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BRIEF REPORT

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Sowing the seeds for interdisciplinary plant research and development in the Tropical Andes

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Societal Impact Statement

In the Tropical Andes millions of people depend upon the use of wild and domesticated biodiversity for their livelihoods, but the complex interactions between the ecological and social components of the region's ecosystems remain poorly understood. Better knowledge of these interactions can help provide solutions to reduce poverty in this region. The joint international laboratory on Biodiversity in Natural and Cultivated phytosystems of the Tropical Andes (BIO_INCA) aims to fill crucial gaps in knowledge by advancing research at the interface between biology, ecology, agronomy, social and human science, and economics, which will not only help address the challenge of ecologically sustainable agriculture, but also contribute to United Nations sustainable development goals on Zero hunger and Life on land.

KEYWORDS

Agriculture, Biodiversity in Natural and Cultivated phytosystems of the Tropical Andes (BIO_INCA), ecology, International Platform for Biodiversity and Ecosystem Services (IPBES), phytobiome, sustainable development, Tropical Andes, United Nations

1 | INTRODUCTION

The Tropical Andes harbors an outstanding diversity and endemism of wild and domesticated plant species and ecosystems. While plant diversity in the region is relatively well-studied, the diversity of bacteria, viruses, fungi, and invertebrates that interact with plants and their environment, in both natural and cropped systems, is still mostly unknown. Nevertheless, the diversity and function of these organisms are essential to provide food security and ecosystem services to local populations. Here we advocate the need for, and present the creation of, an operational international joint laboratory (BIO_INCA), specialized in integrative studies, from genomes to ecosystem services, of the natural and cultivated ecosystems in Colombia and Ecuador. This interdisciplinary platform merges ecological, agronomical, social, and economical expertise, and promotes the development of new technologies in bioinformatics, robotics, image analysis, and modelling. A key aspiration of the platform is to capitalize on plant community interactions and functions to provide novel ways to increase resource-use efficiency and to ensure the conservation of cultivated and natural ecosystems.

2 | SPOTLIGHT ON THE TROPICAL ANDES

In March 2018, Colombia was at the centre of the international biodiversity agenda, as the sixth session of the International Platform for Biodiversity and Ecosystem Services (IPBES) took place in Medellín. A highlight of the conference was the initiation of two new assessments on the sustainable use of wild species, and on tools and methodologies regarding the multiple values of

biodiversity to human societies (IISD, 2018). Colombia was an extremely appropriate location for the IPBES conference, as Tropical Andean countries host some of the world's most outstanding biodiversity and endemism of domesticated and wild plants species and ecosystems. For example, the unique coffee cultural landscapes of Colombia are classified as a UNESCO world heritage site, and the *páramos* are a spectacular and endangered endemic montane biome with vegetation dominated by giant rosette plants, shrubs and grasses. Colombia and Ecuador share three biodiversity hotspots—the Tropical Andes, the Western Amazon, and the Túmbes-Chocó region—and shelter a total of 2,944 and 2,302 genera of plants, respectively (Dangles, Nowicki, & Mena, 2009). Within a single family, the Solanaceae, a total of 441 species are reported for Colombia and 368 species for Ecuador (Jørgensen & Ulloa Ulloa, 2011), many of which have agricultural, economic, and ecological importance. The maintenance of their biodiversity and the local habitats where they grow is crucial to support human populations relying on their services (Denison, 2012). Biodiversity conservation and agriculture have long been intimately related in the Tropical Andes, a region that has played a major role in plant domestication, resulting in the cultivation of different crops (e.g., potatoes, beans, cassava, lupine) that are essential in providing agrobiodiversity and food security (Pearsall, 2008). For these reasons, the sustainable use and conservation of cultivated and natural ecosystems in the Tropical Andes are significant challenges of the 21st century.

