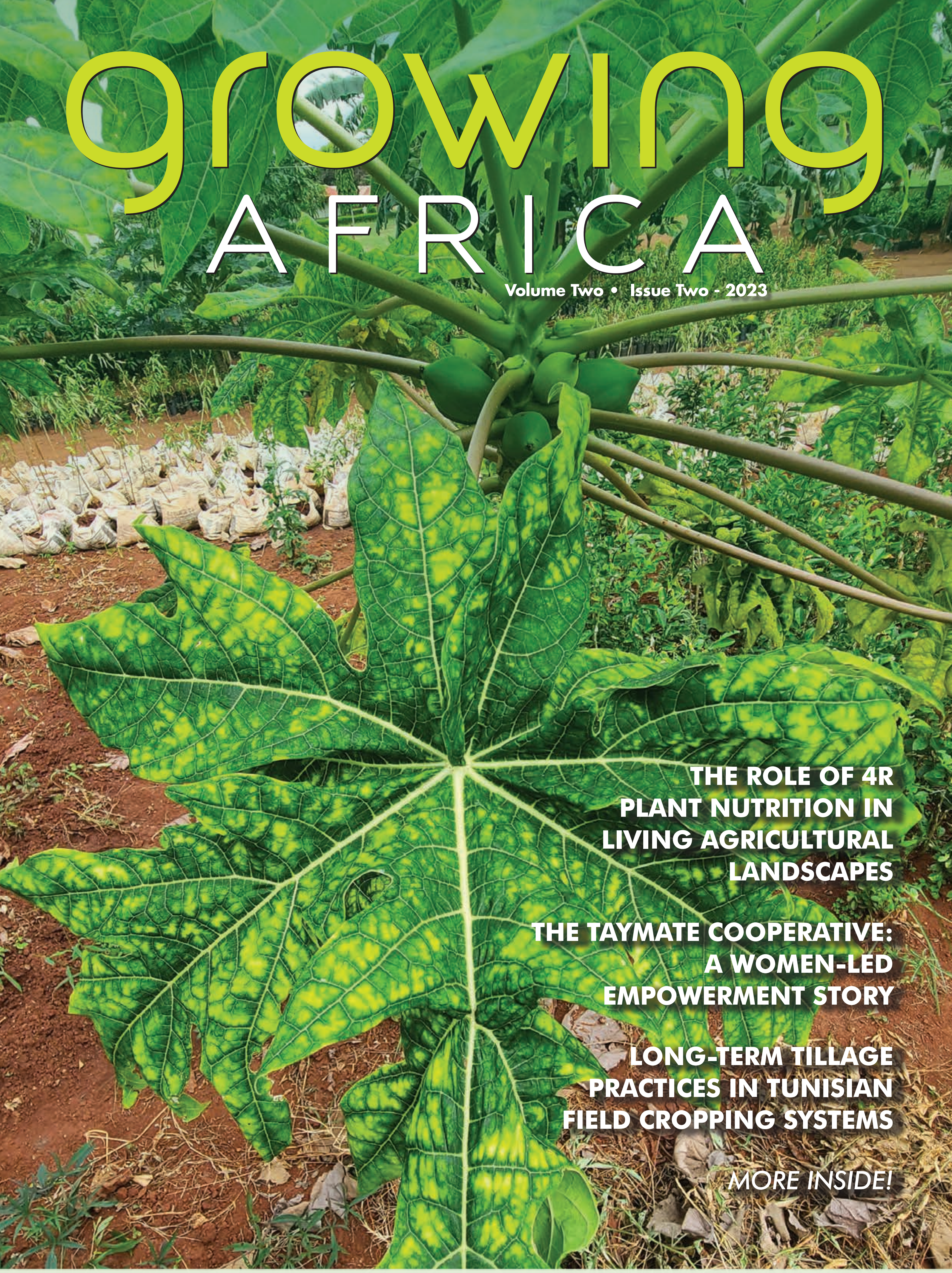

growing AFRICA

Volume Two • Issue Two - 2023

THE ROLE OF 4R PLANT NUTRITION IN LIVING AGRICULTURAL LANDSCAPES

THE TAYMATE COOPERATIVE: A WOMEN-LED EMPOWERMENT STORY

LONG-TERM TILLAGE PRACTICES IN TUNISIAN FIELD CROPPING SYSTEMS

MORE INSIDE!

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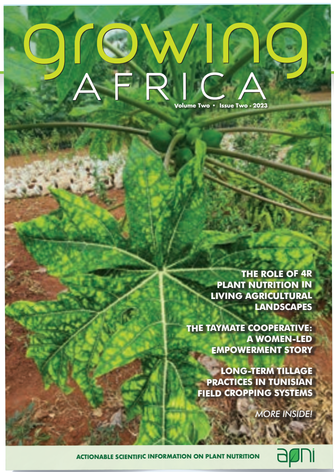

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AFRICAN PLANT NUTRITION INSTITUTE

Growing AFRICA (ISSN: 2791-2914)

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Inside this Issue

Welcome to the second issue of *Growing Africa* for 2023. Our mission is to publish research directed towards sustainable productivity, livelihood improvement, and resilience for African agricultural systems.

This issue begins with our feature, who's authors address the long-standing problem of solving for sustainable production systems within biodiverse living landscapes in Africa, given the demands anticipated from within the continent and beyond. What is the evolving role of 4R Nutrient Stewardship in landscape-scale research? From the field, we present a long-term tillage case study from Tunisia that gives insight on the degree to which conventional intensive cultivation practices are impacting soil quality in its annual cropping systems, and the role no-till can play to reverse this carbon degrading trend. From Morocco, we highlight a study examining the relative effectiveness of phosphogypsum as a soil amendment for salt-affected soils.

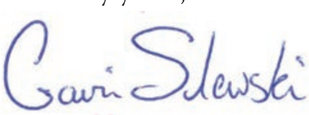
We also like to tell stories of success. Such is our article describing the highly successful, women led Taymate Olive Cooperative operating in northcentral Morocco. This story gives key insights into the components of an inclusive, empowering, and sustainable agricultural production system that has much potential for scaling across North Africa.

This issue also allows us the opportunity to feature our class of award and fellowship recipients for 2023. It is APNI's great honor to support these promising young researchers from across Africa as part of our commitment to developing excellence in crop nutrition research and outreach. Take a moment to review this impressive collection of innovative research projects. Our year-end issue is also a chance to announce the winners of our inaugural photo contest! This effort has been a huge success and is one that we will be sure to start-up next year. So, keep your cameras close by your side and keep us in mind as you are out amongst Africa's diverse and most interesting agro ecosystems.

Other news centers around the return of AfCPA in December 2024. The 3rd African Conference on Precision Agriculture in Kigali, Rwanda, promises to be our most extensive ever. Organizers are working on program details, and we look forward to keeping you updated on the key dates and conference information as they become available early in the new year. Check in at the conference website http://paafrica.org regularly.

We greatly appreciate your interest in Growing Africa. Look to us for unique and practical information for those with a direct stake in agricultural knowledge for Africa. As always, I encourage you to take a moment to participate in one of the publication's forums. We welcome submissions. Review our guide for authors at https://growingafrica.pub/about and contact us for more details on how you can contribute.

Sincerely yours,



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Growing Africa Style Guide
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The Role of 4R Plant Nutrition in Living Agricultural Landscapes: Developing the Nitrogen Water Carbon Nexus

By James Mutegi, Intissare Mouamine, Hakim Boulal, Kokou Adambounou Amouzou, Jhon B. Valencia, Thomas Oberthür, and Simon Cook

Vision

Food systems around the world must sustainably increase their performance to meet the growing demand for the foods and ecosystem services they provide. This issue is global in nature but is particularly sensitive in Africa because food systems there, which have hardly improved over the previous 50 years, are being looked upon to meet surging regional, continental, and global needs. Our vision for agriculture is to move ever closer to satisfying a booming world demand for food while sustaining the system on which food production depends. Smallholder farms contribute to 80% of the overall food production in Africa, and around 300 million people who are dependent on these small-scale farms frequently encounter food insecurity (ILRI, 2022). The population in Africa has experienced substantial growth and projections estimate it will reach 2.5 billion by 2050 and around 4 billion by 2100 (ILRI, 2022; UN population, 2022). The significant impact of climate change on agricultural productivity and food security in developing countries in Africa is also widely recognized (Mutengwa et al., 2023).

Therefore, our goal is to develop a productive and sustainable agriculture that enables investment into these systems. This is accomplished by optimizing the interactions between climate, soil, plants, and management at the agricultural landscape scale according to the resources available to smallholder farms. Mitigating the impacts of climate change faced by these food-insecure smallholders involves both innovative and traditional indigenous land farming techniques including integrated soil fertility management practices, conservation agriculture, land restoration, and effective water management strategies (Mutengwa et al., 2023).

We aim for an agricultural system that captures solar energy and allows biological and chemical elements to sustain food production with efficient use of nitrogen (N) and phosphorus (P) that does not overload the environment, and with a reversal of the historic losses of soil carbon (C). Sustainable

Dryland landscape supporting olive groves in El Kelâat Es-Sraghna Province, Marrakesh-Safi region of Morocco (left), and a more humid coffee-banana-grazing landscape in western Uganda (right). Water has a universal control over the highly variable nutrient balances and flows within a landscape so our knowledge about nutrient x water x carbon management is a key to creating, and maintaining, sustainable food systems at the living landscape scale. The development of impactful interventions within dryland systems are of critical importance, and even larger opportunities may exist for the more water rich environments of the sub-humid and humid tropics.

crop management practices optimize climate-soil-plant interactions, enhance nutrient use efficiency (NUE), and contribute to C sequestration into the soil ecosystem (Meena et al., 2020). Such an approach is conducive to stimulate and reward on-farm innovation to meet society's demands for food, and its goals for water and C management.

As custodian of the 4R Nutrient Stewardship approach, the African Plant Nutrition Institute (APNI) is well positioned to operationalize such use of plant nutrition within innovative agronomy. According to Zingore and Johnston (2013), the 4R model has allowed farmers in various regions of the world to sustainably improve their yields, incomes, and livelihoods. Nitrogen and other fertilizer inputs (including manure) are managed to increase uptake and substantially support increases in biomass, water, land, and labour productivity through an expanded 4R concept. We envision this to improve green water (i.e., rainwater and soil moisture) productivity through a combination of water management and crop and pasture productivity gains. The enhancement of the agricultural sector holds the potential to elevate incomes and opportunities, empowering individuals to better cope with unforeseen challenges (Kray et al., 2022). In turn, coupled improvement in nutrient use efficiency and water productivity provides a platform for increased C sequestration within systems. **We term this approach the nitrogen water carbon nexus (NWC).** Furthermore, we envision sustainability in the agricultural landscapes to transcend field and farm boundaries into living agricultural landscapes.

Proposition

Water, carbon, and nitrogen must be managed jointly in landscapes, to maximize positive interactions, minimize trade-offs, and improve socio-economic well-being and resilience (Mutuku et al., 2017). Water is the controlling variable for N and C flows and processes, so knowledge on the flow of water through landscapes is key to understanding the substantial variation that exists (Erkossa, et al., 2015). Nutrition is the most readily managed and is key to stimulating biological production. About 65% of the degradation on African land since 1965 has been due to soil and nutrient exhaustion (WRI, 2001). A lot is known about dual interactions between one and another of these three components (NWC), but little is known about the mechanisms that drive interactions between all three of them at the landscape scale, and how they vary in the landscapes.

First, consider how water can be used better over agricultural landscapes. Water productivity (i.e., the conversion of water to benefit) must improve to avoid potential conflicts between users, and between the needs of the environment. In some places, it is largely a consequence of sustainable intensification (SI), which, as implemented, has not been a balanced fit given the limits of the surrounding ecosystem services (Tilman et al., 2011). Improved water productivity can mitigate the vulnerability of impoverished communities to natural disasters, including droughts (Cai et al., 2013). Adopting a sustainable water use strategy in Africa is essential to cope with climatic risks, economic shocks, and rising food prices (WRI, 2001). In Africa, the vulnerability of food systems to climate change is pronounced, given the predominant reliance on rainfed production and a generally low adaptive capacity across the continent (The African Climate Foundation, 2023). Water productivity of rainfed systems rarely exceeds 10-20% of its potential due to water scarcity, land degradation, and erosion of many landscapes (Koutroulis et al., 2019). Water pollution from agricultural runoff and throughflow is widespread because of inappropriate use of agrochemicals and livestock overloading.

Second, think about C. Water and C dynamics in landscapes are closely coupled (Shrestha et al., 2012). Retaining water in landscapes increases the probability of building up soil organic C through improved biomass production. Reducing overland flow reduces the risks of losing soil C.

