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THE ROLE OF BASIC SCIENCES IN ADDRESSING GLOBAL CHALLENGES TO SUSTAINABLE DEVELOPMENT: EXPERIENCES FROM CIFOR-ICRAF

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Abstract

Purpose — This paper highlights the application of the basic sciences in tackling human-induced global challenges, including climate change, biodiversity loss, land degradation and broken food systems, that militate against the attainment of the United Nations' Sustainable Development Goals (SDGs).
Methods — It adopted a secondary research approach involving a review of current literature.
Findings — It shows that basic studies in different branches of plant biology contribute to the conservation and management of tree and forest genetic resources while studies in soil biology and principles of chemistry and physics contribute to soil health assessment in landscape restoration efforts.
Conclusion & Recommendation — The paper argues that the success of sustainable development initiatives that leverage the ability of trees to provide ecological goods and ecosystem services could be constrained by the growing threat to botanical education and inadequate funding of basic science disciplines. Recommendations are made to improve funding and inclusion of the basic sciences, particularly in African universities, in sustainability-focused research initiatives.

Keywords — Climate resilience, biodiversity conservation, ecosystem restoration, food and nutrition security, science education.

Introduction

Many human activities aimed at development (e.g., agriculture and industrialization) have impacted on the environment at degrees of severity that threaten the sustainability of life on earth. There is evidence to show, for example, that periodic booms in cocoa production in countries like Ghana and Indonesia have been as a result of expansion into new forest frontiers (Asare, 2019; Kelley, 2018) and this has caused extensive forest loss. Reports indicate that West Africa – which provides about 70% of global cocoa production – no longer has enough frontier forests to be exploited by future generations (Gockowski and Sonwa, 2011; Kroeger et al., 2017). Thus, going by the Brundtland Report's definition of sustainable development (WCED, 1987), it can be concluded that the traditional method of cutting down forests for agricultural expansion is no longer sustainable. This is because development that meets the needs of the present must not compromise the ability of future generations to meet their own needs (WCED, 1987). Although sustainable development has been defined in many ways since the publication of the Brundtland Report by WCED (1987), it is generally conceived as development that balances economic, social and environmental sustainability. The seventeen sustainable development goals (SDGs), also referred to as the global goals, adopted by the United Nations (UN) in 2015, provide a framework for achieving this balance. However, human-induced global challenges (e.g., climate change, land degradation, deforestation and biodiversity loss) militate against the attainment of these goals. Forest loss due to agricultural expansion directly causes biodiversity loss. Indirectly, forest loss causes climate change as atmospheric carbon levels increase with the decrease in carbon sinks (Bele et al., 2015). Agriculture further contributes to climate change through the emission of greenhouse gases from agro-ecosystems, e.g., methane and nitrous oxide from rice cropping systems (Minami and Neue, 1994; Qin et al., 2010). Climate change in turn disrupts weather patterns, causing more severe droughts and floods, higher temperatures, increased incidence of pests and diseases; all of which affect biodiversity and ecosystem health (Bach et al., 2020; Skendžić et al., 2021).

Biodiversity is crucial for sustaining life on earth because it provides many ecological goods and services that support human livelihoods (IUCN-UNEP-WWF, 1980). These include provision of fuel, food and fibre, and maintenance of genetic resources as key inputs to agricultural crop varieties and livestock breeds, medicines and other natural products. While attention is often paid to the loss of individual animal species (e.g., elephants) and endangered plant species (e.g., mangroves), it is the fragmentation, degradation and outright loss of forests, wetlands and other ecosystems that pose the gravest threats to biodiversity and, by extension, sustainable development (Secretariat of the CBD, 2000). Biodiversity loss often destabilises and reduces the productivity of ecosystems and weakens their ability to deal with both natural disasters (e.g., floods, droughts, hurricanes) and human-induced stresses (e.g., pollution and climate change). This reduction in productivity and resilience of ecosystems undermines environmental sustainability and, invariably, leads to broken food systems and unsustainable value chains; thereby compromising economic and social sustainability (FAO, 2019).

