in Ethiopian watersheds, where integrated soil management significantly reduced soil loss and improved soil structure stability.

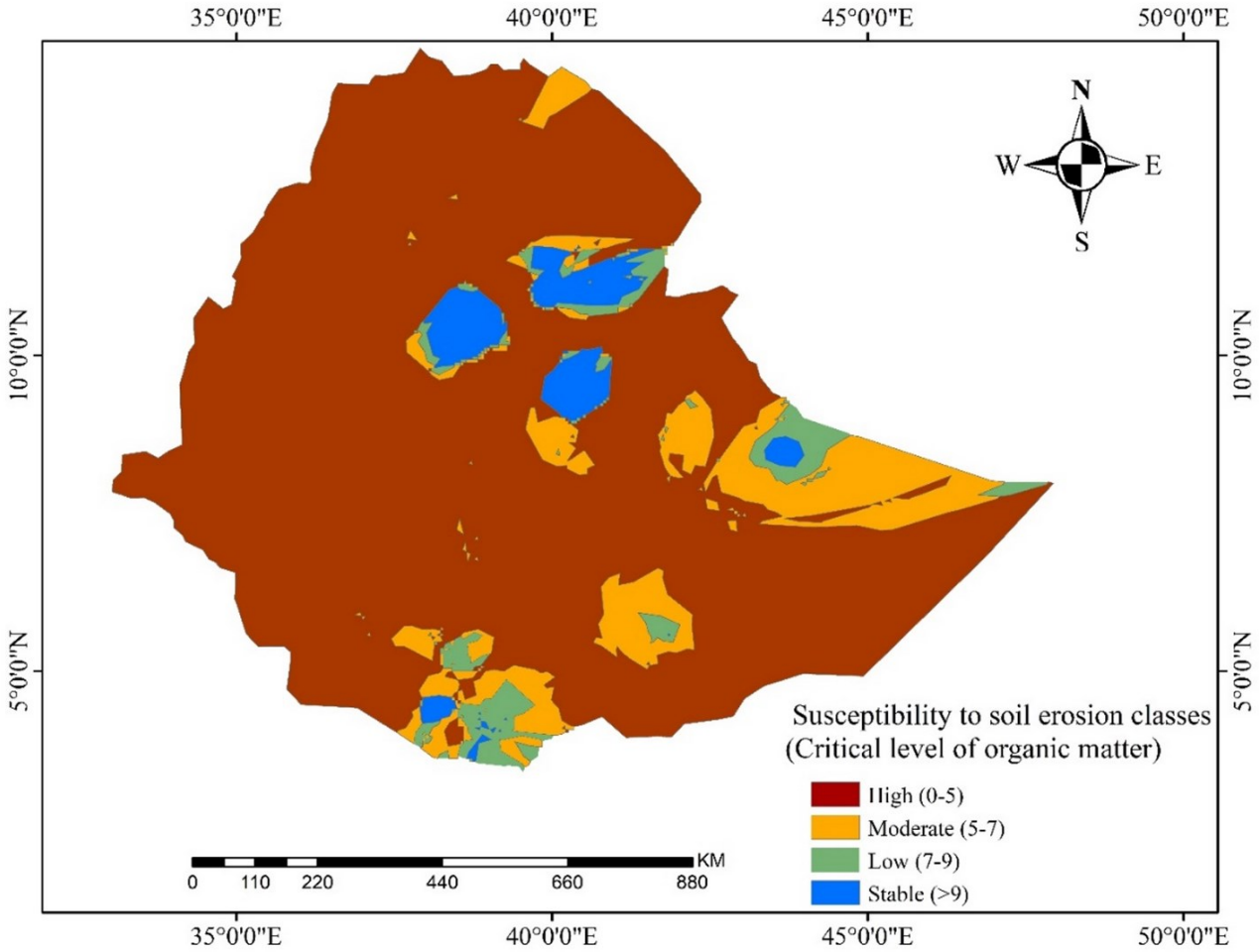


The Clay Ratio (CR) and Modified Clay Ratio (MCR) were calculated based on the percentage content of sand, silt, clay, and SOM present in the soil samples. The average CR and MCR values for Ethiopia were determined to be 1.92% and 1.62%, respectively, with maximum values of 28.82% for CR and 8.49% for MCR. Spatial variations in these indices are visualized in Fig. 8a, where higher values (> 5) were predominantly observed in the northern upper regions of the study area, including Arbaminch, Dire Dawa, Hawassa, and parts of Dessie and Bahir Dar. These differences arise from the inclusion of organic matter in the MCR calculation, which results in lower MCR values compared to CR.

A higher clay ratio suggests a greater potential to avoid soil erosion which means lower susceptibility to soil erosion. Clay Ratio (CR) and Modified Clay Ratio (MCR) were calculated to assess soil susceptibility. Higher CR and MCR values were observed in northern regions, indicating increased erosion risk. Organic matter plays a key role in reducing soil detach-

ment and maintaining aggregation. These results are consistent with earlier studies demonstrating that soil organic carbon improves soil structure and resilience to erosion, particularly in degraded and intensively cultivated landscapes.

These findings are consistent with the classification, where 81.59% of Ethiopia's land, with CLOM levels below 5%, is highly susceptible to erosion. Regions with moderate organic matter require integrated conservation strategies such as agroforestry and soil amendments to sustain productivity. These findings support earlier reports that organic matter thresholds are critical for soil stability and sustainable land management.