Finally, take account of the N that is about to be added to landscapes. Nitrogen fertilizer use will increase over Africa in coming years, as will livestock densities. With a global warming potential of almost 300 (viz 1 kg $N_2O \propto$ 300 kg CO_2 eq), the consequences of failing to manage this input are substantial. On the other hand, if N inputs are managed well and used productively the benefits are substantial, too. As indicated by Schut and Giller (2020), optimal agronomic efficiency leads to a favourable return on investment from fertilizer use among African smallholders. Despite the adoption of new technologies and interventions, a notable proportion of Africans continue to grapple with food security challenges (Ozor et al., 2013).

Now consider our proposal to bring together these components into a single **coherent conceptual framework** to explain the interactions of the three components: Carbon [C], Nitrogen [N], and Water [W]—if reordered from most manageable [N] to the least [C]—the **NWC Framework**. Our understanding of the interactions between the individual components draws substantially on various domains including agronomy, hydrology, economics, and others. We therefore envision assembling the components in a conceptual framework from multiple disciplines.

In summary, APNI proposes to lead the development and practical demonstration of the science that underpins the relationship between N, W and C and therefore enables a catalytic role for plant nutrition to sustain living agricultural landscapes. Key issues include:

- Nitrogen, water, and C are selected to represent changes in system entropy, or ecosystem sustainability (Addiscott, 1995), because NWC is expected to represent the system adequately. But the gap between the effects of these three factors and the total system is likely to be large.
- Thermodynamically, N, W and C make very unequal contributions towards system entropy. We treat them as equal, but we should perhaps scale them, as is done for CO_2 equivalents.
- Sustainability must be represented at the system level. We deem this to be at least at the scale of landscapes since water movement within landscapes is the major source of variation in activity.
- Methods of estimating the conditions of N, W and C at the landscape scale need development, including a means of combining the three components into a single measure such as ternary landscape imagery (**Fig. 1**) used to represent changes in entropy.
- As a philosophical/moral issue that APNI science could help clarify, the consideration of entropy for agricultural systems may reveal that—while more organic and more 'leak-proof' systems are superior to those that require substantial external inputs—*all* agricultural systems increase entropy and are, theoretically speaking, unsustainable. The link to *One Health*, through analysis of a seamless system from input through to nutrition, may emerge in which APNI plays an important role.

Nobel laureate Robert Solow (Solow, 1991) pointed out decades ago that growth based on the consumption of resources is, by definition, unsustainable, and largely a consequence of the undervaluation of the resource on which it depends. This applies to land or consumption of any input that does not account for externalities (e.g., N fertilizer). The true basis of sustainability lies in the development of know-how, an effectively inexhaustible process since there are always ways to do things smarter.

> " APNI proposes to lead the development and practical demonstration of the science that underpins the relationship between N, W and C and therefore enables a catalytic role for plant nutrition to sustain living agricultural landscapes.

Opportunity

The activities of APNI to develop pathways to sustainable production that not only show how to use nutrient inputs better (through the 4Rs), but also to evaluate such use within a sustainability framework will be a major milestone for APNI and partners. The opportunity lies in understanding living agricultural landscapes in such a manner that water, C and N can be managed jointly to:

- Reduce N losses from soil while increasing N inputs to support biomass productivity gain through 4R management sensitized to hydronomic (i.e., water management) zones.
- Maximize the productivity from blue (i.e., surface or groundwater reservoirs) and green water use,

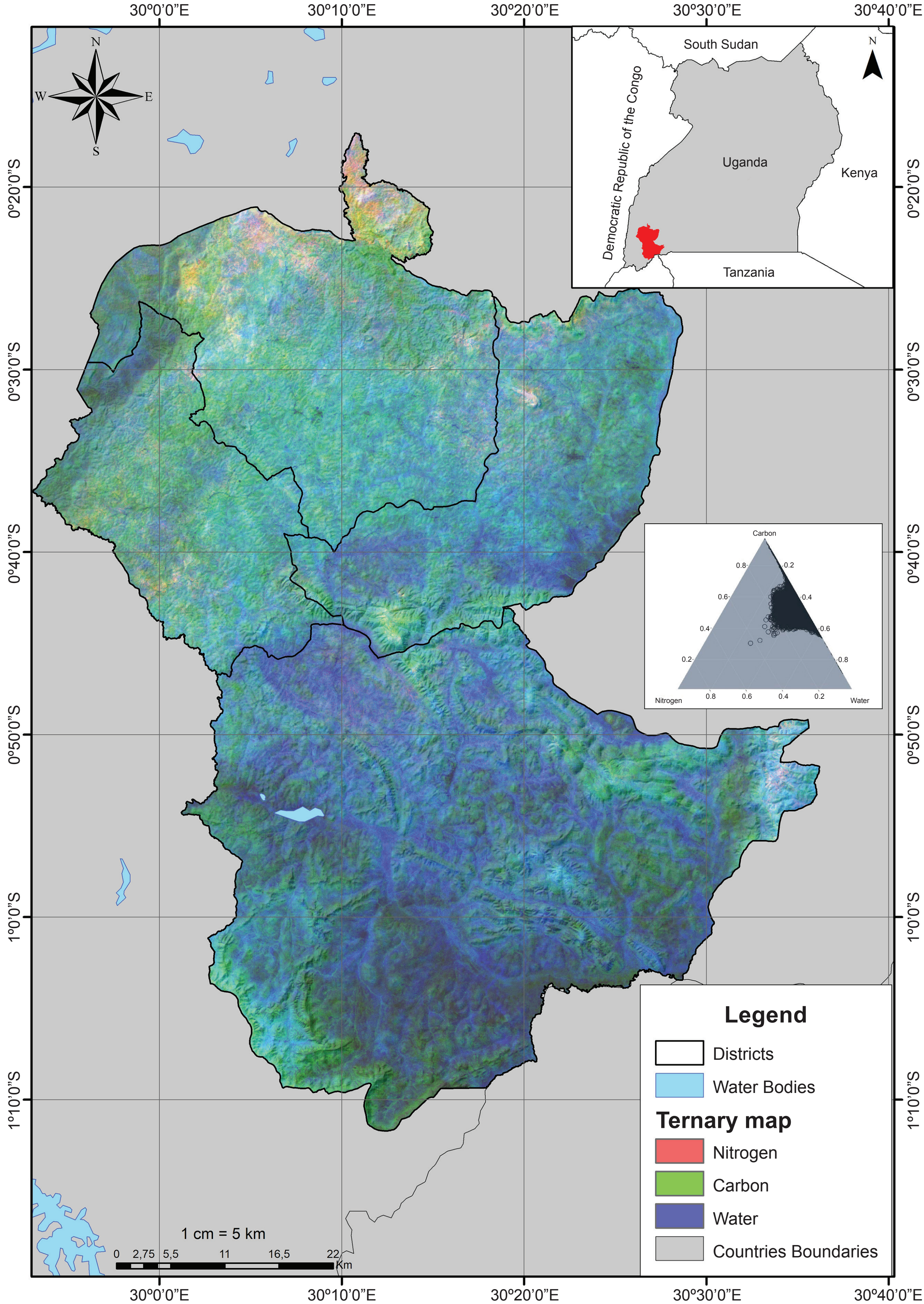

Figure 1. Ternary image to illustrate the conceptual approach. The map shows a section of a Ugandan landscape in which APNI is implementing a crop nutrition project that investigates the role of 4R for coffee yield and carbon sequestration. Red is the condition of factor 1 (nitrogen), green is factor 2 (carbon) and blue is factor 3 (water). Factor values were normalized from 0 to 1 and mixed via ArcGIS to project the simultaneous presence of the three factors across the landscape. Projected data (extracted from Google Earth Engine) includes N and C [0 to 20 cm depth; Hengl et al., 2021)] and plant available water in soil [Hengl et al., (2017)].

while preserving essential environmental flows and protecting humid environments.

- Increase C capture and retention, by reducing soil erosion losses, increasing biomass inputs to soil, and increasing infiltration and throughflow.
- Enhance interaction between the three components to improve water productivity, N use efficiency, and C sequestration.

Some specific examples of the opportunities that 4R-based plant nutrition can unlock within a NWC concept include:

1. **Resilient sustainable intensification (SI).** Intensification is needed throughout Africa. Starting as it is from a low base, the potential for SI is huge. However, a significant rise in inorganic fertilizer use is crucial to initiate system improvement and drive systemic change in Africa. Further, many question this narrow focus as the best strategy for African systems. Increased fertilizer use may be necessary but insufficient to create the systemic change towards the resilient food systems that an estimated 33 million smallholder farmers need to implement. The role of NWC is to ensure that intensification of yield and water productivity is paralleled by a sustained or increased C budget, and without disproportionate increases in emissions of GHG from added N. NWC, therefore, broadens insight beyond yield within a coherent framework.
2. **Smallholder-focused change.** Smallholder farmers (SHFs) carry the risk of economic loss accompanied with higher fertilizer use, which is greater than might first appear in well-managed trial sites. Notwithstanding the overwhelming technical evidence supporting fertilizer use, such risks are greater in Africa than in areas with well-developed supply chains, markets, and financial institutions. SHFs manage multiple assets together, and judge how to increase productivity without jeopardizing other attributes of their systems, such as soil health, valued non-productive areas, and cover crops. The NWC model provides broader insight into biological sustainability than conventional methods and supports a view closer to the SHF perspective. NWC therefore supports farmer-centric decision making by assembling the key components of farming system change.
3. **A measure that balances productivity growth with the need to protect soil health.** Current discourses around soil health point out that this and several other concepts of sustainable agriculture (including conservation agriculture) are poorly defined, hence a risky basis for promoting development. However, scientists need to support change by reducing the structural uncertainty that obstructs it. The NWC concept therefore provides a rational, if still incomplete, basis on which to evaluate production landscapes.

Implementation

Agronomy that aims to implement the NCW Framework likely requires two innovative aspects that support targeted investment in crop nutrition at integrated scales (i.e., from continental to farm levels). **Firstly, a top-down approach** using data analyses to tackle the uncertainty connected to fertilizer use. Data sources include soil and socio-economic data, APNI legacy data, and high-resolution imagery. All data is interpreted through interdisciplinary science for 4R solutions, based on decades of agronomic insight from APNI. **Secondly, a bottom-up approach** captures on-farm innovation in 4R-driven improvements that create value across the chain. Viability is assessed through testing and revision.

To operationalize the NWC concept on the ground, strategic business intelligence is used for large-scale analysis to overcome uncertainties in crop nutrient response, return on investment, economic and social preparedness, and the impact of climate change. This cropping system analysis is a tool to identify specific constraints and improve components in production systems in target countries and regions. In addition, living labs promote site-specific solutions addressing SHF production expectations, resilience, intensification, GHG balance, C and N management, and water productivity. First approximations guide the right source formulations, foster farmer-centric innovation through networks for accelerated learning, and enable regions to adapt, fine-tune and adopt the right rate, time, and placement of nutrients. The NWC framework is proposed as a systemic approach that threads innovative agronomy and 4R from the regional scale to the cropping systems scale. ■

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Award and Fellowship Recipients for 2023

African Plant Nutrition Scholarships

Recipients of the 2023 African Plant Nutrition Scholar Award included ten students selected from advanced science programs focused on plant nutrition and the management of nutrients applied to crops in Africa. Each student received $2,000 (U.S. Dollars). This initiative strives to encourage the brightest minds to focus on the critical target of continued advancement of the science of crop nutrition in Africa.

CAMEROON

Mr. Maurice Njiandoh MBEBOH (Doctorate Program), **University of Buea, Cameroon**

AREA OF STUDY: *Evaluating the Effects of Plant Growth-Promoting Microorganisms and Plant Bioactive Materials on Soil Fertility, Plant Nutrition and Soybean Grain Yield.*

Growing up in a subsistence farming household and community, Mr. Mebeboh had first-hand experience of the challenges involved in agricultural production, which stimulated a natural desire to become an agronomist with special interest on soil fertility management and plant nutrition. His Ph.D. thesis aims to provide the best bet management practices that can restore the soil microbiota and functionality, enhance soybean nutrition as well as grain yield.

The specific objectives of this research are principally focused on formulating consortia of effective microbial inoculants and suitable bioactive plant materials that are adapted to the specific needs of farmers and promoting their effective use for managing major abiotic (nutrient deficiency) and biotic (pests) constraints under sustainable intensification, within the nexus of integrated soil fertility management. This research will foster sustainable development by improving plant nutrition and protection, which will enhance soybean productivity, increase farmers' income and welfare, reduce hunger and malnutrition, and decrease food and nutrition insecurity especially in Sub-Saharan Africa.