Several international bodies including the United Nations Environment Programme (UNEP), United Nations Food and Agriculture Organization (FAO) and the Consultative Group for International Agricultural Research (CGIAR) have, for many decades, conducted research aimed at achieving sustainable development. This paper focuses on successes of two CGIAR centres – the Centre for International Forestry Research (CIFOR) and World Agroforestry, also known as International Centre for Research in Agroforestry (ICRAF). In 2019, the two centres merged to become CIFOR-ICRAF with a common goal of addressing the most pressing challenges facing the world's forests and agroforestry landscapes (CIFOR-ICRAF, 2023a). It is important to note that CIFOR-ICRAF's work recognizes and holistically addresses the complexity of interactions between people and ecosystems and, therefore, entails more of applied research (CIFOR-ICRAF, 2023b). Here, we highlight the contribution of basic scientific studies to efforts aimed at tackling the global challenges.

In the next two sections, we provide a brief profile of CIFOR-ICRAF followed by an overview of the functions of selected laboratories and research units located at the organization's Nairobi campus in Kenya. The discussion section focuses on the relevance of CIFOR-ICRAF's work to key sustainable development initiatives and the constraints posed by a growing decline in botanical education to effective harnessing of trees and forest resources for sustainable development. In the light of challenges faced by basic science departments in African universities in attracting students and research funds, the paper concludes with recommendations to improve their inclusion in sustainability-focused research initiatives.

Brief profile of CIFOR-ICRAF

CIFOR-ICRAF works mostly in the Global South – Africa, Asia and Latin America – to spearhead research in development initiatives that aim at finding evidence-based solutions to the interconnected issues of climate change, deforestation and biodiversity loss, broken food systems (including degradation of land and water resources), inequality, and unsustainable value chains (Evans & Sinclair, 2022). Hence, the organization's work is hinged on the crucial role of forests, trees and agroforestry in the management and conservation of biodiversity. The term 'agroforestry' is broadly used at CIFOR-ICRAF to mean agro-ecological approaches that involve not just trees, but also farmers, livestock and forests at multiple scales (van Noordwijk et al., 2023). These include remnant trees on farms, deliberate tree-crop production as well as farming in forests or at forest margins – all of which leverage the ability of trees to sequester carbon, record climate history, cycle water and nutrients from soil, build soil organic matter and carbon, and shelter biodiversity (CIFOR-ICRAF, 2022; Somarriba et al., 2021).

Conservation of biodiversity, tree and forest genetic resources has been one of CIFOR-ICRAF's major research themes. Work undertaken under this theme aims at delivering, *inter alia*, evidence-based solutions to the environmental impacts of production of economically important tree crop commodities such as cocoa, coffee, oil palm, rubber and tea. Efforts have been made, especially in coffee and cocoa agroforestry landscapes, to boost productivity and safeguard diversity through domestication and delivery of suitable tree planting material including food, fodder, timber and medicinal trees to growers. Another major research theme pursued at CIFOR-ICRAF is Soil and Land Health which focuses on providing rigorous science-based evidence for soil and land restoration with relevance for food and nutrition security, and national climate commitments. The other themes are 'sustainable value chains and investment', 'governance, equity and well-being' and 'climate change, energy and low-carbon development' (CIFOR-ICRAF, 2023b). Realizing the need for partnerships to meet the global goals (SDG 17), CIFOR-ICRAF has established Transformative Partnership Platforms (TPPs) that serve as knowledge co-creation and delivery channels, each with a specific research focus (CIFOR-ICRAF, 2022).

A notable CIFOR-ICRAF managed project is the Regreening Africa Project which aims to improve the livelihoods, food security and climate resilience of 500,000 households across 100 million hectares in eight sub-Saharan African countries - Ethiopia, Ghana, Kenya, Mali, Niger, Rwanda, Senegal, Somalia - by reversing land degradation and restoring ecosystem services, mainly using agroforestry (Aluoch, 2023; World Agroforestry, 2019). Proven agroforestry technologies, including farmer-managed natural regeneration (FMNR), have been adapted to suit farmer needs under different socio-ecological settings (Chomba et al., 2020). According to Smith et al. (2019), restoring degraded land using agroforestry could increase food security for up to 1.3 billion people. The success of agroforestry technologies that involve tree planting is, however, dependent on the availability of good quality planting material and the ability to choose the right tree, for the right place, and for the right purpose (Graudal et al., 2021).