Article Source

https://link.springer.com/article/10.1007/s44378-026-00214-z

Assessing the Potential of Complex Artificial Neural Networks for Modelling Small-scale Soil Erosion by Water

Abstract

Modelling soil erosion by water is essential for developing effective mitigation strategies and preventing on- and off-site damages in agricultural areas. So far, complex artificial neural networks have rarely been applied in small-scale soil erosion modelling, and their potential still remains unclear. This study compares the performance of different neural network architectures for modelling soil erosion by water at a small spatial scale in agricultural cropland. The analysis was based on erosion rate data (in t ha−1 yr−1) at a 5 m × 5 m resolution, derived from a 20-year monitoring programme, and covers 458 ha of cropland across seven investigation areas in northern Germany. Nineteen predictor variables related to topography, climate, management, and soil properties were selected as inputs to assess their interrelationships with observed erosion patterns. A single-layer neural network (SNN), a deep neural network (DNN), and a convolutional neural network (CNN) were applied and evaluated against a random forest (RF) model used as a benchmark. A leave-one-area-out validation was applied to evaluate how well the models generalize to areas withheld entirely during training. While all models tended to underestimate high erosion rates, they often successfully captured the underlying spatial patterns. All tested models exhibited comparable root mean squared errors (RMSE: 2.2 t ha−1 yr−1). With respect to mean absolute error (MAE), the neural network models achieved slightly lower values (MAE: 0.9 t ha−1 yr−1) than the random forest model (MAE: 1.0 t ha−1 yr−1). Clearer differences between models were observed for the F1 scores, which reflect performance across soil loss classes. Here, the CNN achieved the highest F1 score (0.46) among the tested models. This study demonstrates the potential of complex neural networks to capture erosion patterns at the field-to-landscape scale and provides insights into the relevance of the chosen predictor variables, as well as key modelling limitations, such as the underestimation of very high erosion rates in unseen areas. It also highlights the need for more comprehensive datasets to improve generalization capabilities of the models.

Discussion

Large neural networks have the capacity to

capture complex non-linear relationships between predictor variables and soil erosion rates through an extensive set of weights. This flexibility allows neural networks to model these relationships in greater detail. In our study, the neural network models showed comparable or slightly improved predictive performance relative to the RF. However, in terms of class-based validation metrics (Table 3), the CNN and DNN outperformed the RF and SNN predictions. In this regard, the results align with previous studies, such as Sarkar and Mishra (2018), indicating that increasing model complexity can improve predictive performance.

A large proportion (81.2 %) of the mapped data is below the threshold of 1 t ha−1 yr−1, and this value range therefore had a strong influence on the weighted average F1 score. As a result of underestimating these low erosion rates, the RF achieved a lower weighted average F1 score than the neural network based models. The neural networks, and particularly the CNN and DNN, were able to predict these low erosion rates moderately well, capturing the underlying relationships in this dominant class.

This strong class imbalance and the dominance of low soil erosion values within the dataset also affect the capability of the models to predict higher erosion rates. Additionally, while the applied log-transformation stabilises model training, it further reduces the influence of extreme erosion values. As shown in Table 3, all models fail to reproduce very high erosion rates (≥5 t ha−1 yr−1). Since these high values are rare, representing only 3.9 % of the overall mapped training data, they provide too few examples for the models to learn the corresponding relationships reliably, which is a common problem in soil science for prediction tasks using machine learning (Sharififar and Sarmadian, 2023). In addition, the left-out areas have different landscape structures, land management practices, and topographic patterns, leading to combinations of predictor variables that the models have not encountered during training. This distribution shift places many erosion features outside the range of conditions represented during training, making accurate prediction in previously unseen areas particularly challenging. For example, the underestimation in Barum can be explained by substantial differences in crop rotations compared to other monitoring areas, resulting in a higher C factor that was not rep-

resented in the respective training data.

As shown in the visualizations of the predictions, all models were able to reproduce parts of the spatial erosion patterns in the unseen areas, although the predicted magnitudes were often underestimated. Only the neural network models predicted very high soil erosion rates, with maximum values of 6.0 and 12.1 t ha−1 yr−1, respectively. Both SNN and DNN produced very similar soil erosion patterns, likely due to the comparable architectures of the two modelling approaches, despite differences in their complexity. The CNN output appeared notably smoother than that of the solely pixel-based models, albeit with a lower maximum predicted erosion rate. This smoothness can be attributed to the integration of local spatial context by the convolutional layers (Fu et al., 2019; Hilburn, 2023).

Conclusions

By comparing different artificial neural network architectures and using a random forest model as a benchmark, this study highlights the potential of neural networks for modelling non-linear relationships between predictor variables and soil erosion at a field-to-landscape scale. Overall, all models showed very similar RMSE and MAE values, indicating comparable performance in predicting continuous soil erosion rates. The convolutional neural network achieved a marginally higher F1 score, followed closely by the deep neural network. When applied to previously unseen areas, all models were able to partially reproduce spatial erosion patterns but tended to strongly underestimate features with high erosion rates. The permutation importance analysis further indicates the relevance of variables such as slope and machining direction vs. aspect. Furthermore, the analysis provides guidance on which predictors may be omitted in soil erosion modelling. To build upon these findings, future research should focus on further identifying and quantifying model uncertainties, as well as improving the generalizability of these models and their scalability to larger areas.

Article Source

https://soil.copernicus.org/articles/12/321/2026/soil-12-321-2026.html

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Comparison of approaches using MUSLE, USLE-M and RUSLE2 for large-scale hydrosedimentological modelling

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