3 | NATURE-BASED SOLUTIONS IN NATURAL AND CULTIVATED PHYTOBIOMES

To meet these challenges, it is important to take into consideration that wild and crop plant species interact with a great number of microorganisms, including bacteria, viruses and fungi, as well as insects, animals, and other plants; these are all encompassed by the concept of the phytobiome (Busby et al., 2017; DeLonge, Miles, & Carlisle, 2016). To date our knowledge of phytobiome networks in the Tropical Andes is extremely limited. The phytobiome plays a fundamental role in the biological performance of organisims (survival, growth, and reproduction), and ensures the provision of ecosystem services, such as pollination, pest control, seed dispersal, water filtering, carbon sequestration, nutrient cycling, and genetic flux (Berendsen, Pieterse, & Bakker, 2012), all of which contribute to human health and well-being (Naeem, Chazdon, Duffy, Prager, & Worm, 2016). Natural and cropped phytobiomes can also be a source of nature-based solutions (sensu Cohen-Shacham et al., 2016), such as increased productivity, resistance to diseases, biocontrol of crop pests, adaptations to local conditions, bioenergy, and restoration, which enhance human well-being and support sustainable economies (Maes & Jacobs, 2017). Additionally, humans are one of the major engineers of phytobiomes, and their practices and social dynamics have a strong impact on the dynamics of phytobiome networks (e.g., Dangles et al., 2010). In view of the growing threats imposed by ecosystem degradation, land intensification, and climate change, maximizing ecological functions in both natural and agricultural phytobiomes has been described as a prerequisite for a sustainable future (Toju et al., 2018). To optimize ecological functions, it is crucial and timely to increase our knowledge of the complex interactions upon which natural and cultivated ecosystem functions rely (Saleem & Moe, 2014).

4 | TWO MAIN BOTTLENECKS: DISCIPLINARY SILOS AND COLLABORATION GEOGRAPHY

In our view, an increase in the knowledge of agricultural and natural phytobiome networks in the Tropical Andean region faces two major bottlenecks. First, research on cultivated and natural plant systems is generally divided between different scientific communities: crop species are considered in the context of agriculture, while their wild relatives are mainly studied by ecologists, ethnobotanists, or conservation biologists (Denison, 2012). Although many scientific concepts are similar and shared across different disciplines, others are not. For example, there is a rich theoretical basis in community ecology (e.g., interactions between species and ecosystem functioning; Isbell et al., 2017) that has not been fully utilized for understanding agronomical systems. Conversely, agronomists have been pioneers in microclimatic studies, whereas ecologists have considered them only recently (e.g., Faye, Rebaudo, Carpio, Herrera, & Dangles, 2017). A joint approach seems opportune, given the fact that crops and their wild relatives coexist and share organisms of their phytobiomes in complex socio-ecological landscapes (Figure 1). Studies on these interactions would result in methodological and conceptual advancements in both disciplines (Bennett, 2017) and respond to an ever-increasing societal demand for agricultural systems that are less harmful to human health and the environment (Specht et al., 2015). Yet, the potential collaboration between agricultural

FIGURE 1 A typical complex "cultivated-natural" landscape matrix in the Northern Tropical Andes. The sustainable use and conservation of this plant system needs interdisciplinary research approaches which encompass biology, ecology, agronomy, social and human science, and economics. Photograph by Olivier Dangles

scientists and ecologists in interdisciplinary and integrative research projects on natural and agricultural phytobiomes has yet to be fully realized, in particular in tropical countries.

The second challenge that needs to be addressed to foster the sustainable use and conservation of cropped and natural ecosystems in the tropics is to build strong "south–south" scientific cooperation between countries. To date, these interactions are extremely scarce, and most South American universities have higher levels of collaboration with European and North American partners than with fellow South American institutions (Dangles et al., 2016). South–south scientific collaborations should be promoted to (i) help countries to increase engagement with mutual learning and solution-sharing for more efficient progress in development and conservation; (ii) improve the visibility of research of scientists from South American countries that could increase integration into global research networks; and (iii) develop research on common study models that better integrate multiple scientific disciplines and better support decision-making. For example, Colombia and Ecuador could better coordinate their research on the Andean *páramo*, a cross-border ecosystem with a high priority for conservation. Similarly, conservation knowledge and experiences gained in sustainable cocoa production in the Ecuadorian lowlands (e.g., Waldron, Justicia, Smith, & Sanchez, 2012) could help integrate biodiversity conservation into local economies in nearby Colombia (Baptiste et al., 2017), where communities are recovering from years of conflict. Recent political changes in both Colombia and Ecuador make this an opportune time for these countries to implement new paradigms for the development of their natural capital (e.g., Clerici et al., 2016).