The next section throws light on how various research units and laboratories at CIFOR-ICRAF's Nairobi campus contribute not only to effective conservation and distribution of disease-free tree planting materials, but also to building the rigorous scientific evidence required to ensure that project targets (e.g., soil fertility improvement, food security, climate adaptation and resilience, poverty reduction, and sustainable value chains) are met. With reference to relevant literature, we highlight the basic scientific studies and/or principles that contribute to the functions of each research unit/laboratory.

Methods and Materials

Overview of functions and related research of selected CIFOR-ICRAF units/laboratories

Genetic Resources Unit (GRU)

CIFOR-ICRAF's Genetic Resources Unit houses a tree seed laboratory and a seed genebank. The core functions of the GRU are to collect, document, conserve, characterize and distribute high quality agroforestry tree genetic resources mainly for agricultural and ecosystem restoration purposes. The seed genebank holds over 6000 accessions from 190 tree species. Categories of use of the conserved tree species include food, fodder, timber, medicine, and soil fertility improvement. The unit also has field genebanks for about 67 tree species with non-orthodox or recalcitrant seeds located in 42 sites in 17 countries. One of the field genebanks for *Allanblackia* is located in Ghana at the National Tree Seed Centre, which is managed by the Forestry Research Institute of Ghana (FORIG) – one of thirteen national research institutes that constitute Ghana's Council for Scientific and Industrial Research (CSIR). Various types of germplasm – fruits, seeds and semi-extracted seeds (fruits mixed with pulp) – are received and processed by the GRU. Barcoding of all accessions in the seed genebank enhances tracking of each accession as it is taken through the various genebank processes; namely, material verification, seed extraction (when necessary), seed cleaning, seed purity analysis, seed drying, seed characterization, seed viability testing and storage. Information captured on seed storage packages include accession number, species name, provenance, country, weight and barcode number. Data management of the seed genebank processes are all automated and standard operating procedures (SOPs) have been developed for each stage. Below, we highlight the contribution of plant biology to the functions of the GRU.

Collection of tree germplasm for conservation requires accurate identification of the species. Therefore, plant taxonomy plays a role in the functions of the GRU. Different plant taxonomic characters (e.g., morphological, physiological, molecular) are used in plant identification. Morphological traits used in species characterization include leaf, fruit and seed parameters such as shape, colour and texture (Nyarko et al., 2012; Odoi et al., 2020).

Plant and seed physiology is also crucial to the work of the GRU as the viability and longevity of stored germplasm is affected by various physiological factors including seed moisture content and desiccation tolerance (Nya et al., 2000; Dickie and Pritchard, 2002). Relevant studies in this regard include investigation into seed dormancy breaking methods (e.g., Frederick et al., 2017; Noor Mohamed et al., 2021) since dormancy poses a challenge to germination, which is necessary for seed viability testing and the ultimate use of the seeds for their intended purpose. Investigation into varietal differences in seedling growth performance of important tree species such as shea (*Vitellaria paradoxa*) provide valuable information for the selection of suitable varieties for the establishment of field genebanks (Odoi et al., 2020).

Germplasm Health Unit (GHU)

Plants and their seeds possess an inherent ability to serve as carriers of pests and diseases and, hence, pose a high risk of transboundary spread through germplasm distribution activities (Kumar et al., 2021). In Africa, for example, emerging native and invasive tree pests and diseases pose a threat to agroforestry-based strategies designed to enhance biodiversity, build climate resilience, and bridge gaps in food and nutrition security (Cherotich, 2022). Hence, the core function of the GHU is to ensure the phytosanitary safety of tree seeds and other propagules that are received for processing and distribution by CIFOR-ICRAF's genebank.

Basic plant pathology procedures are used to diagnose and identify microbial pathogens (e.g., fungi, bacteria and viruses). Entomology and parasitology also come to play as insect pests and parasitic nematodes are identified using morphological characterization.