ETHIOPIA

Mr. Sisay Negash ABOYE (M.Sc. Program), **Hawassa University, Wendo Genet College of Forestry and Natural Resource or Oromia Agricultural Research Institute**

AREA OF STUDY: *Effect of Scattered Acacia Tortilis and Acacia Nilotica Trees on Selected Soil Physio-Chemical Properties and Yield of Sorghum at Babile District, Eastern Ethiopia.*

Scattered *Acacia tortilis* and *Acacia nilotica* trees are purposively managed by farmers as a parkland agroforestry practice for addition of nutrient to the soil through nitrogen fixation, litter addition, nutrient uptake from below the reach of crop roots and moderating soil environment. There is limited scientific studies in the area on tree-crop interaction and quantity of nutrient added to the soil due to those trees in the study area. The study aimed to determine the effects of *Acacia tortilis* and *Acacia nilotica* trees on selected physicochemical properties of soil at different distance and soil depth, and to assess effect on yield and yield components of sorghum grown at different distances from the tree trunk. Positive tree-crop interactions, through which the tree can add more nutrient to the soil, might increase crop yield, can lead to both food security for the farmer and sustainably managed trees on farmland. The information can also help in designing sustainable land use that could enhance productivity of crops while maintaining and improving the resource base and resistance for climatic event.

Mr. Aboye hopes to be an agricultural and natural resource researcher using his knowledge to enhance agricultural production through managed nature in the country. He would like to work in an international research environment, which will give him the privilege of meeting and associating with people from all over the world with different points of view.

Mr. Moges TADESSE (M.Sc. Program), **Hawassa University, Ethiopia**

AREA OF STUDY: *Fractionation and Availability of Phosphorus in Acid Soils under Different Land Uses of Dalle and Wonsho District of Sidama Region, Ethiopia.*

Mr. Tadesse's study is aimed to quantify the various labile and stable pools of inorganic and organic phosphorus (P) in acidic soils of Dale and Wonsho woredas, Sidama region. Although little is known about Ethiopian soil P distribution, transformations, and fertility in that P availability in the country's dominant soils is relatively low, the low levels of plant-available P are an inherent limitation to crop production on most Ethiopian soils, yet the nature of soil P has not been assessed across the wide range of soil types that are present across the country. A complete budget of the P forms present in soil is required to comprehend the fate of applied P fertilizers. This can be done by identifying the labile and non-labile soil pools at the study area particularly (Dale and Wonsho Sidama Ethiopia) as well as across the country and abroad with similar soil types. Evaluating the effects of different land uses on soil P pools and assessing soil P availability and soil properties under different land uses are essential, and therefore this study was initiated to solve these problems in the study area.

Moges's future goal is to improve agricultural production and productivity by implementing healthy and quality agricultural research systems to help change farmers' lives through best soil management practice.

Ms. Eleni Nigussie WELDEMARIAM (M.Sc. Program), **University of Gondar, Gondar, Ethiopia**

AREA OF STUDY: *Enhancing Soil Health and Wheat Yields through Integrating Cost-Effective Nutrient Management Practices in Northwest Ethiopia*

Ms. Weldemariam is pursuing her M.Sc. degree at the University of Gondar and is developing a research proposal on 'Enhancing soil health and wheat yields through integrating cost-effective nutrient management practices in Northwest Ethiopia'. Her objectives are (1) to determine mechanisms that make lupin grow in highly acidic and nutrient poor soils, (2) to quantify the amount of nitrogen (N) fixed by lupin and vetch legumes and (3) to explore effect of green manure and legume rotation integrated with N fertilizer on nutrient availability and use efficiency, soil carbon stock, microbial communities, and wheat yields. To address the objectives, field experiments will be conducted at Farta and Guna districts from 2023-2025 cropping seasons. In this project, best nutrient management practices for alleviating soil acidity, enhancing nutrient use efficiency, soil carbon stock, microbial communities and crop productivity will be developed. Further, this study will create insights for land users and policy makers about the contribution of legumes-cereal integration in enhancing soil quality, crop yields and food security.

Her interests and future career goals include (1) conducting scientific research on integrated nutrient management, nutrient bioavailability, nutrient use efficiency and sustainable crop production, (2) giving quality community services to solve the problems and needs of the society, (3) teaching and advising students on plant nutrition, soil chemistry, nutrient cycling and agronomy courses and (4) develop her profession through innovative research, publishing articles on peer reviewed journals and presenting research findings at international conferences.

GHANA

Mr. Erion BWAMBALE (Doctorate Program), **West African Centre for Water, Irrigation, and Sustainable Agriculture (WACWISA), University for Development Studies, Tamale, Ghana**

AREA OF STUDY: *Development and Application of Smart Fertigation Systems to Enhance the Efficiency of Water and Nutrient Usage*

Erion is working on creating advanced models that simulate soil moisture dynamics using data-driven approaches. These models will facilitate the creation of optimized schedules for smart fertigation. Additionally, he is designing a model predictive controller specifically tailored for fertigation scheduling. To put his research into practice, Erion plans to implement the developed control algorithm on a microcontroller. This microcontroller will then be deployed in a real-world experiment involving open field tomato cultivation under a drip fertigation setup.

The goal of this research is to contribute to more efficient utilization of water and fertilizers in irrigated agriculture. Erion's academic contributions are noteworthy, with over 10 published articles in Scopus indexed journals. He is an active member of several professional organizations including the American Society of Agricultural and Biological Engineers (ASABE), the International Society of Precision Agriculture (ISPA), the American Society of Civil Engineers (ASCE), the International Water Association (IWA), the Pan African Society for Agricultural Engineering (PASAE), and the International Commission of Agricultural and Biosystems Engineering. He also holds the title of Young Water Professional of the International Commission on Irrigation and Drainage (ICID).

Erion's passion lies at the intersection of precision agriculture, irrigation and drainage, dynamics and control, hydraulic and hydrological modelling, and artificial intelligence. His overarching aim is to align his work with the sustainable development goals, particularly by advancing precision fertigation strategies that can play a pivotal role in enhancing food security across Africa.

KENYA

Ms. Rosebell Achieng OWUOR (Doctorate Program), **Maseno University, Kenya**

AREA OF STUDY: *Comparative Economic Analysis of Tea Yield Response to Nitrogen Fertilizer Use and Plucking Intervals in East Africa*.

Currently, blanket input recommendations for nitrogen (N) fertilizer application and plucking intervals are contingent on response trials conducted in Kenya. Hence, locations where these recommendations are exported fail to replicate results similar to the trial locations because of the heterogeneous aspects of the locations. The objectives of Rosebell's research are to determine site-specific optimal economic N fertilizer rate and harvesting intervals of tea clone TRFK 6/8 in selected tea-growing areas in East Africa (i.e., Kenya, Tanzania, and Rwanda), and to determine the economically efficient site-specific interaction effects of various N fertilizer rates and plucking intervals. Information from this study will enable the formulation of recommendations that are site-specific and act as a guide for fertilizer rate and plucking intervals recommendation in different areas as a less expensive alternative to trials for all released clones in all regions, thus realizing cost savings in adaptive research.

Her immediate goal is to finish her doctoral dissertation and publish in prestigious journals and ensure these findings assist scientists, academics, and farmers to economically optimize tea output from agronomic inputs, and ultimately precision farming for different tea clones. She is looking forward to collaborating with a global policy and research organization that will provide her the opportunity to put her knowledge and experience to use for issues impacting precision agriculture. Her goals for the future are to establish herself as a prominent academic lecturer in agricultural economics, and a researcher dedicated to providing farmers with tools for sustainable and competitive optimum economic crop productivity.

MOROCCO

Ms. Yousra EL-MEJJAOUY (Doctorate Program), **University Mohamed VI Polytechnic (UM6P), Benguérir, Morocco and Gembloux Agro-Bio Tech, University of Liège, France**

AREA OF STUDY: *Multi-scale Phosphorus Monitoring in Soil-plant Systems Using Spectroscopic Proximal Sensing and UAV-based Multispectral Imaging*.

Ms. El-Mejjaouy's research focuses on using technology for precision agriculture and monitoring nutrients in soil-plant systems. It enhances our understanding of how phosphorus (P) affects plant and soil optical properties and provides comprehensive and predictive models for P using a combination of multiple techniques: proximal-based spectroscopy, such as chlorophyll a fluorescence and visible near-infrared spectroscopy, as well as UAV-based multispectral imagery. A major contribution of the research is the utilization of a variety of data sources, ranging from point-based measurements to remote sensing using unmanned aerial vehicles, to assess the P status in both wheat plants and soil at different scales.

Having a keen interest in sustainable agriculture, Yousra is interested in positively impacting the environment and contributing to the development of monitoring practices that utilize cutting-edge technologies to accurately assess soil and plant properties.

NIGERIA

Mr. Kehinde Afeez OJENIYI (M.Sc. Program), **University of Mohammed VI Polytechnic (UM6P), Benguérir, Morocco**

AREA OF STUDY: *Assessment of Maize Yield Gap and Nutrient Use Efficiencies through the Application of National and Regional Fertilizer Recommendations as Straight and Compound Fertilizer in Mid-belt Nigeria*

The lack of advanced technology in the blending company has led to instances of segregation in the blended fertilizer, consequently, certain nutrient application rates might not adequately meet the requirements of plant. With straight fertilizer, each nutrient can be applied at recommended rate and time of plant uptake. Efficient fertilizer management practices have the potential to significantly increase maize yields in the mid-region of Nigeria beyond the levels achieved through current farming methods. This research aimed to assess the effects of national and regional fertilizer recommendations, applied as straight and compound fertilizers, on soil properties, nutrient efficiency, and maize yield in the mid-belt region of Nigeria. Despite the intention of blend fertilizers to reduce costs and create customized formulas, the findings revealed that the split application of nutrients enhanced nitrogen uptake efficiency and resulted in higher maize grain yields compared to the NPK blend application, emphasizing the need for adopting regional fertilizer recommendation applied as split using straight fertilizers to increase maize yields and improved economic returns in the mid-belt region of Nigeria.

Mr. Ojeniyi's, ultimate career goal is to become a leading agronomy researcher, making impactful changes in agricultural practices including integrated nutrient management, fertilizer recommendations, crop nutrition, and contributing to improved food security and sustainability, not only in Nigeria but also globally. He intends to proceed to enroll for a Ph.D. after the master program to increase his knowledge and research experience in agronomy.

TANZANIA

Mr. Escain KIWONDE (Doctorate Program), **University of Dar es Salaam, Tanzania**

AREA OF STUDY: *Investigation of the Effects of Macro-nutrients and Water Stress on Avocado Growth and Productivity in Njombe District Council, Tanzania*

The overall goal of Escain's study is to increase the yield productivity per tree of Hass avocado by optimizing nutrient application techniques through targeting specific tree phenological processes. His specific objectives include: the assessment of the effect of organic manure and NPK fertilizer application on the phenological character and yield of Hass avocado; determining the effect of organic manure and NPK fertilizer application on nutritional variation in Hass avocado; establishing the effects of water stress on growth and nutrient uptake of Hass avocado seedlings; and assessing the spatial distribution of soil macro-nutrients in Hass avocado production areas of Njombe District Council.

At the end of his study, Escain expects to provide guidelines to farmers with necessary information on quantities of fertilizers to be applied and the best time of application. This information will help farmers to increase productivity per tree of Hass avocado while minimizing nutrient losses and contamination to the environment.

Upon finishing his studies, Escain's goal is to continue doing research, share findings through publications and become the best plant nutrition researcher in vegetables and fruit trees production. He will also continue his teaching role at the University of Dar es Salaam which will include guiding and supervising students with interests in studying plant nutrition and fertilizer application.

TOGO

Mr. Mouhamadou LARE (Doctorate Program), **Laboratoire Interface Sciences du Sol, Climat et Production Végétale de l'Ecole Supérieure d'Agronomie de l'Université de Lomé (LISSCPV/ESA/UL), Togo**

AREA OF STUDY: *Endogenous Soil Fertility and Management Strategies for Improving Productivity and Economic Profitability of Maize Cultivation in the Savanes Region of Togo*

The objective of Mouhamadou's thesis is to sustainably improve maize production in the Savanes region of Togo through agronomic management practices embodying the soil-climate-plant interface. This research is a response to the degradation of the basic resource and the continued decline in maize yields, the main crop and staple food of the population of the Savanes region in Togo to such an extent that food security seem to be limited to its spatio-temporal availability but also to its accessibility for households. At the end of this thesis, Mouhamadou wishes to have improved our understanding of the causes of the spatial variability of maize grain yields, the endogenous fertility of the soils of the Savanes region of Togo, agronomic management practices for maize production in the region based on the soil-climate-plant interface, and recommendations for technically, socially and economically justified management practices for maize production in the region.

Mouhamadou's career objective is above all to achieve the objective of the thesis with attractive results, which will provide him with solid scientific knowledge allowing him to set up research and development programs at the national, regional, and even international level.

Young African Phosphorus Fellowships

The Young African Phosphorus Fellowship supports early career researchers working within scientific programs contributing to our understanding and improved phosphorus management in African agro ecosystems. Each recipient receives $5,000 (U.S. dollars).