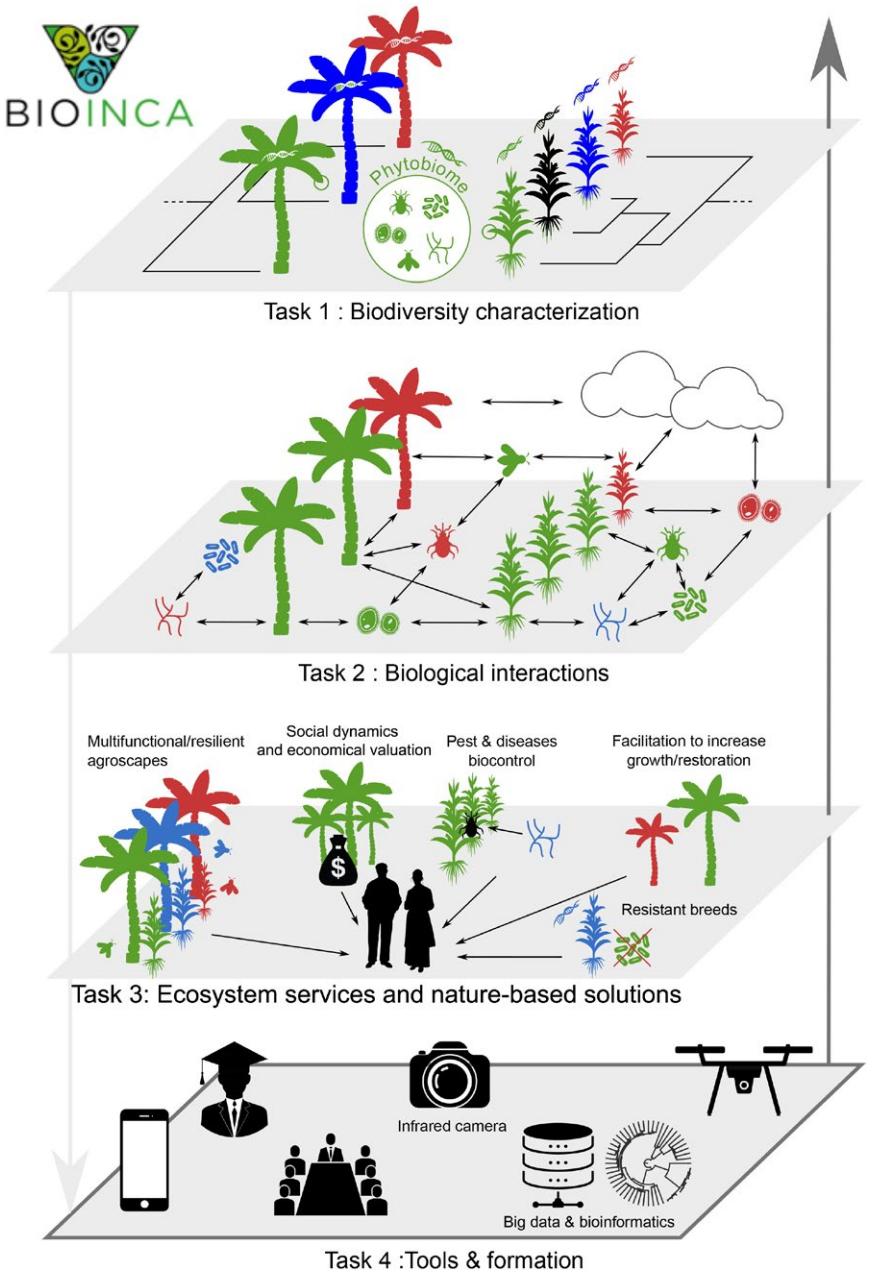

FIGURE 2 Schematic representation of the four scientific tasks that compose the BIO_INCA platform. Task 1: Biodiversity characterization of cultivated (green) and natural species (black, red, blue) and their associated phytobiomes. This includes potential genetic transfers between wild and cultivated organisms. Task 2: The study of biological interactions (plants, microbes, arthropods) within cultivated and natural phytosystems, specifically in interactions with abiotic factors (e.g., soils, climate). Task 3: The study of the relationship between biodiversity and ecosystem services (including social sciences and economics) to provide stakeholders (farmer, biodiversity managers) with nature-based solutions for sustainable agro-ecosystems. Task 4: Is an intersecting task dealing with the development of new tools and methods (bioinformatics, eco-informatics, drones, crowd-sourcing) and training (Massive Open Online Courses (MOOCS), summer schools)