African Orphan Crops Consortium Genomics Laboratory

CIFOR-ICRAF is a member of the African Orphan Crops Consortium (AOCC) – a global partnership with the goal to mainstream 'orphan' crops (neglected, under-utilized and/or under-researched crops) into African food systems to tackle "hidden hunger" (micronutrient deficiencies) and improve nutrition. The objectives of the AOCC Genomics laboratory are to sequence, assemble and annotate the genomes of 101 traditional African orphan crops including 43 tree species, to facilitate their genetic improvement (AOCC, 2023). An understanding of fundamental genetic principles taught in biology is integral to the objectives of the AOCC Genomics Lab. Whole genome sequencing has been made possible due to tremendous improvement in the DNA sequencing methods developed in the 1970s to determine the order of the four nucleotide bases (adenine, thymine, cytosine, and guanine) that make up a single strand of the DNA molecule. The complementary base-pairing of adenine with thymine (A-T) and cytosine with guanine (C-G) in the DNA double helix underlies most DNA sequencing methods and is also the basis for the mechanism by which DNA molecules are copied, transcribed and translated (Mardis, 2017). The whole genome of an organism contains millions of base pairs containing a vast amount of important genetic information that regulates the development and maintenance of the form and functions of the organism. Thus, DNA sequencing of the orphan crops would enhance determination of the genes involved in various plant functions, e.g., nutrient uptake, translocation and storage, yield, pest and disease resistance, shelf-life and climate adaptation. This information can then be used in breeding technologies for crop improvement. So far, about 8 crops on the AOCC list have been fully sequenced. These include *Vitellaria paradoxa* (shea tree), *Artocarpus heterophyllus* (jack tree), *Artocarpus altilis* (breadfruit tree), *Moringa oleifera* (horseradish or drumstick tree) and *Slerocarya birrea* (marula). There are on-going efforts to expedite whole genome sequencing of the remaining target crops (AOCC, 2023). The AOCC is working in collaboration with the African Plant Breeding Academy (AfPBA) to equip practising African plant breeders with advanced genetic technologies to harness the diversity of neglected crops to meet the needs of producers, processors and consumers (Jamnadass et al., 2020).

Dendrochronology Laboratory

Though trees and forests are important for climate change adaptation and mitigation, trees themselves are vulnerable to climate change. Extreme weather events such as floods, droughts, and increased frequency and intensity of dry spells are impacting on the vitality, productivity, and quality of ecosystems and ecosystem services. To ensure progress toward attaining the SDGs, it is crucial that the negative impacts of climate change on trees and forests, and forest-dependent communities be addressed. In Africa, knowledge on tree growth and population dynamics, the range of natural climate variability and the range of tree species tolerance to climatic extremes is scarce. This information is crucial for sustainable natural forest management and to support decisions in agroforestry and reforestation efforts (Gebrekirstos et al., 2014). The Dendrochronology Laboratory was, therefore, established in 2013 to conduct studies aimed at generating the requisite information to address climate change challenges. Dendrochronology is the discipline of dating tree rings to the year of their formation and using exactly dated tree rings to detect environmental signals that are common for a population of trees. Methods/tools including tree-ring analysis, wood anatomy, stable isotopes and dendrometers are applied to decode minutes, decades to multi-centuries of information stored in trees, to address spatio-temporal changes across scales. The results provide insight into past climate and environmental variability at annual resolution, and from local to regional scales. Dendrochronology, therefore, elucidates climate change impacts on tree growth and provides evidence and data to help understand long-term ecological processes (Mokria et al., 2017) and address a broad variety of questions: e.g., which species is productive (Mokria et al., 2015), which species is resilient (Gebrekirstos et al., 2008), which species sequesters more carbon (Sanogo et al., 2022) or which species is drought tolerant (Boakye et al., 2016). On the basis of tree-ring widths in *Juniperus procera* in Ethiopia, Gebrekirstos et al. (2008) and Mokria et al. (2017) developed a climate reconstruction spanning 350 years. Gebrekirstos et al. (2008) also characterized co-occurring savanna species in Ethiopia into opportunist and resilient species based on their response to rainfall variability.

Ecological studies have shown a strong association between tree growth rings and temperature and precipitation data (Boakye et al., 2016; Upadhyay and Tripathi, 2019). Some study findings also show trade-offs between stomatal conductance, water use efficiency and carbon sequestration (Gebrekirstos et al., 2011). Stomatal closure due to higher atmospheric carbon dioxide levels causes a decrease in transpiration rates and, therefore, improved water use; but also implies less carbon dioxide uptake and, hence, reduced carbon sequestration (Palandrani et al., 2021). The findings of such eco-physiological studies underpin the application of dendrochronology in assessing population dynamics (Abiyu et al. 2018), carbon sequestration, and trends of biomass production (Mokria et al., 2015; Sanogo et al., 2022). These studies have, therefore, demonstrated the large potential of dendroecological techniques in different climatic zones of Africa.