TANZANIA

Dr. Primitiva Andrea Mboyerwa, College of Agriculture, Department of Soil and Geological Sciences, Sokoine University of Agriculture, Morogoro, Tanzania

AREA OF STUDY: *Nexus of Alternate Wetting and Drying Regime and Phosphorus in Rice Cropping System of Tanzania*

Dr. Mboyerwa will be investigating the influences of alternate wet/dry (AWD) irrigation regimes and phosphorus (P) fertilizer application on rice yield and P use efficiency. Her study will compare these responses in both upland and lowland rice production systems with study sites in Morogoro (eastern Tanzania) and the higher yield potential region of Mbeya (southern Tanzania).

Phosphorus deficiency constitutes a major growth and yield-limiting factor in irrigated and rainfed rice systems in Tanzania. Most soils in Tanzania are highly weathered with high P sorption capacity and low P availability. Often farmers do not apply mineral P fertilizers which further contributes to a continuous decline in soil P fertility. This research will guide our knowledge for Tanzania rice production through its focus on yield improvement and the development of improved agronomic practices that can increase P availability, improve P fertilizer use efficiency, and encourage the judicious application of P inputs. Results are expected to support the development of best management practices for rice irrigation, fertilizer application and plant breeding technologies.

MOROCCO

Dr. Mohamed Chtouki, College of Agriculture and Environmental Sciences, Mohammed VI Polytechnic University (UM6P), Benguérir, Morocco

AREA OF STUDY: *Improving Water and Phosphorus Use Efficiency in Moroccan Cereal and Legume Cropping Systems Using Precision Agricultural Techniques: Electromagnetic Induction System, Crop Imaging, and Geospatial Modelling.*

The objective of Dr. Mohamed Chtouki's research is to improve water and nutrient use efficiency from phosphorus (P)-based fertilizers applied to Moroccan cereal-legumes crop rotations. Based within the College of Agriculture and Environmental Sciences, Mohammed VI Polytechnic University (UM6P) in Benguérir, Morocco, Dr. Chtouki is interested in the novel application of the emerging technologies of spatial analysis using crop imaging and field mapping, geospatial modeling, and field-scale soil moisture assessment.

Under the arid and semi-arid conditions of Morocco, the impact of climate change on water resource availability and soil quality is more and more emphasized under Moroccan pedoclimatic conditions, mostly characterized by drought and extreme weather events, which negatively impact crop yield and quality. In this context, the development of innovative techniques to improve water and nutrient use efficiency has become a primary research question amongst soil and plant scientists, and agricultural stakeholders.

This innovative precision agriculture study will help our understanding of the dynamics of water and nutrients in the soil-plant continuum after P fertilizer application, guide P fertilizer use, assess soil spatial variability, and aid in the delineation of crop management zones for Moroccan cereal crop production systems.

African Plant Nutrition Outreach Fellowships

The Outreach Fellowship support education, training, and communication programs relevant to improving the use and efficiency of plant nutrients in African agro ecosystems. Each year, awards of USD $5,000 each are available to innovative scientists, extension specialists, or educators working in Africa.

GHANA

Prof. Vincent Logah, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana

AREA OF STUDY: *Boosting Productivity and Nutrient Use Efficiency of Smallholder Cropping Systems in Ghana through 4R Nutrient Stewardship.*

Most of the smallholder farmers in Ghana have yet to benefit from recent research findings and new initiatives by agricultural scientists in Ghana. In most instances, farmers do not use the right type of fertilizers, which are also either under- or over applied using unsuitable methods. This work plans targeted educational and outreach activities to train farmers on the 4Rs of nutrient stewardship and to introduce them to the outcome of new research initiatives in nutrient management in Ghana. It also involves collaboration between key stakeholders to translate research into practice.

The main objective is to increase nutrient use efficiency and productivity of smallholder farms in the breadbasket regions of Ghana through tailor-made outreach and hands-on training programs. Specifically, the proposal seeks to develop customized training modules and manuals for farmers on good nutrient stewardship and new research findings, deliver hands-on training for the targeted farmers using the modules and manuals developed. The work will contribute to increased productivity of agro ecosystems in Ghana. This will also ensure nutrient use efficiency and environmental sustainability, partly serving as a pilot activity for implementation of recent fertilizer research in Ghana. More so, the capacity of key stakeholders in the agricultural value chain will be built to facilitate replication and dissemination of the strategies and technologies taught.

TANZANIA

Ms. Rose Moses Massawe, Regional Agricultural Extension Advisory, Arusha Region Secretariat, Arusha, Tanzania

AREA OF STUDY: ACCELERATE-CSA: *Accelerating uptake of Climate-Smart Agriculture (CSA) Interventions in Longido Climate-Smart Villages, Tanzania*

Longido District is in the north-eastern corner of Tanzania in Arusha Region, on the leeward sides of Meru and Kilimanjaro mountains. In Tanzania drought has significantly worsened food insecurity, livestock and crop losses, and outbreaks of insect pests and diseases. Drought is more common in different regions of Tanzania including Arusha Region. Londigo is among the most drought-stricken districts of Arusha region, where poverty is also estimated to be high.

As a response to the climate related risks in Longido, this project seeks to accelerate the uptake of the Climate Smart Agriculture (CSA) activities for strengthening local adaptation and building resilience, and training farmers on improved agronomic practices. Specific objectives include the establishment of demonstration trials for promotion of CSA and improved agronomic practices for maize, beans and Irish potatoes (i.e., early planting, crop rotation, and intercropping). Field days will be organized to further promote the new strategies to farmers and extension officers and disseminate educational material planned for development. The project intends to use the established or existing village savings and credit organizations (SACCOS) as a vehicle for accelerating the uptake of CSA activities for strengthening local adaptation and building resilience.

Our Scholarships and Fellowships are made possible through APNI's partnership with Mohammed VI Polytechnic University (UM6P) and OCP Group (OCP S.A.).

Learn more about our Award and Fellowship programs at https://apni.net/awards.

Long-term Tillage Practices Impact Soil Aggregation and Climate Resilience in Tunisian Field Cropping Systems

By Mouna Mechri, Taqi Raza, Khedija Bouajila, Noura Ziadi, Elsayed Fathi Abd_Allah, and Naceur Jedidi

Soil degradation poses a major challenge for agricultural and socio-economic development in Tunisia. *The conventional intensive cultivation practices commonly used by farmers cause rapid depletion of soil organic matter, which is adversely affecting the physio-chemical properties of soil and is accelerating soil erosion. The decrease in soil organic carbon stocks is a major factor aggravating the impacts of climate change.*

There is urgent need for adoption of sustainable farming practices to address growing climate change, environmental and socio-economic challenges, regionally and globally. Reduced chemical input and tillage practices offer opportunities to lower production costs, preserve soil biodiversity, promote soil carbon (C) sequestration, and lower greenhouse gas emissions. One of the major challenges faced by the current agricultural system is reconciling the aims of sustainable agriculture with the need to maintain economic viability by ensuring competitive yields and crop quality. Organic matter is an important indicator of soil quality due its multiple soil functions. The intensification of cultivation has led to a decrease in the organic matter content in cropping systems, reducing soil fertility and increasing vulnerability to soil degradation. The decline of soil organic matter is also known to reduce soil aggregation.

In Tunisia, the use of intense cropping and monoculture systems has led to a severe reduction in the organic matter content of cultivated soils, and thus in soil fertility and crop productivity. No-till direct seeding and crop residue management practices have been recently introduced in the country to improve

The experimental site design at Le Krib-Siliana region; Durum wheat (DW), Oats (O); No-tillage (NT), moldboard plowing (MP). Google Earth, May 29, 2023.

Table 1. Physiochemical properties of soil, collected from Le Krib, Tunisia

Parameters	[1]Durum wheat NT	Durum wheat MP		[1]Oat NT	Oat MP
Sand (%)			78.45		
Silt (%)			11.1		
Clay (%)			10.95		
Textural class			Sandy-Loam		
Soil pH	7.04 ± 0.04	7.23 ± 0.09		7.51 ± 0.06	7.68 ± 0.16
Organic C (%)	1.22 ± 0.07	0.96 ± 0.07		1.16 ± 0.07	0.91 ± 0.05
Total N (%)	0.095 ± 0.004	0.070 ± 0.002		0.088 ± 0.002	0.059 ± 0.002
C/N ratio	12.89 ± 1.51	13.71 ± 1.72		13.18 ± 0.88	15.34 ± 0.15
$N\text{-}NO_3$ ($mg\ kg^{-1}$)	3.66 ± 0.23	1.61 ± 0.20		3.86 ±0.09	1.63 ± 0.13
$N\text{-}NH_4$ ($mg\ kg^{-1}$)	7.30 ± 0.10	5.81 ± 0.56		11.43 ± 0.25	4.47 ± 0.49
Available P ($mg\ kg^{-1}$)	74.12 ± 3.88	67.38 ± 3.35		64.32 ± 3.21	45.74 ± 2.12
Exch. K ($mg\ kg^{-1}$)	195.24 ± 4.55	153.0 ± 11.69		137.57 ± 9.51	99.08 ± 20.85

[1]Durum wheat and oats were sown prior to this study's establishment.
(±): Standard deviation from the average value presented ($n = 3$). NT: No-till; MP: moldboard plowing.

soil fertility. Few studies have been conducted to evaluate the interaction between different tillage practices and the resulting soil aggregate classes under different cropping systems in Tunisia.

This study evaluates the effects of the previous cropping system [durum wheat, (Triticum aestivum) and oat (Avena sativa)] and two types of tillage regimes [no-till direct seeding (NT) and moldboard plowing (MP)] on soil organic carbon (SOC) and nitrogen (N) content, and their distribution in various soil aggregate classes.

The study was conducted at an 8 ha long-term experimental site in a farm field (36.3862979 N, 9.1856103 E) in Le Krib in the Siliana region of northwestern Tunisia. The site was established in 1999 on sandy-loam soil. Slopes were < 2% and the site had little soil redistribution or desposition from within the landscape or alluvial actions. The site was divided into eight 1 ha plots, where two different tillage systems (NT and MP) and four different rotation systems (wheat-faba bean, faba bean-wheat, oats-faba bean, and faba bean-oats) were used, respectively. This article focuses on the faba bean-oats and faba bean-wheat rotation systems under NT and MP.

Results

The physiochemical soil properties after 13 years of long-term experimentation are shown in **Table 1**.

Distribution of the Different Classes of Aggregates

Amongst the four different classes of soil aggregate size presented in **Table 2**, the percentage of macro-

Table 2. The different aggregate classes in percentage according to the previous crop and the method of tillage.

	Factors	Macro-aggregates (2000–250 μm)	Meso-aggregates (250–180 μm)	Micro-aggregates (180–53 μm)	Clay + silt particles (<53 μm)
Previous crop	DW	45.13 ± 10.51 a	14.68 ± 1.39 a	26.95 ± 9.96 a	**5.53** ± **1.64 a**
	O	44.00 ± 5.72 a	16.45 ± 1.31 b	27.39 ± 7.06 a	**6.03** ± **1.53 a**
Tillage method	NT	51.87 ± 3.39 a	15.70 ± 2.14 a	19.53 ± 2.47 b	**4.38** ± **0.53 b**
	MP	37.27 ± 2.16 b	15.43 ± 0.94 a	34.80 ± 1.80 a	**7.18** ± **0.47 a**

(±): Standard deviation from the average value presented ($n = 6$). In the same column, the values with the same letter do not differ significantly according to the SNK test.

aggregates (2000–250 μm) was not influenced by the previous crop but was significantly affected by the tillage regime. The highest percentage of macro-aggregates was recorded in NT plots (51.2%), while soils managed under the MP regime had the lowest proportion (37.3%). Tillage method did not have an influence on meso-aggregates (250–180 μm), but previous crop did and was highest in oat plots (16.4%) versus wheat plots (14.7%). Micro-aggregates (180–53 μm) were influenced by the tillage regime and was highest in MP plots (34.8%) versus 19.5% in NT plots. Similarly, the percentage of clay and silt particles (< 53 μm) was influenced solely by the tillage regime, with soils from NT plots containing 4.38% of this aggregate class, compared to 7.18% for soils from MP plots. Thus, NT plots were associated with the highest proportion of aggregates larger than 250 μm and the lowest proportion of aggregates smaller than 180 μm.

According to Pearson's correlation coefficient, a significant positive correlation between SOC and the percentage of macro-aggregates was observed (0.84). Conversely, the correlations between SOC and the percentage of micro-aggregates, and the clay + silt fraction, were negative and significant (-0.88 and -0.90, respectively).

Carbon Associated with Aggregates

Tillage had a consistent influence on C content across the soil aggregate classes. Regardless of the previous crop, all aggregate classes had higher C content under NT compared to MP (**Fig. 1**).

The influence of the previous crop was more varied across soil aggregate classes. Under NT, the C content of macro-aggregates was higher in plots previously planted to wheat than oats. However, the reverse was observed for the other three aggregate classes, where oat plots under NT had higher C contents than wheat. Under the MP tillage regime, plots previously planted to wheat had higher C contents, compared to oat, in the macro-, micro-, and clay and silt particles classes.