5 | AN INTERDISCIPLINARY RESEARCH PLATFORM FOR PLANT RESEARCH

As a key step toward these goals, and alongside the sixth IPBES session in Medellín, the BIO_INCA "*Biodiversity in Natural and Cultivated phytosystems of the Tropical Andes*" international joint laboratory was launched in March 2018 in Bogotá, Colombia. BIO_INCA is an interdisciplinary initiative to promote the emergence of an operational research platform, specialized in integrative studies, from genomes to ecosystem services, of the natural and cultivated ecosystems of the Tropical Andes. To date, the core of the BIO_INCA platform includes over 40 scientists from three countries: Colombia (mainly the Universidad Los Andes); Ecuador (mainly the Pontificia Universidad Católica del Ecuador); and France (mainly the Institut de Recherche pour le Développement). However, the broader network of the collaborative platform is made up of more than 20 institutions, including universities from low- and high-income countries (e.g., Universidad Nacional de Colombia, Columbia; Escuela Politécnica del Chimborazo, Ecuador; Cornell University, USA; and Aarhus University, Denmark), research centres (e.g. Consultative Group for International Agricultural Research (CGIAR); the Centre de coopération internationale en recherche agronomique pour le développement (CIRAD); the Instituto Humboldt), private companies (e.g., Corpogen), funding bodies (e.g., The McKnight Foundation; l'Agence française de développement [AFD]) and public entities (e.g., Instituto Nacional de Biodiversidad del Ecuador). Such a network will enable research produced by the platform to be at the interface between basic and applied sciences, with the aim of proposing concrete solutions to the adaptive management of natural and agricultural ecosystems.

The main lines of research of the platform fit broadly under four themes: (i) the characterization of cultivated and wild biodiversity; (ii) the study of biological interactions; (iii) the study of ecosystem services and nature-based solutions; and (iv) the development of tools and training (as an intersecting task, see Figure 2 and legend for details). While plant biodiversity and agronomical research are typically considered distant, or even conflicting, fields of research, they are now converging through the use of common approaches, in particular through 'omics, pattern recognition techniques and platforms that provide increasingly high volumes of species and environmental data (e.g., Rosenheim & Gratton, 2017, Wolfert, Ge, Verdouw, & Bogaardt, 2017). A key aspiration of the platform is to support projects that engage communities, businesses, and policymakers (e.g., governmental institutions) so that academic knowledge can be transformed into application-driven science, with up-scaling potential, and socioeconomic relevance. Coupling laboratory, field-based, and participatory research should increase opportunities to train students and professionals, particularly in industry, and to communicate technical information to the public.

6 | A PLATFORM TO TRIGGER SOCIETAL IMPACT

In the Tropical Andes, millions of people depend on the use of wild and domesticated biodiversity. Better knowledge of the dynamic and complex interactions between ecological and social components of phytosystems is needed to provide solutions to reduce poverty in the region. To this end, the BIO_INCA platform intends to put great emphasis on studies at the interface between biology, ecology, agronomy, social and human science, and economics (Díaz et al., 2018). This will be mandatory not only to address the challenges of ecological and sustainable agriculture for local and national economies (Mathez-Stiefel et al., 2017), but also to contribute toward the United Nations sustainable development goals (SDGs)—in particular SDG 3 and 15 (Zero hunger and Life on land, respectively).

In view of the urgent and fundamental challenges in biodiversity and human development emphasized by the IPBES sixth session, the foundation of an interdisciplinary research and development platform dedicated to better understanding tropical phytobiome diversity and function is now, more than ever, timely and important. Our hope is that the BIO_INCA seed will develop into a perennial structure proposing concrete solutions for more secure and resilient ecosystems in the Tropical Andes, and act as inspiration for similar initiatives in other endangered tropical regions of the world.

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