A high number of tree species show datable annual tree rings and reach a considerable age. Thus, by using tree rings as precisely dated high-resolution climate proxies, the dendrochronology lab has helped to put the existing short-term and sparse instrumental climate records in Africa into a longer perspective. This could enhance the simulation of tree/forest growth trajectory models and, hence, minimize the high transaction costs of monitoring long-term research plots.

Soil and Land Health Unit's Land Degradation Surveillance Framework (LDSF)
Estimates by the UN Food and Agriculture Organization (FAO) indicate that each year 12 million hectares of land are degraded, and 24 billion tonnes of fertile soils are lost due to soil erosion (FAO, 2023). The resulting decline in soil and land health affects agricultural productivity, food security, human livelihoods and climate resilience. The LDSF is a robust monitoring tool designed by CIFOR-ICRAF scientists to assess and monitor soil and land health at farm, landscape and global levels. It uses a consistent set of indicators and field sampling methods to assess vegetation cover and structure, current and historic land use, tree, shrub and grass species diversity, land degradation status, soil infiltration capacity and other soil characteristics (Vågen & Winowiecki, 2023). An important contribution of biology to the LDSF is the reliable identification of plant species encountered during field surveys. For example, three different species of *Acacia* – *Acacia nubica*, *Acacia tortilis* and *Acacia thomasii* – were encountered during an LDSF survey of a rangeland in the Kajiado County of Kenya. This knowledge on diversification of species is attributable to plant taxonomy and systematics. At Kajiado, the different species of *Acacia* were identified based on their unique taxonomic/morphological traits including tree architecture and presence or absence of special structures (e.g., thorns). It is worth noting that studies on ecological characters such as plant adaptation to specific habitats have also informed the use of plants as biological indicators of environmental stressors. For example, *Salvadora persica* - another species encountered during the Kajiado survey - and some *Acacia* species are known for their tolerance of salinity (Arya, 2017; Reddy et al., 2008).

Soil-Plant Spectral Diagnostics Laboratory
The Soil-Plant Spectral Diagnostics Laboratory – also called the Infrared Spectroscopy Lab – is a state-of-the-art laboratory that serves as a reference lab for more than 20 regional spectroscopy labs around the world. Spectroscopy is the measurement and interpretation of the electromagnetic spectra produced by matter due to absorption and emission of light (or more precisely electromagnetic radiation) into its constituent wavelengths. Since different types of matter interact differently with different types of radiation (e.g., visible light, infrared, and ultra-violet rays), spectroscopy is a valuable tool for elucidating the chemical composition of different substances. CIFOR-ICRAF's Spectral Diagnostics Lab provides cost-efficient, reliable and rapid analysis of soil, plants and agricultural inputs (e.g., fertilizers and manure) using mainly infrared diffuse reflectance spectroscopy (simply, infrared spectroscopy) and x-ray fluorescence (Viscarra Rossel et al., 2022).
With the infrared spectroscopy method, dry samples are illuminated and the emitted electromagnetic radiation is measured in narrow wavebands over the mid-infrared (MIR) range (4,000 – 400 cm^{-1}) and near infrared (NIR) range (12,500 – 4,000 cm^{-1}). When illuminated, the molecules in the samples rotate and vibrate at specific frequencies corresponding to discrete energy levels (vibrational modes). The vibrations occur either due to changes in bond angle (bending) or bond length (stretching). Analysis of the resulting spectral signature – a summary of the energy absorption features at each wavelength - reveals details about the composition and molecular structure of the sample, e.g., organic matter quality. Infrared spectroscopy, however, only allows prediction of soil properties (e.g., pH, particle size distribution, electrical conductivity, nitrogen, carbon) and plant properties (e.g., available nitrogen, phosphorus, and other nutrient elements). The x-ray fluorescence method is used for determination and quantification of total concentrations of nutrient elements as well as heavy metals (e.g., titanium, chromium, arsenic, cadmium and lead) in soil, plant and fertilizer samples. This is because x-rays enable more in-depth investigation of the chemical bonds, structure and orientation of molecules in space.