Total Nitrogen Associated with Aggregates

Comparisons across soil aggregate classes found, for macro-aggregates, N content was influenced solely by the tillage regime (**Table 3**). Soil macro-aggregates from NT plots contained less N compared to those from MP plots (**Table 3**). Similarly, the N contents of meso- and micro-aggregates were also higher in MP plots. For clay and silt, N content was highest in soils from NT plots.

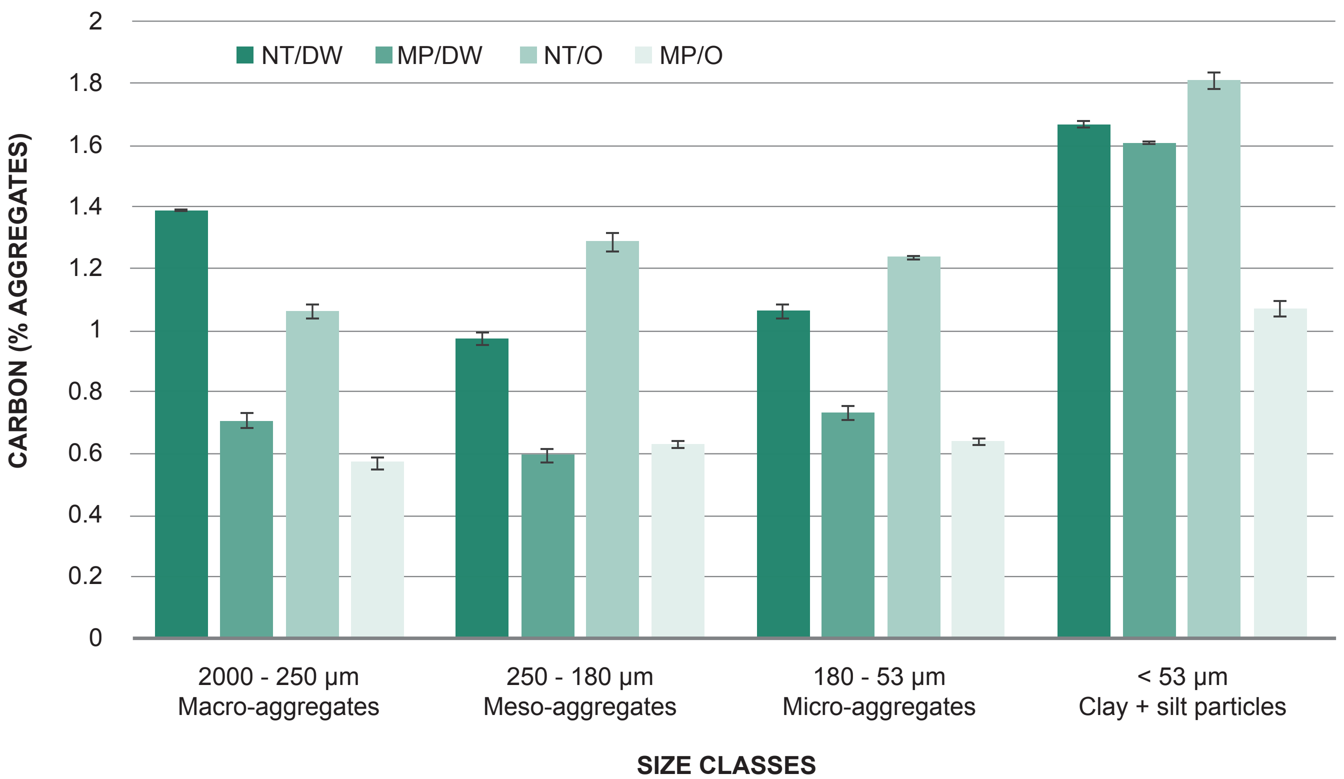

Figure 1. Effect of tillage methods [no-tillage (NT), moldboard plowing (MP)] and the previous crop [durum wheat (DW), oats (O)] on the C content associated with aggregates.

Table 3. Total N concentrations (%) associated with aggregates according to previous crop and tillage method.

	Factors	Macro-aggregates (2000–250 µm)	Meso-aggregates (250–180 µm)	Micro-aggregates (180–53 µm)	Clay + silt particles (<53 µm)
Previous crop	DW	0.0067 a	0.3580 a	0.2391 a	**0.0177 b**
	O	0.0072 a	0.1388 b	0.1307b	**0.0211 a**
Tillage method	NT	0.0064 b	0.2035 b	0.1627 b	**0.0269 a**
	MP	0.0074 a	0.2934 a	0.2071 a	**0.0120 b**

In the same column, the values with the same letter do not differ significantly according to the SNK test ($p = 0.05$), PC: previous crop, durum wheat (DW), oats (O), tillage method (TM), no-tillage (NT), moldboard plowing (MP).

The influence of the previous crop was consistent across meso- and micro-aggregates where wheat cropping resulted in higher N contents compared to oat cropping. The reverse was observed for clay and silt where a previous crop of oats resulted in higher N contents. The results show that the N content of soils is significantly influenced by previous crop and tillage method and their interactions, as well as the soil aggregate distribution.

> Soils in plots under a no-till direct seeding regime have a higher macro-aggregate mass than soils in plots with a conventional regime indicating that no-till direct seeding practices are the most effective in improving soil aggregation.

Summary

Conventional tillage was associated with lower macro-aggregates. In general, soils in plots under a no-till direct seeding regime had a higher macro-aggregate mass (and lower micro-aggregate mass) than soils in plots with a conventional regime (moldboard plowing), indicating that no-till direct seeding practices are the most effective in improving soil aggregation. The higher percentage of macro-aggregates found under no-till regimes are attributed to a reduction in macro-aggregate turnover. Macro-aggregate mass in the soil's surface layer is probably increased by the layer's high biomass content and root activity. Scientists found that cereal root systems positively influenced macro-aggregate formation (Zotarelli et al., 2005). Conversely, soil under moldboard plowing tillage had the highest effective micro-aggregate content. These results are explained by the fact that MP tillage methods affect the largest aggregates first, which results in a greater mass of smaller aggregates.

Our results show that macro-aggregates have a greater SOC content than meso- and micro-aggregates. The SOC content in the clay + silt fraction was higher in soil under the NT regime than in soil under the MP regime. These results could be explained by the greater physical protection of SOC in this fraction under NT than under MP.

Tillage method had significant effects on aggregate stability. No-tillage practice with a legume was also effective at improving aggregate stability and increasing the concentration of the soil organic matter. These soil properties are crucial for sustainable soil health and fertility management. By reducing the soil disturbance, SOC, microbial biomass, and other nutrients can be preserved which contribute to improved soil biological, physical and chemical properties.

After 13 years of the study, the no-tillage (direct seeding) regime had significantly improved soil aggregation and structure, leading to an increase in SOC contents because of C sequestration. ■

Cereal crop production landscape near Kasra, Siliana Region, Northwest Tunisia.

Acknowledgement

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Photo Contest Results

PHOTO CONTEST

NUTRIENT DEFICIENCY SYMPTOMS IN CROPS

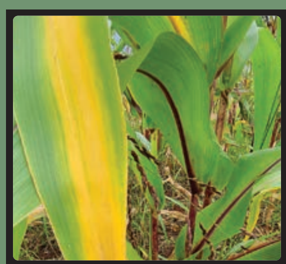
PLANT NUTRITION RESEARCH IN ACTION

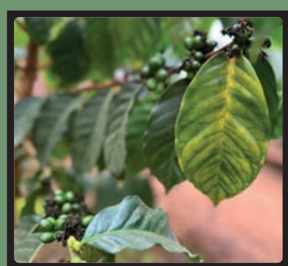
THE RESULTS ARE IN!

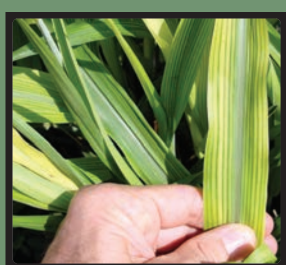
Throughout this past year we have been in search of outstanding examples of crop nutrient deficiency and plant nutrition research or application from Africa. We collected many submissions, which we are very grateful for, and it's our pleasure to announce our two winners for this inaugural edition of the contest. We also would like to take this opportunity to feature several photos deserving an honourable mention.

We plan to reopen this contest in the 2024 so look for those details here in *Growing Africa*, through our website, or social media channels.

For more details about the contest and how to submit your entry visit:
https://apni.net/photo-contest



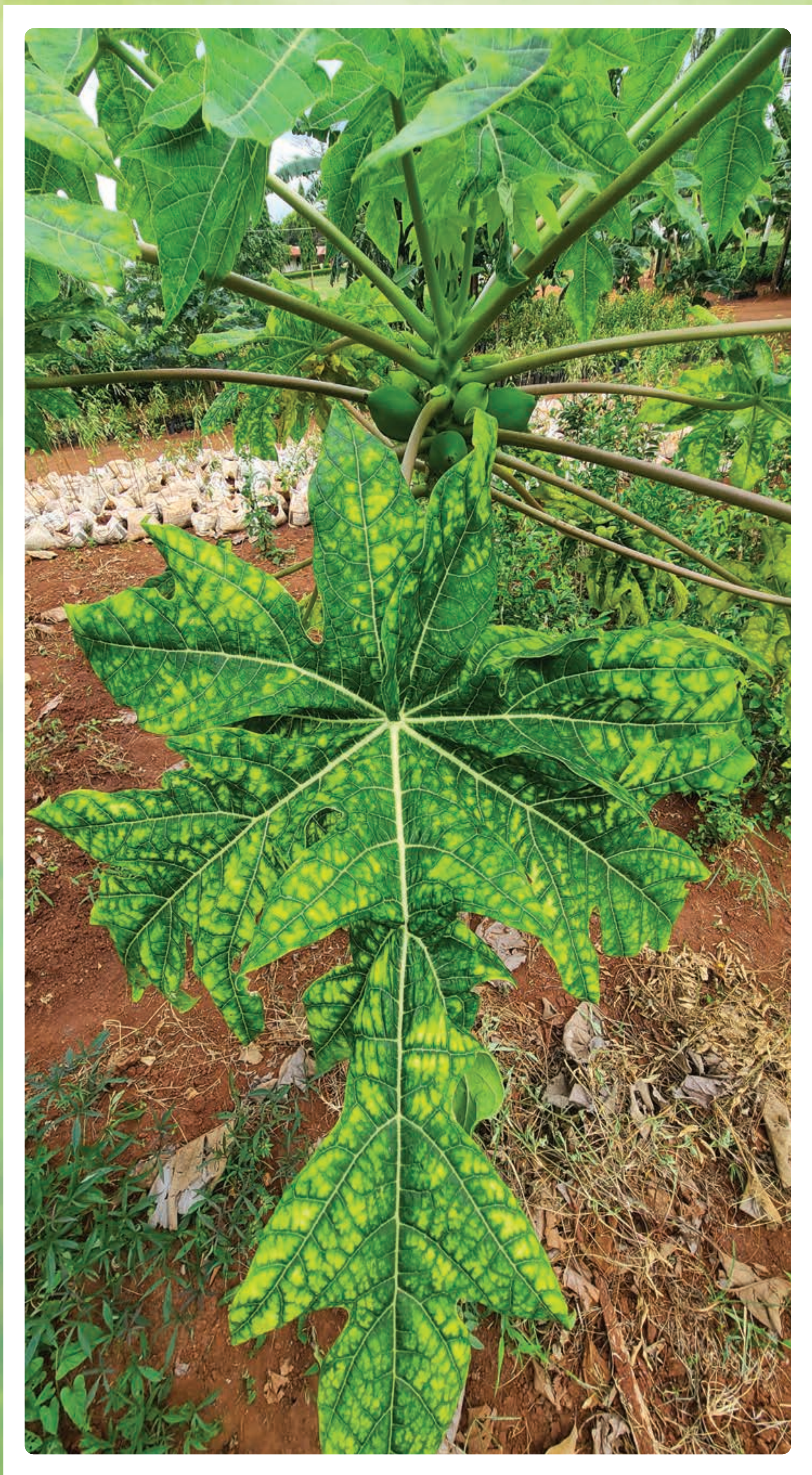




CROP NUTRIENT DEFICIENCY CATEGORY:
FIRST PRIZE

WINNING ENTRY:

Khalfan Awadhi
Mtua, Tanzania



Khalfan Awadhi Mtua gave us this vivid example of magnesium deficiency from a papaya orchard (featured on our cover). This deficiency is characterized by distinct yellowing between leaf veins. The orchard, located near Mlingano village, Muheza District, Tanga Region, Tanzania, was established under a ferralsol soil type, which typically have low calcium and magnesium concentrations due to a high degree of weathering.

CROP NUTRIENT DEFICIENCY CATEGORY:
HONORABLE MENTIONS

Clockwise starting Top Left:

Aiman Achemrk shot this image of iron deficiency in a maize crop growing near Oulad Bourhmoune (Fkih Ben Salah, Morocco). This deficiency appears as chlorotic leaves with interveinal stripes.

Siddu Malakannavar submitted a photo from Nakuru, Kenya of magnesium deficiency in coffee characterized by interveinal chlorosis and prominent green veins on older leaves.

Khalfan Awadhi Mtua submitted a nice example of a maize plant growing near Holili, Rombo district, Kilimanjaro region, Tanzania, showing nitrogen deficiency symptoms on the older leaves which have a V-shaped golden yellowing starting from the leaf tips and progresses towards the base.

Dominic Mutambu took this image from a farmer's field in Siaya county, Kenya, featuring the whitish stripes common to zinc deficiency in maize. Zinc deficiency in sub-Sahara African soils is a serious soil, crop, and human health problem that especially impacts children and expectant mothers to health risks.

PLANT NUTRIENT RESEARCH CATEGORY:

WINNING ENTRY:

Dimitri Ndikuryayo
Bubanza, Burundi

Dimitri Ndikuryayo took this picture in Bubanza, Burundi province of Bubanza Gihanga commune. Two undergraduate agronomy students are shown working in field plots used in the research on the effect of leguminous nutrients on rice crop rotation profitability. This day they were using a leaf colour chart to assess plant leaf greenness, a parameter that can be related to nitrogen uptake in the plant because of soil N supply.

PLANT NUTRIENT RESEARCH CATEGORY:
HONORABLE MENTIONS

Clockwise starting Top Left:

James Mlanda gave us this photo of a Zai pit taken at Kenyatta University as part of his undergraduate research focusing on reducing water loss to increase crop yields and prevent soil erosion.

Gratias Hougni submitted this photo from an on-farm trial initiated under the CocoaSoils program in Nigeria of a farmer applying fertilizer around a 20-year-old cocoa tree after having removed the litter layer. Traditional cocoa farming in Nigeria is done without any fertilizer inputs, leading to soil nutrient mining over time.

Siddu Malakannavar provides us with a look at their advanced drip irrigation system at Nakuru, Kenya. Their use of fertigation is a promising approach for synchronizing soil nutrient supply with crop nutrient demand both in terms of time and rate of nutrient application to follow 4R Nutrient Stewardship.

Beatrix Namulo Alweendo provides a look at cauliflower biomass sample collection for crop productivity (seed production) under a conservation agriculture system at Lutzville, South Africa, aimed at soil health improvement for sustainable cauliflower seed production.

Phosphogypsum Application Improves the Physical Properties of Salt-Affected Soils

By M Barka Outbakat, Khalil El Mejahed, Mohamed El Gharous, Kamal El Omari, and Adnane Beniaich

Salinity presents a major challenge to food security, especially in arid and semi-arid regions. *It negatively affects soil chemical and physical properties and ultimately crop yields. The use of phosphogypsum as an affordable amendment is a sustainable approach to overcome the effects of soil salinity. This research demonstrates phosphogypsum's beneficial impacts on the physical properties of salt-affected soils including improved water aggregate stability, water retention capacity, total porosity, and bulk density.*

Soil is a vital natural resource, providing several ecosystem services such as carbon sequestration, water purification, and nutrient cycling. However, soil is susceptible to various forms of physical, chemical, and biological degradation. Soil salinization is one form of chemical degradation that is significantly challenging crop production in arid and semi-arid regions. The presence of salts in the soil rhizosphere induces an osmotic effect that limits the uptake of both water and nutrients by plant roots (Rahneshan et al., 2018).

Salinity reduces the number of chloroplasts in leaf cells and damages the anatomy of the roots and leaves (Hasana and Miyake, 2017). Furthermore, salinity and sodicity harm soil physical properties. It causes soil swelling and erosion (Rengasamy, 2016). Moreover, salinity stress reduces soil water retention and increases soil dispersion, destroying soil aggregate stability (Saidi et al., 2004). The use of inorganic amendments, such as phosphogypsum, is a promising and low-cost strategy for saline-sodic soil reclamation (Outbakat et al., 2022). Phosphogypsum is a coproduct of the phosphate fertilizer industry according to the following reaction:

$$Ca_{10}(PO_2)6F2 + 10H_2SO_4 + 20H_2O \longrightarrow 6H_3PO_4 + 2HF + 10(CaSO_4 \cdot 2H_2O)$$

Integrating phosphogypsum into circular economy models minimizes reliance on conventional disposal methods on land and in the sea. This reduces environmental impact and enhances the overall efficiency and sustainability for phosphogypsum production and use.

What is the difference between salinity and sodicity?

Generally, there are three types of salt-affect soils, saline, sodic, and saline-sodic soils.

Saline soils have excessive amounts of soluble salts (Na, Cl, Mg…) in the soil water solution. Saline soils have an electrical conductivity of saturated soil paste higher than 4 dS/m. High concentrations of soluble salts are harmful for most crop species.

Sodic soils have significant amounts of sodium (Na) present on the exchangeable surface sites of clay minerals. Sodic soils have an exchangeable sodium percentage greater than 15%. These soils have poor structure that often closes the soil pores spaces and prevents soil aeration and water infiltration.

Saline-sodic soils have an electrical conductivity higher than 4 dS/m and an exchangeable sodium percentage greater than 15%.

Soil class	Electrical conductivity (dS/m)	Exchangeable sodium percentage (%)
Saline	>4.0	<15
Sodic	<4.0	>15
Saline-Sodic	>4.0	>15

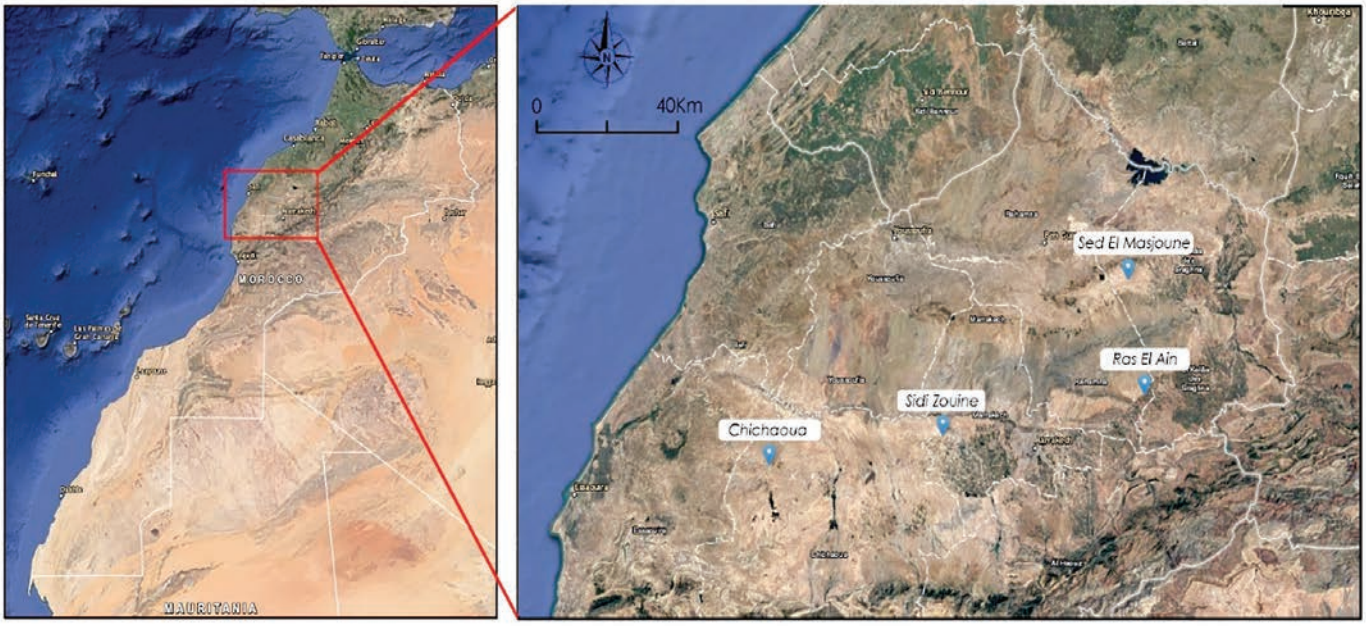


Figure 1. Location of studied salt-affected soils.

Arid and semi-arid conditions dominate Morocco, and the salt-affected soil area is estimated to be 1.148 M ha (FAO, 1988). Morocco is also among the significant phosphogypsum producers in the world. Few studies have evaluated the effect of phosphogypsum on physical properties of saline soils, which is the aim of the research presented below.

Study description

Soil samples were collected from four regions of Morocco: Chichaoua, Ras El Ain, Sidi Zouine, and Sed El Masjoune (**Fig. 1**). Each soil was classified for their salinity and sodicity status. The soil of Chichaoua is highly saline, while Ras Al Ain, Sidi Zouine, and Sed El Masjoune soils are very strongly saline–sodic (**Table 1**).

A pot trial was carried out under greenhouse conditions at the experimental farm of Mohammed VI Polytechnic University (UM6P) in Ben Guerir, Morocco. Each pot was filled with 10 kg of soil. The soil amendments included Moroccan phosphogypsum (PG) and natural gypsum (G) (**Table 2**). The treatments included a control, 15, 30, and 45 t/ha of PG, and 15 t/ha of G.

Table 1. Chemical properties of studied soils.

Properties	Chichaoua	Ras El Ain	Sidi Zouine	Sed El Masjoune
ECe (mS/cm)	11.7	26.47	94.6	140.6
pH	8.1	8.3	8.1	8.1
SO_4 (mg/kg)	3,210	2,145	2,323	2,728
Na_2O (mg/kg)	759	2,873	11,027	26,628
K_2O (mg/kg)	308	351	817	697
CaO (mg/kg)	7,984	7,973	10,754	10,923
MgO (mg/kg)	1,067	814	2,157	2,496
ESP (%)	7%	22%	41%	62%
SAR (mEq/l)	1.9	9.9	29.7	69.6

Table 2. Phosphogypsum and Gypsum properties.

Properties	Phosphogypsum	Gypsum
pH	5.8	8.1
EC (mS/cm)	2.4	2.3
Solubility (g/l)	2.5	2.03
Ca (%)	22.8	17.0
S (%)	23.7	13.1
K (mg/kg)	869	969
Mg (mg/kg)	259	7,587

A view of the pot trial experimental setup located at the UM6P Experimental Farm greenhouse in Ben Guerir, Morocco.

Soil physical evaluation

Soil physical properties were assessed after a Faba bean harvest. Soil bulk density (BD) was determined according to the method proposed by Blake and Hartge (2018). The saturated volumetric soil water content was used to determine total porosity (TP). Soil water aggregate stability (WAS) was measured using the wet sieving apparatus, while a pressure plate apparatus was used to determine field capacity (FC) and permanent wilting point (PWP) (**Fig. 2**). The available water capacity (AWC) for plants was estimated according to the following equation:

$$AWC = FC - PWP$$

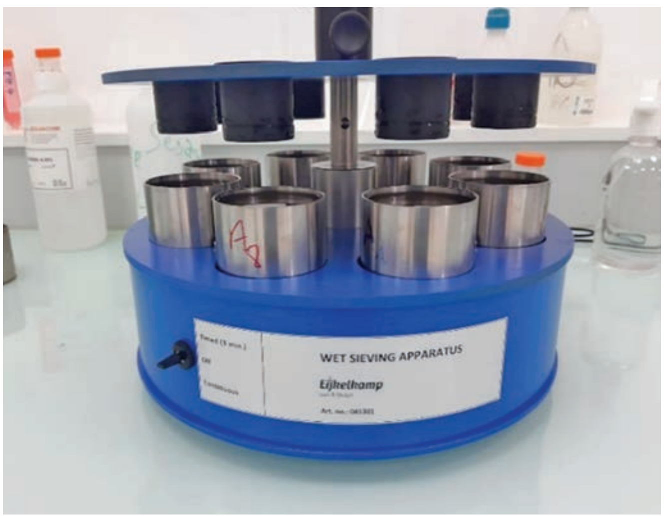


Figure 2. Wet sieving apparatus (left) and pressure plate apparatus (right).