In effect, fundamental principles of physics (e.g., optics, electromagnetism, quantum mechanics) and chemistry (e.g., chemical bonding, molecular structure, behaviour of atoms, properties of functional groups) underpin the science of spectroscopy. Thus, although much of the work conducted in the Soil-Plant Spectral Diagnostics Lab is automated, human knowledge of the underlying principles is irreplaceable for troubleshooting and interpretation of the data generated. Also worth noting is the fact that ecological studies on soil properties, plant mineral nutrition and plant-soil interactions in different landscapes have provided knowledge on the acceptable/permissible concentrations of various chemical elements in soil, plants, and other environmental media. This knowledge provides a basis for comparison and interpretation of the elemental concentrations in analysed samples and, hence, enables assessment of the success of agricultural interventions and restoration efforts undertaken in the landscapes from which the samples of soil, plants and/or agricultural inputs are obtained. The ability to match data from LDSF surveys with that generated by the Spectral Diagnostics Lab on such properties as soil organic carbon (SOC) is of significance as it provides opportunity to include soil carbon storage in the development of Nationally Determined Contributions (NDCs) to the Paris Agreement on Climate Change (Diwediga et al., 2022).

Living Soils Laboratory

Soil fertility is the ability of soils to sustain plant growth by providing essential plant nutrients and favourable chemical, physical and biological conditions. It is believed that microbiology drives most geochemical processes and, thus, soil function is influenced by the microorganisms present. Soil biodiversity is, therefore, important to ecosystem health (Bach et al., 2020; Pulleman et al., 2022). CIFOR-ICRAF's Living Soils Laboratory works mainly on the living component of soil with the aim of understanding the roles of soil biota in maintaining and improving soil fertility, particularly in agroforestry systems. Activities carried out in the Living Soils Lab include assessment of the diversity of arbuscular mycorrhizal fungi (AMF) and determination of fungal-to-bacterial (F:B) biomass ratios as an indication of soil health. The diversity of soil macrofauna (e.g., ants, termites, earthworms, millipedes, centipedes and beetles) whose activities affect soil physical and chemical properties, are also determined. Studies of AMF abundance and diversity, F:B ratio and status of other soil biota along gradients of climate, land use and degradation status provide an understanding of the interactions between soil organisms, soil processes, plant species and ecosystem services, e.g., nutrient cycling and soil carbon storage (Fall et al., 2022). This then informs such decisions as the appropriate combination of trees and other plant species to be selected for different sites and planting purposes (Lemanceau et al., 2015).

Results and Discussion

The foregoing exposition on the functions of selected CIFOR-ICRAF research units and laboratories has demonstrated the contribution of basic studies in different branches of plant biology (e.g., anatomy, ecology, genetics, pathology, physiology, taxonomy) as well as soil science, chemistry and physics to efforts aimed at addressing the global challenges to sustainable development. The world cannot preserve and enhance biodiversity, improve food and nutrition security, reverse and prevent soil and land degradation, meet carbon sequestration targets, and realise the global goals without the basic sciences. Ensuring continued capacity development in the afore-mentioned fields of study is, therefore, necessary for generating the site- and species-specific data that gets synthesised (e.g., via meta-analysis) to inform global policy decisions on ecosystem restoration and other sustainability-focused initiatives.

Meanwhile, there are reports of declining interest in such fields of study as forestry (Shanahan et al., 2021) and botany/plant biology (Crisci et al., 2020; Stagg & Donkin, 2013). A CIFOR-ICRAF led survey by the Global Forest Education Project revealed that forest-related knowledge is often inadequately covered in school curricula in most regions of the world, particularly in the Global South (Taber & Decristofaro, 2021). A study undertaken in the United Kingdom revealed that out of approximately 104,895 students who graduated from general biology programmes between 2007 and 2019, less than 0.05% (n = 565) were enrolled in plant science or plant biology programmes (Stroud et al., 2022). Even for the plant biology programmes, Stroud et al. (2022)

found that modules with a dedicated plant focus contributed only 22% of the taught content with plant identification accounting for only 1%. The growing threat to botanical education has been attributed to a misunderstanding of the broad spectrum of scientific skills that plant biologists/botanists draw upon which go beyond plant identification (Manzano, 2021).

By highlighting the range of basic biological, chemical and physical studies/principles that contribute to CIFOR-ICRAF's work, this paper has demonstrated their relevance to key global and regional restoration initiatives. Notable among these are the Bonn Challenge, that aims to restore 350 million hectares of deforested and degraded land by 2030 (IUCN, 2020), Africa Union's Great Green Wall Restoration Initiative which has a target of restoring 10 million hectares of arid and semi-arid land around the Sahara every year until 2030 (FAO, 2023), and the African Forest Landscape Restoration Initiative (AFR100) – a country-led, community-focused effort that seeks to restore 100 million hectares of deforested and degraded land in Africa by 2030 (WRI, 2023). Landscape restoration contributes to achieving SDG1 - no poverty, SDG2 - zero hunger, SDG3 – good health and well-being, SDG6 - clean water and sanitation, SDG13 - climate action and, especially, SDG15 - life on land, which aims to "protect, restore and promote the sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss". Incidentally, one of the 23 targets listed for achievement by 2030 in the Kunming-Montreal Global Biodiversity Framework (GBF) is to have restoration completed or underway on at least 30% of degraded terrestrial, inland waters, and coastal and marine ecosystems. It is noteworthy that the UN Decade of Action to deliver the Sustainable Development Goals (2021 – 2030) is also earmarked as the UN Decade on Ecosystem Restoration. Therefore, the role of basic sciences in achieving the SDGs, through their contribution to biodiversity conservation and ecosystem restoration efforts, has been brought to the fore in this paper.

However, efforts aimed at tackling the global challenges which, like those of CIFOR-ICRAF, leverage the power of trees to provide ecological goods and ecosystem services could be constrained by inadequate financial support for the study of biology and other basic sciences, especially in African universities. In Ghana, for example, calls for grants like the World Bank's Teaching and Learning Innovation Fund (TALIF) - implemented in the early 2000s to support tertiary institutions to improve their academic facilities/programmes - are now few and far between. Current research grant calls are skewed towards the applied sciences (e.g., agriculture, nutrition, health) as the world races to meet the SDGs. Consequently, university departments that remain focused on their mandate to contribute to the training of competent basic science teachers and/or conduct research that leads to the generation of new knowledge, tend to be financially handicapped, with run-down facilities and obsolete equipment that are not fit for teaching and learning. This situation undermines the very foundation on which solutions to the global challenges are built. Thus, in line with research grant calls that request applicants to demonstrate compliance with gender equality (SDG5) and a recent proposal by Carsan et al. (2022) for tree planting project proponents to indicate how tree seed sourcing will be done, we propose that grant funders request university-based applicants - particularly in Africa - to identify and indicate the role of the basic sciences in meeting project targets. A percentage of the applying university's overhead costs (where applicable) could then be paid into a dedicated fund to support teaching, learning and research in the basic sciences. Such a fund would facilitate the acquisition of equipment and enhance fieldwork, student internships, and on-the-job training for technical staff. In line with SDG17 - partnerships for the goals, we recommend that within- and between-university research partnerships that integrate the basic and applied sciences should be encouraged to enhance the creation of multidisciplinary/transdisciplinary research teams that are more likely to attract funding. Meanwhile, to improve accessibility to research and training opportunities, African universities could consider partnerships with national research institutes, such as those under Ghana's Council for Scientific and Industrial Research (CSIR), and international research organizations like CIFOR-ICRAF. Where distance is a barrier, a good start would be virtual participation in scientific colloquia that are organized by such research institutes to keep abreast with on-going national/international projects and research needs. Properly negotiated memoranda of understanding (MOU) would ensure long-term partnerships with effective outcomes. Without losing the essence of the basic sciences, efforts could also be made to incorporate emerging research topics in basic science textbooks used at all levels of the educational system, especially at the tertiary level. Tropical dendrochronology, for example, is a new research frontier which is still in its infancy in Africa. There is, however, a strong interest to develop and ensure a wider use of dendrochronology science in Africa, which will require collaborative efforts.

Conclusion and Recommendation

This paper has demonstrated that basic scientific research plays a role in the functions of CIFOR-ICRAF's Nairobi-based research units and laboratories, which support the organization's efforts at addressing global environmental, social and economic challenges. Therefore, building capacity in the basic sciences, encouraging research partnerships across disciplines and including new research frontiers in basic science curricula at all educational levels would ensure creation of the knowledge required for effective execution of sustainable development initiatives. This would promote attainment of the SDGs.

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Competing Interests

The researchers declare that there is no competing interest.

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