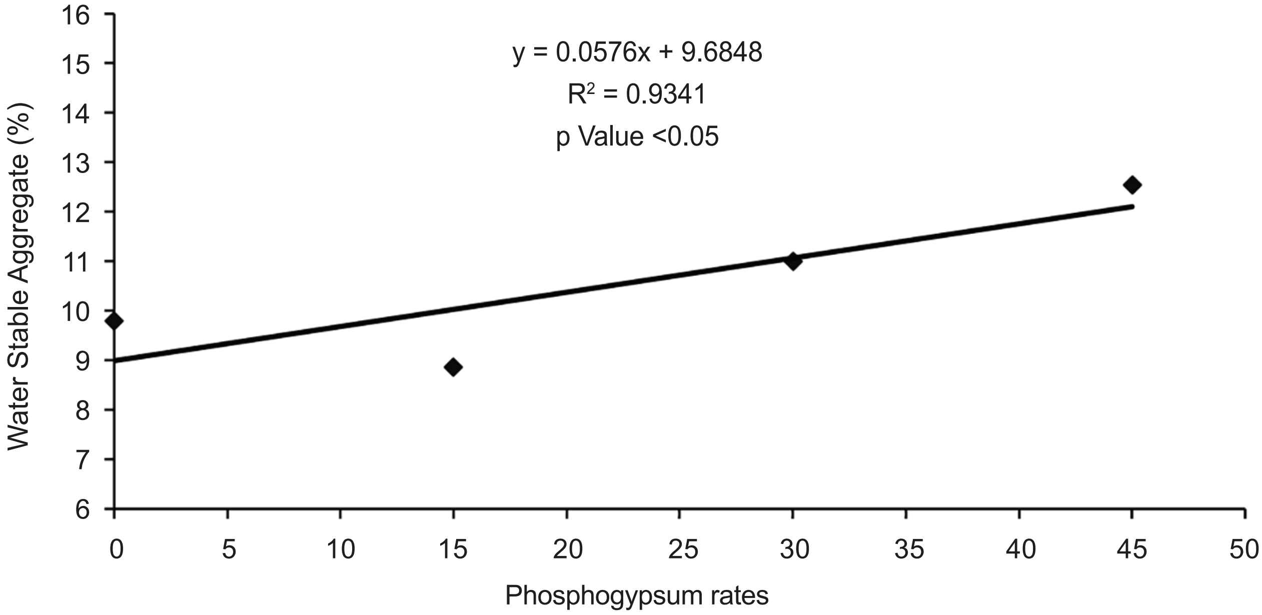


Figure 3. Linear regression between phosphogypsum rates and water aggregate stability.

Water Aggregate Stability and Available Water Capacity

Fig. 3 shows the linear regression between phosphogypsum application rate and water aggregate stability for all studied soils. In fact, WAS increased, with a high coefficient of determination (R^2=93.41%) as the phosphogypsum dose rose. Phosphogypsum affects soil aggregation by ensuring cation and electrolyte concentration balance in the soil. It can also alter the soil's susceptibility to dispersion by impacting the balance between attractive and repulsive forces at the soil-water interface.

Phosphogypsum application enhanced the available water capacity, especially in the Chichaoua and Ras El Ain soils (data not shown). This increase in soil water retention is attributed to sodium substitution by the calcium contained within the phosphogypsum (Melo et al., 2008).

The lyotropic series of cations presents the relative strength of ion adsorption onto clay fraction for the principal cations in the soil (i.e., Ca^{2+} > Mg^{2+} > K^+ ≈ NH^{4+} > Na^+). The application of phosphogypsum introduces a high concentration of calcium, and since sodium is in the last position in this sequence, it is easily replaced by calcium due to valence and low adsorption selectivity (**Fig. 4**).

Soil Porosity and Bulk Density

The relative impact of phosphogypsum on total soil porosity is different between soil types,

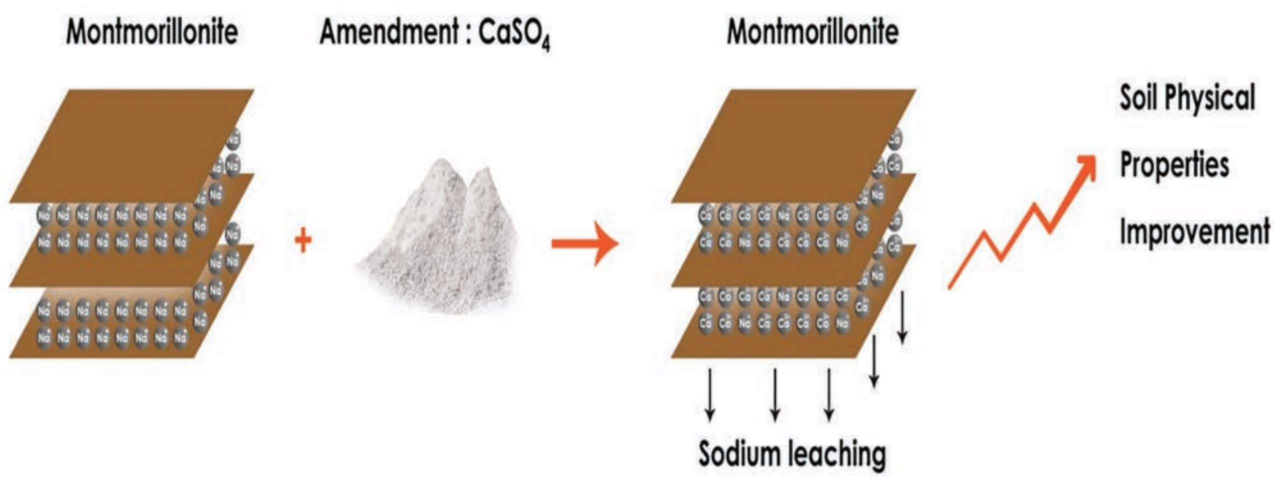


Figure 4. Effect of phosphogypsum on soil physical properties.

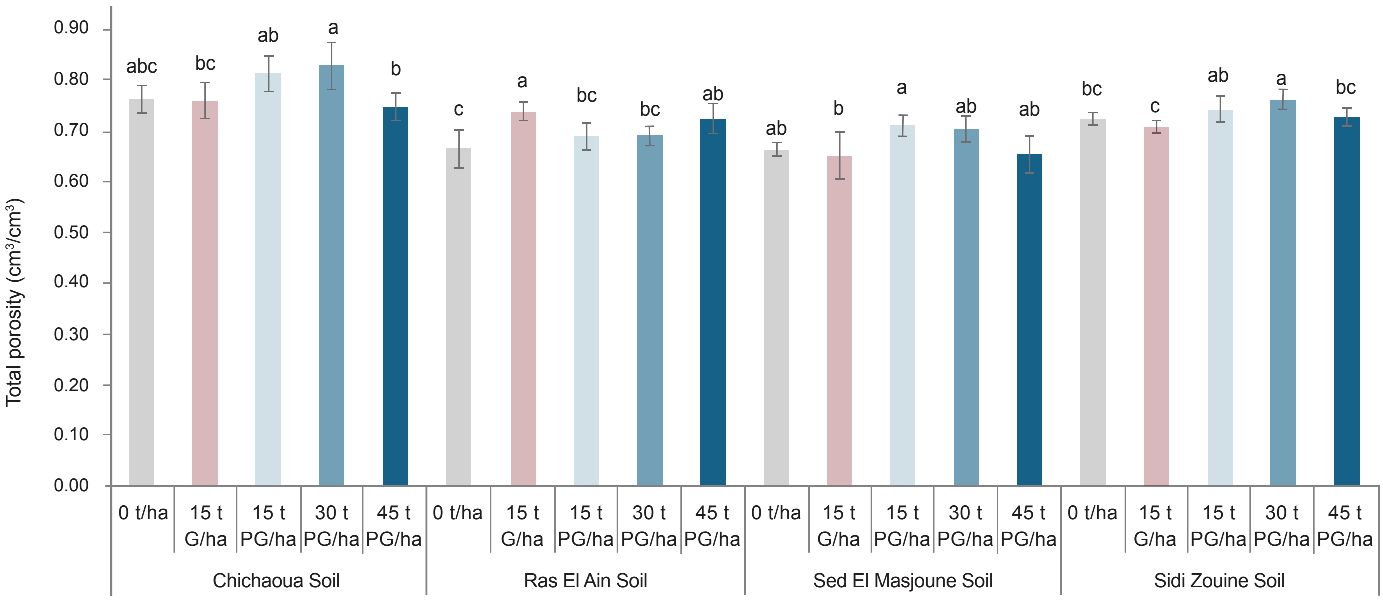


Figure 5. Effects of phosphogypsum rates on total soil porosity. Lower-case letters compare treatments applied to the same soil, using the Tukey test ($p < 0.05$).

but overall, its application had a positive effect on TP (**Fig. 5**). For instance, in Chichaoua, TP was 8% greater than the untreated control with the application of 30 t PG/ha. However, in Ras El Ain, 45 t PG/ha resulted in an 8% increase in TP compared to the control. A decrease in soil bulk density was only observed in Chichaoua where it was 5% lower than the control if amended with 45 t PG/ha (**Fig. 6**).

Phosphogypsum was similar to gypsum in its capacity to improve soil physical properties. However, evidence suggests cases where it was more effective, which is possibly explained by phosphogypsum's potential to promote greater calcium and sulfate concentrations than gypsum (**Table 2**). Furthermore, the acidifying effect of phosphogypsum can enhance the solubilization of soil calcium carbonates and further improve Ca^{2+} concentrations in the soil. Since the demand for natural gypsum is increasing, phosphogypsum can be a viable alternative to alleviate any demand-driven pressures on natural resources.

Summary

Phosphogypsum application enhanced the structure of salt-affected soils by improving water

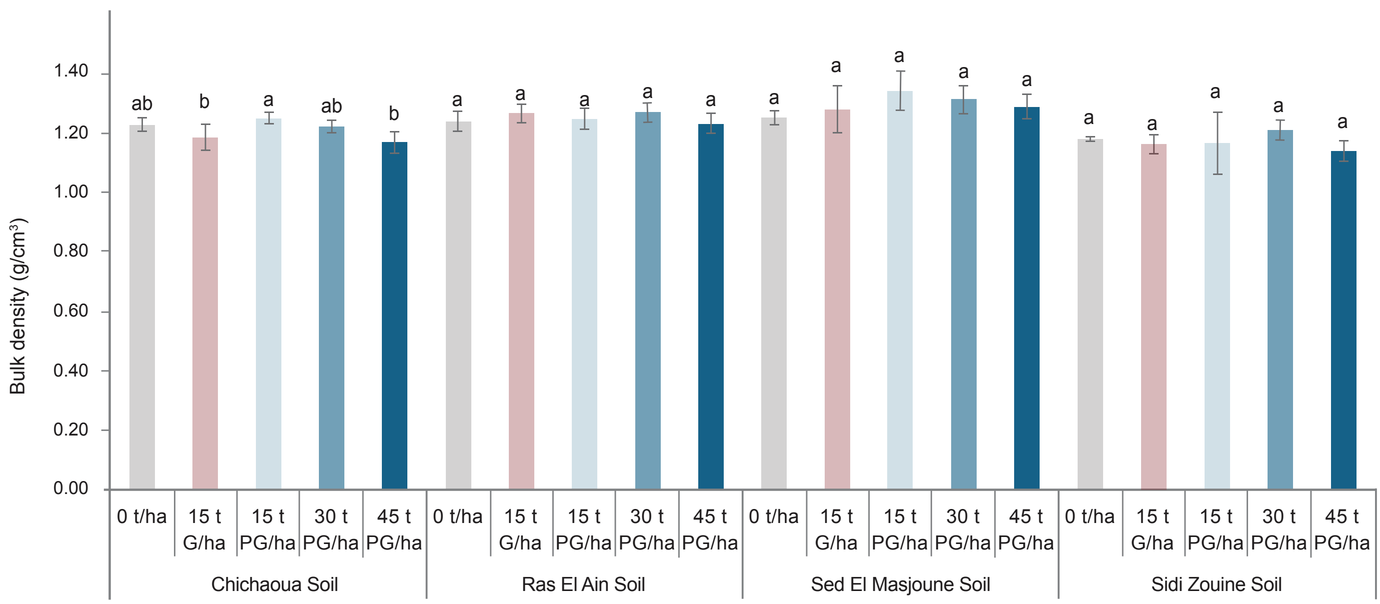


Figure 6. Effects of phosphogypsum rates on the bulk density. Lower-case letters compare treatments applied to the same soil using the Tukey test ($p < 0.05$).

aggregate stability, water retention, total porosity, and decreasing bulk density. Improving the soil's physical properties can enhance the growth of below and aboveground biomass, and the development of harvestable crop products, especially in arid and semiarid areas. Therefore, phosphogypsum could revitalize salt-affected soils into productive and resilient ecosystems, promoting sustainable land management practices.

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The Taymate Cooperative: A Women-led Empowerment Story

By Aziza Tangi, Ngonidzashe Chirinda, Hakim Boulal, and Thomas Oberthür

When success stories from agricultural cooperatives are identified they deserve to be studied and told to inform actions for scaling out best management. *We explore how cooperatives encourage strategies for livelihood improvement and support economic and social innovations to foster community adaptation to climate change. Lessons from the Taymate Olive Cooperative inform the design and implementation of effective policies and programs supporting the growth and sustainability of gender-sensitive agricultural cooperatives in Morocco and contribute to the socioeconomic development of rural communities.*

The history of the Taymate Cooperative

Livelihood-driven cooperatives are constituted by independent groups or individuals that voluntarily agree to address shared economic, social, and cultural needs and goals through a jointly owned and democratically run business (Zeuli and Cropp, 2004). In 2008, motivated to generate income to support their families, a group of young women with diplomas created such an agricultural cooperative. The cooperative is located in Timoulilt commune, Azilal, in Morocco's northcentral Beni Mellal-Khenifra region. Currently the Taymate Cooperative has 20 members, including 15 women and five men, and a capacity to produce 50 t of table olives from olive orchards covering an area of around 70 ha. The main activities of the cooperative include producing, collecting, packaging, and processing olives. The cooperative aims to add value to harvested olives, preserve the olive trees of the Timoulilt commune, and engage women to improve their income levels and, subsequently, their family's standard of living.

In 2011, the cooperative built its olive preservation unit with support from a National Initiative for Human Development (INDH) program in Azilal province and the European Committee for Agricultural Training

Meeting establishing the Taymate Cooperative in March 2008.

(CEFA). Then, in 2014, the French Foundation further equipped the cooperative with other modern machinery. The cooperative has benefited from a supporting ecosystem fostered by the Green Morocco Plan's (2008–2020) strategy centered on growth in the agricultural sector based on cooperatives, state actors including the INDH and Ministries of Agriculture and Industry, and several other national and international institutions.

Working within the cooperative has provided members the opportunity to be more independent financially, even if the gain was small. For these women, belonging to the cooperative provides a relief that gives them a sense of freedom.

> "*The Taymate Cooperative members are women warriors who can do great things with little. Can you imagine what they can achieve if given a chance and the resources to improve their lives and their local communities? These women were happy despite their initial working conditions in a small building without electricity or running water since it gave them a chance to escape the arrogance of their bosses at the farms as agricultural wage workers."*
>
> **- Rabha, Cooperative President**

Why is Taymate Cooperative a success story?

While there is a myriad of factors that contribute to the success of a cooperative, including the financial and capacity building support systems that they have accessed, quotes from members of the Tayamate cooperative explain their experiences:

> "*Since joining the Taymate Cooperative, I felt that I am blessed; it is a gift from God; it has enabled me to support my family, my sick husband, and my two deaf and mute boys. My life has started changing, and my passion for my work has grown. The challenge for me has been limited to the extent of my success in acquiring autonomy at work and my ability to support my family. As a poor woman raised in a rural area, I have never imagined that one day I would travel in a plane outside Morocco or shake hands and receive a gold medal from the Moroccan Minister of Agriculture. That was unimaginable."*
>
> **- Fatiha, 60 years-old, Treasurer of the Cooperative, and an Ex-wage Worker**

> "*Our members have benefited from the cooperative since part of our income is shared among ourselves and another part is reinvested into the cooperative. This money has helped them enroll their children in school and buy clothes and books. In addition, 70% of the members have been able to continue building their houses and brought small livestock to generate more money for their livelihoods. Thanks to human development programs and the support of the Regional Directorate of Agriculture, Regional Agricultural Development Office, the Chamber of Agriculture, State authorities, the Social Development Agency (ADS), the National Office of Sanitary Safety and Food Products (ONSSA), elected councils, etc., the cooperative has been able to ensure its presence on a large scale, despite national competition. This has enabled us to participate in numerous national and international exhibitions, notably in France, Switzerland, the Emirates, Tunisia, and Morocco. We have customers in Rabat, Marrakech, Azilal, Beni Mellal, and Ouzoud in Morocco. It is a small quantity, but we sell continuously."*
>
> **- Halima, Vice President**

The Taymate Cooperative has received several certificates, including the "Terroir du Maroc" product label, the food safety certificate from the National Office of Sanitary Safety and Food Products (ONSSA) in 2014 for table olives and an extra virgin olive oil certificate in 2018. In addition, they obtained the Independent Export Control and Coordination Organization (EACCE) certificate for table olives in 2015. They have also won the gold medal for its extra-virgin olive oil product and the bronze medal for its herb-flavored black olives product in 2020.

Research has demonstrated that successful agricultural cooperatives have proven to be an effective tool for the socioeconomic development of regions. They often catalyze a reduction in social and spatial inequality and leverage social and environmental protection and sociopolitical emancipation (ODCO, 2012). In the Timoulilt commune, the creation of the cooperative has influenced the behaviors and attitudes of the farmers regarding several agricultural practices such as the pruning of the olive orchard. According to Si Mustapha, a member of the cooperative, "*In the*

Participants of kick-off meeting to discuss opportunities for improving the inclusion and empowerment of women within the smallholder olive value chain, Timoulilt commune, Morocco.

beginning, the farmers refused to practice pruning because they considered the olive as a sacred tree that should not be touched, but after different discussions and training, they started practicing it, especially the farmers who are engaged with the cooperatives to provide olives."

Crafting a coherent group for a sustainable cooperative

The creation of a homogeneous group is critical to making cooperatives work. Being a cooperative member is the individual's first decision, and the motivation is primarily economic. Farmers participate because they obtain direct and indirect benefits. The more diverse the membership and vision, the more difficult it is to achieve agreement on goals, and as a result, there are higher decision-making costs, including the costs of gathering information on the member's preferences, voting cycles between them, as well as attending meetings and other activities associated with collective decision-making (Hansmann, 1999). Farmers' attitudes toward agricultural cooperatives and participation behavior may differ depending on their age, education, or the size of the farm under their responsibility (Hansen et al., 2002; Osterberg et al., 2009). Because cooperatives are owned and controlled by their members (Dunn, 1988), active participation in cooperative decision-making is critical to the organization's operation and viability (Spear, 2004).

The Taymate Cooperative members have different education levels but they share a common goal: looking for income-generating activities to cope with the impact of climate change. It is essential to remember that large group sizes can make cooperation and survival more difficult. Cooperation and efficiency, according to the theory of collective action, necessitate unanimous action (Olson, 1971). Large groups may encounter the problem of free riders, which can hinder group efforts. Furthermore, management theory studies have shown that larger group sizes can lead to increased conflict and decreased group cohesiveness (Valentinov, 2004).

Studies reveal that about 20% of cooperatives fail in the first few years of operation (Ibourk and El Aynaoui, 2023; Chlebicka et al., 2018; Grashuis, 2018). The high failure rate is caused mainly by barriers to marketing, governance, management, legislation, supervision, and funding, as well as fundamental issues with leadership and project formalization, mainly brought on by the beneficiaries' low skill levels (Ibourk and El Aynaoui, 2023).

The cooperative members always look for solutions because they are self-motivated. According to Al Mehrzi et al. (2016), a significant and positive relationship exists between member motivation and performance. During the creation process, the founders of the Taymate Cooperative tried to gather motivated members who were determined to work hard to improve their livelihoods and preserve their ancestors' olive orchards. That is among the keys to the cooperative's success and sustainability. The motivation of the Taymate members arises from self-will, and usually, intrinsic motivations are more durable than the motivation that comes from outside. Solidarity and mutual respect are other principles that shape the relationships between the members of the cooperative; they work together as a family. An exogenous factor influencing agricultural cooperative survival is the local culture's attitude toward the concept and values of cooperation (Giagnocavo et al., 2018).

Cooperative members sorting olives for further processing at the Timoulilt for Development Association.

Women leaders can empower others – and themselves

Cooperatives play an important role because they can meet women's practical and strategic needs by providing access to income-generating activities as worker-owners (Maleko, 2015). Women are the Taymate Cooperative's backbone because they provide and participate in all activities. The cooperatives have been led by two women, Halima and Rabha, since the start. Both have demonstrated their ability to help other women members overcome gender-specific constraints to improve their self-confidence, knowledge, income, access to inputs, and social network and create a space for these women and themselves in the table olive value chain.

> *"I noticed a shift in my personality after years of joining the cooperative. I gained self-confidence and can now speak in front of people. I feel that my voice is heard and can change my community. I like the new me, and I am not afraid anymore. Now, I am convinced that alone, we go fast. However, together, we go further."*
>
> **- Mina, cooperative member**

Several studies have found that notions of leadership are implicitly or explicitly assumed, with leadership being linked to gender (Bajcar et al. (2019); Hassan et al., 2008). Women's leadership styles are more participative and less directive than their male counterparts. Women are people-oriented and "transformational" rather than task-oriented and "transactional," and this is a distinct style (Eagley et al., 1990).

Most of the cooperative members are women and they have demonstrated remarkable effectiveness and cooperation, which has contributed to its success and survival. Women are more active in cooperation than men due to several factors. Firstly, women show a greater inclination to cooperate in interaction with strangers. At the same time, men tend to be more sensitive to the effects of society and make cooperative decisions more often when friends are in the group (Peshkovskaya et al., 2018; Capraro et al., 2018). Additionally, women's attraction to cooperative incentives may result from their more optimistic assessments of their prospective teammate's ability and their advantageous inequity aversion (Peshkovskaya et al., 2017). Furthermore, women's behavior is more reactive to the social conditions of different games, and they are not less competitive than men when the games evoke a parenting frame or include a pro-social option (Kuhn et al., 2015). Overall, women's cooperative behavior may be influenced by their evolutionary adaptation to strategically suppress competitiveness to elicit cooperation for raising offspring (Cassar et al., 2023).

Important Insights

Taymate's Cooperative provided women with support and training and gave them a source of income, independence, control, and self-esteem. The success stories of this cooperative reflect the efforts made by the members, particularly women, to build their success in small but specific ways. However, it is essential to note that despite efforts to combat poverty and gender inequality, rural women still face marginalization in development programs, with limited participation in decision-making processes and unequal economic benefits within cooperatives (Montanari et al., 2019).

From the Taymate Cooperative's story, women should adhere to certain principles to succeed in agricultural cooperatives. **Firstly,** cooperatives should prioritize accountability, fair wages, and competitiveness in high-end markets to avoid failure, as Dossa (2012) confirmed. **Secondly,** overcoming barriers to women's participation, such as low levels of education, domestic and childcare responsibilities, and cultural constraints. Illiteracy among rural women should be addressed through education and empowerment initiatives to promote their active participation in decision-making processes (Housseine, 2021). **Thirdly,** adopting sustainable management practices can positively impact women's cooperatives' community, environment and competitiveness (Omari et al., 2013). Additionally, women's participation in decision-making processes and fostering cooperative networks contribute to their success in agricultural cooperatives (Esayas et al., 2017). **Lastly,** women's involvement in income-generating activities and cooperative decision-making should be promoted to ensure economic empowerment and gender equality (Montanari et al., 2019).

The Taymate story of women empowering women must be scaled out to other regions. Overall, women's cooperatives have proven to be a valuable avenue for women's social inclusion, empowerment and economic advancement. Still, we must always keep in mind the sociocultural differences in each area because they influence how people intervene, behave, and are willing to engage in efficient collective actions. ■

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FORUM

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KEY DATES ON OUR 2024 CALENDAR

MARCH

AFRICAN PLANT NUTRITION SCHOLAR AWARD

This award encourages development and success within graduate student programs specializing in the sciences of plant nutrition and management of crop nutrients in Africa. Students in the disciplines of soil science, agronomy, and horticultural science or tree crop science with a focus on plant nutrition are encouraged to apply.

Funding: Awards of USD $2,000 are available to ten graduate students.

Eligibility: Candidates must be currently enrolled in a Ph.D. program, or in the second year of a M.Sc., M.Phil. program at the closing date for applications.

Call for Applications: March 2024

Application deadline: April 30, 2024

Learn more at: www.apni.net/scholar-apply

MAY

AFRICAN PHOSPHORUS FELLOWSHIP AWARD

This fellowship award supports scientific programs focused on understanding and improving phosphorus management in Africa's field or tree crop agro-ecosystems.

Funding: Awards of USD $5,000 are available to for five scientists.

Eligibility: Applicants must be full time scientists working at an African NARES institution or university. Applications from scientists in Post Doctorate positions are also eligible for this award. Only applicants who have completed their Ph.D. program will be considered.

Call for Applications: May 2024

Application deadline: June 30, 2024

Learn more at: www.apni.net/p-fellowship-apply

JULY

AFRICAN PLANT NUTRITION OUTREACH FELLOWSHIP AWARD

The fellowship award supports education, training, and communication programs relevant to improving the use and efficiency of plant nutrients in African agro-ecosystems.

Funding: Awards of USD $5,000 are available to for two innovative scientists, extension specialists, or educators in Africa.

Eligibility: Applicants must be full time scientists, extension specialists or educators working at an African NARES institution (National Agricultural Research and Extension System), university, non-profit organization, or in the private sector to be eligible. Students are not eligible for this award.

Call for Applications: July, 2024

Application deadline: Sept 30, 2024

Learn more at: www.apni.net/outreach-fellowship-apply

For any additional information about our Awards and Grant Program see www.apni.net/awards

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Contributed by Joses Muthamia

Embu Road - "This photo taken during a successful farmers' field day held at one of our #NUTCAT project sites in Runyenyes, Embu County, Kenya. This event gathered over 300 farmers who were trained on various aspects of cereal production. The farmers, together with researchers and other agricultural stakeholders addressed a wide range of challenges including soil fertility and nutrient management, good agronomic practices for improved maize productivity and health, postharvest losses, climate change, and strategies to achieve greater sustainability."

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